Climate Security and the Armed Forces
Concepts, Strategies and Partnerships

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CLIMATE SECURITY AND THE MILITARY

Concepts, Strategies and Partnerships

NL ARMS – 2023

Edited by
GEORG FRERKS | RINZE GEERTSMA | JEROEN KLOMP | TOM MIDDENDORP

LEIDEN UNIVERSITY PRESS

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Preface by the Dean of the Faculty, Prof. dr. Patrick Oonincx

Every year the Faculty of Military Sciences (FMS) of the Netherlands Defence Academy presents part of its research activities in a book related to an urgent theme. Climate change is one of such urgent themes that affects our society on a daily basis and the energy transition associated with it is another one. Of course, this is an area of interest that contains many aspects from a scientific point of view, and we would need a series of books to cover them all. In this volume, we focus on the military scientific perspective, which turns out to be an interesting topic on its own.

Climate change is shifting climate zones on our planet with various consequences, such as drought and floods and therefore failed harvests and food shortages, but it also creates changes in for example the accessibility to certain minerals. These changes irrevocably lead to local but also global tensions. These tensions will eventually affect the main tasks of the Defence organisation. A well-defined scientific interpretation of this evolving situation in the aforementioned areas is necessary, as it can provide Defence with the necessary insights into tomorrow's conflict backgrounds. Also, it becomes more and more important for the Ministry of Defence (MoD) to think along mitigating measures in this climate crisis.

For several years, we have been seeing river floods appear all over the World and particularly in Western Europe, where several major rivers come together in river deltas. The MoD's commitment to this as part of its third main task – to assist civilian authorities in case of emergency – will only increase, making it even more important that research has been carried out already for years by FMS both on methods for dike reinforcement and on Defence cooperation with civilian (emergency) services. Both topics have been addressed in this volume.

Research at the FMS that also has been carried out successfully for several years concerns future zero emission fuels. I consider it the MoD's duty to work closely together with civil knowledge institutes and industry, and participate in solutions to climate change. Shortages of current fossil fuels are forcing the MoD to think ahead, when acquiring new naval vessels, army vehicles or aircrafts. This equipment should be able to meet the challenges of tomorrow with the resources available at that time. In Den Helder, FMS is currently setting up a large military energy systems laboratory to be able to conduct research on this topic with (inter) national partners.

In this preface, I tried to highlight some of the research topics of our faculty. However, there is so much more to tell on ongoing research making this book well worth reading. My thanks go to all the authors for their contributions, not only from our institute, but also from our partner universities and knowledge institutes. A special word of thanks should go to the editors of this volume, who have managed to position the various perspectives throughout this book in an excellent manner.

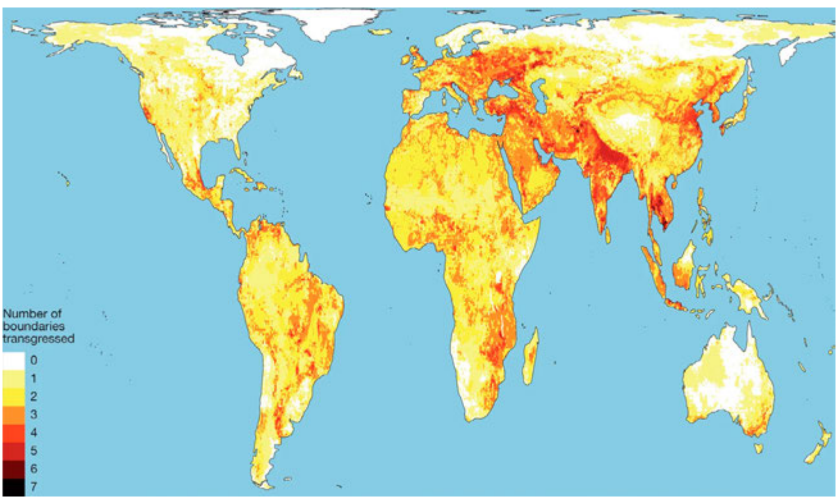
Prof. dr. Patrick Oonincx
Dean Faculty Military Sciences
Netherlands Defence Academy

Introduction to Climate Security and the Military

Rinze Geertsma, Georg Frerks, Jeroen Klomp and Tom Middendorp

Climate change and the overuse of resources has a serious impact on human well-being across the world and leads to increasing security risks and conflicts (Scheffrena & Battaglini, 2011). While the impact of climate change is global, its effect on access to food, water, energy and infrastructure and the associated security risk varies strongly across regions of the world (Rockström, et al., 2023; Scheffrena & Battaglini, 2011). Many hotspots of climate change impact are in conflict areas, such as the Middle East, Afghanistan and Ukraine, as shown in Figure 0.1 (from Rockström, et al., 2023; Scheffrena & Battaglini, 2011). The scarcity of resources in these conflict areas often increases tensions and worsens conflicts and can be used by rival factions as leverage to local populations (Middendorp, 2023; Scheffrena &

Figure 0.1. Overview of the number of local transgressions of Earth System Boundaries from Rockström, et al., 2023 ©, indicating areas in the world that suffer most from system changes in climate, natural ecosystems, water systems, nutrient cycles and the atmosphere.



Battaglini, 2011). Moreover, climate change increases the risk of natural disasters (Ghazali, et al., 2018; Aalst, 2006). These natural disasters provide security challenges for the military and local populations (Aalst, 2006; Scheffrena & Battaglini, 2011). Therefore, climate and security directly influence each other, and thus the military needs to understand the climate-security nexus and how it can contribute to adaptation and mitigation through the design of climate security strategies.

This book, Climate Security and the Military – Concepts, Strategies and Partnerships, reviews the climate-security nexus from the military angle and proposes the design of climate security strategies and how they can contribute to adaptation and mitigation of the related challenges. Part 1 reviews the understanding of the climate-security nexus. Part 2 assesses the potential design of climate security strategies. In Part 3, adaptation to climate change by the military is reviewed. Finally, Part 4 discusses the potential contribution of the military to climate mitigation from the angle of operations on land, at sea, in the air, and through solar geoengineering. By thus analysing the impact climate has on security around the world and military operations, this book provides a unique and much needed view on the mutual influence of climate security and the military and provides suggestions to adapt to and mitigate the resulting challenges.

The first part analyses the climate-security nexus through the angle of extensive military experience, disaster studies, climate intelligence and small arms prices. In Chapter 1, Dutch Former Chief of Defence Staff (CDS) Tom Middendorp highlights the main interfaces between climate change, security and the military and outlines geopolitical and local impacts of climate change and the role of the military in adaptation through an interview. Chapter 2 provides a review of the main paradigmatic shifts in disaster studies over the last fifty years and lessons to be learned, and highlights some of climate security's own particular features. In Chapter 3, an overview of climate intelligence is discussed. The article highlights the potential scope and methodology for additional military taskings to support data collection for climate intelligence as well as the integration of climate intelligence capabilities across defence and beyond. Chapter 4 explores the relationship between major droughts and the likelihood of local conflicts through the correlation between small arms prices and climatic events and suggests local conflicts and arms prices increase after droughts, but only in fragile countries. Concluding, this part provides a broad review of the climate-security nexus through experience, intelligence, disaster studies and data analysis.

The second part discusses the design of climate security strategies and policies and its required partnerships in five chapters. Chapter 5 proposes a climate security intervention framework to support operational and strategic decision making. This framework, based on a broad range of studies, employs an implementation logic based on an integrated and multi-level stakeholder approach and is demonstrated on a case study of Iraq. Subsequently, Chapter 6 analyses how Dutch strategies and policies address climate security. It then proposes to integrate climate security into development, diplomacy, and defence (3D) activities, as an integral part of the 3D approach and to consider climate security and conflict risk in international climate action. Chapter 7 investigates the influence of climate misinformation, by reviewing the implications of an alternative causal correction approach for minimising the effect of climate misinformation. The subsequent chapters focus on the partnership with industry by exploring Defence industry codes of conduct. Chapter 8 explores the codes of conduct of the largest Defence contractors and identifies opportunities in Defence procurement and supply-chain management. In Chapter 9, a conceptual model is proposed to identify the most important policy decisions on environmental sustainability performance, which should focus on both operational endurance and environmental sustainability, while maintaining information security. In summary, this part proposes addressing climate security strategy with all stakeholders and engagement with Defence industry to drive innovation for operational endurance and environmental sustainability.

The third part investigates how the Armed Forces can adapt to changing global climate security conditions. In this part, first the changing role of the military in crisis management and disaster response is reviewed in Chapter 10. Three changes in military posture are proposed in dealing with crises and disasters: the military needs to shift from a security to a humanitarian mindset, from autonomous to civil-military operations, and from crisis response to improving resilience. Chapter 11 proposes novel emergency response interventions for flood resilience, as part of the changing role of the military. It also reviews the role of the military in emergency response and presents the results of large-scale experiments under high-water conditions that demonstrate novel methods for flood prevention. These methods can be applied in the home nation or during operations far afield. Finally, in Chapter 12 a novel framework for the protection of vital but also vulnerable sustainable energy infrastructure at sea is proposed. The framework based on a quantitative operational analysis approach provides a structure for optimal surveillance patrols, to adapt to new vulnerabilities in energy security. In conclusion, the military needs to be prepared for collaboration in crisis management and disaster response, consider using novel methods for flood prevention and ensure protection of vital energy infrastructure, at home and during worldwide operations.

The final part covers the military's contribution to mitigation, from the angle of operations on land, at sea, and in the air, with a final review of the threat of solar geoengineering to climate security and state sovereignty. Chapter 13 reviews how adaptive military strategies and operations can be combined with more sustainable solutions. The chapter proposes to address the technical, logistic, and operational aspects of integrating renewable energy technologies into the Dutch army by shifting towards collaboration, open innovation and ecosystem thinking. In Chapter 14, the energy transition of the Royal Netherlands Navy is addressed. It provides a critical review of the challenges and opportunities of the transition to alternative energy carriers and energy systems and proposes a direction for the required research and development towards the future navy fleet that can operate independently of fossil fuels and with minimal emissions and signatures. Chapter 15 proposes to improve mission effectiveness by applying helicopter formation flight. The work demonstrates both the operational improvement and establishes a potential fuel saving of about 10% with a new mathematical model. Finally, Chapter 16 reviews how solar geo-engineering, a potential mitigation technique for global warming, can be a threat to climate security, cooperation, and state sovereignty. In summary, this chapter investigates the impact of the energy transition for the army, the navy and the air force and provides an analysis on solar geoengineering as a potential new geopolitical threat, thus promoting that the military can contribute to mitigation of climate change and the environmental impact of military operations.

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PART 1

Understanding the climate-security nexus

CHAPTER 1

Climate, Security and the Military – A Call to Action

Interview with General (ret.) Tom Middendorp

Georg Frerks

Abstract

Dutch Former Chief of Defense Staff (CDS) Tom Middendorp raised considerable political, media and public interest with his repeated calls to take climate change into account as a serious security risk. His analysis and call to action were disseminated through several well-received speeches ranging from Halifax, Munich to the Peace Palace in the Hague, and culminated in a book 'The Climate General – Stepping up the Fight.' After his retirement Middendorp became the Chair of the International Military Council on Climate and Security (IMCCS). In this interview Middendorp describes how and why he reached his convictions about climate security and highlights the main interfaces between climate change, security and the military. He outlines both the wider geopolitical and local security impacts of climate change, among which is the issue of climate migration, and elaborates on the tasks and roles of the military in reducing their own footprint.

Keywords: climate security, military, climate change, security, geopolitics.

Figure 1.1. Dutch Former Chief of Defense Staff (CDS) Tom Middendorp calls for action on climate, security, and the military.

Interview

Georg Frerks (GF): *In a speech in 2017 – when you were the Dutch Chief of Defense Staff – you asked urgent attention for the link between climate change and security. Can you describe how in your trajectory from the beginning of your career till the moment of fulfilling the highest military post in the Netherlands you got convinced that this problem needed such a prominent place in politics, policy and media?*

Tom Middendorp (TM): For a long time, I was unaware of the climate-security nexus. A growing awareness emerged from the experiences I had in the many missions I was part of. This was of course the case in Afghanistan where I was the commander of the Uruzgan mission, but also in the about twenty other operations I was involved in as a Director of Operations and later as the Chief of Defense of The Netherlands.

Environmental conditions have always played a key role in the planning of any military mission. Every military operational planning starts with an analysis of weather and terrain: how can we use the terrain to our advantage and where does it limit our operations? What is the impact of weather conditions on our equipment and our ability to operate? This was, however, limited to the effects of current environmental conditions on our operations. But gradually my view became much broader. In the different missions I experienced how climate acts as a risk multiplier and sometimes even as a root cause of conflict. In Afghanistan, I saw how the increasing droughts created water shortages, resulting in tensions among the population in Afghanistan and how the Taliban used those tensions to gain leverage over the local population. In Iraq, IS used water as an instrument of power. They occupied the Mosul Dam and by controlling the distribution of water they forced the population to cooperate with them. In Somalia the droughts and the warming of coastal waters turned desperate farmers and fishermen into pirates to sustain their families. In Northern Mali, I saw how the Tuareg population struggled with the increasing droughts and felt neglected by the Malian government which made them susceptible to the influence of extremists, who married into their families and used the prevailing frustration amongst the population to recruit fighters, resulting in the current conflict.

In most of these crisis areas, we are reacting to situations that grow out of control, and we often end up dealing with the symptoms of a problem without understanding and addressing the root causes. It is like putting a bandage on an infected wound, we cover the wound, but we don't heal the infection. I realised that climate-related conditions are among those root causes and can push fragile countries over the edge of internal conflicts. It was later when I became Chief of Defense that I connected these experiences with the long-term trend of climate change. As Chief of Defense, I was also responsible for the long-term design of our future armed forces. In this process you make an analysis of drivers-of-change and what they imply. Here climate change emerged not only as a source of instability, but also as a risk multiplier and a potential root cause of conflicts, which makes climate change also a matter of national security. So, I can say that beginning from a fairly modest understanding in purely operational terms my view broadened when I connected my own mission experiences with a strategic analysis of the different drivers-of-change.

This was a new and for many also uncomfortable insight. In all NATO and EU Military Council meetings of Chiefs of Defense I have attended during my 5 ½ years in office, climate or climate change was never even mentioned. I first addressed this publicly during a panel-discussion at the Halifax Security Conference in Canada in 2016. This attracted much attention because it was election-time in the U.S. where president-elect Trump dominated the discussion with his controversial ideas on climate.

GF: *Was there a special event or experience that was determinant or most important in reaching this point?*

TM: My growing awareness turned into a firm belief that climate change might well be the biggest challenge of this century, resulting in geopolitical friction, regional conflicts and increasing migration flows. End of 2016 our Minister of Foreign Affairs, Bert Koenders, invited me to address this topic at the Planetary Security Conference. This was a high-profile conference at the Peace Palace in The Hague. Here I explained how climate change could be a root cause of conflict, create breeding grounds for extremism and trigger migration flows. I concluded there could be no security without climate security. This went viral on the national and social media and also triggered a parliamentary debate.

GF: *In your book you describe you used your own discretion and authority to get this message out without consulting your staff or political boss at that time, minister of defense Jeanine Hennis-Plasschaert. Was this a conscious decision to take them off guard and create a more momentous effect or were you afraid that they would otherwise object to your initiative?*

TM: This was not a conscious tactic to bypass anyone. I had a very good relationship with our minister, I gave dozens of public speeches all the time and all the key players knew my public speech agenda. After Halifax, my views on climate change were also well known and even led to the invitation of Minister Koenders for this speech in the Peace Palace. It was election time and therefore the press jumped at it and turned it into big headlines. They were triggered by the fact that a military leader stressed the importance of an issue like climate change, which at that time was seen as a left-wing topic.

GF: *What were the main responses and how did you look at them that time and in retrospect?*

TM: Many people were surprised that the Chief of Defense raised such an issue. Politically, defense and security is a more right-wing topic and climate change more left-wing. As a result, my speech fueled the political debate on this topic in the run-up to the elections. Some commentators insinuated I was securitising climate to raise more budget for defense. Others were pleasantly surprised that a general made this connection and thought that this might help bridge the political gap and put the issue higher on the agenda. Within the military, it hardly attracted attention, probably because they understood the logic of the reasoning and had similar experiences in their own deployments.

All in all, I got the nickname the 'green general'. This in fact encouraged me to do more and I adopted 'climate general' as a title of honour and used it also as the title for my book. When I retired at the end of 2017, I decided to continue and devote my time and energy to this issue. I started to work with Clingendael and the Hague Centre for Strategic Studies (HCSS) on this topic and became chair of the IMCCS.

GF: *Can you briefly describe the aims and activities of this Council and who are its members? To what degree is the council successful or effective? Can you give some examples?*

TM: The IMCCS was officially launched during a Planetary Security Conference in The Hague on February 19th, 2019. It is run by a consortium of four research institutes: Clingendael and HCSS in The Netherlands, IRIS in Paris and The Center for Climate and Security (CSS) in Washington DC. The aim is to create a global and non-political network of senior military leaders, security experts, and security institutions across the globe dedicated to anticipating, analysing, and addressing the security risks of the changing climate. Next to this expert group, the Consortium is made up by an Executive Committee and a Secretariat who govern all the activities of the IMCCS. Former US Deputy Undersecretary of Defense Sherri Goodman is serving as IMCCS's Secretary General, and I became the chairman. In a few years the IMCCS has grown considerably and now has about 25 institutional partners and a council comprising more than fifty experts from over forty countries.

Apart from the institutional build-up, we have also been successful in our mission. At first, it felt like fighting an up-hill battle. In my 5 ½ years as Chief of

Defense, the word climate hadn't been mentioned once during all the international meetings I participated in. We had a long way to go. To start raising that awareness, our first publication was the World Climate and Security Report 2020. We launched that report at the Munich Security Conference triggering a lot of attention in the security communities around the world. From that moment on the ball started rolling and now, three years later, the climate-security nexus is widely recognised, allowing us to shift our attention from raising awareness towards helping find solutions. NATO, for example, is developing mitigation and adaptation policies and has announced its goal to be a net-zero organisation by 2050.

GF: *Now, let us dive a bit deeper in the substance. There are many interfaces between climate, climate change, security, and the military, as you also extensively describe in your book. What in your mind is the main or most important link between climate change and security?*

TM: Well, in fact there are links at three levels. The first is at the global, geopolitical level. In that context, we need to look at climate change in the context of three other main drivers of change: resource scarcity, population growth and geopolitical fragmentation. According to the UN, our world population is almost doubling in size during this century, resulting in a more than doubling demand for water, food, and materials. At the same time, the required resources are becoming increasingly scarce. As a result, we can expect a growing global gap between demand and supply that can trigger all kinds of global competition and frictions.

Climate change affects and limits the livable and arable space on our planet, making it harder to bridge that gap. Our geopolitical environment also makes it harder to come to solutions. The Ukraine crisis shows us how our world is becoming more fragmented with regions wanting to secure their autonomy. This fragmentation affects the ability of multilateral institutions to come to global solutions since they can only function on a certain level of international consensus and interaction.

So, the big question is 'How are we going to sustain 11 billion people in the foreseeable future?' Doubling our production to meet that demand simply means that we will deplete our global resources more rapidly. The only way to achieve this is by making our production more resource independent by designing products and production processes in such a way that we can use materials that are less scarce and that we can re-use materials and components. At this moment, we use about 100 billion tons of new raw materials per year, of which we re-use only 8%. This is a dead-end street resulting in more global competition if we don't make a rapid transition towards more circularity.

GF: *What are the dynamics at regional level?*

TM: At the regional level climate change acts as a risk multiplier, especially in fragile and conflict-affected countries across the central belt around the earth. These are often vulnerable places with poor governmental institutions and economies, and facing a high level of population growth, where people are already struggling to survive and often rely on what they can grow on their lands. Here climate change hits hardest and creates the largest disruption. Take the Arab Spring as an example. A disruption in the food security was one of the main causal factors here. These regions are the proverbial '*canaries in the coal mine*', warning indicators for other regions of what to expect. In the Sahel region for instance, the increasing droughts and desertification directly affect food security, a basic requirement for survival. It drives local populations to despair. Looking for ways to support their families, there aren't many choices, so they increasingly decide to move away and migrate, resulting in all kinds of internal frictions and conflicts between herders and farmers. Others become susceptible to the influence of extremist- or criminal organisations. In my book, I quote farmers in the US who state: 'Whiskey is for drinking and water is for fighting over'. This shows the importance but also the conflict potential of water- and food scarcity.

Many regions face longer periods of drought and shorter periods of very erratic rainfall or – in contrast – heavier rains leading to soil degradation. Even in the Netherlands with a moderate climate, we need to change our water management to make it future proof. In many developing countries, governments are unable to deal with such changes, resulting in breeding grounds for extremism and instability that force people to resort to organised crime. In Afghanistan, we see farmers growing opium, in Somalia, they turned to piracy, and in many other countries, people support the trafficking of humans, drugs or weapons.

The third level is the local one where the direct impact of climate change is noticeable in the form of severe weather conditions, such as heat waves, droughts, hurricanes, wildfires etc. I experienced the devastating and disrupting impact of severe weather events in Sint Maarten, where nearly the complete infrastructure was wiped away by Hurricane Irma in 2017. Other examples are the wildfires in Australia, the US and southern Europe, or the floodings in Pakistan covering 12% of the whole country, or in 2023 the heat waves all over the world with temperatures between 40 and 50 degrees Celsius.

GF: *How can climate change affect the strategic balance of power in the world, say between NATO and other countries, if you will Russia, China etc.?*

TM: Next to the above-mentioned geopolitical competition around access to resources, there is also the direct effect of a melting Arctic area. Experts expect the ice in the Arctic to melt to such a degree that within the next five years shipping lanes over the north of Russia will be accessible throughout the year. This offers Russia the opportunity to shift its Naval fleet – and much of its nuclear power – to the North, allowing it to access both the Atlantic and Pacific oceans much quicker than now through the Black Sea. Also, for China this is an opportunity to gain a more direct access to natural resources in the Arctic area and open a new 'Silk Route' through the North.

GF: *Climate change and lack of livelihoods and resulting violence may lead people to seek refuge elsewhere and could lead to massive migration movements. Can you explain more about these risks? Do you see them happening already?*

TM: Climate change brings droughts and extreme temperatures, turning large parts of countries into deserts and making them unlivable. It forces parts of populations to move away from their homelands to other areas where they are often not welcome. The World Bank expects migration flows up to hundreds of millions within 20–30 years. We must recognise migration as something that will not go away any time soon. We need more long-term strategies to deal with it, but we often seem to fight symptoms rather than solving the underlying problems. It becomes increasingly important to also invest in longer-term adaptation programs that help developing and fragile countries to become more resilient against the effects of climate change.

GF: *It seems that the present migration crisis just leads to the use of more defensive approaches (such as push-backs, walls etc.) rather than addressing the root causes. What is your opinion on that? What should we do?*

TM: Border protection can be part of a future solution but doesn't solve the problem. As I stated, we need to do more than just fight the symptoms. Within the EU we probably need to mainstream climate resilience into our foreign policy and development programs.

GF: *This also brings the link between the climate-security nexus and development and good governance to the fore. This reminds us of the 3-D approach or integrated approach where instruments of defense, diplomacy and development were used in combination to bring about desirable change. The War on Terror (WoT) and now the war in the Ukraine seem to have pushed this type of thinking to the back burner. What are your experiences with the 3-D approach in dealing with the climate-security* *nexus? Can you give examples? Is there a need to re-incentivise its use? How can this be done?*

TM: Climate change is not a military problem *per se,* and we shouldn't securitise it. However, it does have huge potential security consequences and can act as an accelerator of frictions leading to conflicts. This makes climate change also a matter of (inter)national security and makes it imperative that the security sector becomes part of the wider whole-of-government efforts to address it. From a security perspective, dealing with climate change is also a matter of conflict prevention. We need a paradigm shift away from the functional and often stove-piped departmental approaches. Building resilience against severe weather events, extremism, migration, or local level conflicts, requires a comprehensive effort, integrating the strengths of several departments into a joint approach. It is promising to see this recognised in the Netherlands. The latest National Security Strategy includes climate as a main driver of change and calls for a comprehensive approach.

However, we still have a long way to go. Not all countries recognise this need and for most militaries climate change still feels very unfamiliar and abstract. They rather focus on the current security concerns and on their conventional tasks like defending the national territory and helping stabilise conflict areas. It is however equally important to help prevent and be prepared for future conflicts. Many military leaders don't realise that climate change will most likely bring more insecurity and conflicts and will shape their future security environment. But times are changing. We have an unprecedented foresight of the likely (security) implications of our changing climate, which gives us a responsibility to be prepared and to help prevent. It was Eisenhower who famously called the tension between the urgent and the important. As the urgent is about today's crises, it usually wins from the important, which is about tomorrow's crises. In other words, the daily issues often draw the attention away from what is important in the longer term, which keeps us in a reactive mode. To govern is to look ahead. The Dutch province of Zeeland, after the flooding disaster of 1953, is a good example. The government back then did not decide to simply repair the dikes, to fix the problem of the day, but decided to put extra money in a future-proof Delta-works system for which we as a younger generation are still grateful.

The Ukraine war is of course a wake-up call to invest more in defense. But if we rebuild or strengthen our defense force it should be done in a future-proof way. Not just preparing for the last war, but use the lessons learned to prepare for the future and climate change is part of that as it increasingly becomes a driver or a root-cause of future conflicts.

GF: *In this connection, it seems that the EU has taken a protagonist role in the European continent by issuing all types of laws and guidelines. For some this is a beacon of light to be followed, while others deplore it as supranational meddling that undermines our national sovereignty. How do you look at this?*

TM: The EU Green Deal was urgently needed. Without it we would never have moved to the required energy transition. The Ukraine war of course drove the issue home that we needed to be self-sufficient and reduce our external dependency. We are still in the phase of windmills and solar panels, but we have to move further in the direction of circularity as that really changes our supply chains and reduces our dependency fundamentally. The EU needs to become a more global player than earlier when it was mainly concerned with the internal market. To secure its internal economic interests, the EU needs to mature its external role as a global player and become part of the solution in dealing with the increasing geopolitical competition. In that regard, it is important to consolidate the fragmented European industrial base in such a way that we can use our enormous innovative strength to become more resource-independent and lead the way towards reducing our ecological footprints. Innovating on circularity can help Europe become more resource-independent and make the economies of its member states future-proof.

GF: *Is sovereignty still an issue in the climate-security debate or perhaps of little value or irrelevant in connection with the cross-border nature of the issue?*

TM: In the short term, reducing our international dependencies requires us to secure our access to sufficient natural resources. But we do need to realise that this will lead to more geopolitical competition and is a dead-end street because at some moment we will run out of these resources. This means we have to work on the longer-term solution of becoming more resource independent and changing our industrial-age way of producing and consuming into a more circular and sustainable way of living. It is obvious that this is a global matter which cannot be resolved in isolation and requires much international cooperation and joint action.

GF: *In your book you argue that about climate change a broad coalition is needed with the defense sector as an indispensable partner. Can you explain why this is so?*

TM: The military can play several roles when it comes to dealing with climate change. In the first place, there is the topic of climate intelligence, forecasting, and early warning. This should include the security effects of climate change. Look for example at fragile regions. If you realise that climate change is a risk multiplier, you can integrate climate change into your risk models, meanwhile helping other departments to build a more comprehensive picture for the planning of mitigation and adaptation programs. A second role concerns building of resilience by adapting militaries to operate under increasingly extreme conditions, such as with temperatures of over 50 degrees without the availability of water. Our infrastructure needs to be suitable for such circumstances. But there is also the need to build external resilience, such as of African regions to prevent them turning into conflict areas. I do see a role here for the military in partnering with countries and their armies to help them operate effectively. International military cooperation should include climate change just as climate programs should include security. This is already happening as evident from the work of the Global Centre on Adaptation supported by Bill Gates. They carry out large-scale adaptation programs in fragile regions in collaboration with the World Bank, the African Bank and the UN and recognise the link between climate change and security. These programs can truly be seen as stabilisation programs. A third role is military assistance in the field of disaster relief and humanitarian assistance. As the risks of severe weather events will increase, it becomes more important to further professionalise our response mechanisms. For instance, developing a standing regional cooperation mechanism in the Caribbean ensures a more rapid and coordinated multi-agency response.

GF: *Defense is one of the largest polluters among all government agencies. What can defense do to change or at least reduce this? You state that within defense, sustainability was for long a non-issue of low priority. Is this changing now and do you feel there are serious plans in place to tackle this. What are for example several good initiatives you see happening nowadays?*

TM: In most countries Defense is one of the biggest polluters and it is promising to see many countries looking at ways to make their military more self-sufficient without negatively affecting its operational readiness. An electric tank that has a limited range wouldn't be very effective. Countries like the UK, US, France, and Denmark are putting mitigation efforts in place. It is important to explore the military potential of new 'green' technologies. Logistics are the largest cost-driver and the largest vulnerability to any military mission. So, innovating on self-sufficiency regarding energy, water, food, spare parts, etc. can help reduce that logistical footprint and help military units to become more self-supporting, which would have a huge operational benefit.

GF: *What more can be done by defense in terms of energy transition?*

TM: I am currently involved in the development of a smart energy hub in an industrial area in the Netherlands that wants to become energy neutral. These same technologies can be used in the defense real estate. The same is the case when we talk about the electrification of vehicles where the whole automotive sector is in full transition. These are areas where Defense can follow civil standards and innovations.

A harder nut to crack is the heavy military capabilities that use high power energy sources. These are the combat tanks, the naval vessels and (ultimately) the air fighters. For these areas, alternative energy sources are not available yet, but they are becoming a focus area of innovation around the world. Here, the defense sector can act as a platform for innovation in cooperation with the civil sector and the defense industries. For instance, the sector can join forces with industries, research centers, civil developers and start-ups on the development of a next generation naval vessel that is fully self-sustaining. The propulsion- and power supply system of such a vessel would consist of dual-use technologies that can also be used more widely in the civil sector.

GF: *The current budget increase seems to be a good opportunity to invest in an environmentally smart way. Do you see this happening in a sufficient manner?*

TM: Certainly, with money flowing again, more is possible. On the other hand, this thinking is still quite new for the defense sector, and I see also some reluctance or fear that it will absorb funds that will then not be available for other operational deficiencies. It is important to integrate requirements regarding self-sufficiency and emission reduction into the research, development, and procurement of new military capabilities. The civil sector is moving rapidly towards alternative energy sources, and we can't have a military that is the only one that is still running on diesel and kerosine. The defense sector has always been at the forefront of developing, testing, and adopting new technologies that always cost more money, but at the same time boast operational effectiveness.

GF: *Many people nowadays seem dissatisfied with the progress made so far in dealing with climate change. Activists, civil groups, NGOs, and academics have joined groups like Extinction Rebellion to push the message home that more needs to be done by using peaceful but at the same time more radical demonstrations. In your book, you also express some impatience at the slow speed of change and accuse people of being blind while seeing. How do you look at such movements like Extinction Rebellion?*

TM: Any movements who promote similar goals to deal with climate change are useful. They see the same urgency as I do. However, for me actions should always be within the limits of the law to be acceptable. You want to convince others that change is needed, you don't want to alienate them.

GF: *Finally, if you had to give a message to your readers, what would be the thing you would like to say to them?*

TM: For many people climate change is very big, very complex and way above their heads. At the same time, there is a growing recognition that climate change will affect not just our ecology, but also our security, our economy, and our social stability. My message would be to "*Think big, act small, start somewhere!*". We can all contribute and there is an old Chinese saying: "*many drops also make a river*". It starts by becoming aware of our own footprint. If I buy one shirt less, it saves hundreds of litres of water in the production process. We are still children of the industrial revolution, but we need to become children of the circular economy!

CHAPTER 2

Climate Security between Acts of God and the Anthropocene: Lessons from Paradigmatic Shifts in Disaster Studies[1]

Georg Frerks

Abstract

This chapter focuses on the challenge of addressing climate security threats. Though climate change and its threats to human security are in many ways unique and unprecedented, there is a lot to be learned from experiences with disasters in the past and the ways these were understood and managed. Whereas early mankind resorted to religion and ritual to deal with adverse events, the emerging academic field of disaster studies has since World War II begun to explain disasters from a scientific point of view. Moreover, it has seen considerable development and change over the last couple of decades which can be summarised via several significant paradigmatic shifts. This chapter starts by outlining the main features of the current climate change crisis based on the insights from the UN Intergovernmental Panel on Climate Change, and its (human) security impacts. It then turns to the field of disaster studies to see how subsequent approaches have tried to deal with disaster, including the role of the military. I give an overview of the main paradigmatic shifts in disaster studies over the last fifty years. I intend to show that these paradigmatic shifts in disaster studies are important to climate security as well. I identify seven themes derived from my discussion of disaster studies that I deem relevant to climate change. I also highlight some of climate security's own idiosyncratic features that go beyond the field of disaster studies expertise so far and will require innovative steps. These concern the seriousness, scope and scale of climate change impacts that supersede those of conventional disaster, as climate change is a global and chronic condition in contrast to most conventional disasters that strike in only limited areas and time frames. Other distinctive features of climate change are the role of vested interests that mitigate against climate policies, and the phenomenon of denialism. This chapter is partly based on earlier work by the author in the field of disaster and security studies and on secondary sources specially collected or perused for writing this chapter.

Keywords: climate change (impacts), disaster studies, paradigm shift, vulnerability, agency, resilience, co-governance.

2.1 Climate Change and Climate Security

The most authoritative source on climate change is the Intergovernmental Panel on Climate Change (IPCC) that publishes periodic assessment reports (AR) and underlying studies. Its most recent assessment report, the Sixth Assessment Report or AR6 published in 2021, "addresses the most up-to-date physical understanding of the climate system and climate change, bringing together the latest advances in climate science, and combining multiple lines of evidence …." The report in fact comprised four reports, namely: The Physical Science Basis; Impacts, Adaptation & Vulnerability; Mitigation of Climate Change; and the Synthesis Report that builds on the findings from all three reports.[2] In addition, the IPCC published an AR6 Synthesis Report, Climate Change 2023[3], including a summary for policy-makers (SPM) (IPPC, 2023: 8).

The reported findings in these publications are absolutely serious, if not outright alarming. Regarding global warming the SPM states that: "Human activities, principally through emissions of greenhouse gases (GHG), have unequivocally caused global warming, with global surface temperature reaching 1.1°C above 1850–1900 in 2011–2020. Global greenhouse gas emissions have continued to increase, with unequal historical and ongoing contributions arising from unsustainable energy use, land use and land-use change, lifestyles and patterns of consumption and production across regions, between and within countries, and among individuals". It adds that: "differences in CO_2 emissions vary substantially across regions in terms of total magnitude. … The 10% of households with the highest per capita emissions contribute 34–45% of global consumption-based household GHG emissions, while the bottom 50% contribute 13–15%" (IPCC, 2023: 4 and 5).

The Panel confirms that widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have already taken place with human-caused climate change affecting many weather and climate extremes in every region across the globe. This has led to widespread adverse impacts and related losses and damage to nature and people (IPCC, 2023: 5).

Approximately 3.3 to 3.6 billion people live in contexts that are highly vulnerable to climate change, often in least developed countries and increasing weather and climate extreme events have exposed millions of people already to acute food insecurity and reduced water security, next to causing irreversible losses to nature. Extreme heat events have resulted in human mortality and morbidity, while the occurrence of climate-related food-borne and water-borne diseases and the incidence of vector-borne diseases have increased (IPCC, 2023: 6). The effects of climate change have also led to displacement and migration due to disappearing livelihoods. Over 216 million people could move within their countries by 2050 across six regions, according to the World Bank's latest Groundswell report (Clement et al., 2021).

With regard to adaptation to climate change, prevailing patterns are highly unequal with progress in limited fields and regions, combined with serious gaps, challenges and maladaptation in other regions and sectors with the largest adaptation gaps among lower income groups (IPCC, 2023: 8).

The SPM asserts that key barriers to adaptation are, among others, limited resources, lack of private sector and citizen engagement, lack of political commitment, limited research and uptake of adaptation science, and a low sense of urgency. There are widening disparities between the estimated costs of adaptation and the finance allocated to it (IPCC, 2023: 9).

While mitigation measures have expanded and contributed to reduced emissions, this has not been sufficient to guarantee that temperatures will remain below the agreed threshold of 1.5˚C in the 21st century and make it harder to remain below 2˚C. Mitigation policy coverage is also uneven with finance lacking for low-emission technologies for developing countries (IPPC, 2023: 10–11).[4]

The Panel asserts that the prospects for the future are grim. Global warming will continue to increase in the near term (2021–2040) and is more likely than not to reach 1.5°C even under a very low GHG emission scenario. This will intensify multiple and concurrent hazards with extremes becoming larger. Risks and projected adverse impacts and related losses and damage from climate change escalate with every increment of global warming. For any given future warming level, most climate-related risks are higher than assessed in the last AR5, and projected long-term impacts are up to multiple times higher than currently observed (IPCC, 2023: 12 and 15).

With further warming, climate change risks will become increasingly complex and more difficult to manage. Multiple climatic and non-climatic risk drivers will interact, according to the SPM, resulting in compounding overall risk and risks cascading across sectors and regions and adding to the vulnerability of those already most vulnerable (IPCC, 2023: 15).

For adaptations to be effective speedy action is needed, as adaptation options that are feasible and effective today will become constrained and less effective with increasing global warming, which causes losses and damage to increase and human and natural systems to reach adaptation limits. The Panel warns that the window of opportunity to secure a livable and sustainable future for all is closing rapidly (IPCC, 2023: 19 and 24). Deep, rapid, and sustained mitigation and accelerated implementation of adaptation actions is urgently required, necessitating scaled-up action, aligned with the sustainable development goals (SDGs) and “prioritizing equity, climate justice, social justice, inclusion and just transition processes” (IPPC, 2023: 28–31).

Needless to say that such actions demand political commitment, well-aligned multilevel governance and institutional and legal frameworks, proper coordination and enhanced access to finance and technology (IPCC, 2023: 32). These are wanting in many parts of the world.

It is obvious that climate change has a severe impact on the human security of millions in terms of income, employment, health, environment, and a sustainable livelihood and future. Also in a stricter, physical sense, the security of people, societies and regions is at stake. Climate change can lead to conflicts over scarce resources or operate as a conflict multiplier in situations where relations are already tense. It is also documented that extremist groups have mobilised climate change-affected individuals and groups for their malign purposes. Finally, climate-change induced dynamics can also play out in geopolitics with increased global competition and strife. Middendorp in his interview with Frerks, and Nugee et al. in this volume have documented the intricacies of the climate-conflict nexus in larger detail and several other authors have elaborated on the role of and impact on the military.

2.2 Learning from Disaster Studies

How can we now learn from the field of disaster studies to deal with climate change and improve climate security? It seems to me there are several useful lessons to draw from this field, but also issues that require new thinking. Below I discuss some pertinent issues and debates from the field of disaster studies and indicate their relevance or otherwise for the challenges of climate change.

2.2.1 Disasters in pre-modern times

Let us start at the very beginning. Climate-related disasters have both frightened and fascinated people since times immemorial. Both oral and written history is replete with references to such events across the globe. Floods, fires, high winds, earthquakes, plagues and famines have castigated millions of people throughout history and affected their daily security, if not survival.

The most well-known story is perhaps that of the Ark of Noah as told in the Bible (Genesis 6: 13–19). The forty-days deluge that inundated the whole of the earth was the punishment of God for the corrupted and violent mankind that inhabited the earth by then, but the Ark that God instructed the righteous Noah to build, saved Noah and his family as well as 'two of every sort of animal' till the Ark landed in the mountains of Ararat and thus began a new episode for the human race under a covenant with God.

Similar myths of a Great Flood can be found in earlier Babylonian stories, including the *Gilgamesh Epic*; in the *Eridu Genesis*, an ancient Sumerian religious epic; in the *Manu* mythology of India as recounted in the *Shatapatha Brahmana;* and in the ancient Greek legend of Prometheus' son *Deucalion*.[5] We see here the divine origin of disaster, often as punishment for a sinful existence of mankind.

One should realise that such explanations persist till the present. For example, in a memorial speech by the Rev. Quist in 2013 the storm surge of 1953 that inundated the Dutch province of Zeeland and parts of Zuid-Holland with over 1800 casualties, was still attributed to "the hand of God who always chastised people with an intention", and explicitly not to the "misconception that it was a coincidental combination of a storm surge and a North-West storm."[6]

Countless myths also exist about fire. Prometheus stole the fire from Olympus and delivered it to mankind, followed by an eternal punishment by an angered Zeus. Similar themes are encountered in Indian and Japanese creation myths where fire is delivered from heaven. In Central and South America fire played a foremost role in rituals of Aztecs, Mayas and Incas. In Europe it played an important role in Keltic, Icelandic and German myths and rituals, as it did among Zoroastrians and Hindus in Asia. Fire symbolised both a destructive and benevolent force (Devish, 2021). In the wake of the wildfires in Hawaii in August 2023, Hawaiians were seen to resort to traditional rituals for spiritual healing.[7]

Apart from fire and floods, myths and legends abound on earthquakes, volcano eruptions, tsunamis and plagues. These are too many to be elaborated here, but it serves to show the ubiquitous respect, fascination and awe that disaster phenomena invoked on people around the world and how particular mythical narratives were woven around these events accompanied by rituals to deal with them.[8]

As for climate change, one should not simply assume that the scientific evidence presented and the measures recommended by the IPCC are generally accepted at face value. There is a burgeoning scholarship on the relationship between religion and climate change which pays "specific attention to the ways in which climatic processes appear within the logic of a particular cultural lifeworld" […] where "perceptions of climate change are rooted in intimately local frames of reference, which are often tied to ritual and mythological traditions associated with living in a particular place" (2018: 89). But also in the so called 'modern' world, scientific evidence is not always accepted. In several rural states in the US over half of the population does not believe in anthropogenic climate change. In the first place there is an active and powerful climate denialist movement, especially in the US but also elsewhere, of scientists and think tanks that try to obstruct the dissemination of the anthropogenic view of climate change. They do this on the basis of misleading information often supported and funded by powerful corporate and political interests. The Social Science Research Council refers to them as 'a minority with an outsized ability to shape domestic climate science, policy, and communications'. Its report shows how climate change denial has become woven into certain cultural, political, racial, and religious identities. It further traces the tactics for spreading climate change denial, like social media targeting and conspiracy theories designed to cast doubt on scientific findings (Weddig, 2022). Petersen et al. (2019) arrive at similar conclusions. Through an analysis of twelve prominent climate change countermovement coalitions from 1989 to 2015, Brulle shows that over 2,000 organisations were members of these coalitions and that a core of 179 organisations belonged to multiple coalitions. Organisations from the coal and electrical utility sectors were the most numerous and influential organisations in these coalitions (Brulle, 2019).

2.2.2 The modernist turn: The role of science in explaining disaster[9]

Whereas early disaster narratives saw disaster as a supernatural divine or mythical phenomenon, explanatory narratives and associated disaster policy practice gradually shifted to explanations foregrounding a focus on natural hazards as agents and a role of science in understanding them. The academic field of disaster studies and disaster management as a systematic and explicit endeavour started around World War II in the United States in response to real-world events and demands from the policy world. Whereas US policy was characterised for a long time by a laissez-faire attitude, the Tennessee Valley Authority set up in the 1930s was a game-changer with its aim to reduce flooding, while "the Flood Control Act of 1934 granted greater authority to the U.S. Army Corps of Engineers to design and craft flood-control projects" (Dyson, 2007: 38 and 51).

Disaster management originally focused on the hazards or natural agents that lay at the root of disasters and tried to mediate these mainly by technocratic, planning or infrastructural solutions and measures by public agencies such as the U.S. Army Corps of Engineers and, since 1979, the often-criticised Federal Emergency Management Agency FEMA (Rubin, 2012). In those early years there was an emphasis on constructing levies and dams and zoning policies rather than seeking to implement behavioural change or addressing the root causes of vulnerability, as emerged as a disaster policy in the 1990s. In the conceptualisation of disaster in the immediate post-World War II context, the natural hazard or agent took a prime place and remedies were sought through technocratic and managerial measures that were implemented in a centralistic, top-down, and military-style manner, often with the involvement of the Department of Defense.

In the 1970s and 1980s the discipline and policy practice started to change and also spread outside the United States to various applied and academic centres around the world, including the Netherlands with the establishment of the *COT* (Crisis Research-Team); Institute for Security- and Crisis Management in the late 1980s and *Disaster Studies* at Wageningen University in the late 1990s. The discipline also experienced a shift in focus: from what was initially a more natural science and hazard orientation to including a social-science perspective with attention to the human context and the affected populations, i.e. by looking at people's vulnerability. This was accompanied by a more explicit anthropological and ethnographic focus as well as a more critical stance vis-à-vis governmental policy instead of being only instrumental to it. Overall, it could be stated that disaster studies witnessed paradigmatic shifts in line with developments in the broader social sciences from a positivistic to a more interpretivist and constructivist approach. In the next sections, I highlight some of those shifts.

2.2.3 The vulnerability perspective

The vulnerability perspective came into being in the 1980s as a reaction to the technical-managerial disaster approaches developed in the previous decades. The emphasis on vulnerability was associated with a shift to a more sociologically oriented interpretation of disaster as a complex, socially (as well as politically, environmentally and economically) constructed process. Vulnerability was defined by Wisner et al. as:

> "the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard (an extreme natural event or process). It involves a combination of factors that determine the degree to which someone's life, livelihood, property and other assets are put at risk by a discrete and identifiable event (or series or 'cascades' of such events) in nature and in society" (Wisner et al., 2004: 11)·.

In this manner, the risk of being exposed to disaster had become recognised as a product of hazard and vulnerability. Vulnerability was seen in turn as actively created by factors such as bad governance, bad development practice and political and military destabilisation. Vulnerability, therefore, was an outcome, a product of a particular economic, social, and political context. Whereas it might have been deemed difficult or even nearly impossible in many circumstances to reduce risk by influencing the underlying hazard, vulnerability as the resultant of socio-economic and political processes was more conducive to policy action. This was especially the case as vulnerability became increasingly associated with its opposite: namely, the element of capacity engendered in individuals, groups, and local communities to cope with crisis, as elaborated below.

In an overview article about the state of disaster studies David Alexander asserted that the emergence of the notion of vulnerability was one of the most salient achievements in the field of disaster studies during the last decades (1997: 283–304). It convincingly did away with the notion of disaster as a natural phenomenon, as Alexander observed:

> "it is now widely recognized that 'natural disaster' is a convenience term that amounts to a misnomer. Neither disasters nor the conditions that give rise to them are undeniably natural" (1997: 289).

It was now acknowledged that disasters were anthropogenic, 'man-made', caused by human action or negligence. The vulnerability approach also called into question earlier, ill-conceived ideas of 'normality' and 'abnormality' that pervaded much thinking about disaster. As Oliver-Smith observes:

> Disasters in general are portrayed as non-routine, destabilizing, causing uncertainty, disorder and socio-cultural collapse. In such descriptions there is clearly an emphasis on distinguishing disasters from ordinary, everyday realties (…) Such an assumption dangerously ignores that most disasters are ultimately explainable in terms of the normal order" (1999: 23).

Lavell, for example, showed that in El Salvador 'disaster risk' was combined with 'lifestyle' or 'everyday' risk, stating that "the sum of their permanent living conditions signifies that the poor or destitute live under permanent conditions of disaster" (2004: 72). Here the exceptionalism of disaster got replaced by an emphasis of the every-day nature of disaster conditions for large parts of the world's population.

While the vulnerability approach was widely welcomed in the 1990s as a step forward in disaster studies compared to the naturalistic hazard paradigm, there were also critical voices. One criticism pointed out that it victimises and disempowers people by over-emphasising the weaknesses and victimhood of disaster-affected populations. It would engender a fatalistic and passive outlook and take away the agency from people, thereby creating external dependency and passivity instead of empowering them. Therefore, a next paradigm shift occurred in the first decade of the 2000s that put the emphasis on people's capacity and resilience, in short, people's agency.

2.2.4 The agential perspective

In their well-received publication of 1989, Mary Anderson and Peter Woodrow had already stressed the capacities that disaster victims possess:

> "Disaster victims have important capacities that are not destroyed in a disaster. Outside aid to these victims must be provided in ways that recognize and support these capacities if it is to have a long-term effect" (1989: 136).

Capacity refers to the actors' skills, resources and strengths to help themselves and others. In the volume *Mapping Vulnerability, Disasters, Development & People*, the authors drew explicit attention to the agency of disaster survivors and their capacities and showed how disasters and disaster knowledge were historical and social constructions and the product of perceptions, social practices, and discourses (Bankoff et al., 2004). This dynamic perspective opened a window for coping and ameliorative action by those involved themselves, something that also figured prominently in the International Decade for Natural Disaster Reduction (IDNDR) and the resulting Yokohama Strategy and Plan of Action for a Safer World that among others promoted a 'people-centered approach' (Scientific Committee of the International Decade for Natural Disaster Reduction 1999). In its follow-up, the International Strategy for Disaster Reduction (ISDR) and the Hyogo Declaration and Framework for Action a further emphasis was placed on capacity building in order to strengthen disaster resilience (UNISDR, 2006). The notion of resilience has quickly become mainstreamed in the last decade. According, to Cutter et al. resilience refers to:

> "The ability of human systems to respond and to recover. It includes those inherent conditions that allow the system to absorb impacts and cope with the event, as well as post-event adaptive processes that facilitate the ability of the systems to recognize, change and learn in response to the event" (2008: 599).

Those capacities and abilities are not some mysteriously in-built systemic properties or even a capability 'owned' by individual persons or organisations, but a collective, shared, or networked property based on and requiring specific forms of management and interaction. On the basis of these considerations, Frerks et al. define resilience as:

> "The shared capacity (of a group, community or society) to anticipate, resist, absorb, and recover from an adverse or disturbing event or process through adaptive and innovative social processes of change, entrepreneurship, learning and increased competence" (2011: 113).

In this connection, the strength of the resilience approach is that it is human-centered and community-focused, but simultaneously situated in a larger macro-setting of environmental, macro-economic, and policy processes and cognisant of global-local dynamics.

Though resilience thinking could be considered a step forward by further elaborating the agential approach in a societally more encompassing manner, it also received serious criticisms due to its covert political agenda. Frerks asserts in this connection that the resilience approach can be considered as part of the larger neoliberal project that is taking hold of contemporary society by promoting a liberalised economy and a retreating state (Frerks, 2015). Frerks refers to several authors who have claimed that this neoliberal ordering of the world has led, on the one hand, to an interventionist attempt to govern and control parts of the globe, implying the erosion of civil rights and liberties, while on the other hand it is excluding and marginalising those people deemed useless, who have been called the 'insecured' or 'surplus life' (Duffield, 2007) or 'wasted lives' (Bauman, 2003). Reid suggests that "the resilient subject is a subject which must permanently struggle to accommodate itself to the world". In doing so, resilience backgrounds the political, the imagining of alternatives, and foregrounds adaptivity, accepting "the imperative not to resist or secure themselves from the difficulties they are faced with" (Reid, 2010: 3). Frerks concludes that the emphasis on resilience is the product of a political discourse that seeks to shift the responsibility for mediating the impact of disasters from the state to the society or the individual and therefore may engender the same problems and feelings of disenchantment as the neoliberal project creates in other societal domains and the economy at large (Frerks, 2015: 493). This leads me to the theme of multi-stakeholder disaster governance or co-governance.

2.2.5 Multi-stakeholder disaster governance or co-governance[10]

The role of the public sector and of public policies is crucial in attempts to prevent, mitigate, and respond to disasters. This necessitates an analysis of the government institutions, the political culture, and the functioning of the public sector in disaster response. However, in many societies facing disaster, governments are weak, failing, or even collapsing. Others are plagued by corruption, 'spoils politics', dictatorial rule, and predatory regimes. Disasters like the Indian Ocean tsunami and Katrina were a wake-up call as to the failures and weaknesses of governments and institutions to prevent and mitigate disaster. As stated above, early disaster governance was organised around an emergency style of top-down, state-centred, military-inspired policies and institutions. The past three decades, however, have seen a global development shifting disaster response from reactive to proactive, from singular to more holistic, with a focus on disaster risk reduction (DRR), and from a state-centred model to forms of co-governance that recognise the importance of non-state actor involvement in disaster governance and of community-based initiatives and resilience, next to the necessary backing of international initiatives and funding. These shifts have made disaster response more robust and effective.

2.2.6 The interface with the military and humanitarian aid during conflict

Many disasters happen in war- or conflict-affected and fragile countries. The Global Facility for Disaster Reduction and Recovery (GFDRR) reports, for example, that "between 2005 and 2009, more than 50 percent of people affected by disasters lived in fragile and conflict-affected states; in some years this reached 80 percent (ODI, 2013).” Moreover, it asserts that “Of the 15 countries with the highest vulnerability to disasters, 14 are among the top 50 fragile states”(GFDDR, 2015: 6–7).

Understandably, disaster response and humanitarian aid are seriously compromised by situations of war. This affected in 2004, for example, aid to tsunami victims in both Sri Lanka and Aceh. Whereas in Aceh the army restricted aid to the victims, in Sri Lanka it became subject to the conflict dynamics between the Government of Sri Lanka and the Liberation Tigers of Tamil Eelam. Whereas it was hoped that this common disaster would lead to mutual solidarity and unite the protagonists, it in fact led to more contention and dissent. In both cases, humanitarian aid became subservient to the logic of war at the cost of the humanitarian imperative (Frerks, 2008 and Frerks & Klem, 2011).

Collaboration between civilian actors and international military forces during disaster in a conflict setting is problematic, as the latter often find it difficult to remain neutral and impartial. They run the risk of getting associated – rightly or wrongly – with one of the protagonist parties. NGOs are afraid that military presence leads to a ‘blurring of lines’, called by Studer (2001: 374) the ‘contagious effect’ resulting from association. This would undermine the very essence of humanitarian action (Studer, 2001: 367) and jeopardise the required unimpeded access by aid agencies to the suffering population. Operational dependence on military logistics might have a similar effect, it is argued.

In non-conflict settings, dealing with disaster is the primary responsibility of the civilian authorities, but the scope and impacts of disasters have regularly necessitated them to rely on the military. In large-scale catastrophes, local civilian authorities are often overwhelmed by the events and call upon military actors to assist by giving first aid and providing the logistics and heavy machinery required to deal with the destruction wrought by the forces of nature. Recent examples of such occasions include the earthquake in Turkey (2023) and the floods in Pakistan (2022). Nearly two decades ago hurricane Katrina (2005) in the US constituted a clear case where the disaster response failed dramatically due to a lack of coordination and preparation. The US House of Representatives bipartisan committee’s report ‘A Failure of Initiative’ outlines in detail the shortcomings in the military preparations for and response to Katrina (2006: 201–231) regarding quality, speed and effectiveness.

Though perhaps there may be no problems in principle involved in such cases of domestic support, collaboration with the military has not always been without bottlenecks. These were mostly related to differences of organisation and culture that originally were characteristic of those sectors (Frerks, 2016). Militaries were usually organised as hierarchies, with chains of command and the giving and receiving of orders. Most civilian organisations, and NGOs in particular, were organised horizontally with empowered, independent and self-reliant employees.

Such differences could easily result in institutional incompatibility. Several studies have been devoted to the differences of organisation and culture that beset civil-military relations. Military felt that NGOs were less predictable as they did not have a single command and clear lines of operation (Borgomano-Loup, 2007: 36) and NGOs were also perceived to be ideologically hostile to the military which inhibited effective collaboration (Frerks et al., 2006: 56–64 and 87–96). NGOs, on the other hand, often felt that the military lacked a nuanced understanding of local realities, and acted in a top-down, heavy-handed and culturally insensitive manner. They also considered them largely ineffective and expensive.

However, the field has seen rapid change and development over the last two decades, partly due to more intensive joint learning, preparation, training and collaboration during actions in the field. The emergence of integrated or comprehensive approaches in the Netherlands and internationally has promoted institutionalised forms of interaction and cooperation and much of the original mutual unease and unfamiliarity between civilian and military actors has disappeared. Such efforts need to be sustained in the future, as otherwise old unproductive patterns of distrust and unfamiliarity may reappear.

2.3 Implications for Climate Change and Climate Security

How can we situate the issue of climate change and climate security in the context of those developments and paradigmatic shifts in disaster studies as outlined above? In this connection I would like to highlight seven themes that are discussed in subsequent sections below before arriving at a conclusion.

2.3.1 The anthropogenic nature of climate change

As with disaster in general, climate change-induced disaster is also a product of political, social and economic factors and resulting vulnerabilities. It is therefore a man-made product or construction and part of what nowadays is fashionably called the Anthropocene, the geological period during which human activity has been the dominant influence on climate and the environment. Climate change therefore also needs man-made solutions and interventions to be resolved. Here, all approaches outlined above for disaster studies, namely the technological and managerial, vulnerability, agential and resilience and co-governance approaches need to be mobilised in a well-balanced collaboration to execute parts of the required efforts to prevent, reduce, mitigate and adapt to climate change. In fact, only the expeditious combination of all those efforts and approaches in a ‘whole-of-society’ approach will suffice to deal with the increasingly dangerous threat of climate change and climate change-induced disaster. Whereas many, if not most, conventional disasters had a fairly limited impact in locale and time, climate-change induced disaster impacts are global and chronic, even though such impacts show some differentiation. This requires mobilisation of resources on a global scale to deal with it, which will demand massive political will and a struggle against vested interests as shown below under the fifth theme.

Though the anthropogenic standpoint with regard to the origin of climate is scientifically widely accepted, it is much more controversial in a political, economic and cultural sense. As discussed above, significant sections of the population do not share or believe this point of view. Many consider climate change as an act of nature or see it as a hoax. They may be actively influenced by politicians, influencers, lobby groups, social media, denialists etc. who often have vested interests to deny and oppose the anthropogenic view on climate change.

2.3.2 Centring vulnerability, inequities and injustice

Like with disaster in general, climate change is not ‘honest’ or ‘fair’. It disproportionally hits the poorest countries, populations, groups and individuals. This is clearly analysed in the IPCC’s assessment reports. It is also easy to understand why this is the case. Poor countries, communities and persons lack the resources, knowledge and capacities to deal with threats and their socio-economic position and lack of resources make them vulnerable to disaster impact. Very often, these conditions have forced them to live in marginal and dangerous places that lack infrastructures to protect them. Tackling those vulnerabilities is one of the most effective and efficient ways to reduce disaster impact, as evidence from years of development assistance has shown. This also helps reduce prevailing societal inequities and injustices.

2.3.3 Investing in people’s coping capacities and resilience

As argued above, strengthening local capacities and resilience is a promising pathway to reduce vulnerability, dependency and passivity and raise capabilities to withstand climate change impacts. On the other hand, such an endeavour must not imply the cynical shifting of burdens from the state and society at large to those segments of society that are least capable of carrying them. There needs to be a solid mechanism to reign in such neoliberal impulses and to achieve acceptable levels of equity and fairness. Otherwise, promoting local coping and resilience simply amounts to a degenerative cycle that disadvantages the poor as they are left alone with negative impacts without the resources to tackle them.

2.3.4 The lost opportunity of prevention?

Disaster policy has emphasised incessantly the need for prevention as shown in the IDNDR and ISDR action plans and frameworks and the SDGs. Preventative action has been shown not only to be effective, but also much cheaper than reactive disaster responses. One could argue that in the case of climate change, preventive action is already 'much too little' and 'much too late'. However, one can take inspiration of late UN Secretary-General Kofi Annan's call to establish a 'culture of prevention' and the idea that a preventative mind-set can be applied, before, during and after disaster in order to be prepared for a next round of calamity. This seems to be perfectly applicable to climate change-induced disaster with its chronic nature instead of considering prevention a lost opportunity.

2.3.5 The struggle against established interests

Even though climate change is affecting nearly everyone – though to very different degrees – it has to be understood that the status quo does not only generate losers, but also many actors have a vested interest in the continuation of that status quo. This applies obviously to oil producing countries, oil firms, the energy sector that uses fossil fuels, the automotive industry and many other sectors that heavily depend on fossil fuels such as horticulture. But also sectors that emit GHG such as agriculture, aviation and shipping need to undergo drastic and expensive adjustments. This may even apply to individual households when fossil fuels are phased out. As outlined above, many of these sectors tend to delay or frustrate attempts to decarbonise their sectors and lobby against the necessary policies. Though some of these may be seduced by subsidies or frightened by taxes and sanctions, it will not be easy to muster their support for the necessary reforms. On the other hand, some may also be convinced that innovative technologies may give them an edge in what they believe will be a future market with great potential. This situation requires subtle and diplomatic manoeuvring in order to muster the necessary widespread support that climate-sensitive action needs. In this connection, one may derive some hope from the results of the Dubai 2023 COP28.

2.3.6 The need for co-governance and people's power

Due to the all-encompassing nature of climate change and the overall impact of required climate-related policies, all relevant actors at all levels need to engage. The Dutch example of setting up 'climate tables' with all relevant actors on board is a good example to do so. This also applies to international consultations and summits. The COP28 hosted a lot of actors varying from international organisations to government representatives, NGOs and the corporate sector. This is in line with the notion of multistakeholder or co-governance that is already attempted in conventional disaster reduction practice. We also see currently a level of more radical activism, such as Extinction Rebellion that demands drastic measures and is not afraid to seek the boundaries of the law in its proclaimed search for climate justice.

2.3.7 The role for the military

The role of the military in climate-related disaster is most obvious when its assistance is sought to help with Humanitarian Assistance and Disaster Relief (HADR) and through Military Aid to Civilian Authorities (MACA) deployments. This is always based on a request by the respective civilian authorities. Experiences in this field have been mixed. Whereas the military can provide the necessary capabilities and equipment for disaster response, this has not always been done in a manner that fits the situation and is sensitive to the role of other actors involved. When disaster hits in situations of conflict or war, the situation is compounded by the conflict dynamics and antagonisms involved. Pre-disaster familiarisation and joint training can help address these challenges. Experience has shown that significant improvement can be made if this is done systematically as for example in the context of the comprehensive or integrated approaches or training as witnessed in the Common Effort exercises by the German Netherlands Corps. Next to this the military can contribute by reducing its own footprint and future-proof its operations as elucidated in other chapters in this volume.

2.4 Conclusion

Disaster Studies has developed over more than half a century into an applied field that has seen several paradigmatic shifts that complement each other and signify the evolving insights in disaster causation and reduction. This chapter has provided an overview of the challenges of climate change and resulting disasters, followed by a description of the most salient paradigmatic shifts in disaster studies. It was shown that these showed striking parallels with and relevance to the current problem of climate change and the disasters that it engenders. As a whole, the approaches in the field of disaster studies were applicable to climate change as well, though the seriousness, scope and scale of the latter may supersede those of conventional disaster, as climate change is a global and chronic condition in contrast to most conventional disasters that strike in only limited areas and time frames. Also, the obstacles that climate-related policies face are more momentous that those in the conventional disaster domain. Conventional disaster is typically called a solidarity disaster, where the public is able to sympathise with those affected and prepared to help out. In contrast, this is much less so in the case of climate change. In the first place there are the vested interests that mitigate against climate policies and the massive costs involved. Second, there is the phenomenon of denialism that affects the perceived necessity of remedial action and the preparedness to invest. Yet, taking the lessons learned from disaster studies on board may ultimately result in more effective and efficient climate action.

Notes

1 This chapter comprises partly an abridged compilation of the author's previous work on disasters and disaster management (references added).
2 See: https://www.ipcc.ch/report/ar6/wg1/#FullReport, accessed 29-08-2023.
3 See: https://www.ipcc.ch/report/ar6/syr/.
4 SPM 2023: 10–11.
5 Source: https://www.britannica.com/topic/flood-myth, accessed on 25-08-2023.
6 https://www.trouw.nl/nieuws/watersnood-was-een-straf-van-god~b00ca8dc/?referrer=https://www.google.com/.
7 Source: After the Fires, Native Hawaiians Seek Revival Through Ritual, *New York Times*, August 25, 2023.
8 See for the link between disaster and ritual: Hoondert et al. 2021.
9 Parts of this section are abbreviated and adjusted selections from: Frerks & Hilhorst 2021.
10 This section is derived from Frerks & Hilhorst (2021).

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CHAPTER 3

Defence Evolution: Climate Intelligence & Modern Militaries

Richard Nugee, Louise Selisny, Tristan Burwell, and Tim Clack

Abstract
Intelligence creates the foundation for successful strategic combat. Climate Intelligence is the next stage in 'Defence Evolution'; underpinning modern warfare in a climate changed world where the physical environment is at once a shaping threat, a threat multiplier, and a direct threat itself. This article provides an overview of climate intelligence and its potential applications for military engagement with the climate and security agenda. The article highlights the potential scope and methodology for additional military taskings to support data collection as well as the integration of climate intelligence capabilities across defence and beyond. Key areas of focus include widening the breadth of indicators routinely reported on, the methodology required to facilitate enhanced military taskings, as well as increasing collaboration with academic institutions in order to enhance climate security forecasting and predictive analysis.

Keywords: Intelligence, warfare, climate change, military, security

In The Art of War, Sun Tzu stated that foreknowledge enables "the wise sovereign and the good general to strike and conquer, and achieve things beyond the reach of ordinary men." And so, for 2,500 years, it has been recognised that intelligence creates the foundation for successful strategy. However, in terms of success over the long term, as noted by Charles Darwin, it is not the strongest of the species that survives, nor the most intelligent, but the one most responsive to change. Defence must be appropriate and adaptive – responsive to all elements of the contemporary operating environment. Climate Intelligence is the next stage in Defence Evolution; sustaining successful strategy and operations in a climate changed world.

Numerous peer reviewed studies demonstrate that climate has changed over time, and that these changes are having profound effects on human society. By 2050, as many as 3.4 billion people will be facing catastrophic ecological threats, with the potential for up to 1.2 billion climate refugees (McAlister, 2023). In our complex and interconnected international system, global impacts are felt locally. The Institute for Economics and Peace highlights that 27 countries already "face catastrophic ecological threats, while also having the lowest levels of societal resilience. These countries are home to 768 million people…the cyclic relationship between ecological degradation, societal resilience and conflict cannot be overemphasised…The total population of the 40 least peaceful countries is projected to increase by 1.3 billion by 2050, representing 49.5% of the world's population. These countries also face the worst ecological threats" (The Institute for Economics and Peace 2022: 2 and 3).

Most alarming today is the speed at which these changes and threats are accelerating. Never before in human history has the climate, environment, and weather changed its characteristics so rapidly. Unpredictable cascades and tipping points with potentially catastrophic consequences for humanity, necessitate an urgent and comprehensive security response. It is imperative that defence organisations are able to understand and predict both current and future trends in order to fulfil their purposes of protecting populations, mitigating conflict, and safeguarding prosperity. This chapter will demonstrate, from a UK perspective, that Climate Intelligence supports overall Defence mission aims and objectives as articulated in the Sustainable Support Strategy (Strategic Command Defence Support 2022), the Climate Change and Sustainability Strategic Approach (Ministry of Defence, 2021a), and the Integrated Operating Concept (Ministry of Defence (2021b), as well as key international legislation such as UN Security Council Resolution 1325 (on Women, Peace, and Security) and additional UN concepts such as Human Security.

This chapter offers a number of examples of where, largely based on UK experience from personal observation, interviews with UK deployed personnel and through a study of relevant literature, Climate Intelligence through the use of deployed troops could improve or enhance understanding of local areas particularly vulnerable to climate change and therefore susceptible to tension and conflict. By developing the concept of Climate Intelligence, where the troops contribute to the understanding of the effects of climate change, the increased ability to understand the causes of conflict and other malign outcomes such as displacement, will lead to enhanced security, better prepared peace-keeping forces and improved action to tackle the security consequences of climate change. Inevitably, in a chapter that is laying out the potential opportunities for such a tool, some examples will be more realisable than others. While at this stage we do not wish to state which is more likely, inevitably within a military context, those ideas and opportunities that are within the control of the military will be easier to deliver.

3.1 Key Concerns and Causation

From the High North, through Europe, across the Sahel and the Horn of Africa, the concept of climate and security is becoming an increasingly prominent issue. As the consequences of a warming world become more obvious, with unprecedented droughts, fires, floods, and storms, the role of the military is becoming clearer. Militaries are being deployed more often to assist with climate disaster relief, both domestically and internationally. *A growing body of evidence demonstrates that extreme weather is exacerbating the drivers of conflict. Enhancing understanding of the climate-security nexus will facilitate proactive, coordinated, and sufficiently resourced adaptation to climatic changes as opposed to reactive, ad hoc responses to unanticipated events.*

3.1.1 Water

Over half the world will face water scarcity by 2025 – with some 700 million people displaced by intense water scarcity by 2030 (UNICEF, n.d.). This situation will drive disputes in the coming decades as competition over this most vital of resources increases. Evidence of this is already being seen in Somalia where inter-clan conflict over water between nomadic and semi-nomadic herding groups is being intensified by repeated cycles of drought. The human security implications for vulnerable and marginalised groups will be further exacerbated as water is increasingly weaponised and commoditised by malign actors. As well as enhancing the recruitment of terrorist organisations, ongoing water scarcity undermines the perception of state legitimacy, leading to political instability and potentially armed conflict.

Water, as a vital resource for human existence, becomes an extremely sensitive issue when changes are made to its current flows: the damming of the Mekong by China has led to significant volume reductions further downstream, which has increased geopolitical tension across the South Asian region; the Great Ethiopian Renaissance Dam, by damming the Nile, has already raised geopolitical tensions between Egypt, Sudan and Ethiopia, even before it has been completed. Similarly, the predicted melting of the Arctic Sea is already raising tensions, with both Russia and NATO increasingly militarising the region with fixed bases and deployments; China declaring itself as a near-Arctic country probably does nothing to reduce tension.

3.1.2 Food

Similarly food and its potential scarcity can have significant geopolitical implications, not least in terms of production and subsequent trade. If global heating increases by 2–2.5°C, the IPCC predicts that by 2070, large parts of the world will be unable to support food production. This will drive displacement, ferment social unrest, and undermine food security globally. This situation will also drive geopolitical repositioning as allies, competitors, and aggressors attempt to secure long-term access to food. At the local level, as with water, food has the potential to be weaponised, with access used to punish resistance within communities and expose weaknesses of government / other external agencies. 'Violent Extremist Organisations' (VEOs) will disrupt and divert aid distribution to gain power and control, as well as influence 'hearts and minds', threatening even some of the more secure governments in affected regions.

3.1.3 Energy

The transition to renewables presents security challenges in terms of maintaining adequate energy supply and creating an alternative energy infrastructure. The rare earth elements (REE) required by the renewable energy industry are most heavily concentrated in parts of the world that are controlled or (in)directly influenced by adversaries and competitors. Further, extraction creates its own environmental damage, as well as being linked to exploitative labour practices. The price volatility of commodities can create price spikes that exacerbate existing tensions in fragile states. It is also worth noting that Russia's invasion of Ukraine vested control of major lithium, cobalt and nickel deposits. Moreover, the Russian state proxy, 'Wagner Group,' is dominating terrain across Africa with a view to exerting control over known deposits and mining concessions (Cohen, 2022). But even above the practicalities of moving to renewables, there are two features that make this infinitely more difficult, and potentially more geopolitically stressful than any other energy transition in the past. The first is the fact that we are, for the first time, trying to replace a fuel source – fossil fuels – not just add another. This has never been tried before (we still use the original source of fuel, wood, in many parts of the world) and will inevitably lead to winners and losers on a global scale. Those who have most to lose, whose economies depend on exporting fossil fuels, have the potential to become flashpoints of civil and political unrest. The second is the speed at which the world is trying to divest itself of fossil fuels. Compared to the introduction of fossil fuels, the most efficient fuel that exists, we are trying to replace them at a rate twice as fast as it took for oil to become entrenched as the fuel of choice. This is going to lead to extraordinary tension, and does not allow enough time for oil producers to diversify, to find alternative sources of income, with the resultant potential downturn in their economies.

3.1.4 Migration

The UN Secretary General, António Guterres, warned of a climate-related 'mass exodus' of 'biblical scale' – forecasting over 1 billion climate migrants by 2050 (Carrington, 2022). Given how politically divisive migration is in many countries, there is the potential for strategic shock. Both traditional conflict and climate change directly result in the forced displacement of vulnerable people. Peoples displaced by traditional conflict, even if they lose most or all of their livelihood in the conflict itself, usually have a very strong desire to return 'home', as soon as it is safe to do so, in order to rebuild their lives in their native country. Those displaced by climate change, however, are more likely to leave only when their financial and subsistence resources have been exhausted, and will not have the ability to leave behind any of their family as surety or guarantee of the safety of their home. Further, they will more than likely have no 'home' that is sustainable for them to go back to. As a result, those displaced by climate change are even more vulnerable to disputes and instability instigated and exacerbated by malign actors. As such, optimal solutions need to address the drivers of migration at source. Supporting and investing in upstream capacity building and resilience programmes that reduce conflict, preserve environments, and provide sustainable economic and subsistence prospects should be prioritised. Addressing the shortfalls in the current distribution of global climate finance is central to this topic. With $600B spent on climate finance between 2019–20, only around one-third of the global finance target was reached, and just 10% of this went towards climate adaptation. Reducing this shortfall in spending is crucial as climate adaptation will provide the resiliency needed to allow would-be migrants to remain in their places of origin and not be forcibly displaced by climatic shocks.

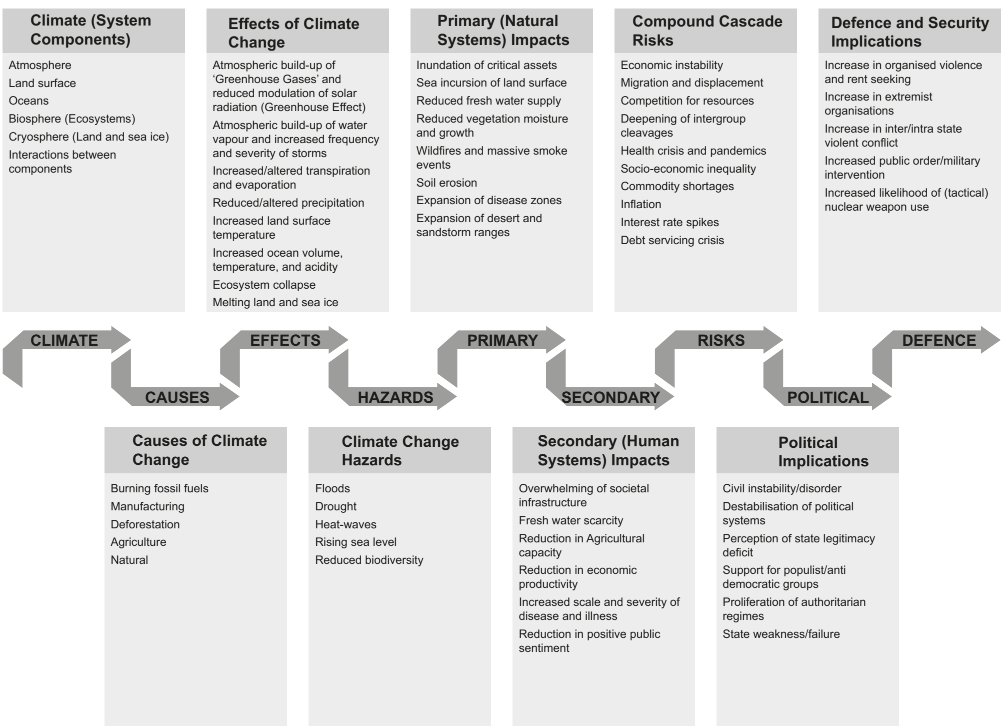
3.1.5 Military capacity

Without sufficient civilian capacity building, Humanitarian and Disaster Relief (HADR) and Military Aid to Civilian Authorities (MACA) deployments will increase (Retter et al., 2021). In response to domestic emergencies in the UK for example, in recent years the military has been mobilised to support relief efforts following floods, droughts, and disease. As global temperatures rise, climate change hazards will increase in scale, frequency and intensity. Unless civilian capabilities are enhanced, military resources are likely to become increasingly committed to assist with 'emergency' responses. The result potentially could be a Force less well trained in their primary role – the protection of citizens. Militaries must not risk diminishing the pool of specialised equipment and trained personnel that provides military capability.

3.1.6 Political and security implications

As summarised in the chain of causation below, there are a number of possible non-linear pathways that lead from climate change hazards and impacts to political and security implications. The 'compound cascade risks' are indicative of the innumerable and complex myriad of risks that are increased and amplified by climate change.

Figure 3.1. The chain of causation for political and security implications of climate change, credit: Louise Selisny.



3.2 Climate Intelligence in Context

Designed as a tool to manage risk, Climate Intelligence has the potential to provide historic, current, and predictive information on natural (primary) and human (secondary) systems, thereby facilitating informed decision-making for climate security mitigation and adaptation. Its genesis has been driven by advances in artificial intelligence, machine learning, and the acceleration in the processing time for climate data. This synthesis has the potential to create an enhanced understanding of climate hazards and impacts, as well as their implications for security at local, national, and regional levels.

As well as supporting military operations, Climate Intelligence also provides data that can be used by academics, civil society, and policymakers to examine the interactive drivers of conflict within the context of climate change. If harnessed correctly, Climate Intelligence holds a powerful capacity to understand and thereby address tactical to strategic level climate risks. It is only with this deeper understanding that some of the world's most vulnerable communities will be able to clearly address the consequences of climate change.

In 2022, Nugee et al. outlined the potential for an enhanced UK military offering in relation to Climate Intelligence, with a focus on widening the breadth of indicators reported on, as well as increasing collaboration with academic institutions in order to enhance climate security forecasting and predictive analysis. Moreover in 2023 Erin Sikorsky outlined other areas where intelligence on climate could be usefully collected and incorporated into existing NATO intelligence programmes. These include: integrating climate and environmental change data into analysis; evaluating and developing climate security risk assessment frameworks; and refining climate security intelligence education for member nations and their intelligencers (Sikorsky, 2023). Selisny et al. (in Press) develop the concept further and incorporate collaboration with the British Army's Long Range Reconnaissance Group (LRRG) deployed to support the United Nations Multidimensional Integrated Stabilisation Mission in Mali (MINUSMA).

Military responses are often reactive, deployed to stabilise (potential) insecurity and end conflict. A full analysis of the need to transition to a hybrid 'peacebuilding methodology' is beyond the scope of this chapter; however, the necessity of adaptation to a forecasted operating environment remains central to mainstream military planning. Sustainability, operating in harsher conditions, and responding to the impacts of climate change through activities such as Humanitarian Assistance and Disaster Relief (HADR), Military Aid to Civil Authorities (MACA), and augmenting military estates are commonly cited as ways in which Defence will have to adapt.

Climate Intelligence would be an additional resource in this battle. With the intersection of parts of the world that are much more vulnerable to the effects of a warming world, and the lack of strong governance, economy and politics, often in areas already overpopulated or under resourced, it is possible to predict broadly where climate change is likely to have the greatest humanitarian impact. And from that, it is possible to look at some form of support, in order to avoid conflict, either through bolstering governance, the economy or supporting adaptation for the authorities, who may lack the capacity to address climate-related threats.

For the UK, the 2021 UK Defence Command Paper (Ministry of Defence, 2021c) provided the foundation for this pre-emptive action and expressed an intent for the UK to become a world leader in responding to threats exacerbated by climate change. As well as setting out a strategic vision to confront climate threats, this paper also speaks of the need to build resilience to more extreme weather conditions, mitigate the impact of Defence's carbon footprint, and seize opportunities to improve sustainability. In doing so it addresses the Ministry of Defence's 'Climate Change and Sustainability Strategic Approach' which highlighted that Defence accounts for 50% of the UK central government's emissions and prescribed the identification of products, practices and behaviours that are more climate aware, environmentally sound, and work towards reducing emissions (Ministry of Defence, 2021a).

3.3 Climate Intelligence as a Military Offering

Climate change is a shaping threat and a threat multiplier, as well as a direct threat. Climate Intelligence informs the multifaceted understanding of the drivers and catalysts of climate conflict, as well as changes to operating environments. Climate Intelligence also provides the necessary nuance for understanding that climate impacts vary between groups and individuals, by gender, ethnicity, poverty, unequal social and political power, and other processes of exclusion and marginalisation. It is not covert in a traditional intelligence sense; it is about providing policymakers with decision advantages to influence events which requires access to a vast database of information.

When Land Forces deploy internationally, their reach and risk thresholds facilitate penetration beyond civilian capabilities. In collaboration with domestic and international academic institutions, Climate Intelligence sourced by military stakeholders and units could greatly enhance climate security forecasting and predictive analysis. In this context, the impact of military data collection should not be underestimated. Militaries have the capacity to maintain operational effectiveness in the fragile environments where the impacts of climate change are most acute, and they therefore offer a capability to collect data in areas inaccessible to civilian counterparts.

By exploiting this inherent reach and flexibility, the military could be in the vanguard of a more considered and holistic approach to climate security. In this context, the military would play a vital role in enhancing the understanding of some of the world's most fragile and climate impacted communities. Given the increasing awareness of the climate-security nexus, the collection of this data can be used to identify 'targets' for necessary engagement and resources, thus mitigating the security risks posed by climate variation and change. The collection, collation, storage, and analysis of climate data would establish a baseline to facilitate coherent and ongoing analysis and the targeting of these relevant resources.

This is particularly significant because climate change increases the requirement to integrate planning across in-theatre military, police, and civilian actors. Information sharing could enhance this necessary cooperation with non-traditional bodies such as existing civilian climate databases and non-state actors such as Non-Governmental Organisations. This would create a vital link between threat analysis and decision analysis, thus maximising prospects to support stabilisation, mitigate threats, and strengthen connections between in-field activity and headquarters' deliberation.

This information flow would support serving soldiers with immediate effect and military procurement in the long term. Selisny et al. (in press) highlight specific observations that include how lack of local climate data compromised effective operational and tactical decision making, and how Climate Intelligence would develop a broader understanding of seasonal dynamics and water / food security. In addition, increased temperatures exhaust soldiers on patrol more quickly, requiring a re-evaluation of expectations for tactical level engagement in terms of distance, duration, and tasking. From personal experience it is obvious that operations in climate change-impacted environments amplify the requirement for specialist kit that is designed specifically for temperature and weather extremes.

Integrating Climate Intelligence into military intelligence collection plans is about enhancing predictive analysis and advance warning for climate risks. By default, it complements the Global Britain in a Competitive Age: the Integrated Review of Security, Defence, Development and Foreign Policy (Cabinet Office, 2021) and the subsequent March 2021 Command Paper's vision of a persistent and proactive global engagement that increases understanding and pre-empts threats to UK national security and economic interests (Ministry of Defence, 2021c). The paper states that the UK military must remain "persistently engaged globally" and regain a pro-active stance, in acknowledgement that the UK's "approach to warfare has evolved relatively slowly in recent years, while our adversaries have invested in equipment and forces that expose our vulnerabilities". The paper goes on to direct a focus for the UK that will see it emerging as a global leader in climate change security.

Climate Intelligence could also be used to inform wargame development and future / foresight strategic planning. The UK Ministry of Defence's 'Global Strategic

Trends: The Future Starts Today' (6th Edition) is heavily focused on "increasing environmental stress", with a dedicated thematic overview and cross-cutting geographical specifics. It considers "increasing disruption and cost of climate change" to be a 'high impact – high certainty' trend. It predicts that climate change hazards will disrupt trade, reduce biodiversity, increase migration and that, "if not handled effectively" could lead to increased tension and conflict (Ministry of Defence, 2018). Climate Intelligence could inform analyses and subsequent military doctrine by supporting reliable baseline and ongoing assessments. This will allow the military to be both readily responsive and presciently proactive.

Climate Intelligence could also be used to inform research and development. The report, 'Decarbonized Defense: The Need for Clean Military Power in the Age of Climate Change' by the International Military Council on Climate Security underscored the need for governments around the world to reduce carbon emissions within their militaries. The report highlights technological advances such as heat pumps, electric vehicles, and solar panels in bases at home and abroad, as well as the logistics of decarbonising fighter jets, tanks, and warships whilst maintaining operational readiness and national security (Expert Group of the International Military Council on Climate and Security, 2022). Within this context, Climate Intelligence could play a vital role in supporting relevant technology and military procurement.

3.4 How Could Climate Intelligence be Integrated into Mainstream Tactics, Techniques, and Procedures?

The Intergovernmental Panel on Climate Change (IPCC) provides a repository of socioeconomic information that offers a consistent framework of factors that can be applied in climate change impact assessments. The collection of this data was conducted at the macro (global – aggregate regional) level. Arguably, micro (granular – local) level research would improve information on population estimates, economic conditions, land use, water access, agricultural activity, and biodiversity. Engagement with local stakeholders and the observation of local assets would generate a useful bank of data and information.

Human Terrain Reconnaissance (HTR) requires specialist training to develop skillsets (rapport building) and mindsets (desire to understand) to enhance effectiveness. This has implications for pre-deployment training (PDT) and decisions around the selection of deployed soldiers. This PDT should include coverage of climate change threats, including how impacts become drivers of conflict at the local level. The benefits of equipping soldiers with this knowledge are twofold and mutually beneficial. First, it provides understanding of the evolving character of conflict and warfare – an aspect that all those involved in Defence should be cognisant of. Second, by developing a holistic approach within our forces, those on the frontline and operating in global peripheries are best armed with an awareness of the data that is needed to provide insight into the role that climate change is having on the operating environment. This should include a focus on second and third order effects so that our soldiers can be part of the analytical process that considers the impact of climatic variables. Given the disproportionate role that climate-threats have on women and girls, female engagement offers significant potential to understand dimensions of the battlespace, human terrain, and the impacts of climate change on security. The training and deployment of female engagement personnel should be prioritised in climate change impacted theatres and form a core part of HTR.

Climate Intelligence could utilise sensor data collection to provide hyper-localised insights. The collation of specific environmental data over time is vital for forecasting. Drought and flood forecasting has been improved by using sub-seasonal diagnostics with high resolution topography to better understand the role of low-level jets (fast flowing ribbons of air in the atmosphere). Similarly, sub-basin scale seasonal forecasting has been enhanced where global teleconnections (relationships between geographically distant weather phenomena) have been referenced alongside surface sea temperatures.

Climate Intelligence, and by default therefore an intelligence gathering of the environmental conditions in a given area, could also support local access to water by the mapping of perennial watercourses as well as the numbers and levels of wells. It could monitor the rate of bush encroachment, scale of wildfires, and the salinity of groundwater. A focus on internal migration and rangeland mobility would also provide important data sets for resource allocation and decision-making in relation to emerging / shifting power dynamics, marginalisation, and inclusion. Such data could be used by academics, civil society, and policymakers to examine the drivers of conflict within the context of climate change, as well as equip troops to maintain peace more effectively.

In the same way, investigation into loss of livelihoods due to environmental degradation and extreme weather, as well as food insecurity and its secondary impact on social tensions, would increase and inform contextual understanding. Thus the understanding of how this impacts public sentiment and the legitimacy / strength of governance would add huge significance for managing climate-related security risks. In addition, local and regional techniques for combatting the effects of climate change could be gathered for wider use. In the context of a horizon scanning, knowledge of local capacity to adapt to wider climatic stresses becomes a core part of conflict forecasting and mitigation.

As an example, indigenous centric case studies such as those examined by Ritu Bharadwaj and Clare Shakya (2021) in their article on loss and damage, and subsequent socio-economic insecurity, caused by climate change, are useful reference points. The distinction between the oft referenced 'mitigation and adaption' is that loss and damage relates to the impacts of anthropogenic climate change that exceed the capacity to mitigate or adapt. The work of Bharadwaj and Shakya brings together urgent case studies that include climate-vulnerable developing countries such as Bangladesh, Tuvalu, and Vanuatu with a view to illustrating the additional support required to achieve sustainable development.

To achieve the necessary level of granularity across socio-political themes that are atypical to routine intelligence collection, the concept of augmenting forces with genuine expertise should be considered. Just as 'Cultural Advisors' are embedded within military units to enhance situational awareness, attaching 'Climate Advisors' who could analyse local climate-impacted economic and political dynamics would increase operational effectiveness and allow Defence to offer a valued contribution to upstream conflict prevention. Minor adjustments could have a major impact. Initial briefings, for example, could be tailored to include climate impacts as part of the understanding of the operating environment from an environmental and threat perspective.

In this way, Climate Intelligence also enshrines the concept of 'Human Security,' as utilised by a number of Western militaries, including the UK and the US. Human Security is also used by the United Nations Intergovernmental Panel on Climate Change (IPCC) in order to integrate relevant socio-economic and development factors into climate change security considerations. The 'Human Security Approach' of the UN presents five fundamental principles that should steer decision making. Security considerations should be: people-centred; comprehensive; context-specific; prevention-orientated; and facilitate protection and empowerment (Adger et al., 2014). Climate Intelligence would support these key principles.

The ability of military sources to provide the ground truth, cross reference satellite imagery, and provide mapping in the absence of satellite data is invaluable. A commonly cited result of climate-related insecurity is conflict between farmers and herders over diminishing arable and pastoral land. Analysis conducted by Mercy Corps in Mali used geo-coded Armed Conflict Location and Event Data Project (ACLED) data that mapped the distribution of conflict across the country and then overlaid it with several different environmentally linked factors, including transhumance patterns. A wider network on the ground, with the skillset and reach to operate in volatile areas would greatly enhance future offerings. Military assets could add value by fact-checking satellite data to ensure that it still represents the ground truth at the time an incident takes place. Military assets could also, by default of their reach, form part of a predictive response to anticipated farmer-herder conflict and deploy to interdict groups assessed as being at risk of exhibiting violence. Filling high resolution satellite imagery gaps to enable detailed conflict analysis would also add value. Reconnaissance units could be engaged to provide real time information on vegetation health, land use, and water source capacity. This small vignette provides a thought-provoking example of how militaries could be better utilised in climate-insecure contexts.

Military assets also have the ability to conduct human terrain mapping which could help with the identification of specific transhumance routes and forced displacement. Furthermore, through their own networks and assets they may be aware of conflict incidents that go undetected on ACLED but are logged on their own systems, such as the Tactical Ground Reporting System (TIGR) (General Dynamics, n.d.). Such data could be overlaid with other data sources to enrich climate security analysis. Such assessments could include how climate-induced scarcity escalates sectarian violence, shapes sentiment towards government, drives civil unrest, and exacerbates displacement (internal and cross-border); the economic implications of climate change on an area of operations, including issues of capital flight, re-configuration of supply and demand, health shocks, out-migration of skills and labour, and foreign food aid undermining local markets; and failure to deliver on commitments on climate change mitigation, such as the distribution of food aid and completion of water access projects, all of which significantly reduce positive sentiment towards military and government actors.

Climate change insecurity disproportionately impacts women, particularly those subject to additional vulnerabilities. Understanding the local Climate Intelligence picture would support the Women, Peace and Security (WPS) Agenda. A number of case studies highlight how climate change insecurity exacerbates 'gender-based violence' (GBV) (see Gevers, Tmusuya and Bukuluki, 2019, Castañeda Carney et al., 2020, UN Women Asia and the Pacific, 2015, UN Women, 2009, UN Women, 2016). For example, water scarcity can increase the frequency and distances women and girls travel to access water supplies. This makes them more vulnerable to sexual assault and also results in girls missing days from school or being withdrawn completely in order to assist with increasingly protracted household chores. Case studies have also highlighted examples of girls being traded for resources during times of peak scarcity, thereby increasing their vulnerability to sexual exploitation and trafficking. Girls are also married off at increasingly younger ages in order to pass the burden of provision from the parents to the husband's family.

Climate Intelligence would reinforce international commitments to the WPS Agenda and, specifically, UN Security Council Resolution 1325 and additional UN Security Council Resolutions on Women, Peace, and Security. In 2019, the UK MOD adopted the statement of policy 'Joint Service Publication 1325 Human Security in Military Operations' which formalised the implementation of the UN Security Council Resolution 1325 and additional UN Security Council Resolutions on Women, Peace, and Security. The then UK Secretary of State for Defence, Gavin Williamson, stated that "the implementation of the UNSCR 1325 will spark a deeper analysis, broader plans, and more effective operations. By ignoring this area, or viewing it as a humanitarian agenda, we are missing the clear link between the security of an individual and an enduring stability for all…this policy is to be implemented throughout the Department of State, from the strategic planning process through to the activity we perform at the operational and tactical levels." Again, Climate Intelligence could be used to operationalise policy and political commitments.

Climate Intelligence could also be used to support and inform context-sensitive decision making regarding infrastructural investment into renewables, for example, geothermal, solar, and wind. It could also be used to support infrastructure resourcing and decision making in relation to sustainable military estates (Deloitte, n.d.) and Forward Operating Bases (Jivnani & Kang, 2021).

3.5 The Essential Element: Strength in Unity

In order to develop military understanding of the complex and nonlinear relationship between climate change and conflict, it is important that Climate Intelligence is not siloed from wider government and scientific expertise. Climate change will continue to compromise both military and civil capacity unless new forms of integration across military, humanitarian, development, and climate change intervention are established. Climate security requires collaboration with government departments beyond Defence, as well as with international allies and civil society stakeholders in order to produce effective and coherent responses. Climate Intelligence would build foundations, pillars, and networks for this necessary integration and collaboration. In this context in the UK, the optimal structure is one that amplifies the 2018 National Security and Capability Review's Fusion Doctrine, as well as the vision of the Integrated Review to genuinely integrate and interface UK national assets, thereby allowing climate security to be tackled collaboratively.

Arguably, this vision should be grander and drive national defence organisations to coordinate with international organisations such as the United Nations Environment Programme's *Strata* platform that seeks to 'democratize environmental and climate security intelligence by making analytical capacity available to practitioners and policy-makers'. *Strata* works by overlaying environmental and climate indicators, socio-economic indicators, and indicators related to conflict and crisis, in order to identify potential conflict flashpoints. As with other early warning platforms, its utility is based on the quality and strength of its components; Climate Intelligence offers a valuable input. Another potential partner is the International Organization for Migration's Transhumance Tracking Tool (TTT) which monitors transhumance routes and provides early warning of potential conflicts that may arise due to food and water insecurity or the movement of rival groups into contested territories.

Similarly, NATO is set to continue its ambitious programme of climate security deliverables, with enhanced climate impact assessments, forecasting, and exercises. The UK has much to offer the Alliance with direct contributions to the NATO work strands of Allied Command Transformation (ACT), Emerging Security Challenges Division (ESCD), and the Climate and Security Centre of Excellence (CASCOE).

Sharing Climate Intelligence would enhance this international offering and would enhance the (in)direct benefit to national interests at home and abroad. Collaboration with such platforms, and sharing of intelligence amongst wider databases would also strengthen the (inter)national policy decisions made to strengthen our collective defence against climate insecurity.

In order to better understand the drivers of climate conflict, reinforcing this kind of positive engagement with civil actors, including academia and Non-Governmental Organisations, is essential. As well as Climate Intelligence, militaries could share broader climate security best practice, insights and innovations. Experts would be able to constructively challenge prospective responses, as well as steer in terms of focus. Specialists could also assist in the development of relevant curricula and exercises that could be disseminated through military academies, units, and workshops. Sharing information and insights as widely as possible would ensure that resources are utilised effectively. Such collaboration would create a strong foundation for strategic horizon scanning and risk mapping, thereby forming a central part of climate change adaptation within the military and across government.

3.6 Conclusion

The crucible of climate change has forged an inextricable link between environmental hazards and modern warfare. For example, currently, 26 out of the 54 African countries which are highly vulnerable to climate change are considered fragile or extremely fragile. Out of the ten most vulnerable countries to climate change, eight are in Africa, and six are currently facing armed conflict. Climate and environmental change are never the sole causes of conflict and migration; instead, they interact in complex and context-dependent ways. However, people living in conflict-prone settings are highly vulnerable to climate change[1]. Whilst accepting that climate change is rarely the sole cause of conflict – the intersections are far more numerous than that – Climate Intelligence is the next stage of Defence Evolution, an effective and conflict-sensitive adaptation that enables strategic planning and enhances tactical responses. Climate Intelligence also sets the foundation for constructive collaboration across the academic, humanitarian, and corporate sectors; and across the defence, diplomacy and development organs of state. With minor adjustments, it is our view that the UK military has the opportunity to take the lead in developing this offering. This offering would enhance both civilian and military capabilities, thereby strengthening our collective climate defence and security.

Notes

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CHAPTER 4

Does a Warming Climate Heat up the Small Arms Market?

Jeroen Klomp and Esmee de Bruin

Abstract

This study explores whether major droughts caused by a lack of rainfall or extraordinary evaporation affect the local small arms prices. The starting point of this relationship is that widespread evidence suggests that the negative societal consequences of climate change increase the likelihood of an armed conflict. However, it is possible that the parties that are involved in these climate change induced conflicts anticipate the higher conflict risk in the wake of a climatic event by strengthening their armed capabilities. As a result, the demand for small arms will increase in the aftermath of a climatic event. This increase in demand is, in turn, likely to be translated into higher local prices paid for small arms. The findings presented throughout this study support this idea but only for fragile countries, as these countries suffer more from weak governance and threats to national security.

Keywords: small arms prices; climate change; conflict

4.1 Introduction

The long-term consequences of climate change, such as rising sea levels, extreme weather events, and the increasing frequency and intensity of droughts, are identified as one of the major global security challenges of the twenty-first century (IPCC, 2023). Especially developing countries face increasing pressure on their societal structures due to climate change. Climate change is often seen as a factor that intensifies already existing tensions within or between societies and which could, if left unchecked, escalate into a widespread violent conflict. This urgency makes the possible relationship between climate change and armed conflict a popular topic on the agenda of academic scholars, policymakers, and politicians. In the past decade, a large and still growing body of research has tried to explain the nexus between climate change and the outbreak or duration of violent conflict (see, for instance, Buhaug, 2016; 2015, Buhaug et al., 2008; Hsiang et al., 2011; Hsiang et al., 2013, 2014; Adger et al., 2014; Bernauer et al., 2012; Gleditsch, 2012; Hendrix and Glaser, 2007; Klomp and Bulte, 2013; Meierding, 2013; Scheffran et al., 2012; Theisen et al., 2013; Zografos et al., 2014; Roche et al., 2020; Mach et al., 2019; Burke et al., 2009; Koubi, 2019; Mach et al., 2019). Despite the vast number of articles, the empirical literature still struggles with many conflicting empirical results. One explanation for this inconclusiveness is that the literature is still indecisively on the pathways underlying the empirical findings (Hsiang and Burke, 2014)[1]. The relationship between climate change and violent conflict is complicated and likely to be rather context-specific. It is recognised that underlying conditions, such as poor governance, poverty, severe resource competition, food insecurity, and water scarcity will magnify the climate impacts (Mach et al., 2020).

Because of the lack of consensus on the existence of a direct relationship, the field has shifted its focus by trying to reveal the underlying dynamics through which climate change may affect the risk of a violent conflict. One key element in this debate that is largely missing so far is whether climate change affects the armed capabilities of the conflict groups active in a country. The logic underlying this relationship is based on backward induction. The parties competing for power may see climate-induced events as a window of opportunity to gain more influence or achieve specific strategic goals. However, to take advantage of this opportunity, these parties must be ready and prepared. Thus, in the wake of these climatic events, parties may already anticipate the higher risk of conflict by strengthening their armed capabilities. In particular, climatic shocks may act as a learning mechanism. When these events occur more frequently, violent groups more easily recognise their opportunities and act accordingly. This is especially the case with droughts, as these shocks typically have a slow onset and the negative impact accumulates over a longer period. This leaves some time for the violent groups to prepare for an armed dispute or an attack on the ruling powers in the region or country.

Based on the existing evidence, the adverse consequences of climate change are typically associated with fueling civil conflicts rather than interstate conflicts. Apart from the government, the parties involved in civil conflicts usually have limited access to major conventional arms. Instead, in these kinds of conflicts, small arms and light weapons (SALWs) are predominantly used (Small Arms Survey 2005, Kopel et al., 2004; Lacina and Gleditsch, 2005; Greene and Marsh, 2011). The apparent easy access that all sorts of violent organisations have to SALWs is a major cause of the escalation of violence perceived in open conflict situations (Marsh, 2013; Bourne, 2007). According to the Small Arms Survey, SALWs are responsible for the death of more people than any other type of weapon (Small Arms Survey, 2018). In some conflicts, SALWs may produce up to 93% of casualties, as was the case in the Republic of Congo. Although the parties involved in a civil conflict differ along many dimensions, such as degree of organisation, number of members, financial resources, geographic reach, and motives, one thing they have all in common is that they need weapons to gain power, defend themselves against attacks of other adversary actors, or to achieve specific strategic goals. The armed capabilities are a visible signal of the intention of a group to resolve any dispute by force.

The question this study tries to answer is if the small arms demand increases in response to the expected security concerns of climate change shocks. One major complicating factor in measuring the demand for small arms is that most transfers occur on the black market. According to an estimate of the Small Arms Survey, more than 75% of the global total of all SALWs are outside the control of a state and subject to diversion. In practice, there are many ways in which the diversion of weapons might occur, including theft, smuggling, barter, military aid, and even through handouts to rebels or militias. In this way, arms are easily transferred from the legal to the illicit market (McDougal et al., 2019).

Despite this limitation, a large body of academic and policy literature has, in the last decade, tried to map the scale, structure, and geographic scope of the trafficking of weapons (Markowski et al., 2009, 2008; Killicoat, 2007; Karp, 2012; Brauer and Muggah, 2006; Brauer, 2013; Dreyfus et al., 2010; McDougal et al., 2014; McDougal et al., 2015). Recently, a more forensic-based method for detecting and quantifying illicit trade volumes has been proposed. This method entails analysing the small arms prices in response to certain events, shocks, or situations (McDougal et al., 2014; McDougal et al., 2019). Simplistically stated, if demand, licit supply, local production, and domestic flows amongst stocks could be perfectly controlled for in a given market and time period, negative and positive deviations from predicted prices would respectively indicate illicit imports to and exports from that market (see, for instance, Killicoat, 2007; Bhatia and Sedra, 2008; Florquin, 2014; McDougal et al., 2019).

In this research, we follow this approach to explore the price impact of climate change to make some inferences about the small arms demand in climate change-affected countries. More specifically, as the dependent variable in our panel model, we use the small arms price index reported in the Illicit Small Arms Prices (iSAP) dataset constructed by Marsh and McDougal (2017). The small arms price index is primarily based on the local prices for assault rifles. The climate change variable is based on the onset of severe droughts caused by a shortage of rainfall or extraordinary evaporation due to extreme temperatures. After testing for the sensitivity of the results, our main empirical findings indicate that droughts significantly increase the small arms demand in LDCs, especially in fragile countries.

The remainder of the chapter is structured as follows. Section 2 provides the theoretical foundation underlying the relationship between climate change and small arms demand. Section 3 describes the data used, while Section 4 explains the methodology applied. Section 5 shows our empirical results for the influence of climate change on the small arms demand. The final section offers the conclusions.

4.2 Theoretical Foundation

In an article published in the *New York Times*, Homer-Dixon (2007) argued that climate stress may well represent a challenge to international security just as dangerous as the arms race between rogue states. However, the question remains whether these risks are not intertwined, making the current arms races taking place in several countries around the globe partly fuelled by the adverse societal impact resulting from climate change. To theoretically underpin this idea, we follow the influential work of Most and Starr (1989), arguing that the onset of an armed conflict is the product of two concepts – the opportunity and willingness of conflict. These concepts describe the conditions that are necessary for events to escalate into a violent dispute (Most and Starr, 1989; Siverson and Starr, 1989). However, these two concepts also form the basis for linking climate risk factors to the behaviour of decision-makers to start a conflict. In particular, opportunity represents the total set of macro-level constraints and possibilities that are available within any environment. It captures the cause or motive of a conflict, in our case, climate shocks. In turn, willingness represents the choice processes that occur on the micro-level and is related to the intention of a decision maker, typically based on the calculation of cost and benefits. It is through willingness that decision-makers recognise opportunities and then translate those opportunities into alternatives that are weighed in some manner. In other words, opportunity is essentially the motivation for a violent conflict between states or groups, while willingness refers to the desire by states or groups to engage in violent conflict. To become involved in an armed conflict, parties must have both the opportunity and willingness to fight. Thus, opportunity and willingness should be viewed as jointly required conditions, and neither alone is sufficient (Most and Starr, 1989; Siverson and Starr, 1989).

Moreover, the theory on which this chapter is built is also related to the influential work of Hirschleifer, arguing that scarce resources may be invested either in production or predation of the production of others. In times of hardship, scarce resources might run more easily to the former (see, for instance, Hirschleifer, 2001). In this case, it would imply that after a climate shock, the resources are invested to strengthen the armed capacity.

In the literature so far, weather-related shocks and climate change are mainly linked with the opportunity of an armed conflict. Based on a brief review of the earlier studies, there are various theoretical pathways identified about how climate change influences this opportunity. First, climate change-induced shocks cause poverty and worsen livelihood conditions, making affected individuals more attracted to the selective benefits of rebel leaders for fighting. Second, deprivation and resource scarcity caused by adverse climate events might create grievances that spur violence. Third, adverse climate-related factors can force people to migrate and cause conflicts by creating struggles between hosts and newcomers over scarce resources or when newcomers alter local power relations. Fourth, weather-induced crop failures typically lead to food price hikes that ultimately might escalate into armed violence. Meanwhile, lower crop yields will mean that the same amount of food will require more land and water. In other words, it is a classic negative-sum game in which even trading water economically will require the predation of one's neighbours. Finally, the negative societal impact of climate change is strongly linked to exacerbating ethnic, political, and social divisions among the affected populace, leading to conflict (see, for instance, Burke et al., 2015; Buhaug and Uexkull, 2021; Koubi, 2019).

However, it is also possible that climate-related events also affect the willingness of armed groups to get involved or even start a civil conflict. This willingness is likely to be closely related to their ability. In particular, increasing the armed capabilities of rebel groups or other violent organisations such as militias might send out a powerful deterrence message to other domestic challengers, government troops, opposition groups, or even foreign powers by signaling the intent to resolve latent or future disputes through the use of armed force. In other words, arms purchases may be interpreted as a visible signal of the unwillingness of parties to comprise or settle in diplomatic ways. Potential challengers can observe these arms acquisitions and need to decide whether to initiate or get involved in a violent challenge.

Using deductive reasoning implies that when climate change would lead to a conflict, it may also strengthen the armed capacity as a means of readiness of the armed groups that are willing to participate in the conflict. The decision to strengthen the armed capabilities could be made in anticipation of a conflict, as parties might expect violent challenges by competing rebel groups or the domestic armed forces in the near future (Powell, 2013). Therefore, it is likely that the materialisation of the conflict risk depends both on the occurrence of an event that creates a fighting motive, such as the adverse societal impacts of climate change, and the willingness or ability of the violent parties to act on this fighting motive, such as the armed capabilities. Various studies claim the existence of a causal link between arms acquisitions and the onset or duration of armed conflicts (see, e.g. Craft and Smaldone, 2003). For example, Benson and Ramsay (2016) conclude that arms imports produce a law of conservation of violence. As one civil war ends, the resulting changes in the international market lead other war-torn countries' imports to increase, which in turn increases the number of casualties in ongoing civil wars.

Thus, based on these theoretical considerations, we argue that the chain of causality runs from opportunity (climatic shock) to willingness (increasing capabilities) and finally to the materialisation of the armed conflict risk. However, having a violent option available does not automatically mean that this final stage will be reached and the rebel groups are actually willing to use force. The basic premise is that conflicts do not arise over arms, as they arise first and foremost over certain contested issues (Fearon and Laitin, 2003; Collier and Hoeffler, 2004). For instance, the empirical results reported by Pamp et al. (2018) clearly show that while arms imports are not a genuine cause of armed conflicts, they significantly increase the probability of onset in countries where conditions are notoriously conducive to conflict. To deter competing groups from posing a violent challenge, armed groups are incentivised to gain a reputation for being resolute and thus willing to meet any challenge with force. If successful, just such a signal would already discourage challengers and make conflict less likely.

Meanwhile, there might be an interaction between the opportunity and willingness to get involved in an armed dispute due to climate change. For instance, because of a higher opportunity – more climate-related events – rebels might adjust their willingness. As a response, the rebel groups have the incentive to increase the acquisition of weaponry to increase their armed capacity after a climate shock, even when a conflict is not likely to occur. This suggests that climate change may work like a learning mechanism for the parties that are potentially involved in a conflict as it challenges the competencies of the government. The disruptions caused by climate events can create opportunities for rebel groups to exploit and amplify the existing grievances of marginalised communities. One of the key ways in which climate events can work as a learning device is by exposing the weaknesses of existing governance structures. In many countries, the government may be unable to respond effectively to the impacts of climate events, leaving communities vulnerable to further hardship and suffering. This can fuel anger and frustration toward the government and provide a rallying point for rebel groups seeking to overthrow it (Koubi, 2019; Burke et al., 2015). Climate change may provide an opportunity for rebel groups to fill the resulting power vacuum, providing them with a means of gaining support from local communities. Additionally, the chaos and confusion caused by climate events can also provide an opening for rebel groups to exploit and amplify existing social, economic, and political tensions (IPCC, 2007).

This learning effect is particularly present during a drought due to two reasons. First, droughts are slow-onset climatic disasters, providing the rebels and other government-challenging groups the opportunity to observe the disaster response of the government. It especially provides the opportunity for these violent groups to get better prepared in contrast to other sudden natural shocks, such as earthquakes or hurricanes. One element in this preparation phase is to strengthen the armed capabilities. Second, based on figures reported by EM-DAT, droughts are the natural hazard that affects the most people, both in terms of people killed, people affected, and economic damage (Guha-Sapir et al., 2020). This implies that droughts provide contemporary, visible, and distinct phenomena to analyse.

However, based on the earlier evidence in this area, it is expected that the impact of climate change on small arms trade is not the same among countries. In particular, climate change is expected to have a predominantly empirical effect on the arms demand in developing countries. The justification underlying this claim is based on two key arguments. First, more than 80% of the population identified to be vulnerable to climate change live in developing countries, especially in Africa, Asia, and Oceania (Guha-Sapir et al., 2020). This prevalence problem, in turn, in these countries is explained by a combination of three features that are most present in developing countries: a higher physical exposure in many areas to weather shocks (e.g. proximity to temperature thresholds), a higher economic vulnerability to climate events (e.g. heavier reliance on agriculture) and a lower adaptive capacity (i.e., a lower ability to deal with climate stress) (Loayza et al., 2012; Fomby et al., 2009; Noy, 2009).

Thus, based on these considerations, the hypothesis that will be tested in this study is given by:

H1: *Droughts increase the small arms demand in developing countries.*

4.3 Research Design

4.3.1 Dependent variable – Small arms prices

The global market for small arms and light weapons is massive and generates substantial profits for producers, brokers, distributors, and, not surprisingly, arms traffickers. In 2018, the global arms trade was estimated to exceed 100 billion US dollars (Small Arms Survey, 2018). This figure may even be short by a few hundred million US dollars, as the proliferation of small arms and light weapons is extremely difficult to track. The international market for small arms comprises a broad set of weaponry, including revolvers, self-loading pistols, rifles, carbines, heavy machine guns, grenade launchers, portable anti-aircraft weapons, recoilless rifles, anti-tank weapons, and their ammunition. It also includes missiles, grenades, landmines, various sizes of mortars, and other explosives (United Nations, 1997). Although the trade occurs globally, it is mainly concentrated in areas of armed interstate conflict, civil violence, and organised crime.

However, the fact that most of the SALW transactions occur on the black market creates a large limitation on doing cross-country research, as there are no reliable country estimates on the volume of the small arms transfers between and within countries. The only data that is currently available is on authorised quantities (see, for instance, the UN Comtrade Database or the Norwegian Initiative on Small Arms Transfers) or data on seized arms trade flows (UNODOCA). However, based on these data sources, it is impossible to make any inference about the size of the illicit market as this is rather endogenous (i.e., depends on the efforts to combat illegal proliferation).

This study builds on the alternative premise that current market prices of small arms can be obtained by observing individual transactions. For our dependent variable, we use data on small arms prices collected by the Illicit Small Arms Prices (iSAP) project. This project records illegal small arms transactions worldwide (Marsh and McDougal, 2017; 2021). The main advantage of transaction data is that its observations are all directly reported, documented, and gathered entirely based on verifiable and reliable sources ranging from the journalistic media to reports from the Small Arms Survey, individual researchers, NGOs, and industry reports. The time, location, type of weapon, and transaction price are recorded for each transaction.

However, the initial setup of the transaction dataset does not directly allow for a longitudinal analysis, which requires panel data. Marsh and McDougal (2017) follow a two-step approach to prepare the price data for panel analysis. In the first step, the transaction price data is standardised as empirical research requires an operational definition of the variable of interest that will provide consistency across time, countries, and especially across the different types of SALW. To make the observed transaction price data comparable, Marsh and McDougal (2017) converted it into weapons-adjusted prices. Weapons-adjustment is intended to align all weapons' prices to a common standard so that they might be compared with one another. Specifically, the authors have aligned the dataset based on PRIO category two weapons – small arms. The choice of adjusting prices to this category of weapons is that it refers to assault rifles such as the AK-47, which are the most common among illicit small arms (Marsh and McDougal, 2017; Small Arms Survey, 2004). In the second step, the recorded transactions are weighted and combined to build a country-year dataset. The transformation into such a structure involved collapsing data into means, linear interpolation between data points, and spatial and temporal lags to fill data holes in the panel (Marsh and McDougal, 2017). However, by collapsing the data, the data becomes more subject to a measurement error. Nevertheless, the fact that the price data is uncertain is less problematic in our case because we are foremost interested in how prices change from year to year, not the prices in themselves. Although the price estimates are uncertain, interannual changes in these estimates aim to reflect the true direction and magnitude of price growth as long as the measurement error is random. As a result, the price index should be regarded as an approximation of the actual small arms price in each country-year. This obtained collapsed data set covers the period between 1960 and 2015 and reports the small price index in constant 2010 U.S. dollars. However, the index in the period between 1960 and 1990 is only based on a limited number of transactions, producing a less reliable index and creating only low variation between years within a country. As a response, we decided to base our analysis only on the period from 1990 to 2015. Figure 4.1 shows the price development of small arms over the period of our analysis.

Figure 4.1. Distribution of droughts and small arms prices.

Note: the small arms price index is weighted by the real GDP per capita.

4.3.2 Independent variable – Climatic droughts

Following the most recent studies on climate and conflict, we base our climate change variable on meteorological droughts (see, for example, Von Uexkull et al., 2016; Ide et al., 2020; Schleussner et al., 2016; Thiesen et al., 2011; 2013). One of the main challenges in the literature about the impacts of droughts is the identification strategy of these events, as they are the product of hazard, exposure, and vulnerability. Most scholars agree that a large part of the hazard to a natural event is beyond government control or the behaviour of an individual (exogenous). In contrast, the exposure and vulnerability part of a disaster event, in terms of the number of people affected or physical damage created, depends to some extent on the socio-economic situation or government choices made (Kellenberg and Mobarak, 2008; Neumayer et al., 2014). For instance, the total damage created by a disaster is usually positively related to the level of income, while the number of people affected is negatively affected by the level of income. To estimate the impact of droughts, it is therefore essential to separate the exposure and vulnerability element from the drought impact and focus exclusively on the hazard part. As a response, a meteorological drought is typically defined as a prolonged lack of or below-normal rainfall (Keyantash and Dracup, 2002), possibly aggravated by hot temperatures causing high evapotranspiration rates (Vicente-Serrano et al., 2015). It is argued that the ongoing process of climate change will lead to longer spells of drought and shorter periods with more intensive rainfall. However, there is not a single consensus in the meteorological literature as to how the hazard risk of drought should be measured or captured (Guttman, 1998; Wells et al., 2004; Vicente-Serrano et al., 2010). This study uses the Standardised Precipitation-Evapotranspiration Index (SPEI) as it offers an important advantage. Whereas many studies have focused exclusively on rainfall, the SPEI is more effective at capturing drought conditions as it also accounts for temperature[2]. This is rather important, considering that evapotranspiration is the major form of water loss in dry regions with high temperatures. In essence, the SPEI measures drought severity in terms of climatic water balance, which is the difference between the available water (precipitation) and the atmospheric evaporative demand. Thus, the SPEI compares the actual biophysical and climatic situation to normal conditions in various natural and managed systems such as crops, ecosystems, rivers, water resources, etc. A statistical probability distribution is fitted over a baseline period to compute the standardised indicator that fits the input variables (Středová et al., 2011; Vicente-Serrano et al., 2010).

SPEI-based data has the advantage of being exogenous to the outcome. Following Spinoni et al. (2019), a drought starts once the SPEI within a particular territory falls below the value corresponding to a given standard deviation for at least two consecutive months and ends when the indicator rises above zero. The data on these events used in this study is collected by the Global Drought Observatory of the European Commission's Joint Research Centre and is available from three spatial scales: global at 0.5° spatial resolution, macro-regional, and country scale (Spinoni et al., 2019). In total, the database includes approximately 4,800 events in the past decades. Each event is described in the dataset by its start and end date, duration, intensity, severity, peak, average, and maximum area in drought.

Given the distribution of the drought severity in the dataset, it is conceivable that less severe droughts will have only a negligible impact on the security situation of a country and, therefore, on the incentive to strengthen the armed capabilities.

For a drought to have an empirical effect, it should be of a magnitude that can directly harm the socio-economic situation of a country. For this reason, we adopt a decision rule that filters out the extreme droughts based on severity, intensity, and area affected. Based on a detailed scoring system, each drought is assigned a severity score ranging from zero to 25. Using the threshold from Spinoni et al. (2019), an extreme drought is recognised when it scores at least 12 points. This condition reduces the number of droughts considerably by two-thirds.

To assess the impact of climate change on the arms trade, we construct for each country-year a drought variable that considers the timing of a drought in the course of a year. This allows droughts happening at the beginning of the year to have a different impact than those that occur near the end of the year. Since the contemporaneous impact of a drought within one year is considered, our annual disaster measure is weighted by the month M when the respective drought starts. That is, we assign the value $(12 - M)/12$ to a drought year and $M/12$ to the post-drought year. In all other years, its value is set to zero. This drought variable gives equal weight to the drought events. This has the advantage of reducing the potential influence of outlier events at the upper end of the SPEI distribution. Finally, we normalise the number of droughts by the land area. Obviously, larger countries have a higher probability of experiencing a climatic event[3].

As shown in Figure 4.1, a clear time trend is visible in the number of droughts during the analysis period. On average, there are about 23 droughts each year. We compare the arms price index before and after a drought as a preliminary statistical test. According to a simple Chi-squared test, this difference is statistically significant at common significance levels ($p = 0.05$). However, this nonparametric test is only suggestive, as unobserved country heterogeneity and other confounding variables are not considered.

4.3.3 Empirical model

The model used to estimate the effect of climatic droughts on the annual change in the country-specific small arms price index is given by

$$\Delta \ln sap_{it} = \alpha + \delta_i + \mu \ln sap_{it-1} + \beta_k \mathbf{x}^k + \sum_{t'=t-2}^{t} \gamma_{t'}\, drought_{it} + \varepsilon_{it} \qquad (1)$$

Where the dependent variable is the log-change in the small arms price index in country i in year t. The parameter α is the intercept, while δ_i is a country-specific fixed effect captured by a series of country dummies. By using country-fixed effects, we control for observable and unobservable time-invariant country-specific characteristics, such as the location of a country (i.e., landlocked, porous borders, etc.) that might influence the illicit small arms market of a country. Besides, this approach will place the emphasis of the regression on the identification of the within-country variation over time. The variable $drought_{it}$ is our constructed climate change measure discussed above. The hypothesis tested suggests that γ is expected to be statistically larger than zero. Equation (1) is formulated as an augmented diff-in-diff estimator, where the country-years when a drought has started are the "treated", and those without droughts are the "controls". This expectation is based on the economic laws of supply and demand, which determine the illicit small arms prices in many countries. Since supply is largely guaranteed by porous borders of most arms-importing countries, price changes should primarily reflect changes in demand (Killicoat, 2007). The discussion in the theoretical section implies that the small arms demand increases after a climatic event as the conflict risk rises. Simple economic reasoning suggests that this increase in demand is translated into higher local small arms prices. However, this expectation thrives on a crucial assumption that arms prices are flexible to a certain extent. When arms prices are completely rigid and cannot adjust in the short run, there would be no statistical relationship between these climatic events and small arms prices, making γ insignificant. Moreover, rebel organisations may not react directly to the start of a drought since these events are recognised to have a slow onset, and the complete societal impact is not immediately clear. To capture this rigidity and response lag, we consider the contemporaneous impact of two successive years after the start of a drought.

To estimate the price equation given in equation (1), it is necessary to include a set of k-lagged control variables $\mathbf{x}^k$ to avoid any omitted variable bias. The set used is based on the earlier literature and related to the arms demand motives, supply cost, and regulatory effectiveness (see, for instance, Killicoat, 2007; McDougal et al., 2019). More specifically, the vector includes the real GDP per capita, armed conflict dummy, regional armed conflict dummy, number of terrorist attacks, military spending, democracy dummy, UN arms embargoes target dummy, and institutional quality. All variables are included with a one-year lag to avoid any simultaneous issues. Table 4.A1 in the appendix provides the source and definition of the control variables used. The final parameter ε_{it} is the error term.

The dynamic panel specification provided in equation (1) contains a potential bias owing to the inclusion of the lagged dependent variable that could make the estimation results biased when not controlling for it. As a response, we estimate the model using a bias-corrected fixed effects specification (Bun and Kiviet, 2003). The Least Squares Dummy Variable Corrected (LSDVC) estimation avoids the Nickell bias but assumes strict exogeneity of the explanatory variables. Especially, in this estimation, we can safely assume that this restriction is fulfilled, as small arms prices do not affect the occurrence of climatic droughts.

4.4 Empirical Findings

In Table 4.1, we present our estimation results of the effect of climate change on small arms prices. In view of the unequal distribution of droughts across countries, we cluster the standard errors on the country level and use the bootstrap procedure with 1,000 replicators to obtain robust standard errors. We start first using a global panel including about 160 countries. To make the interpretation easier, we have normalised the coefficients on the drought variable by the average country size in our sample. In columns (1)-(3), we start estimating the main model with and without control variables and including and excluding country-fixed effects. The size effect reported is based on the sum of two consecutive years after the start of the drought, while the significance is based on the joint significance test on this aggregate effect. The results of the pooled model in column (1) indicate a significant positive effect of droughts on small arms prices. However, as demonstrated in columns (2) and (3), including country-fixed effects or control variables makes this positive relationship disappear. Based on this finding, one can argue that a large part of the variation in the small arms price index is explained by country-specific factors. Controlling for these factors reduces the observed variation in the data, especially since the time period of our analysis is relatively short.

However, one drawback of these first results is that it implicitly assumes that the empirical relationship between droughts and small arms prices is the same for all countries considered in the sample. As already mentioned in the theoretical section above, it is highly likely that the impact differs between developing states and other countries. Developing and developed countries differ in their exposure and vulnerability to climate change and their capacity to implement efficient coping policies that limit conflict risk. Thus, climate change is expected to have the most adverse economic and societal impact in low-income countries. Meanwhile, a large part of the arms proliferation in the last decade has taken place in these countries.

To capture this issue in more detail, we create an interaction term between a developing country dummy and the drought variable. The developing country dummy takes the value one when a country is classified as being a developing country in a particular year by the United Nations Development Programme (UNDP). One major advantage of the UNDP classification, compared to, for instance, the definition used by the World Bank or IMF, is that it is not only based on the level of income per head, but also includes other aspects of development such as the social situation. This is of importance as the difference between developing and developed countries goes beyond an economic development gap[4]. For instance, improved access to education will enhance job opportunities and reduce the reliance on agriculture as an economic sector. This will, in turn, reduce the risk of an armed conflict after an adverse natural shock and improve institutional quality (Kamdar and Basak, 2005; Paulsen, 1991; Wezel et al., 2018).

The results presented in column (4) indicate that, although the general effect of droughts remains insignificant, the interaction between the developing country dummy and the drought dummy is statistically significant at common confidence levels. Interpreting this finding, one additional drought increases the local price of SALWs by approximately 2% annually in the two years following the start of a drought. This finding suggests that violent parties in developing countries that suffer from major droughts are likely to increase their arms acquisitions in the following years[5].

However, these results may still suffer from an identification problem as it is possible that droughts already caused a violent conflict before there was an increase in arms purchases. In that case, the outbreak of the conflict might have caused an increase in the arms demand instead of the occurrence of a drought. This argument would make our findings spurious. To explore whether this is the case and if our results are affected by this simultaneity bias, we re-estimate in column (5) of Table 4.1 the main model but exclude all country-year observations when there was a violent conflict ongoing in a time window of two years before and after a particular year[6]. Although the significance slightly drops on the drought indicator, the results still show that droughts create upward pressure on the local small arms prices in LDCs. This strengthens the idea that rebel groups increase their capabilities in the wake of a drought, regardless of whether a conflict is already ongoing or escalating, as arms acquisitions provide a visible signal of deterrence to other parties.

So far, the results do not provide any insight into the underlying mechanism that drives the relationship between climate change and arms demand. Many developing countries are recognised as fragile states. Fragile states have characteristics that substantially impair their economic and social performance, including weak governance, limited administrative capacity, weak state legitimacy, chronic humanitarian crises, persistent social tensions, and often, a legacy of armed conflict. In practice, the term fragile states refers to a broad range of failing, failed, and recovering states that are unable or unwilling to adequately assure the provision of security within their borders, the institutional capacity to provide basic social needs to a significant portion of their populations, and where the political legitimacy of the governments to represent their citizens at home or abroad effectively is in question. As a result of these adverse conditions, fragile countries have a lower adaptive capacity to deal with climate stress and, at the same time, lack the necessary effective bureaucracy to combat illicit arms trade or avoid a violent conflict (Loayza et al., 2012; Fomby et al., 2009; Noy, 2009). For instance, more than two-thirds of the countries in sub-Saharan Africa have experienced civil conflict in the last five decades.

Table 4.1. Droughts and small arms prices – Baseline findings.

	(1)	(2)	(3)	(4)	(5)
Droughts	0.100* (0.061)	0.032 (0.023)	0.029 (0.021)	0.026 (0.037)	0.016 (0.014)
Droughts x LDC dummy				0.020** (0.015)	0.008* (0.004)
Sample	ALL	ALL	ALL	ALL	Excluding conflict years
Estimation method	LSDVC	LSDVC	LSDVC	LSDVC	LSDVC
Control variables	NO	YES	YES	YES	YES
Country-fixed effects	NO	NO	YES	YES	YES
Number of observations	4261	3844	3844	3844	2691

*Note: **/* Indicating significance levels of respectively 5 and 10 percent. Bootstrapped standard errors are shown between brackets.*

To take these issues into account, we include an interaction term between the drought dummy and the annual country-specific score in the Fragile State Index developed by the Fund For Peace. This index is a composite index on the degree of fragility based on four different dimensions: 1) cohesion and internal security, thereby considering the security apparatus, fractionalised elites, and group grievance; 2) economic conditions, including economic decline, unequal economic development, and human capital and brain drain; 3) political conditions referring to state legitimacy, public service, and human rights, and the rule of law and 4) social conditions capturing demographic pressure, refugees and IDPs, and external intervention. For each of these dimensions, a country receives a score of a maximum of thirty points, with higher values indicating more fragility. We classify a country as fragile when it is rated in the top 25% of the overall ranking. The results in columns (1) and (2) of Table 4.2 indicate that, although the general drought effect remains insignificant, the interaction between the fragile country dummy and the drought dummy is statistically significant at common confidence levels. This finding suggests that especially fragile LDC countries that suffer from major droughts increase the small arms price index in the following years.

Moreover, as argued above, droughts might work as a learning mechanism. Rebels might identify the opportunity to gain influence after a drought shock more easily when these shocks occur more frequently. To test this idea, we re-estimate the main model, including only countries that are regularly affected by a drought. We classified a country as being regularly hit by a drought when they have been struck at least five times by a large-scale drought during our period of analysis. The results in column (3) confirm this idea.

Finally, to test for the robustness of the results, we estimate in columns (4)-(5) of Table 4.2 the main models using an alternative estimation technique (OLS-FE). These findings confirm our earlier results and imply that the estimation method applied does not affect our main conclusions. However, one important note is that using the simple OLS estimation technique with fixed effects might yield biased estimators since our model specification poses a dynamic component.

Table 4.2. Droughts and small arms prices – Fragile states and mechanisms.

	(6)	(7)	(8)	(9)	(10)
Droughts	0.013 (0.023)	0.014 (0.012)	0.017* (0.010)	0.017 (0.012)	0.030 (0.045)
Droughts x LDC dummy				0.007* (0.004)	0.027* (0.014)
Droughts x fragile country dummy	0.041** (0.008)	0.023* (0.011)	0.050* (0.005)		
Sample	ALL	Excluding conflict years	Frequently affected countries	ALL	ALL
Estimation method	LSDVC	LSDVC	LSDVC	OLS-FE	OLS-FE
Control variables	YES	YES	YES	NO	YES
Country-fixed effects	YES	YES	YES	YES	YES
Number of observations	3460	2422	1713	3959	3959

*Note: **/* Indicating significance levels of respectively 5 and 10 percent. Bootstrapped standard errors are shown between brackets.*

4.5 Conclusions

This chapter explored whether there is a statistically significant relationship between small arms prices and the occurrence of extreme droughts. The idea underlying this relationship is that climate change potentially increases the demand for small arms as the risk of a violent conflict rises. Based on the findings, one can draw several conclusions. First, there exists a significant positive effect of droughts on the price of small arms in developing countries. Second, this positive effect is mainly explained by weak governance and a higher conflict risk in many of these countries. Finally, droughts create a learning mechanism since the climate change effect is larger in countries that are regularly affected by a drought. Future research could be focused on disentangling in more detail the vulnerability and coping capacity channels underlying the present results.

Appendix

Table 4.A1. Data and sources used.

Variable	Definition	Source
Real GDP per capita	GDP per capita in constant 2010 U.S. dollars taken in logarithms.	World Development Indicators
Armed conflict dummy	Dummy taking the value one when a country is involved in an armed interstate or intrastate conflict, and zero otherwise.	UCDP/PRIO
Regional conflict dummy	Dummy taking the value one when an armed interstate or intrastate conflict is ongoing in the region where the country is located, and zero otherwise. The regions are based on the classification of the World Bank.	UCDP/PRIO
Terroristic attacks	Number of terroristic attacks in a particular country-year.	Global Terrorism Index
Military spending	Military expenditures as a share of GDP.	World Development Indicators
Democracy dummy	Dummy taking the value one when a country is recognised as a democracy in a particular year based on the Polity V, and zero otherwise. The Polity V identifies a country as a full democracy when it receives a score of at least seven on the scale running from +10 democracies to -10 (autocracies).	Polity V
UN arms embargoes dummy	Dummy variable taking one when a country is subject to a United Nations arms embargo, and zero otherwise.	PRIO
Institutional quality	Dummy variable based on the median value of the first-principal component in the indices on voice and accountability, government effectiveness, regulatory quality, rule of law and control of corruption.	Worldwide Governance Indicators

Notes

1. This conclusion is shared among several literature reviews on this topic (see, for instance, Burke et al., 2015; Buhaug et al., 2014; Buhaug and Nordkvelle, 2014; Hsiang et al., 2014a,b).
2. For instance, the SPEI is considered to be superior to the Standardized Precipitation Index, which only takes precipitation into account.
3. When not controlling for the land size, our drought measure may be correlated with the error term in our empirical estimation.
4. The classification is primarily based on the Human Development Index which is a composite index of three indices measuring countries' achievement in health, education and income per head.
5. These results are also confirmed using a simple stratified sample split between fragile and non-fragile country-years.
6. The data on the occurrence of an armed conflict is taken from PRIO.

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PART 2

Designing climate security strategies and partnerships

CHAPTER 5

Cooling the Cauldron: A Climate Security Intervention Framework

Laura Birkman, Irina Patrahau, Matti Suomenaro, and Tim Sweijs

Abstract

To support strategic and operational decision making, we need to move beyond current thinking of climate change as a conflict multiplier and consider the causal mechanisms that lead from climate change to conflict outcomes. This chapter offers a framework for the design of climate security interventions that may prevent and mitigate climate-related security effects. The framework is based on qualitative and quantitative studies of the climate and conflict nexus, theoretical and empirical studies on early warning and public policy programming, and in-depth case studies. In their combination, these methods inform interventions that can reduce the security risks of climate change and bolster climate adaptation policy and programming. The framework employs an implementation logic based on an integrated and multi-level stakeholder approach, that includes the security sector. Using the case of Iraq, this chapter builds on but goes beyond the current body of academic literature by showcasing concrete intervention options that are conflict-sensitive and inclusive, leveraging local knowledge and capabilities.

Keywords: climate security, climate change, security, military, military conflict, conflict prevention, causality

5.1 Introduction

The role of climate change as a conflict multiplier has been well established in academic literature, but awareness and understanding of how this knowledge can be used to support the development of climate security interventions is still lacking (Buhaug, 2018; Cederman & Weidmann, 2017; de Bruin et al., 2018; Mach et al., 2019; Sakaguchi et al., 2017). This policy gap is a serious challenge for decision makers active in fragile societies, which are often not only climate vulnerable but face great difficulties in coping with climate-related shocks.

This chapter offers a framework for the design of climate security interventions that can help to prevent and mitigate climate-related violent conflict in fragile countries. For the purpose of this chapter, the authors refer to ‘climate security interventions’ to mean interventions that address the root causes and mediating factors of the climate-conflict nexus and, in this way, support the adaptive capacity and resilience of communities. The framework employs an implementation logic based on an integrated, inclusive, and multi-level stakeholder approach, that includes national and provincial authorities, local civil society, private sector actors, and international organisations. The security sector, including armed forces, has a key role to play in climate security interventions. In conflict-settings, the security sector is an important stakeholder because of its ability to respond to national disasters and resource-related instability. In fragile country contexts, the extent to which security sector services abide by principles of good governance and contribute to social cohesion varies, which the framework takes into consideration.

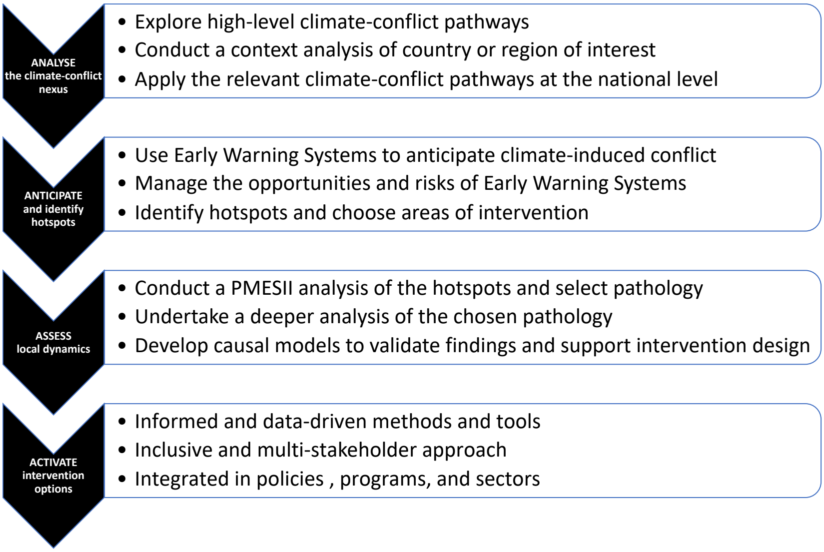
The framework is applied to assess the situation in Iraq[1]. Faced with severe water and climate stress, Iraq’s ability to mitigate and adapt to climate change has been constrained by consecutive wars and prolonged political, social, and economic instability. The United Nations Environmental Programme (UNEP) sixth Global Environmental Outlook ranked Iraq as the fifth most climate-vulnerable country in the world (UN Environment, 2019). Defining climate security interventions to address the causes of climate-related conflict and adaptation challenges in Iraq is thus a key step to supporting the country’s future resilience.

The chapter is structured as follows: following the introduction, section two introduces the intervention framework, provides an in-depth explanation of each of its four stages, and describes how they inform the design of climate security interventions. The framework is based on qualitative and quantitative studies of the climate-conflict nexus, theoretical and empirical studies on early warning and public policy programming, and in-depth case studies. Section three applies the framework to a contemporary case study of Iraq. The case study is used to illustrate the application of intervention options that can leverage climate security practices. Section four summarises key findings and conclusions.

5.2 Climate Security Intervention Framework

The impact of climate change on security is context-specific and determined by local level dynamics and the interactions of multiple factors. In fragile and conflict-affected states, climate change may initiate a series of negative feedback loops that can trigger security challenges. These can foster social unrest, forced migration, organised crime, and violent extremism (United Nations, 2020). In some cases, climate-related security challenges can lead to violent conflict, which is the focus of this chapter. The intervention framework developed in this chapter consists of four lines of effort: (1) analyse the climate-conflict nexus; (2) anticipate and identify hotspots; (3) assess local dynamics; (4) activate intervention options (see Figure 5.1). They are described in more detail below.

Figure 5.1. Climate security intervention framework.



5.2.1 Analyse: Unpacking the climate and conflict nexus

In order to analyse the different factors that drive climate-related security challenges and the eruption of violent conflict, completing the first step of the framework requires a two-fold analysis: first, the analysis of the context of the area of interest; and second, the application of relevant pathways to the chosen context.

The context analysis provides an understanding of the macro-level dynamics and trends that define the political, socio-cultural, economic, and environmental situation of the chosen area. Based on this situational analysis, pathways of climate-conflict can be identified and analysed. In this way, the context analysis helps to narrow down the research and concentrate on climate-related security dynamics and challenges in a given geography.

To explore the high-level climate-conflict pathways in more detail, the framework makes use of seven *pathologies* identified based on a large literature review conducted in a previous study that connect climate change to conflict (Sweijs et al., 2022). A climate-related pathology is a specific pathway through which the interaction between climate change and social, economic, political, and environmental factors leads to violent conflict. Each pathology identifies the relevant factors, describes how they interact with climate change, and elucidates the ways through which they lead to different forms of violent conflict. The seven pathologies are summarised in Table 5.1 below.

Table 5.1. Seven climate-related conflict pathologies (Source: Sweijs et al., 2022).

Pathology description	
Climate change-related resource scarcity leads to conflict between pastoralist and stationary communities	Changes in temperature and precipitation cause forms of scarcity that force pastoralist groups to alter their transhumance routes. This precipitates resource competition between groups, infringes on traditional customary regulations, and increases conflict risk.
Climate change-related resource scarcity leads to larger-scale inter-communal violence	Climate change-induced scarcity of water, food, and land resources, in combination with social, political, geographic, and economic variables, can trigger inter-communal tensions.
Climate change precipitates (internal) migration, leading to social unrest	Climate change can lead to migration, whether from rural to urban areas or between rural areas. This can spark social unrest by increasing resource competition and exacerbating feelings of relative deprivation, as well as the severity of inter-cultural clashes.
Climate change-related social unrest empowers nonstate armed groups	Climate change interacts with state fragility and contributes to livelihood deterioration, creating fertile ground for the emergence and expansion of non-state armed groups (NSAGs).
Policies aimed at mitigating the effects of climate change have adverse effects	Climate change policies can trigger political exploitation and marginalization of groups, aggravating existing grievances and tensions.
Climate change-related social unrest precipitates large-scale political movements, provoking a government crackdown	Climate hazards can provoke a window of opportunity for violent and non-violent opposition to further undermine authorities. This erodes state capacity and exacerbates social vulnerability. Conflict arises as a result of the state's (violent) crackdown on dissent.
Disputes over transboundary resources cascade into intrastate conflict	Climate change can foster tensions over transboundary resources in three main ways: 1) water scarcity raises tensions over transboundary freshwater resources; 2) temperature increases create a new frontier for disputes in the Arctic; 3) diplomatic disputes over climate mitigation measures and responsibility.

In combination, the seven pathologies describe climate-conflict patterns at the local, the national, and the transboundary levels. At the local level, we find more straightforward links between resource scarcity and conflict amongst individuals that depend on water, food and land for their livelihoods, including pastoralist groups, as well as individual farmers and fishermen. These micro-conflicts can escalate into inter-communal conflict when tensions merge with ethnic and tribal conditions. At the national level, rural-urban displacement and social unrest result from increased internal migration, weaponisation of resources by non-state armed groups, and broader misappropriation of resources as a result of inadequate or exploitative policies. This puts pressure on governmental bodies that may not be able to respond adequately to the challenges, eroding trust and leaving the door open to violent and non-violent opposition that may undermine state authority. Finally, at the transboundary level, there are disputes over natural resources such as water, food, and energy. These tensions will continue with increased water stress and competition over resources, not least as many of the critical materials needed for the energy transition are located in fragile and vulnerable countries. The seven pathologies are not mutually exclusive. The degree of a country's vulnerability to climate-related conflict rests on the intensity of the pathologies and the ability of government, society, and other actors to cope with and adapt to their dynamics.

The identification of high-level climate-conflict pathways offers a number of benefits that are instrumental for the design of climate security interventions: first, they provide a baseline understanding of the complex interactions between climate change and conflict. The typology can help pinpoint the broader factors and actors that are relevant to consider when dealing with the nexus. Second, the pathologies support the refinement of deep case studies designed to unpack the link between climatic conditions and conflict onset in a specific context (Birkman, Sweijs, et al., 2022). As climate-related security challenges differ across regions and contexts, it is essential to consider the unique vulnerabilities, risks and capacities of different regions and communities. Third, they allow for forward-looking perspectives, risk assessments, and early warning, by exploring potential future trajectories. An advance understanding of the different ways through which climate change might trigger conflict can help decision makers improve their preparedness against climate security risk by targeting the root causes and mediating factors rather than the conflict outcomes.[2] Fourth, they bring valuable insights for policy formulation. This helps prioritise actions, allocate resources, and develop adaptive strategies that are tailored to the unique circumstances of each pathology. Finally, the pathways support interdisciplinary collaboration among experts from diverse fields. By identifying the various mechanisms which contribute to climate-related security challenges, a combination of expertise may be channelled to facilitate the development of more effective and integrated policy responses. In sum, the seven pathologies can help to support the development of more effective strategies for climate adaptation, resilience, and conflict prevention. The World Bank recognises the added value of the typology of pathways for policy programming purposes. Section 2 of its 2022 report "Defueling Conflict: Environment and Natural Resource Management as a Pathway to Peace", extensively references the pathways to inform climate security interventions (Ahmadnia et al., 2022).

5.2.2 Anticipate: Early warning systems and hotspots of risk

Given the understanding of the complex dynamics between climate stress and conflict, the second step in the framework is the identification of climate-related hotspots of security risk. Advanced Early Warning Systems (EWS) facilitate this process, employing a combination of climate data, socio-economic indicators, and machine learning approaches. There is no shortage of EWS that can support the identification of climate- or hazard-related areas of risk at different geographical levels[3]. Similarly, there is a rich collection of conflict EWS that focus mainly on predicting conflict. Despite the availability of climate and conflict EWS, there are still only a few publicly available machine-learning based EWS that focus on predicting climate-related *conflict* risks[4]. These integrated EWS make an important contribution to improving anticipatory action on climate security, A noteworthy example is the Global Early Warning Tool developed by the Water, Peace, and Security (WPS) partnership (*Global Early Warning Tool*, n.d.). The WPS Global Early Warning Tool uses a machine-learning based methodology to forecast conflict over the next 12 months with the aim of identifying conflict hotspots before violence erupts. It makes use of a comprehensive conflict database developed by the Armed Conflict Location & Event Data Project (ACLED) that collects real time data on political violence, including conflicts related to climate change. It has been developed by a consortium of partners, which the authors are part of, and builds on the ACLED database by providing further granularity about the role of water-related stresses.

EWS present a number of opportunities. First, they allow for more timely warnings of conflict risk. With additional domain knowledge, validated data, and historical accuracy, the legitimacy of EWS is further reinforced. This is especially the case when EWS can interact and be deployed at multiple levels. Second, EWS play a pivotal role in early action. If relevant policy and decision makers have access to EWS information, they can use it to take proactive measures to manage conflicts related to climate change. This assumes that EWS can support increased and shared awareness, so that policy efforts can be aligned across national, provincial, and local levels. It also requires effective channels of communication within and across government, non-governmental organisations, and other actors. Third, early-action initiatives brought forward by EWS can spill over into other policy domains, enhancing the use of data-driven analysis, delivering efficiency gains, and improving transparency and accountability across user groups (Sweijs & Teer, 2022).

Of course, there are also a number of risks associated with EWS. Their inherent complexity makes them difficult to use and maintain. A key challenge is that EWS may suffer from information inaccuracies. They can predict "false positives" (high conflict risk prediction, but the risk is low), or "false negatives" (low conflict risk prediction, but the risk is high), which can lead to a lack of trust in the system, increasing the likelihood that policy and decision makers will not use the EWS, or use it in a limited way. This issue can be mitigated by triangulating the data and models included in EWS. Another (related) risk is the ethical issues that may arise from misuse of data. The potential for exploitative extraction of data in unregulated environments may have enormous repercussions. It is therefore imperative that ethical and legal guidelines are developed to make processes as transparent as possible. Finally, the actions prescribed by EWS to prevent conflict may sometimes worsen or create new forms of conflict if it creates pressures on existing local economic and political dynamics. It is therefore important that any prescriptions are carefully integrated into broader risk assessments (Global Center on Adaptation, 2022).

5.2.3 Assess: Understanding local dynamics

Following the identification of the geographical area that the climate intervention should target, a deep dive into the local dynamics that drive climate-related conflict represents the next step in the framework. The deep dive makes use of three analytical instruments: the PMESII (Political, Military, Economic, Social, Information, and Infrastructural) framework; empirical analysis of relevant climate-conflict pathways; and causal models.

First, a comprehensive analysis of the PMESII factors is used to understand conflict dynamics and relevant stakeholders within the typology of the seven pathways. The PMESII analysis was developed by the United States military and is a method commonly deployed by militaries to undertake context-specific and case-based assessments.[5] It is a useful technique to better understand unfamiliar or uncertain environments and helps organise information and develop a strategy (see Box 5.1).

Second, the specific pathways linking climate change to conflict are empirically assessed based on the PMESII analysis. This is done using the seven high-level pathologies, which help to better analyse the local dynamics underpinning climate and conflict dynamics.

Box 5.1. The PMESII analysis framework (Source: PMESII-PT Research Analysis Framework, 2023).

The PMESII factors	
Political	The political factor refers to the distribution of responsibility and influence across levels of governance, including both formal and informal political power.
Military	The military factor assesses the military and paramilitary capabilities of relevant actors.
Economic	The economic factor includes an overview of the sectoral organization of the country's economy (agriculture, manufacturing, technology etc.); unemployment rate; the make-up of international trade; as well as foreign aid and finance system.
Social	The social factor concerns the religious, cultural, ethnic and demographic configuration of a country; inter-group dynamics; values, norms, and belief systems.

Third, the causal linkages between the climate conflict factors are further substantiated through the use of formal causal models. Formal causal models can provide a rigorous validation of qualitative insights in climate conflict research (Malekovic et al., 2023). Specifically, causal models allow for the examination of the statistical significance of the effects of climatic and environmental causes on conflict activity and other security-related risks (Malekovic, 2023). Unlike EWS that identify correlations between variables, machine-learning applications are currently being developed to formally identify and assess causal relationships between variables of interest. These causal models provide a new frontier for analysing and assessing causal dynamics between climate onset and conflict outcomes, and are employed in the fourth step of the framework, described below (Birkman, Sweijs, et al., 2022). The statistical validation of relevant factors and variables identified in the analysis of local dynamics, provides more robustness to the findings of the broader approach, and can support the identification of optimal intervention options. Hence, they are a key instrument to support strategic decision making and operational planning.

5.2.4 Activate: Informed, integrated and inclusive interventions

The previous three steps of the framework – analyse, anticipate, assess – ultimately feed into the development of climate security interventions. Climate security interventions refer to a range of actions, policies, and strategies aimed at addressing the root causes and mediating factors of climate-related security risks and increase the adaptive capacity of communities faced with these risks. Interventions should aim to strengthen the long-term adaptive capacity of at-risk communities which, in the process, would mitigate the likelihood of conflict. Designing informed, integrated, and inclusive interventions is essential in ensuring long-term sustainability and tangible results. The Water, Peace and Security Partnership's approach provides a prototype to follow in developing interventions that address water-related security risks, but the approach can be expanded to apply more broadly to climate-related risks as well (Meijer et al., 2023).

Informed. Ensuring that the available information can be tailored to local contexts and translated into action is essential (*Locally Led Adaptation – Global Center on Adaptation*, n.d.). The application of data-driven research and models can prove challenging in practice when local knowledge is insufficiently integrated and local leadership is not involved in the process (Global Center on Adaptation, 2022). Most times, the communities that are affected by climate change have already developed local processes and approaches to deal with these risks. Their work can be supplemented by early warning and causal modelling only to the extent to which these local communities are involved in the development and implementation of interventions. Participatory approaches to tool development can ensure local ownership of the process and maximise the effectiveness of such models.

Integrated. Furthermore, interventions must be designed following an integrated approach that includes relevant stakeholders both in and outside of the government, maximises effectiveness, and facilitates the development of synergies. Good governance is essential in mitigating climate security risk. The likelihood of climate change leading to violence depends on a wide range of social, economic, and political factors, and the degree to which good governance can mitigate some of these challenges. Governments in fragile contexts often struggle with corruption, unclear division of responsibility or the inefficient use of public funds and resources. Given that climate security adaptation is closely interconnected with a wide range of governance areas like water, food, energy, biodiversity, health or infrastructure, a whole-of-government approach is essential. Not only should the different relevant departments (agriculture, infrastructure, security) be involved in climate security interventions, but also the various levels of government (local, provincial, national). International players can support capacity development and programming efforts in good governance, natural resource management and climate adaptation.

The security sector, including armed forces, can bring significant contributions to prevent, prepare and respond to climate-related risks (Canyon & Ryan, 2021; Jayaram, 2020; Jayaram & Brisbois, 2021). On the one hand, armed forces themselves are increasingly affected by climate change in terms of their operational capabilities, so their involvement in the climate security realm benefits their awareness and learning (Patrahau et al., 2023). On the other hand, the role of security forces is likely to increase in responding to climate-related security challenges. The International Military Council on Climate and Security (IMCCS) brings together members of militaries and national security communities in order to better anticipate, analyse, and address the security risks of climate change (*International Military Council on Climate and Security*, n.d.). This global network of security and defence experts operates from the assumption that armed forces have a key role to play in mitigating the security risks of climate change.

The responsibility for climate security interventions does not primarily belong to the security sector, but security actors are often at the forefront of disaster emergency planning and response given their clear and well-established protocols and forward-looking approach. Especially in the Indo-Pacific, the region most vulnerable to natural hazards and sea-level rise in the world, militaries have gained an increasingly large role in Humanitarian Assistance and Disaster Relief (HADR) in the aftermath of climate hazards (Canyon & Ryan, 2021; Jayaram, 2020). The ASEAN Militaries Ready Group on HADR has been established to coordinate regional responses to climate disasters and enhance military-to-military and military-civilian integration (*ASEAN Militaries Ready Group on Humanitarian Assistance and Disaster Relief (AMRG on HADR)*, n.d.; Canyon & Ryan, 2021).

In fragile contexts where civilian violence is prevalent and trust in state authorities is low, the role of the security sector may be questioned and even negated, but solutions such as multi-stakeholder committees that include armed forces may be found. In this way, the civil sector can apply good practices and lessons learned in their planning and collaborate with the security sector in the implementation of climate security adaptation interventions.

Inclusive. Furthermore, an inclusive multi-stakeholder approach is essential to ensure the long-term sustainability of the intervention as well as avoid maladaptation. Representatives of relevant stakeholder groups that are affected by climate security adaptation interventions should be consulted both in the planning and implementation process. Integrating dialogue processes and public consultations in the development of an intervention ensures that all interests are heard and addressed or at least compensated. Especially the interests of marginalised groups can be overlooked in, for instance, the design of a large-scale infrastructure project. Certain groups may in fact lose at the expense of the well-being of the broader community, leading to long-term inter-group instability and grievances. In order to avoid maladaptation, relevant groups must be taken on board from the early stages of planning an intervention until the end of the implementation period. Moreover, monitoring and evaluation after an intervention has been implemented is essential in ensuring its long-term sustainability and effectiveness.

By adopting the climate security intervention framework, policy makers and operational planners are presented with the opportunity to unpack the factors that lie between a climate-related event and a conflict outcome, enabling them to intervene on the causes of climate-related risks rather than their outcomes. Apart from the obvious benefits this brings for designing more effective adaptation programmes and projects, it also allows for the development of smarter, security-proof interventions. Ultimately, a climate security intervention framework is a key instrument in a broader climate adaptation toolbox.

5.3 The Case Of Dhi Qar Province, Iraq

This section applies the four steps of the climate security intervention framework to a case study of Dhi Qar province in Iraq. It starts with an overview of Iraq's fragility to climate change; it then identifies Dhi Qar as a climate security hotspot and examines local conflict dynamics. Although the case study is intended to demonstrate the applicability of the intervention framework rather than to develop a comprehensive and in-depth climate security intervention, the section does offer a number of observations that can inform future interventions in Dhi Qar.

5.3.1 Analyse: Context analysis and climate-conflict pathways in Iraq

5.3.1.1 Conducting a context analysis: the fragility of Iraq

Iraq is currently facing multiple intersecting risks: a volatile security situation, governance challenges, economic and demographic pressures, extreme weather conditions, and severe environmental degradation. In 2021, the US National Intelligence Estimate on Climate Change identified Iraq as one of eleven countries highly vulnerable to climate change (*US National Intelligence Estimate on Climate Change*, 2021). The 2022 global Fragile States Index measuring conflict risk and vulnerability places Iraq 23rd out of 179 countries (*Fragile States Index*, 2023). This places Iraq in the top tier of countries worldwide deemed particularly likely to face climate-related resource challenges that pose a real risk to water, food, energy, and health security while being vulnerable to the onset of violent conflict.

Water scarcity is a key challenge that the Iraqi population faces, and it is leading to water and food insecurity and loss of livelihoods. The causes of water scarcity include reduced inflow rates from the Euphrates and Tigris rivers and consecutive years of drought, advancing desertification, soil degradation, and increasing salination. Combined with resource-intensive and inefficient agricultural, irrigation, and water management practices, water scarcity is leading to the large-scale abandonment of farming and livestock. This creates food insecurity for many households (Guiu, 2020). Of Iraq's 39 million population, 2.4 million are in acute need of food and livelihood assistance (World Food Programme, Iraq, 2020). This results in an environment conducive to illicit activity, and the aggravation of conflict dynamics along existing fault lines. Women and girls are particularly hit by the adverse impacts of climate change given pre-existing gender norms and persisting inequalities. At the same time, unemployment is high among youth groups (Norwegian Institute of International Affairs & Stockholm International Peace Research Institute, 2022). About 60% of Iraq's population is under the age of 25, yet young Iraqis continue to be excluded from political decision making (Al-Shakeri, 2022). Hence, climate change acts as a threat multiplier, increasing the risk of destabilisation and escalation of conflicts in Iraq.[6] The agricultural sector is still the backbone of rural livelihoods, and while remaining an important basis for national food security, it is reportedly using up to 87% of Iraq's water supply (*Water Use in Iraq*, 2022). The water-agriculture-food nexus has thus become one of the core challenges for the stability of Iraq.

Today, the government of Iraq acknowledges the urgent need for action and reform as well as the interdependence of climate change and security. The Iraq National Adaptation Plan (2020) provides a comprehensive overview of actions needed to address the formidable climate change adaptation challenges of the country. The Iraqi Ministry of Environment has embraced the recommendations of the World Bank 2022 Country Report on Climate Change, which provides a roadmap of the required activities by 2030 (World Bank Group, 2022). Moreover, the Office of the National Security Advisor (ONSA) is integrating climate change into Iraq's forthcoming national security strategy. During the Basra Conference in March 2023, the government announced the mobilisation of USD 7 billion in loans to help modernise the agricultural sector.[7] The government also introduced an initiative to combat desertification as well as other measures to mitigate the physical impacts of climate change. This underscores a political willingness to engage and serves as good foundation for action.

However, Iraq's societal needs to adapt to climate change surpass the current capacities of the government. The pressing climate-related security risks in regions most vulnerable to the escalation of underlying, socio-economic (national and local), communal, ethno-sectarian and tribal tensions, demand immediate action, while larger reform efforts will take at least 5–10 years to materialise. A real challenge for the government is to address the underlying drivers of climate-related instability in an integrated way. To dampen the negative impacts of decreasing agricultural yields and higher food prices, the Iraqi government has for a long time focused on short-term action like the provision of subsidies and compensation instead of investing in long-term adaptation and resilience of its rural population. Lack of timely investments in water storage, wastewater infrastructure, desalination as well as resource efficient water management and usage, has kept Iraq and its agricultural sector from introducing more efficient and effective water management. These developments have affected the country's preparedness for current and future scarcity. The core problem today is not the lack of intent of the government to act, but to coherently formulate and implement responses to climate change induced challenges across national, governorate, and local levels that contribute to stability.

5.3.1.2 Applying climate-conflict pathways to Iraq

In Iraq, the most important climate-related conflict risk is water scarcity, which in turn impacts the country's food and land systems. Whether these resource stresses lead to a conflict situation depends in large part on the adaptive (resilience) or coping (response) capacity of the government, local communities, and/or individuals to prevent or mitigate the impacts (Birkman, Kool, et al., 2022). There are three main trends that summarise how water-related stresses are contributing to conflict risk in Iraq. They are described below and anchored against the pathologies outlined in Section 5.2.1.

First, persistent drought stress and water scarcity lead to increased competition over natural resources enhancing instability, displacement, and reinforcing conflict dynamics at the local and community level. Violent confrontations between farmers and pastoralists are increasingly taking place over access to water and land (pathology 1). Individual conflicts can escalate into inter-communal violence and social unrest where they erupt along existing ethnic-sectarian fault lines (pathology 2). Tensions between groups practicing the same livelihoods (e.g. farmers) may also turn into violent conflict where no dispute settlement is facilitated. This is especially the case between farmers from different tribes, but even members of the same tribe or ethnoreligious identity are increasingly involved in direct conflict over resources (International Organization for Migration, 2023). While tribal courts can resolve disputes in the short term, the sustainability of these agreements is often put into question. Where violent confrontation is avoided, climate-related stresses including acute water scarcity and desertification are forcing more and more rural families to abandon their livelihoods for alternative sources of income. This has led to an enormous proliferation of rural-urban displacement in addition to the already very high numbers of Internally Displaced Persons (IDPs) in Iraq (pathology 3). In 2019, 21,314 IDPs in central and southern Iraq were forced to migrate due to the lack of water associated with high salinity content and/or water disease outbreaks in both urban and rural communities (International Organization for Migration & Deltares, 2020). Once displaced, women and youth moving from rural to urban areas are especially at risk of turning to informal networks to survive, as employment opportunities are increasingly limited, and competition for jobs is fierce. Local government is not able to deal with the additional burdens on existing infrastructure, so criminal groups and militias are increasingly taking advantage of these vulnerabilities and informal settlements to consolidate their power in both rural and urban areas. Moreover, where land is abandoned because of desertification, security vacuums are reinforced, creating so-called 'no man's lands' where militias and other armed groups have a free hand at drug trafficking and other illicit activities, and government rule is absent.

Second, there are increasing tensions between national and governorate authorities and between different governorates over water allocation and distribution, inhibiting effective and decisive action on climate adaptation. While the government of Iraq is putting an enormous effort into managing its transboundary water challenges with Turkey, Syria and Iran, national and inter-governorate water issues are not sufficiently addressed (pathology 4). Government and governorate tensions over water management, while prevalent across Iraq as a whole, are especially pronounced in the south of Iraq (Birkman, Kool, et al., 2022). Located downstream of the Euphrates and Tigris rivers, the southern Iraqi governorates suffer from the lowest levels and poorest quality of water. They rely heavily on upstream governorates for their water supply. This is putting enormous pressure on existing water allocation and distribution systems and causing tensions between neighbouring governorates. Climate change is making this situation worse, as the south of Iraq is the hottest and driest of the country and increasingly hit by a multitude of extreme weather events (heat waves, dust storms, drought stress), depletion of water reservoirs, and water salinisation. According to local experts, the ability to recover from these acute water stresses has been seriously affected because of years of war,[8] outdated water infrastructure, the focus of reconstruction efforts in central and north Iraq, and the additional burdens on urban water supplies caused by the enormous numbers of internally displaced persons. Much more needs to be done to make the water management system in Iraq more adaptive and resilient to climate change. While tackling transboundary issues can help to reduce some of the acute water supply issues, these are unlikely to be resolved in the short term (pathology 7), nor will they resolve the deeper national, provincial, and local level water challenges.

Third, policies aimed at managing the negative effects of climate change can have adverse effects and aggravate existing grievances between the government and local communities, leading to escalating protests and eroding government authority. Dissatisfaction with government services is straining relations between the government of Iraq and Iraqi citizens (pathology 5). The increasing degradation of Iraq's natural environment in general and agricultural sector in particular has made Iraq highly dependent on food imports and thus vulnerable to global food price fluctuations. While food security is still not an immediate concern, the government has struggled to maintain its subsidy schemes, not least in the wake of the Covid-19 crisis when Iraq's oil revenues reached an all-time low (Kool et al., 2021). This problem is exacerbated by the broader tendency to solve the country's unemployment crisis by increasing public sector jobs (Mahmoud et al., 2023) at the cost of government revenues and a shrinking private sector (*The World Bank in Iraq*, 2022). This further inhibits Iraq's ability and potential to develop market-based solutions and innovations for the agriculture sector. The government's inability to respond to fluctuating food prices and broader needs of the agricultural sector with effective interventions serves to further erode citizen trust and could lead to large-scale anti-government protests. A lack of government response to water, food and energy challenges has led to mass protests before. In Basra alone, during the water quality emergency (2018), when at least 118,000 Iraqis were hospitalised due to symptoms related to drinking polluted water ('Iraq', 2019), and the 2022 heat wave electricity crisis, when, amid temperatures exceeding 50 degrees, the government was unable to secure a reliable flow of electricity and people demanded authorities to resolve the blackouts and power cuts (*Iraqis Protest against Third Consecutive Day of Power Cuts amid Extreme Heat*, 2022). Overall, lack of trust and dissatisfaction with government services serves to strengthen informal and local power structures, further eroding government legitimacy in favour of local militias and tribes who are better able to respond to needs on the ground (pathology 6).

The above developments point to the relevance of climate change as a trigger and multiplier of security risks in Iraq. More specifically, it is noteworthy that not one, but *all* seven climate-conflict pathologies can be observed in Iraq, to greater or lesser degrees. This suggests that the escalation of climate-related risks into conflict risks has already reached an advanced stage, and that the physical impacts of climate change are progressively interacting with social, economic, and political factors to increase conflict potential.

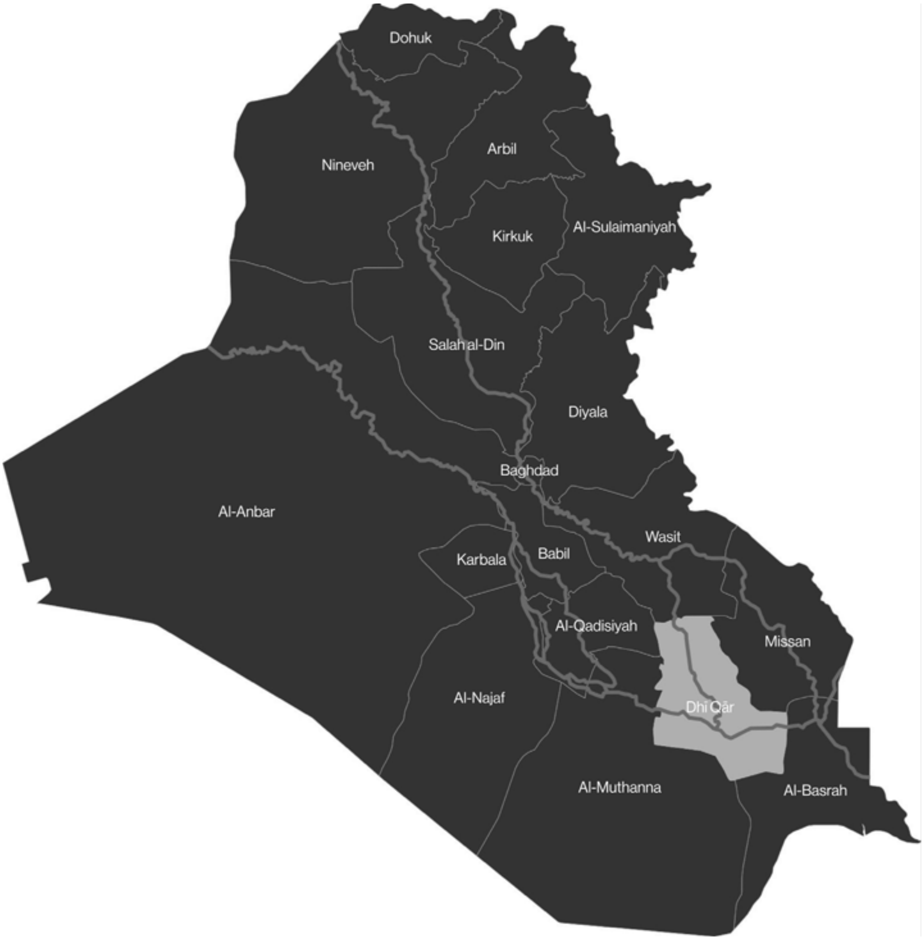
5.3.2 Anticipate: Identifying climate-conflict hotspots in Iraq

Using the WPS early warning tool, we consider the following three provinces in Iraq that contain districts that are identified as high risk: Qadissiya, Dhi Qar and Missan. These provinces are also highlighted in the recent Climate Vulnerability Assessment of Iraq developed by the International Organisation for Migration (IOM) (International Organization for Migration, 2023, p. 3).

What these provinces have in common is that they are highly dependent on agriculture and locally organised along strong tribal and ethno-sectarian lines. The main drivers of displacement in 2022 were low rainfall and low levels of water in rivers and their tributaries. Additional factors include low ground water levels, water salinisation, disputes over water allocation, and restrictions on the use of water.

Dhi Qar has the highest number of climate-induced displacements in Iraq, with five out of a total of ten locations in Iraq that are fully abandoned as a result of displacement situated in this province. For this reason, Dhi Qar ranks as one of the key climate security hotspots in Iraq (see Figure 5.2).

Figure 5.2. Dhi Qar province in Iraq.



5.3.3 Assess: Understanding local climate-conflict dynamics in Dhi Qar province

This section describes in more detail the factors that underpin resource-induced inter-communal violence in Dhi Qar.

5.3.3.1 PMESII analysis of Dhi Qar

The PMESII results – summarised in Table 5.2 – suggest that the most prominent pathway driving the climate and conflict nexus in the Dhi Qar region involves disputes arising from clashes over access to water, often involving members of different tribes or other ethno-sectarian affiliations, leading to broader inter-communal violence (pathology 2).

Table 5.2. PMESII framework applied to the case of Dhi Qar.

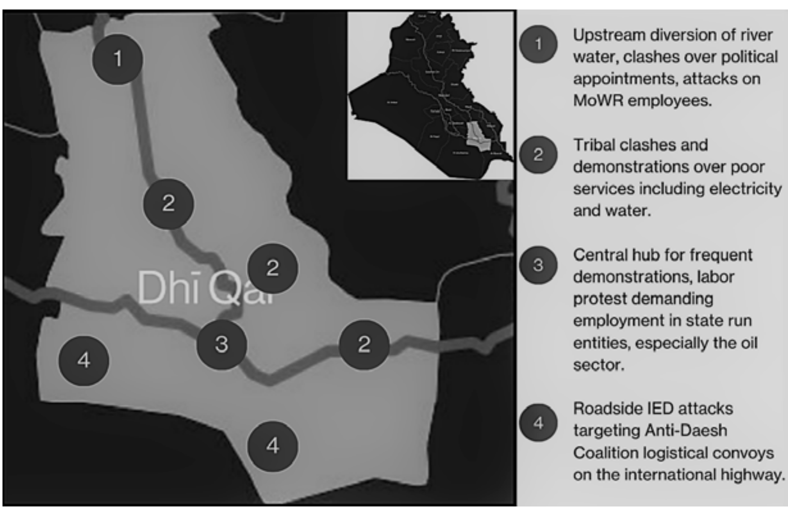
PMESII Analysis of Dhi Qar	
Political	Re-Tribalisation of political identities at the expense of national identity
	Distrust of federal authorities
	Popular Mobilisation Forces commander is Badr-aligned
Military	Many tribal fighters are also members of the Popular Mobilisation Forces
	Proliferation of heavy weapons
	Tribal militias have targeted state security forces and employees
Economic	One of the poorest provinces in Iraq
	High unemployment rate
	Significant agricultural sector
Social	Strong tribal identities and structures
	Shia-majority province
	Tribal courts have an important role in facilitating dispute resolution and enforcing agreements
Information	Misinformation prevalent on social media. Old clashes are sometimes falsely reported as new. Attacks are sometimes attributed incorrectly.
	Tribal violence under reported in media
Infrastructure	Traditional and inefficient irrigation methods are pervasive

5.3.3.2 Empirical analysis of climate-conflict pathways in Dhi Qar

The risk of climate events leading to conflict is not direct but determined by various mediating factors. These factors are context specific and can help policymakers identify how to intervene in a climate-conflict pathway. In Dhi Qar, climate change is increasing the scarcity of water and nurturing violence between tribes reliant on agriculture for their livelihoods. The most important mediating factors in this context are (1) the dependence on river water for irrigation, (2) high poverty rates, (3) re-tribalisation of political identities, (4) power sharing agreements, and (5) the efficiency of dispute resolution mechanisms.

These mediating factors manifest themselves in Dhi Qar in the following manner. Climate change creates deviations in rainfall and increases evaporation, resulting in less water availability downstream on the Tigris and Euphrates rivers. Socio-economic conditions influence how locals respond to this change. Groups struggling with low socio-economic levels in Dhi Qar – particularly in the form of high unemployment and poverty rates – are more vulnerable to water scarcity and the associated lost productivity in the agricultural sector. They also have a weaker adaptive capacity due to the low availability of funds to invest in modern agricultural equipment. Migration in search of alternative employment is also a less reliable coping strategy because of increased competition over a small number of jobs. Federal and local governments may not be capable of adequately responding to these changes due to political instability. Challenges to state authorities – especially in the form of violence between tribal militias and the government – limit the efficacy and legitimacy of state-based water sharing mechanisms. As a result, tribal leaders negotiate and create new power sharing arrangements. These arrangements are then enforced by highly armed tribal militias. The historically unprecedented droughts facing Dhi Qar place more strain on these new power sharing arrangements and have resulted in an increased number of clashes between tribal militants and between tribes and state security forces. When tensions escalate, community members rely on existing dispute resolution mechanisms to resolve the issue. This is commonly done through tribal courts in Dhi Qar. However, the courts do not have unlimited power to enforce agreements. Tribal groups in Dhi Qar are now increasingly violent and in competition with each other over key government positions and even militarily resisting government interference in water management (see Figure 5.3).

Figure 5.3. Overview of security incidents in Dhi Qar 2020-2023. Source: HCSS.



Below is a detailed overview of how these factors manifest themselves in Dhi Qar to provide a more granular understanding of the climate-conflict nexus.

First, Dhi Qar is economically dependent on river water irrigation. Its geographic position and long-standing inefficient water use practices make it particularly vulnerable to water scarcity. The Euphrates River and the Gharraf Canal – a distributary of the Tigris River – join in the provincial capital Nassriya before entering Basrah province and flowing in the Persian Gulf. As a result, Dhi Qar's water supply is particularly vulnerable to water diversions by upstream provinces. Inefficient water use is pervasive despite this vulnerability. The Ministry of Water Resources allocates water quotas to each province based on the previous year's consumptions (Von Lossow et al., 2022). Dhi Qar receives one of the largest water quotas because it is the largest agricultural producer and thus consumer of water in Iraq (Al-Furaiji et al., 2015). This almost-guaranteed high water quota has created distorted water use incentives for farmers. Consuming less water or using it more efficiently may result in a lower share of the quota the following year. As a result, inefficient irrigation methods such as traditional flood irrigation are pervasive in Dhi Qar. Taken together, the downstream position and inefficient water use create outsized water scarcity in Dhi Qar. Upstream dams in neighbouring countries and upstream provinces reduce the overall quantity of water reaching the province. The lower quantity is also used inefficiently, further exacerbating the scarcity of irrigation and drinking water.

Second, high poverty and unemployment rates reduce adaptive capacity in Dhi Qar. The government of Iraq is planning to make modern irrigation techniques a requirement for future shares of the quota to incentivise farmers to use water more efficiently. However, these modernisation requirements are expensive, and farmers have varying degrees of capacity to adopt them. As one the poorest provinces in Iraq (Vishwanath et al., 2015), farmers may not possess the necessary financial capital to effectively transition into modern irrigation methods. Reduced incomes from agriculture further degrade this adaptive capacity. As a result, farmers engage in urban migration to cope with their financial situation (Mahmoud et al., 2023) and sending household members to another location to seek employment is the most common response to climate pressures in Dhi Qar (International Organization for Migration, 2023). Between January 2016 and October 2022, 2,578 families migrated due to climate pressures in Dhi Qar (International Organization for Migration, 2023, p. 3). However, urban migration does not guarantee employment due to the high unemployment rate in the province and results in increased competition for scarce job opportunities. This further increases tensions especially in the provincial capital where protests and riots demanding job opportunities in state-run companies are common.

Third, tribal networks have gained legitimacy at the expense of the central authorities in Baghdad, leading to the re-tribalisation of political identities in Iraq. The state's failure to provide key services has resulted in the re-tribalisation of political identities at the expense of a common Iraqi national identity (Bar, 2020). Since October 2019 Iraq has experienced nationwide demonstrations against the government. The protesters had a range of high-level political demands, but key demands included basic services such as water services and job opportunities. The government responded with violent repression. State security forces and factions of the Popular Mobilisation Forces (PMF) targeted protesters in Baghdad's Tahrir Square and other major cities (*Iraq's Tishreen Uprising: From Barricades to Ballot Box*, 2021). Tribal dynamics were a key reason the protest movement relocated from Baghdad to Nasiriyah, the capital of Dhi Qar. The tribes supported the demonstrations, facilitated negotiations, and provided security (Al-Salhy, 2020; Robin D'Cruz, 2021; Smyth, 2019). The absence of the state has begun to change the patterns of violence. Dhi Qar, Missan, and Basrah account for more than half of all tribal violence incidents and about one-third of fatalities from tribal violence in Iraq since 2020 (Badawi, 2020).

Fourth, tribal competition and power sharing agreements have become a key water allocation mechanism in Dhi Qar. District Commissioners or *Qaymaqams* may choose to allocate water based on their tribal affiliation. In 2021, the Dhi Qar Director of Water Resources stated a District Commissioner in northern Dhi Qar was regularly interfering with the Water Directorate's work and providing extra water for farmers in his district at the expense of downstream districts (سيد دخيل.. أزمة مياه وسط اشتباكات مع متجاوزين, 2021). Provincial authorities have mixed results when intervening to correct these misallocations. A District Commissioner may nominally agree to follow instructions by provincial authorities, but members of the tribe may bypass them. Dhi Qar police who patrol waterways to prevent the construction of illegal water diversions regularly come under attack by armed groups. Similarly, tribal militants have used machine guns and rocket propelled grenades (RPGs) to target employees of the Ministry of Water Resources and their security escorts to remove the illegal water diversion (تعرض دورية أمنية إلى حادث إطلاق نار شمال محافظة ذي قار, 2021; ضمن حملة إزالة التجاوزات عن النظام الإروائي .. إغلاق الدوار لنهر السابلة بقضاء الرفاعي, 2021). Irrigation Directors have also been assassinated because of their tribal affiliations.

Fifth, tribal courts are a critical dispute resolution mechanism that may prevent the escalation of a conflict to violence. Only a small subset of the water disputes serious enough to escalate to the tribal level leads to violent conflict. The vast majority are resolved by tribal courts. However, tribal conflict resolution mechanisms are not always sufficient to address resource competition. Exploiting strong tribal connections to secure favourable water quotas at the district level is likely to foster resentment. This increases a community's risk of being dragged into disputes by reducing other communities' willingness to assume that it is acting in good faith. This erodes trust, which is a vital component of inter-tribal negotiations. The perception of preferential treatment has resulted in riots and clashes between rival tribes. Rioters have occupied government buildings and demanded the dismissal of District Commissioners accused of giving preferential treatment to their kinsmen when allocating water services. Tribal clashes in Al Islah are an example of how these tensions can escalate violence. It is meant to illustrate a known manifestation of the pathway from climate-change to conflict and is not representative of all possible cases.

Box 5.2. Illustrating the inter-communal violence pathology in Al Islah, Dhi Qar.
Source: معركة حقيقية وفشل للمحافظ والقوات الأمنية.. هذا ما حدث في إصلاح ذي قار | إنفوبلاس, *n.d.).*

In March 2023, the drying up of the Abu Lahiya river water used to feed the water purification stations triggered an acute water shortage. The stations went offline due to insufficient water input and the lack of irrigation water damaged crops. Protesters blamed illegal water use and denounced the District Commissioner from the Rumaid tribe for failing to crackdown on the illegal water use. The riots escalated into clashes between riots and police resulting in injuries. Several of the riots were arrested under Article 4 of the Terrorism law. Tribally motivated violence is prosecuted under this article. Tribal Sheikhs and other notables met to negotiate and agreed the District Commissioner would resign in six months. After the agreement, a kinsman of the District Commissioner praised his actions on Facebook. This led to an online argument between the kinsman and a member of the Omari tribe critical of the Qaymaqam. The argument escalated and one of the men went to the house of the other and killed him. A member of the Omari tribe then shot and killed a member of the Rumaid tribe in revenge. The situation then escalated into fatal clashes between the Rumaid and Omar tribes. A member of the Iraqi National Security Service who is also a son of one the Omari sheikhs attempted to negotiate with the Rumaid tribe but was ambushed and killed. Federal and local police, army, and Counter-Terrorism Service deployed to Al Islah to stop the clash and made arrests. Elsewhere on the day of the clashes, Rumaid tribal militants ambushed and killed the irrigation director of Suq Al Shoyok district who is from the Omari tribe.

5.3.3.3 Development of causal models

The third part of understanding local climate-conflict pathways can be fulfilled through the development of causal models that can offer strategic and analytical clarity on why the situation is deteriorating and how to intervene.[9]

5.3.4 Activate: Initial views for climate security interventions in Dhi Qar province

Building on the previous analysis, there are a range of actions, policies and strategies that can help state and non-state actors prevent, mitigate, and respond to climate and resource-related conflict outcomes in Dhi Qar. To leverage these intervention options for the specific context of Dhi Qar, it is critical to identify the root causes of climate-related instability, target the mediating factors responsible for triggering inter-communal tensions, and mobilise the right level of government and local leadership to ensure the intervention is effective.

Dhi Qar is economically dependent on agriculture, which is highly inefficient due to its reliance on river water for irrigation. At the local level, tribes are competing with each other over access and control over water resources. More efficient irrigation practices need to be introduced in Dhi Qar to address the acute water shortages that lead to tensions and violence between farmers, pastoralists, and tribes. Implementing policies geared towards reducing farming communities' dependence on river water – for example, through the erection of additional groundwater pumps – is likely to go a long way to reducing the (perceived) impact of upstream shocks, thus reducing their propensity to take actions which might cascade into conflict in response. To ensure these interventions are successful, it is critical the provincial authorities responsible for implementing water infrastructure projects engage local community or tribal leaders to identify, monitor and evaluate the effectiveness of these measures.

At national level, the federal Ministry of Water Resources is currently updating the Strategy for Water and Land Resource Management in Iraq (SWLRI) and developing implementation projects in hotspot areas such as Dhi Qar, including plans to modernise irrigation infrastructure and practices. This updated strategy needs to be implemented in close consultation with the Ministries of Agriculture and Operational Planning to ensure any water infrastructure interventions are aligned with broader rural development and adaptation plans. Current plans to tie water management and allocation at provincial and local level to the adoption and use of modern irrigation techniques should be carefully managed. While it may reduce water inefficiencies, it could lead to further inequalities and tensions, and should therefore be implemented in a way that does not alienate vulnerable or marginalised groups. Moreover, modern irrigation cannot solve all climate-related and man-made pressures on water availability and should therefore not be judged as a silver bullet that solves all water problems.

Government capacities need to be further strengthened so that the governing bodies responsible for implementing improved water and agriculture systems are better equipped to prevent, prepare, and respond to climate- and water-related emergencies. To avoid a further deterioration of the security situation in the region, it is critical that interventions take into account where and how quickly hotspots of risk are developing. Local communities should be included in the development of early warning systems that inform about emerging hotspot areas of risk, and when planning and prioritising adaptation projects (Global Center on Adaptation, 2022).

These activities should be supported with causal methods and models provided by academic and other research institutions, so that the driving factors can be further validated, providing a data-driven basis for intervention. These activities can be bolstered with practical knowledge on sustainable and efficient agricultural and water management practices.

For greater chances of success, inclusive approaches are essential. Federal action plans and provincial implementation plans should be shared at the local level to get buy-in from the community. Supporting vulnerable groups will pay off. Women are the de-facto head of households in rural areas of Dhi Qar, responsible for the majority of farming activities, and key to food security at community level. Targeting women does not just increase the likelihood that more sustainable farming practices are adopted, but also passed on to the next generation. Young farmers should be especially supported to play a role in adaptation projects. Developing their capacities can bolster a generation of new farmers that do not need to unlearn old farming practices. Finally, by providing a perspective and incentive to stay in rural areas, further migratory pressures in Dhi Qar may be dampened, which is essential to the long term stability of the region.

The key question remains how the government of Iraq will manage climate security interventions in a way that strengthens collaboration between national and provincial level authorities, builds trust with local communities, and keeps all relevant actors engaged in the process, supportive of the required measures, and capable of adapting to new irrigation practices. Ineffective, fragmented, and untransparent action will likely lead to further frustrations and tensions, as local communities are left with uncertainties about the impacts on their livelihoods. Interventions should be designed in a conflict sensitive manner to avoid unintended impacts on local communities that may lead to further distrust and tension.

5.4 Conclusion

The urgency to respond to the effects of climate change has led to the proliferation of quantitative and qualitative research in an effort to support fragile regions in mitigating climate-related security risks. This chapter offers an action-oriented framework for the development of successful climate security intervention options.

High level pathologies linking climate change to conflict offer an understanding of mediating factors – social, political, and economic dynamics – that determine whether climate stress may lead to conflict. The pathway approach allows policymakers to take timely action to mitigate conflict risk by addressing root causes and mediating factors rather than outcomes. Moreover, a comprehensive understanding of the various pathways provides insights into the dynamic interactions between relevant actors across different social, economic, and cultural backgrounds. This ensures that interventions in one area will not have negative unintended consequences that may lead to conflict through a different set of mediating factors.

By using early warning tools, the analysis can be further refined toward climate-conflict hotspots, i.e., the areas that are at most risk of climate related violence and conflict. After identifying an area of intervention, a deep dive into the hotspot of risk using frameworks like PMESII and qualitative and quantitative causal methods offers a good understanding of local dynamics and the different ways in which climate stress can exacerbate security risks.

The analysis of climate-conflict pathways and identification of hotspots also offers opportunities to develop integrated, inclusive, and informed interventions. Employing participatory methods to the development of tools and models maximises the effectiveness of the intervention. Moreover, whole-of-government approaches ensuring cross-disciplinary (climate, water, food, agriculture, welfare, private sector) and inter-departmental (international, national, provincial, local) coordination is essential for the success of interventions. Multi-stakeholder engagement and dialogue ensures that all the relevant perspectives are taken into account and that interventions do not lead to distributional effects across different social, economic, or ethnic groups.

The security sector is becoming increasingly recognised as a key actor in the development and implementation of these interventions. Security actors are impacted by climate change in their operational environment but can also bring important contributions to civil sector climate adaptation plans. The military's ability to anticipate, plan and respond to crises can serve climate action. In certain fragile areas, militaries are not trusted by communities and their involvement in adaptation planning may be controversial. However, it is important to understand the role the security sector can play to address climate-conflict dynamics and how they can be involved in the design, planning, and implementation of interventions. More research is needed on the ways in which the security sector may support climate action in various social, economic, and political environments.

While some of the steps presented in this framework tend to be performed in isolation of each other, a forward-looking plan that tailors its efforts according to the ultimate goal of developing and implementing integrated climate security interventions is essential for maximising the success of research and development efforts and ensures that adaptation-based development funds and assistance are targeted to long-term action from the very beginning.

Notes

1 The methodology presented here draws on insights generated in the context of the Hague Centre for Strategic Studies (HCSS) five-year research and engagement in Iraq on behalf of the Water, Peace and Security partnership, its climate-related causality research in the Middle East and Africa, and broader work as a founding member of the International Military Council on Climate and Security.

2 Root causes are causes that do not depend on other factors to exist, while mediating factors are effects of root causes as well as causes or mediators of causes on other effects. If causation is direct (climate change has a direct effect), there are no mediating factors. If causation is indirect (climate change has an indirect effect), there are mediating factors.

3 For example, The UN has developed the Global Disaster Alert and Coordination System (GDACS) that combines climate hazard data on cyclones, floods, earthquakes, and tsunamis, to provide alerts and impact assessments for specific regions to help them prepare against potential disasters. The European Flood Awareness System (EFAS) operated by the European Centre for Medium-Range Weather Forecasts (ECMWF) combines weather forecasts, river flow observations and hydrological models to identify flood-prone regions and issue alerts. The Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) developed by the University of California, combines satellite imagery with ground station data to provide rainfall projections.

4 Predictive EWS models primarily focus on correlations between variables to determine the likelihood of risk. Correlations reveal patterns, dependencies, and potential risks within the data. By leveraging these correlations, these systems can detect early signals and provide valuable insights about the onset of conflict.

5 Developed by the US military, the PMESII or PMESII-PT framework was originally designed to support the analysis of political, military, economic, social information, infrastructure, physical environment, and time variables while preparing for operations in foreign countries. Source: https://pavilion.dinfos.edu/Template/Article/2156908/pmesii-pt-research-analysis-framework/

6 Our definition of conflict includes non-violent forms of conflict that may lead to further instability. When conflict erupts, it can range from disputes between a few people to a full-blown crisis between entire communities that may or may not involve physical violence.

7 The amount was cited by numerous high-level government officials during a climate security appraisal mission to Iraq conducted by HCSS at the request of GIZ in February 2023. It is not yet clear what falls under this budget, and to what extent this amount consists of additional financial resources or reallocated/reattributed funds from already existing budget lines.

8 In the 1990s, Saddam Hussein dammed and drained the marshes in the 1990s to flush out rebels hiding in the reeds.

9 Examples of causal models and related intervention designs for Iraq have been developed by HCSS for the Water, Peace and Security partnership and will be available for publication in early 2024.

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CHAPTER 6

Low Lands, High Stakes: How the Dutch Navigate Climate Security

Sarah Lokenberg, Louise van Schaik, and Saskia Hollander

Abstract

The impacts of a changing climate are unmistakably evident, globally but also domestically. The security implications of climate change shape the strategic environment of the Netherlands. Climate change impacts increase resource competition and manipulation, disrupt critical infrastructures, and affect military operations and capabilities. The energy transition that is catalysed by climate mitigation policies in turn has its own geopolitical implications as it affects the energy security positions of countries. These strategic security effects mean that the Dutch government cannot overlook the importance of climate security. Followed by an analysis of how climate security is featured in Dutch strategies and policies, this chapter proposes specific entry points for synthesising climate security through a 3D approach, by integrating it into development, diplomacy and defence activities. It moreover points to the need to consider the security and conflict risk dimension more prominently in its international climate action too.

Keywords: climate security, 3D approach, the Netherlands, development, defence, diplomacy

6.1 Introduction

Climate change is a defining challenge and its security implications have been acknowledged for a while. Even for a well-developed and stable country like the Netherlands, climate change has significant security implications, both at home and abroad. A rising sea level leaves a great part of the Netherlands prone to flooding and storm surges, threatening coastal communities, critical infrastructure and the availability of freshwater (Haasnoot et al., 2020). Changing climatic and precipitation patterns affect agricultural productivity and water availability with notable implications for water and food security. Increasingly frequent heatwaves affect public health and can create conditions favourable for the spread of certain diseases (van Loenhout et al., 2016). The Caribbean part of the Kingdom of the Netherlands faces probably even bigger challenges, such as intensified hurricane seasons. All these impacts are cross-sectoral in nature and have far-reaching consequences for the

Dutch military. More frequent and severe extreme weather events increase demand for the military to provide humanitarian assistance and disaster relief (HADR) and raise the possibility of being increasingly deployed for stabilisation missions.

In Dutch policies climate security is recognised as a pressing issue, with climate change perceived as a threat to national and international security. The concept of climate security has been included in Dutch development, foreign, security and climate strategies. Although recognition is a first step, actual implementation is still falling short. Military personnel, diplomats and development actors realise the importance of implementing climate security in foreign, defence, and development policies but still face challenges with operationalisation (Hollander & van Schaik, 2023). It is for instance not yet clear how the relationship between climate and security affects the theory of change of development cooperation in fragile countries with high climate vulnerability and conflict risk. The same is the case for possible implications for early warning and action, including environmental expertise in operations, risk assessments for missions or the potential of exploring climate-security dialogues as part of peacebuilding and stabilisation efforts. Just like other countries, the EU and the UN, the Netherlands is struggling with how climate security affects its international activities.

This chapter aims to identify entry points for a synthesis of climate security through a 3D approach, so with a focus on development, diplomacy and defence. As climate security risks are context-dependent, have a compound character and transmit across time and space, different policy communities have to come together to develop an integrated approach (Mobjörk & Smith, 2017). The chapter also points to the need for international climate action to incorporate security and conflict risk insights. It will not discuss efforts by the EU and NATO, whereas it should be taken into consideration that these institutions are increasingly active on this issue. The chapter begins with outlining the strategic security implications of climate change for the Netherlands, followed by an analysis of how climate security is featured in Dutch strategies and policies. It concludes with entry points for how to better synergise climate security through a 3D approach and consider the security and conflict dimension more explicitly in international climate action that – at least in part – is implemented through the Dutch development spearheads food and water.

6.2 Strategic Security Effects of Climate Change

The security implications of climate change are multifaceted and can have spillover effects, making climate security issues – even beyond Dutch borders – a threat to its national security. Outlined below are the strategic security implications of climate change for the Kingdom of the Netherlands.

6.2.1 Increasing resource competition and manipulation

Climate change leads to a melting Arctic, which in turn opens up new shipping lanes and access to new resources, including oil, gas, scarce metals and fish stocks. In addition to land rights contestation and borders between NATO allies and Russia, this has made the region a new frontier of geopolitical competition. Major powers such as Russia, the United States and China have increased their presence, either militarily or economically. Russia has a great strategic advantage as its Navy has year-round access to both oceans from the North. There are rising concerns that Russia's growing military presence will be used to deny access to the sea line that could drastically shorten transport between the EU and Asia, the Northern Sea Route (Klimenko, 2019). The fact that Finland has now joined NATO, and Sweden may soon follow, augments the Alliance's ability to deter and defend against Russian influence, but also means security risks for the Netherlands have become larger. The melting of the ice does not only pose a geopolitical dilemma, but also potentially leads to an additional increase in sea level rise, a halting of the Gulf Stream and storm surges (Rantanen et al., 2022; Perovich & Richter-Menge, 2009).

While climate change in the Arctic leads to increased access to natural resources, in other parts of the world it results in the opposite. In arid and semi-arid regions such as the Sahel, Horn of Africa and the MENA region, climate change impacts pose intricate challenges. While in these regions the vast majority of the population depends on rural activities such as agriculture, pastoralism and fishing, increasingly unpredictable and extreme weather patterns, periods of droughts, desertification, floods, heatwaves, and land degradation are causing yield losses, damage to crops, and livestock mortality (Sartori & Fattibene, 2019; Heinrigs, 2010). Farmers, herders and fishers are disproportionately affected as pressures on already scarce resources increase. This aggravates food insecurity, malnutrition, increases the risk of resource competition and changes pastoral mobility patterns raising the possibility of conflict between farmers and herders over access to water and pastures (e.g. grazing vs crop cultivation), paving the way for people migrating in search of better living conditions (OCHA, 2023). With large numbers of migrants to Europe coming from or transiting through the Sahel, these regions are of strategic interest to the EU and the Netherlands. In the Netherlands, increasing temperatures and periods of prolonged droughts hit the agricultural sector hard, reducing crop yields, grassland and farmer's income, while reduced surface water impacts drinking water facilities (Utrecht University, n.d.).

Resource scarcity is also creating windows of opportunity for non-state armed groups (NSAG). In fragile and conflict-affected contexts where people's vulnerability and exposure to climate change impacts are greatest, little adaptive capacity forces people to sell their resources or flee their homes. Resulting grievances play into the hands of NSAGs such as AQIM, ISGS, Boko Haram and ISIS. These contexts render a conducive environment for NSAGs to establish a foothold by controlling territory and key access roads, allowing them to recruit young men for their cause – as they lack alternative means for employment and need to support their families. NSAGs such as ISIS have weaponised water – through capture, control, sabotage and looting of water installations – as a means to recruit farmers (Middendorp & Bergema, 2019). Heightened risk of conflict and insecurity caused by climate change impacts possibly necessitates more stabilisation missions and interventions.

6.2.2 Disrupted critical infrastructures

Climate change impacts and natural hazards, specifically droughts, wildfires, and floodings pose great challenges to the densely populated country the Netherlands is. The government-wide Security Strategy has stated that ''it is not a question of *if* but *when* an uncontrollable wildfire will occur'' (Ministerie van Justitie en Veiligheid, 2023). Natural hazards can disrupt critical infrastructures like drinking water, electricity and telecom facilities which in turn affect service provision such as energy, transport, water, food, communications, health, emergency response services and payment/financial services. Since essential services are increasingly becoming interdependent, the risk of systemic failures increases as a breakdown of one critical infrastructure can generate cascading effects.

According to the Joint Research Centre, annual damage to Europe's critical infrastructure could be ten-fold by the end of the century under business-as-usual scenarios due to climate change alone, from the current €3.4 billion to €34 billion (Joint Research Centre, 2017). For the Netherlands specifically, expected annual damage based on multi-hazard multi-sector analysis was €76 million in 2000, which is expected to rise to €105 million in 2020 and €156 million in 2050 (Forzieri et al., 2018). The flooding in 2021 in Germany, Belgium and the Netherlands caused not only 220 casualties but also destroyed critical infrastructure. Germany and Belgium were primarily affected, with critical infrastructure such as hospitals, fire departments, railways, bridges and utility networks heavily damaged. While less affected, physical damage was estimated to be approximately €300–600 million for the Netherlands (Koks et al., 2021). The Caribbean part of the Kingdom has also experienced how climate change can disrupt critical infrastructures. Hurricane Irma hit Sint Maarten in September 2017, extensively damaging buildings, infrastructure and communication networks (van Schaik et al., 2018). The destruction of the airport and the maritime port blocked transportation routes and food and material supply in Sint Maarten and neighbouring islands that rely on them, such as Saba and St. Eustatius. As providing relief goods proved to be highly challenging, water and medicines were largely exhausted after only a week and had to be brought in by military assistance from the Netherlands. Due to damaged telecom masts and failure of power plants, walkie-talkies, radios, the internet, mobile phones, landlines and satellite phones were not working or barely working, significantly limiting communication (Fetzek et al., 2019).

These two examples from the Netherlands and its Caribbean part illustrate the far-reaching consequences of extreme weather events. The intensity and frequency of natural hazards will increase if climate change is not curbed, meaning that there might be a greater role for the Dutch military to provide HADR.

6.2.3 Military deployment, infrastructure and capabilities, and operations

As climate change dynamics aggravate, it is expected that armed forces will be affected in multiple ways. First, an increase in deployment can be expected. The increasing severity and frequency of extreme weather events will increase the deployment of forces for HADR in the short term (van Schaik et al., 2020). Because the Dutch military has a broad range of capabilities (e.g. air and sea transport, reconnaissance and intelligence, communications, engineering, and medical) they might be called upon when assistance is urgently needed[1] (Stoetman et al., 2023). For instance, the Dutch military has already been deployed to provide HADR in response to the 2017 Hurricane Irma and the 2021 floodings in the Netherlands. HADR will have a lead-in time that places a higher demand on early warning and crisis detection.

In addition, as climate change raises the possibility of conflict and instability, an increase in demand for crisis management or stabilisation operations may result (Stoetman et al., 2023). Furthermore, climate change impacts that lead to livelihood insecurity and inhumane situations pave the way for people to migrate in search of better living conditions. This could lead to an increasing role for the Royal Marechaussee at the Schengen area border or on the Caribbean islands to engage in border protection (Stoetman et al., 2023). Lastly, climate impacts in strategically significant areas like the Arctic can also unlock new military operations to protect Dutch strategic interests.

Second, climate change impacts affect military infrastructure and capabilities. Particularly high temperatures, rising sea levels and extreme weather events could damage military assets or render them unfit in certain operation conditions. This leads to higher costs for infrastructure inspection, maintenance, repair and overhaul (da Costa et al., 2023). Helicopters, for example, face difficulty taking off in high temperatures and military infrastructure in harbours and low-lying land areas are vulnerable to sea level rise and flooding. A one-metre rise in sea level has already affected military infrastructure such as the Marines Barracks Savaneta at Aruba. This could lead to new requirements to guarantee its future use. In the long term, infrastructure might need to be relocated to higher altitude areas (Stoetman et al., 2023). Climate hazards can also put the military at risk by impacting civilian entities that operate critical energy infrastructure (CEI) on which the military depends (e.g. electricity for powering systems or fuel for transportation). If such CEI is affected by climate hazards, the services it provides may be disrupted, cascading to military installations and compromising operational effectiveness and readiness. There is therefore a strong link between operational effectiveness and energy resilience (da Costa et al., 2023).

Third, the impacts of climate change affect the characteristics of military operations – be it warfighting operations or humanitarian and stabilisation missions. Armed forces will increasingly have to operate in a rapidly changing and harsh environment where circumstances are extremely challenging. Areas with extreme temperatures and heatwaves, such as in the Sahel, Horn of Africa or MENA region can disrupt logistic activities, and drought and desertification directly impact water availability for land forces (NATO, 2023a). In addition to extreme temperatures, climate change impacts can place a significant burden on the supply chains and logistical capacity of armed forces directly engaged in combat (Stoetman et al., 2023). Another example is that climate change increases salinity levels and changes surface temperatures of seawater, severely affecting submarine and anti-submarine operations (NATO, 2023a).

6.2.4 A geopolitical energy transition

As demand for military deployment will increase in the foreseeable future, it also implies that military emissions will increase. The Russian invasion of Ukraine unveiled the EU's and Dutch critical vulnerabilities, proving to be a wake-up call regarding the risks associated with its energy dependency on Russia (Lokenberg et al., 2023). The defence sector is a large contributor to greenhouse gas (GHG) emissions as its energy use at military bases and fuels used for operations and military equipment are fossil fuel based and have a big carbon footprint (CEO, 2021). Decarbonising the military would result in a win-win-win: curbing climate change by reducing GHG emissions, increasing autonomy in the field by reduced dependency on vulnerable diesel supply lines and diminishing operational vulnerabilities caused by the strategic leverage of petrostates (e.g. weaponisation) like Russia (van Schaik et al., 2022). Hence, phasing out fossil fuels would have advantages beyond GHG emissions reduction (Stoetman et al., 2023).

Transitioning to climate neutrality and green technologies needed for the military increases demand for critical raw materials (CRM) and rare earth elements (REE) and redraws the geopolitical energy map. A country's ability to either generate or export renewable energy (sources) and its dependency on fossil fuel energy influences its international posture (Hollander & van Schaik, 2023).

Paradoxically, while the energy transition has many advantages, the increased demand in CRMs can also cause new climate security risks. First, REEs and CRMs needed to realise a net-zero energy system is currently mined in only a small number of countries, including the DRC, Nigeria, Brazil, Chile and China. Processing and refinery are predominantly dominated by China, as it controls 85% of the processing capacity for REE, 35% for nickel and 50–70% for lithium and cobalt. As most of the CRMs key to the EU and Dutch energy transition are both produced, processed and supplied by non-EU member states, the energy transition creates the risk of new undesired dependencies on undemocratic regimes or even systemic rivals (Lokenberg et al., 2023).

Second, increased demand for REE and CRMs could incite domestic tensions and conflicts in conflict-affected and fragile countries. In the majority of countries where REE and CRMs are found, governments and the mining sector perform poorly in terms of due diligence and ensuring sensitivity to conflict and the needs of local communities. Although supplying 70% of the world's cobalt, institutions in the DRC are still afflicted by patronage systems and little political or economic interests exist to implement the Mining Code. Mismanagement and unequal distribution of mining revenues have led to grievance and conflict (Ateyo, 2022).

Third, and in a similar vein, hydroelectric, wind and solar infrastructure projects can also violate human rights, exacerbate tensions, and fuel conflict. In South and Central America, renewable energy infrastructure projects have violated land, territory and indigenous rights, and attacks against human rights defenders have also been highly prevalent (Hudlet & Hodgkins, 2021). In the Western Sahara, Morocco's plans to construct solar and wind parks have violated the international humanitarian laws protecting civilian populations under occupation and are harming peace efforts in the region (Ateyo, 2022). As demand for CRMs increases, the probability of conflict can also be expected to rise. This also prompts the question from developing countries about what agenda is served by the energy transition (Hollander & van Schaik, 2023). Whereas it is sometimes suggested it would benefit primarily Western countries and China which own most renewable energy technologies, many developing countries will be hit hard by climate change and can reduce energy costs by shifting to locally produced renewable electricity.

6.3. Climate Security in Dutch Climate, Foreign, Security and Defence Strategies

The strategic security implications of climate change mean that the Dutch government cannot overlook the importance of climate security. Until now, Dutch foreign, defence and climate policies have made reference to climate security, albeit in a limited manner and without clear links to implementation. While in 2015, the

Netherlands raised awareness by launching the Planetary Security Initiative, it was hardly on the radar in its own policies. Even in the climate-adaptation field of water, where an additional Water, Peace and Security Programme is funded, the link with conflict and security in actual policies remains insufficient. This is highlighted by the limited allocation of both capacity and financial resources to address climate security risks (Hollander & van Schaik, 2023; Bunse et al., 2022). Several policies and strategies reiterate the recognition that the effects of climate change pose a threat to (national) security. See Table 6.1 for an overview of relevant strategies for climate security.

The **2022** policy on trade and development (**BHOS note**) of the Ministry of Foreign Affairs (MFA) recognises the security implications of climate change and aims to tackle these challenges by directing attention to mitigation, adaptation and disaster relief. Increasing access to renewable energy is a priority as well as combining Dutch expertise in water and food with digital information systems for climate-smart agriculture and sustainable land and water use. However, despite the risk of renewable energy projects in developing countries leading to new climate security risks, this BHOS note does not consider conflict sensitivity in its intention to double the number of people with access to renewable energy to 100 million. The Netherlands also intends to contribute to conflict prevention by supporting early warning early action systems to gain better insights into water-related conflicts and solutions. It pledges to continue its work on emergency response and disaster relief with a specific focus on mental health and psychosocial support (MHPSS; Ministerie van Buitenlandse Zaken, 2022a). While recognising the need for a combined approach of political efforts, trade and development cooperation, conflict prevention and peacebuilding, it does not specify what such an integrated approach should look like. By and large, this BHOS note comes down to pledges of financial support and ways of implementation relate merely to greening trade instruments.

The **International Climate Strategy** (ICS), published in 2022, features climate security (next to climate and health and climate and humanitarian aid) as part of a whole-of-government approach to climate policy. Hence, implementation is the responsibility of several Dutch ministries. The ICS emphasises the critical role of climate adaptation, natural resources management and renewable energy in supporting conflict prevention and peacebuilding initiatives. However, no attention is given to preventing climate interventions from having unintended effects on conflict because they provide support to one group over another (maladaptation). It is also awkward that in the English version the Dutch term “klimaatveiligheid” has been translated into “climate safety” instead of “climate security”. A conflict sensitivity assessment of these interventions could be the first step in this regard.

The ICS does integrate a climate lens in Dutch security policies and development and stability programming and addresses climate risks and resilience in strategic context analyses, conflict analyses and programming. Actions are directed towards accelerating the energy transition in developing countries, fostering inclusive green job creation and sharing Dutch expertise in water security, land use and climate-smart agriculture. Greening funding and trade instruments are proposed as ways for implementation. Furthermore, and similar to the BHOS Policy Note, the ICS is also committed to supporting early warning early action systems (Ministerie van Buitenlandse Zaken, 2022).

With a foremost focus on adopting a climate lens into Dutch development, foreign, and security policies it tends to overlook the integration of a conflict lens into Dutch climate policies. While it does recognise the importance of conflict sensitivity, it does not concretely propose instruments to implement this (Hollander & van Schaik, 2023). This applies also to the **Resources Strategy** published in 2022 which aims to enhance the security of supply of critical raw materials (CRM) in the mid-to-long term. The Dutch government puts efforts into making a strong case within the EU for concluding and strengthening partnerships on CRM, including African and Latin American countries. For many climate activities such as the Just Energy Transition Partnerships (JETP), no analysis is made of their conflict sensitivity – and instruments to do so are missing. As the Dutch government contribute to JETPs in for example South Africa, it is advised to consider conflict sensitivity. However, the Resources Strategy does recognise the intricate challenges of child labour and conflict minerals, and seeks due diligence and responsible sustainable mining practices by supporting public-private financing (Ministerie van Algemene Zaken, 2023). But in proposing actionable steps, this strategy stresses supporting new research and analysis of social and environmental risks in critical supply chains – but does not include conflict risks.

The **Africa Strategy 2023–2032**, published for the first time in February 2023, recognises the impact of climate change as a driver of instability in the Sahel, Horn of Africa and North Africa. The Netherlands works through the EU and in cooperation with EU member states, while also maintaining intensive bilateral relations of its own with many African countries and partners. Given its solid knowledge base on water and food-related conflict, the Netherlands could step up its efforts when it comes to its own bilateral programming, such as supporting the preparation of better climate vulnerability and risk assessments. In addition, these climate interventions can lead to perceptions of inequality between communities that qualify and those that do not if conflict sensitivity is not considered (Darwish, 2023). As most of the Dutch bilateral programmes relate to the water and food sector and are implemented in the Sahel and East Africa – both greatly afflicted by conflict – considering conflict sensitivity is key to avoiding climate interventions that lead to maladaptation.

While implementing the ICS is in close collaboration with the Ministry of Defence (MoD), there are no explicit actions or instruments directed specifically towards the Dutch military. However, climate security has gained traction at the MoD. Climate change has been taken into account in applicable regional cases and strategic foresight activities have increased (van Schaik et al., 2020). Moreover, the MoD is further professionalising its tasks in disaster relief and is incorporating the consequences of climate change into its strategic regional analyses (Ministerie van Defensie, 2022). Despite the prevailing perception that a trade-off exists between going green and maintaining operational effectiveness, efforts on decarbonising the military have heightened by focusing on energy efficiency in military operations through emission reduction (Ministerie van Defensie, 2022).

In 2023, the MoD published the **2030–2050 Roadmap Energy Transition**, including a target to reduce fossil fuel dependency by 2030 by at least 20% compared to 2010, and in 2040 by 70% (Ministerie van Defensie, 2023). To develop policies to meet these targets, knowing how much energy the MoD consumes and which equipment or weapon system consumes most is essential. In its 2022 annual report, numbers on energy consumption were absent. After invoking the Open Government Act, the MoD shared a 2017–2022 overview, which claims that fuel consumption has declined significantly from 193.432m^3 in 2017 to 87.051m^3 in 2022[2]. According to this overview, the MoD would have already met the 2030 target (20% reduction). The only reasonable explanation for this spectacular reduction would be if the MoD had started using much more third-party fuel than its own DBBB (Defensie Brand en Bedrijfsstoffen Bedrijf; Hendriks, 2023a; Hendriks, 2023b).

In its **Defence White Paper**, the MoD has stated its intention to establish a dashboard to better provide insights into its energy consumption. However, how this dashboard will be realised remains vague. In addition, the White Paper stressed the importance of international cooperation on climate security within NATO and the European Defence Agency (EDA), aiming for enhanced interoperability and standardisation within NATO and the EU. The **2022 EU Strategic Compass** and the **NATO Strategic Concept** render entry points for intensification of cooperation. In light of implementing the **Climate Change and Defence Roadmap**, the EU Strategic Compass also requires member states by the end of 2023 to develop national strategies to green the military and prepare them for climate change. This also pertains to improving the ability of the armed forces to support and coordinate with civilian authorities in emergency situations (EEAS, 2022). While this deadline is the end of 2023, not all countries, including the Netherlands have met it.

Other security strategies such as the government-wide Security Strategy and the National Security Strategy highlight that climate and natural disasters have a great impact on security interests and threaten national security. The **2019 National Security Strategy** identifies floods, storms, rising temperatures, long periods of drought and sea level rise as factors affecting the security of the Netherlands and makes the case for enhancing civil-military cooperation in the context of an integrated approach to national security. The **Security Strategy 2023–2029** states that ''the Kingdom incorporates the impact of climate change and climate transitions in the security policy and takes climate risks and resilience into account in the strategic context analyses, conflict analyses and programmes''. It also highlights the need to enhance the Kingdom's adaptive capacity against climate and natural disasters, among other things through climate-resilient spatial planning that will take into account extreme weather, flood risks, the spread of infectious diseases and wildfires. In addition, the strategy acknowledges the importance of strengthening crisis control and increasing the preparedness of society with regard to climate-related threats. This requires joint national planning with attention to specific issues such as the care, shelter and evacuation of vulnerable groups (Ministerie van Justitie en Veiligheid, 2023).

Because the ICS features climate security as part of a whole-of-government approach to climate policy, the Dutch government paves the way for mainstreaming climate security risks into development and security programming. However, the ICS shows deficits when it comes to implementation. The instruments that are proposed include primarily a climate lens in Dutch foreign, security and development strategies while largely leaving conflict sensitivity in Dutch climate policies unnoticed, both within the Netherlands and abroad. The ICS does recognise the importance of the latter, but when it comes to implementation the ICS refers to gender and youth mainstreaming, and the Dutch Diamond Approach (Hollander & van Schaik, 2023). The first are strategies to realise gender equality and youth participation, which involves incorporating a gender and youth perspective throughout the entire process of policy development, implementation, monitoring and evaluation, regulatory measures and funding programmes. The latter means fostering effective cooperation between the private sector, knowledge institutes, NGOs and the government. Yet, these two approaches do not clearly demonstrate their contribution to conflict sensitivity. Despite the prevalent use of these typical Dutch approaches, specific instruments for effective implementation remain largely absent. To put climate security into practice in an integrated manner, the Dutch strategies would benefit from a common, inter-ministerial agenda for implementation.

Table 6.1. Overview of how climate security is featured in Dutch policies and strategies.

Policies/ strategies	**Climate security**	**Proposed actions and instruments for implementation**
BHOS note	• Tackling root causes of climate change • Focus on mitigation and adaptation • Increasing efforts to help make countries more resilient and enhance biodiversity • Supporting developing countries with green economic growth • Strategic autonomy for CRM (production in EU)	• Greening trade instruments and researching by which instruments greening is most effective – with a special focus on SMEs • Analysing strategic CRM dependencies through a geo-strategic monitor • Mobilising private financing (Dutch Fund for Climate and Development; Climate Investor One, International Loan Exchange) • More budget for tackling issues in the food supply chain caused by climate change • Mobilising in 2025, 1.5 billion EUR for climate finance (public & private) • Doubling the number of people with access to renewable energy to 100 million in 2030
International Climate Strategy	• Climate lens in conflict programming and regional context analyses • Convincing multilateral and international partners of the importance of applying conflict-sensitive approaches to climate interventions	• Greening funding and trade instruments • Accelerate green transition in developing countries • Pursuing inclusive green job creation • Sharing Dutch knowledge on water security land-use and climate smart agriculture • Financially support organisations and systems that use big data for early warning early action systems
Africa Strategy	• Climate lens in conflict programming and regional context analyses • Conflict sensitivity into climate adaptation interventions • Include climate risk and resilience in strategic context analyses, conflict analyses and programming • Increasing climate resiliency of people in Africa • Promoting a just energy transition	• Localising humanitarian efforts (including regional, national, local actors in international humanitarian assistance) • Strengthening environmental impact reports in Africa for better investment decisions • Improved access for African countries to digital climate-smart technologies, investment in climate resilient infrastructure, supporting green job creation • Enhancing water infrastructure in 9 African countries • Greening Dutch funding instruments

Policies/ strategies	**Climate security**	**Proposed actions and instruments for implementation**
Resources Strategy	• Seeking due diligence and responsible mining practices • Promote that developing countries benefit from new EU regulations and international agreements • Emphasising CRM, environment and gender equality • Pursuing a just transition • Promoting the inclusion of climate and environmental risks in the OECD guidelines	• Supporting new research and analyses of the social and environmental risks in all critical supply chains • Supporting public-private financing for due diligence • Conducting impact analyses of EU regulations • Reviewing the Conflict Minerals Regulation
National Security Strategy	• Climate adaptation and mitigation • Climate proof groundwater and surface water systems • Climate proof spatial planning and use of land	• The Fresh Water Delta Programme will work out plans to boost water availability. • The Spatial Adaptation Delta Programme will further elaborate the theme of ‘drought’ for use in stress tests and risk dialogues • The Ministry of Agriculture, Nature and Food Quality will take care of the policy objectives relating to the Climate Adaptation for Agriculture and Climate Adaptation for Nature action programmes. • Municipalities and water boards will conduct stress tests and implement operational measures.
Government-wide Security Strategy	• Intensifying climate mitigation and adaptation • Strengthen crisis control capabilities and preparedness of society • Ensure better protection for critical infrastructure • Contribute to greater water security and safety in fragile states	• Climate-resilient spatial planning by considering climate risks • Strengthen the approach to wildfire prevention and suppression • Define long-term approach to climate change impacts for the Caribbean (renewable energy, climate-proofing spatial planning and increase redundancy) • Taking climate risks and resilience into account in strategic context analyses, conflict analyses and programming

Policies/ strategies	Climate security	Proposed actions and instruments for implementation
Defence White Paper	• Contributing to the social challenge of combating climate change • Energy efficient deployment • Decarbonising defence • Professionalising HADR • Increase sustainability of real estate • Exploring opportunities for operational sustainability	• Using simulation for training and exercise • Carrying out pilot scheme to assess the suitability of zero-emissions vehicles for operations • Examine how to produce less waste and research circularity • Consider sustainability as guiding principle in procurement of materiel and real estate projects • Replacing non-operational vehicles with zero-emission alternatives (by 2030, 2800 zero emission vehicles) • Increasing the proportion of biomass or synthetic fuels used in combination with fossil fuels to an average of 30% • Establish a dashboard for its energy consumption • Include climate change impacts in military strategic analyses

6.4 Recommendations for Implementation: Climate Security in 3D

This subchapter identifies entry points which could be part of integrating climate security insights into a 3D approach. A 3D approach, commonly referred to as a whole-of-government approach, refers to a comprehensive strategy that involves coordination and cooperation across the development, diplomacy and defence sector. The aim is to create a holistic approach that leverages the strengths of each dimension to effectively address multifaceted complex issues, such as climate security. On top of this, there is also the other side of the coin: adopting a security or conflict lens in climate policies, both in the Netherlands and abroad.

Implementing climate security through a 3D approach necessitates a substantial level of inter-departmental coordination to enhance coordinated decision-making. It is essential to avoid the potential drawback wherein this strategy might lead to new compartmentalisation or silos in policymaking by prompting stakeholders to differentiate the 3Ds and compete for resources. Nevertheless, it is this whole-of-government approach that is best suited to tackling the intricacies inherent in the contemporary climate security environment (Brock et al., 2021). This is because climate change is context dependent, compound in character and transmits across time and space and its effects affect diverse policy areas, different levels of society (local, national, regional, global) and manifest differently depending on social, economic, political, and institutional factors. The multifaceted nature of climate security requires policy responses from different policy circles at the same time (Mobjörk & Smith, 2017). An integrated, coordinated, cross-departmental approach can leverage departmental expertise, reduce policy redundancies, mainstream climate change into all decision-making, and create cross-departmental synergies for more effective climate governance (McKenzie & Kuehl, 2021).

The following entry points for integrating climate security in development, diplomacy and defence activities could be considered:

– Better cooperation and coordination between policy areas/ministries should not be an end in itself, but a means for improved action, requiring consensus on a common language and framing of climate security (e.g. in development circles climate is linked to conflict risk, whereas defence circles use the word security when talking about similar issues). Establish a **climate security division (or working group) with a clear mandate** to coordinate an inter-ministerial agenda for implementation to overcome departmentalisation and think beyond known patterns.
– To effectively **mainstream climate security** into various policy domains, including development and defence, the Dutch government could designate **climate security advisors (within its new division)** who are responsible for ensuring that climate security plays a role in all policy areas and supporting colleagues to achieve this. Examples could be taken from its own Taskforce Women's Right and Gender Equality, which ensures gender equality in all policy areas. In addition, the Netherlands could conduct a thorough **climate security audit** for its development, climate, foreign and security programmes.
– As the Dutch military has an increasingly important role to play when it comes to providing HADR within and beyond Dutch territory, greater involvement of the **armed forces in early warning early action systems** and a focus on preventive action through increased **actionable foresight capacities** could help to prevent humanitarian disasters after extreme weather events. At the same time, civil-military-cooperation (CMC) could be enhanced as both will work more closely together – because at the moment distrust still exists in climate and development circles towards the military.
– Degraded environmental conditions and natural resource scarcity can fuel conflict. Hence, protecting the environment can contribute to peacebuilding. Appointing climate security envoys in peacebuilding and stabilisation missions can enhance the potential for **climate-sensitive peacebuilding**. The Netherlands could draw lessons from the UN which already deploys climate

security advisors in the mission in Somalia. Moreover, the EU aims to replicate the UN in this respect but lacks financial resources and experts. The Netherlands could support these efforts financially or by providing experts.

- Since climate interventions can be used to support peace and security objectives, it is advised to consider **conflict sensitivity** in Dutch climate and resource interventions. Especially as most bilateral programmes are in the water and food sector and implemented in conflict-affected regions like the Sahel and East Africa.
- Strategies to secure REEs and CRMs needed to **decarbonise the military** could be pursued in a **conflict-sensitive** way. Considering the importance of not creating new undesired strategic dependencies is paramount in the transition to green technologies. Closely monitoring its strategic dependencies and exploring diversification strategies provides greater insight into current and future dependencies. In its efforts to diversify supply chains and restore critical production chains, the Netherlands could incorporate a climate security lens into its policies to secure critical raw materials, which entails analyses of environmental costs, local stakeholder mapping and potential sources of grievances. Lastly, as the Netherlands has green energy partnerships bilaterally and through the EU with developing countries, a better understanding of the conflict and political sensitivity of these partnerships could lead to more mutually appreciated efforts.
- The Netherlands could more actively **promote** the reduction of military emissions at both EU and NATO levels – for example by including decarbonisation in public procurement and by investing in new R&D programmes on decarbonising defence technologies and weapon systems.
- Effective **climate diplomacy** is particularly important when it comes to climate security, given the Netherlands' bilateral partnerships with countries in regions like the Sahel and the Horn of Africa that are prone to climate-related conflicts. Enhancing and expanding the Dutch embassy network as well as appointing climate security advisors in embassies in these countries would be two means to pursue climate diplomacy. Another avenue could be to support climate-security dialogues as part of peacebuilding and stabilisation efforts.

Notes

1 Higher demand for gathering and processing information; firefighting, in particular in areas which are remote or difficult to access; emergency access by air or boat (when entering by land is impossible); delivering water and food supplies; search and rescue; evacuation of civilians; engineering to restore infrastructure, roads and bridges; providing temporary urgent energy supply or communications. In terms of capabilities and equipment: transport capabilities, in particular in the air and at sea (manned aircraft and helicopters, unmanned aerial vehicles); water pumping; divers; small boats; engineering capabilities, in particular to repair, restore or rebuild infrastructure (bridging equipment, bulldozers, cranes, trucks, etc); search and rescue capabilities (helicopters in particular); medical capabilities (up to field-hospital level).

2 For an overview of 2017–2022 fuel consumption, see: https://irp.cdn-website.com/9afbdf10/files/uploaded/brandstofverbruik.jpg.

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CHAPTER 7

Scientific Climate Consensus, Human Causation, and the Divergent Public: The Continued Influence Effect of Misinformation

Berma Klein Goldewijk

Abstract

Climate misinformation has a persistent effect on public perceptions even after corrections. This is the continued influence effect (CIE) of misinformation as explored in the cognitive sciences. The present study regards some noteworthy findings on the CIE as a niche in the search for strategies to address the contrast between a robust consensus among climate scientists (97%) and divergent public perceptions of climate change. The central question concerns the implications of an alternative causal correction approach for minimising the effect of climate misinformation. The main objective is to advance scholarship on the CIE by connecting it to public perceptions of climate change and the communication of the scientific climate consensus. Methods that produce cognitive results, like experimental research, raise some concerns, bringing up the concept of causation as part of the suggested innovations. Some outstanding areas for future study involve improvements with inter- and transdisciplinary approaches, briefly summarised in the conclusions and general discussion.

Keywords: misinformation, continued influence effect, causal correction, causation, climate change, scientific climate consensus

7.1 Introduction

The most troubling aspect of misperceptions is that they persist and continue to influence the public domain long after they have been corrected on a factual basis (Nyhan & Reifler, 2010; Nyhan, 2021). While corrections may have a certain effect, they fail to eliminate the reliance on misinformation in subsequent reasoning. Despite being incorrect, the misinformation continues to influence perceptions and is still utilised in reasoning. This phenomenon, known as the continued influence effect (CIE), exposes the cognitive processes that make misinformation resistant to correction (Lewandowsky et al., 2012: 112).

Misconceptions of human-caused climate change as both an ideology and a myth are prevalent despite a near-unanimous scientific climate consensus and accumulating evidence. This scientific consensus contrasts with heterogeneous and varied public perceptions, including views that reject the consensus among climate scientists (Markowitz & Guckian, 2018: 35–36). The misperceptions have various consequences: they cause public confusion, disrupt communication on the scientific consensus, and erode the effectiveness of policies designed to address climate change. Misperceptions are defined as “factual beliefs that are false or contradict the best available evidence in the public domain” (Flynn et al., 2017: 128). Diverse responses and strategies have emerged to settle the divergence and contrast, dispel misinformation, and encourage increased public engagement.

This study will regard research on the continued influence effect as a *niche*, signifying a space of innovation with potential implications for addressing the discrepancy between the scientific consensus and the divergent public perceptions of climate change. The enduring effect of misinformation is contingent upon perceptions, which in this context are defined as reasoning, beliefs, and attitudes. This effect has been the subject of extensive research in the cognitive and behavioural sciences over the last forty years. For now, however, the resonance of findings on the CIE in climate science and policy is notably limited. To my knowledge, John Cook is an exception (Cook, 2019, 2016), along with a few other scholars who mention it but do not systematically address it (Markowitz & Guckian, 2018: 46; Stubenvoll & Marquart, 2019: 33–35, 41; Drummond et al., 2020: 2; Maertens et al., 2020: 2; Treen et al., 2020: 10, 14).

From prior research on CIE, one type of corrective information effectively dispels misperceptions: this type of rectification centres on the *causal structure* of misinformation. The corresponding correction approach posits that by offering an *alternative* cause and explanation, the correction can diminish the dependence on and confidence in the initial erroneous cause (Johnson & Seifert, 1994). It provides a causal alternative for addressing misinformation and is different from fact-finding, which involves straightforwardly opposing and rejecting unfounded public claims.

The central question concerns the implications of an alternative causal correction approach for minimising the effect of climate misinformation. The main objective is to advance scholarship on the CIE by connecting it to public perceptions of climate change and the communication of the scientific climate consensus. The chapter comprises two main sections. The first examines climate change in terms of misinformation, the CIE, and the causal correction approach. The second section explores what causal correction means for communicating the scientific consensus. It also addresses some issues on theory and methods, such as experimental research and the nexus correlation-causation, resulting in suggested innovations in the concept of causation and the need for inter- and transdisciplinary approaches.

The conclusions and general discussion briefly review the findings and set out some avenues for future research.

7.2 Persistence of Misperceptions and Climate Change

This section explores why misinformation and misperceptions persist and how the continued influence effect of misinformation is understood in the cognitive sciences. What does it mean for climate change, why does it matter, and how is it addressed in causal corrections?

7.2.1 Misinformation and perceptions

Misinformation can be defined as inaccurate or faulty information presented as true. It consists of myths, rumours and errors accidentally or deliberately circulated by the media, governments, or interest groups (e.g. Walter & Tukachinsky, 2020). Misinformation can adopt many forms, like incomplete information, misleading content, circulation of scientifically invalid information, fake news, conspiracy theories, or hate speech. A key element of misinformation is its *dissemination* in the public domain, both inadvertently and purposely (Lewandowsky et al., 2012: 108). Misinformation has to be distinguished from disinformation: fabricated false information deliberately meant to mislead and cause harm. Disinformation is usually seen as a subset of misinformation (Treen et al., 2020). Though misinformation (inaccurate or faulty information) differs from misperception (defined as contradicting the available factual evidence in the public domain), both concern the effects of information exposure.

Both are pervasive, worrisome, and prominent since they create or keep up controversies on issues concerning health and vaccinations, science, intelligence, politics and elections, and climate change. Misinformation holds claims unsupported by scientific evidence, for example, that genetically modified mosquitoes caused the Zika virus outbreak in Brazil, that there is a causal link between autism and childhood vaccinations (Chan et al., 2017: 1531), or that the coronavirus vaccine contained microchips to track citizens (Chan & Albarracin, 2023: 1514). Despite explicit and repeated corrective information, such unfounded claims persist in society. The most illustrious example is the long-continuing disinformed claim that Iraq had weapons of mass destruction, one of the reasons for the US invasion in 2003. Though US intelligence agencies and the government widely and resentfully corrected it after the invasion, more than ten years later, in 2015, a poll showed that 42% of Americans, at least up until 2014, still believed US troops had found weapons of mass destruction or Iraq had hidden them (Nyhan, 2021: 2). Like this, misinformation sticks in perceptions and can involve reluctance to believe in new facts. Those who deliberately rely on deep-rooted misinformation firmly hold misbeliefs, which brings poor judgements and decision-making (Markowitz & Guckian, 2018: 45; Ecker et al., 2022). The most problematic aspect of misinformation is that, despite their occasional effectiveness, corrections typically fall short of countering its persistence.

Climate misinformation has become an issue of global concern because of its similar prevalence and persistence, pressed forward by systematic dissemination efforts. Climate misinformation is about inaccurate facts and incorrect beliefs about the existence, human causation, and the consequences of climate change. This type of misinformation has specific impacts because it creates denial of the evidence of climate change, mistrust in climate science, and unbelief in the severity of climate forecasts. First, misinformation confuses public debates on climate change and biases public beliefs to downplay climate security risks. Second, it discredits climate science and sustains the public divergences about the scientific climate consensus (Treen et al., 2020). Third, it increases societal polarisation and restrains support for climate change policies (Cook, 2019; Cook et al., 2017). However, perceptions "are often malleable rather than fully formed and fixed" (Weber, 2016: 125, 127) and can be corrected.

Public perceptions of climate change refer to how the existence, the causes, and the consequences of climate change are perceived. These perceptions are of interest for assessing to what extent there is support for climate policies. While there is widespread agreement that climate change exists, public beliefs differ on the extent to which humans cause climate change and its consequences (van Valkengoed et al., 2021). Some remain sceptical, persist in contrarianism, and strongly resist climate policies (Treen et al., 2020). In analyses of scepticism-denial, it is widely observed that the arguments have *shifted* from a categorical denial of climate change – which is no longer defendable in the face of scientific evidence – to a denial that humans are the cause of the change and downplaying the consequences (van Valkengoed et al., 2021). It raises the question of what the strategic effects would be: if the existence of climate change is regarded as more commonly acceptable than the fact that it is caused by human behaviour and has adverse consequences, it should have implications for strategies to address it.

Multiple corrective strategies, such as fact-checking, have been developed for decades to counter or reduce misinformation. However, contradicting the facts and declaring misinformation untrue is not enough to set it aside, as explained below. New facts are less likely to be accepted when the counterinformation opposes it and flags the misinformation as false rather than providing new *causal* details. For example, in countering misinformation, the Associated Press (AP) brings out a weekly article called 'Not Real News: A look at what didn't happen this week.' The misinformation claims are derived from widely shared popular messages on social media. The AP-article repeats the false claims and contradicts each claim with the facts, which raises the question of how effective this is (see Kan et al., 2021: 1). Countering misinformed statements by labelling them as untrue makes the removal of the initial misbeliefs more difficult. Contradicting the wrongs by repeating the same details of the misinformed claims reinstates them and ultimately reinforces an enduring imprint in memory. Additional exposure to corrective facts that contradict the explanations provided by the misinformation only more negatively influences how the retracted information is processed in perceptions. It implies, more concretely, that reporting about misinformation (e.g. on the climate consensus in science documents or policy briefs) should be done in ways that avoid echoing and retelling the exact details present in the misinformation (Chan et al., 2017: 1544). Another approach, named causal correction, will be explored in the next section. It brings up a collection of cognitive and behavioural concepts and theories on the continued influence effect of misinformation in which this approach is embedded.

7.2.2 Continued influence effect

Misinformation is hard to correct. It influences perceptions and may continue to shape reasoning and later judgments long after corrected information has been provided (Johnson & Seifert, 1994: 1420–1421; Seifert, 2014: 53). Explanations of the *initial* cause of an event or a story continue to affect cognitive reasoning and judgments, even if it turns out that the original information was inaccurate or wrong. Misinformation resists correction and persists in the logic of thinking and inferential reasoning: it is the continued influence effect.

In 1994, Hollyn Johnson and Colleen Seifert coined the concept of the continued influence effect of misinformation (Johnson & Seifert, 1994: 1420). They focused on the properties and features of misinformation and questioned *how* precisely it influences reasoning and what its sources would be, which they found in memory. Elaborating on earlier canonical studies in cognition, which had noted the centrality of misinformation and already found that it could continue to influence reasoning despite corrections (Wilkes & Leatherbarrow, 1988), they now moved on by further examining the links between perception and misinformation. Based on experimental psychological tests, Johnson and Seifert identified and explained the *causal structure* of misinformation (Johnson & Seifert, 1994: 1421–1433). They found that misinformation provides a comprehensible causal explanation: when a correction merely negates the earlier information, it causes a gap in cognition because it offers no alternative. They also discovered that providing a plausible *causal alternative* explanation mitigates the effect of misinformation instead of refuting and disproving it (Johnson & Seifert, 1994: 1421, 1431–1433).

With their findings on CIE, Johnson and Seifert revealed that misinformation after correction maintains its effect on inferential reasoning *unless* a reasonable causal alternative is provided (Johnson & Seifert, 1994). Based on several experiments, they asserted that rather than simply opposing misinformation, providing an alternative that *replaces* the information's causal explanatory component would reduce the effects of misinformation because the revision restores the coherence of the narrative. The new alternative information *fills the gap* in explaining and is applicable to a new context and the cause of a possible new event. They build on prior work by Amos Tversky and Daniel Kahneman on the influence of information on inferences and judgments and how it becomes part of memory and is retrieved from it (Tversky & Kahneman, 1973; Johnson & Seifert, 1994: 1421).

Briefly, cognitive science illuminated the causal structure that misinformation provides. The continued effect of misinformation on memory diminishes when corrective information presents an alternative for the explanation gap that a correction leaves. The alternative information must replace the initial causal explanation enclosed in misinformation and adequately fill this causal component (Johnson & Seifert, 1994: 1421, 1429, 1431). In effect, Johnson and Seifert offered a strong *explanatory* theory that encompasses issues of method when analysing the links between experiments and theory, which will be taken up in the section on methods below.

After their original contribution, Johnson and Seifert explained their findings in subsequent studies (Johnson & Seifert, 1998; Seifert, 2002, 2014). When observing the field, they achieved a quickly expanding research area on the effects of misinformation with a still-growing follow-up by numerous researchers. They have realised a breakthrough by linking their experiments to persuasive theoretical interpretations and created a focal point of investigations for various subdisciplines of psychology, in all its diversity and far beyond. Scholars followed up to explore the multiple cognitive features of perceptions and how they impact the continued reliance on misinformation after correction. The most relevant features are *worldviews*, prior beliefs and attitudes, and their influence on accepting a correction (Gordon et al., 2019). Cognitive research found that corrections or retractions are less effective when misinformation aligns with pre-existing beliefs and attitudes. If misinformation is consistent with other things assumed to be true and "feels right" (Lewandowsky et al., 2012: 112), the new information provided by corrections is inconsistent with the earlier beliefs, which is a reason why it tends to be rejected (Markowitz & Guckian, 2018: 45). Another cognitive feature of perceptions concerns the *source's credibility*. Source perceptions involve the perceived authority of the misinforming source as more or less expert or trustworthy (Pluviano et al., 2020) or the reliability of the later retracting or correcting sources (Connor Desai et al., 2020; Westbrook et al., 2023). The culmination point of the continued influence effect is framed as the *backfire effect*. This effect is hypothesised in experiments when corrected information about a controversial issue inversely results in a more strongly endorsed misperception. Reinforced misperceptions, due to the backfire effect of corrective information, it was assumed, could specifically be linked to worldview and the credibility of the source when the correction challenges or contests prior beliefs or predispositions (e.g. Swire-Thompson et al., 2020; Nyhan, 2021).

7.2.3 Causal correction and implications

One issue of importance is whether and to what extent misinformation plays a *causal role* in perceptions. As Irene Kan and co-authors argue, by definition, "causal information is central because it has important downstream consequences for the remainder of the story" and "is likely to have more connections with the rest of the story than non-causal information" (e.g. the cause of the fire and the spread of the fire) (Kan et al., 2021: 14, 22).

Multiple experimental cognitive tests of the continued influence effect consistently found that providing alternative causal information is vital since it contributes to the various facets of perception updating. If a correction rejects a core part of the event or a story, it affects the coherence of the perception. The continued influence of misinformation then occurs if this integrative coherence fails or is selective (Ecker et al., 2020: 2). By contrast, renovating and re-establishing the coherence is facilitated if an alternative causal explanation is given: it functions to replace the gap left by the corrected misinformation in the perception. Giving out a correction that offers an alternative explanation is more effective than just the correction, which threatens the coherence in the perception (Seifert, 2014: 46–47; Johnson & Seifert, 1994). In sum, the continued influence of misinformation is the effect of causal explanations in perceptions, particularly in memory.

A central aspect regards the acceptability or rejection of new alternative information. Providing alternative information is mutually exclusive with the original causal misinformation. This is why cognitive reluctance is found in experiments where a central part of misinformation is displaced by the correction but not further explained. Such reluctance emerges because of the substantive change such displacement brings to the overall narrative structure. It has been called a 'state of indecision': the combined effect of reluctance to reject the discredited information and readiness to consider new information (Kan et al., 2021: 22–23). It has been suggested that *both causes*, provided by misinformation and the alternative, can be perceived as equally possible and may co-exist, resulting in partially updated cognitive perceptions. Experiments showed that when the alternative is inserted *within* the correction statement, the new information tends to be maintained *alongside* the misinformation. But when the alternative is *not* part of the correction, the indecision and uncertainty may remain unless additional reasonable replacement information is given for the rest of the narrative (Kan et al., 2021: 23). At this point, as mentioned by Kan and co-authors, future work to investigate the plausibility and acceptability of *both* the misinformation and the corrected content is necessary to understand the rebuilding of perceptive coherence after correction with alternative information.

Some meta-analyses (Walter & Tukachinsky, 2020; Walter & Murphy, 2018; Chan et al., 2017) further document that including an alternative in the correction effectively reduces the continued influence effect of misinformation. Though correction does not completely eradicate the effect of misinformation, it is found more effective when the source of the misinformation delivers the correction itself, and it is coherent with the worldview, but less effective when the misinformation is ascribed to a credible source, is transmitted repeatedly, or when there is a significant interval between the delivery of the misinformation and the subsequent correction (Walter & Tukachinsky, 2020: 172–173). Also, other follow-up research showed that a causal explanation for assimilating new pieces of information is significantly more effective than rejection or denial (Nyhan & Reifler, 2015: 81). However, full elimination of the CIE appears to remain exceptional in almost all studies (e.g. Kan et al., 2021; Lewandowsky et al., 2012; Chan et al., 2017; Ecker et al., 2010; Johnson & Seifert, 1994).

The most challenging argument from the preceding section is that the continued influence of misinformation is rooted in its causal structure. Consequently, the corrective information focuses on the capacity of misinformation to influence perceptions causally. The significance of the causal explanatory element for the outcomes of corrections may shed fresh insight into the role of misinformation in public perceptions of the scientific consensus.

7.3 Scientific Consensus and Human-Caused Climate Change

The scientific consensus on the human causation of climate change is significant in shaping public support for the climate agenda. Much discussion surrounds the disparities between the estimated 97% scientific consensus on anthropogenic global warming (AGW) and the mixture of public perceptions. Despite the agreement by climate scientists that humans are the primary cause of accelerated global warming, significant parts of the public continue to doubt human causation. Particular concerns regard the scenario in the US, where it is extensively studied (e.g. Bayes et al., 2023). Since implementing policies to mitigate and adapt to climate change relies on this consensus and necessitates public acknowledgement and involvement, this debate includes conveying and communicating the consensus. So far, to my knowledge, no research has explored the topic of the CIE and the alternative correction approach for communicating the consensus; this will be addressed further below.

7.3.1 Anthropogenic causation and its communication

The scientific consensus regarding the anthropogenic causation of global warming (AGW) is consistent and shared by a vast majority (97%) of climate scientists (Cook et al., 2013, 2016; Tol, 2014, 2016). Depending on the measures and methodologies used for quantifying this consensus on human causation, there is a discussed margin between 90%–100% and 97% consistency across many investigations (Myers et al., 2021). The consensus was initially proclaimed based on a study of 11,944 abstracts in peer-reviewed science journals from 1991 to 2011, mapping them according to statements in the abstracts. It was considered that papers might disagree with AGW despite the absence of a rejection statement in the abstract (Cook et al., 2013). Studies of journal abstracts in subsequent years found an above 99% consensus on AGW among publishing scientists (Powell, 2015; Powell, 2016; Lynas et al., 2021), though disputed (e.g. Skuce et al., 2016; Dentelski et al., 2023). The primary body of support for the consensus is the Intergovernmental Panel on Climate Change (IPCC), which consists of thousands of climate scientists (Bray, 2010). Within and outside this group, human-caused climate change is not undisputed: the consensus is not unanimous. For example, scholarship on the pre-industrial history of climate change draws attention to natural climatic changes long before the onset of anthropogenic global warming, which has sparked some larger debates (Degroot et al., 2021).

The difficulties of informing the public about the consensus have most often been related to spreading misinformation and the politicisation of climate science (Bayes et al., 2023: 17). Climate misinformation concerns inadequate or false information, raising doubts about the scientific evidence for the anthropogenic causes and consequences of climate change. The 'manufacture of doubt' on the consensus by some political actors, vested corporations with fossil fuel interests and certain media is part of this (Lewandowsky et al., 2013). There has been much research done on the effectiveness of strategic disinformation on climate issues, how it spreads into the public domain, and how climate change has become contentious and politicised (e.g. Lewandowsky, 2021: 5–8; Dunlap & Brulle, 2020). When misinformation and organised disinformation target the scientific climate consensus and exploit scientific dissent, it tends to confuse the wider public and may result in declining support of the climate agenda and adaptive policies (Cook, 2019; Cook et al., 2017). Most importantly, the global climate countermovement not only institutionalises climate denial but also undermines public perceptions of human-caused climate change through targeted efforts, reinforcing public uncertainty regarding the scientific consensus. Such strategies heavily doubt scientific numbers, methods, and figures to mislead the public into believing that the consensus among climate scientists regarding human-induced climate change is significantly lower. In brief, the persistent effects of climate disinformation and disbelief in the human drivers of accelerated climate change are integral to the problems of communicating the consensus and most challenging to correct (e.g. Chan & Albarracin, 2023).

Communicating the scientific consensus comprehensibly to diverse publics and contexts amid such complexities is exceedingly challenging. Effective strategies to respond to misinformation on the scientific consensus are slowly developing, but there is no agreement on how to do so effectively. Justin Farrell and co-authors suggest that scientists may have underestimated the public impact of misinformation and overlooked its institutional embedding, organisational power and financial roots (Farrell et al., 2019: 191). Nevertheless, the issue is studied with lively debates on how to process consensus messaging and when it works, or what strategies of multi-way (engaging scientists in discussions) or one-way communication may contribute.

The scientific climate consensus is groundbreaking because of its occurrence at the intersection of multiple disciplines while incorporating dispersed expertise in climate science and addressing substantial complexities of climate change. Corresponding to the consensus is the need to address the most severe effects of climate change, which requires, among others, a rapid reduction in global emissions. However, misinformation, disinformation, and persistent active denialist opposition to the consensus among some segments of the public are prolific sources of maintaining a 'consensus gap' (Cook et al., 2013: 6; Skuce et al., 2016: 153): the difference between the public perception of the consensus and the majority of scientists' support for it. This gap has raised uncertainties and worries about the international community's ability to act in concert on climate change (Markowitz & Guckian, 2018: 35).

As a result, the public perception of the human causation of climate change has become an important issue in communicating the scientific consensus, which is increasingly studied based on large-scale surveys (e.g., a Gallup poll from April 2021 found a deepening divide in US politics on this issue). Public perception of the consensus is considered an important 'gateway' to science acceptance (van der Linden, 2021). It is suggested that emphasising the consensus in climate change messages will increase the acceptance of AGW, which associates the perception of the consensus with attitude change (Lewandowsky et al., 2013).

The effectiveness of a specific focus on human-caused climate change for communicating the scientific consensus to the general public has, for such reasons, become the subject of wider debate (Bayes et al., 2023). However, the continued influence effect of misinformation on communicating the consensus is not addressed as yet in the literature, though it may offer promising pathways. As previously mentioned, in sceptical-denialist arguments, the focus has shifted from denying the existence of climate change (not tenable anymore) to rejecting its causes and consequences. In this perspective, Teresa Myers and co-authors have offered a most helpful contribution to consensus messaging by distinguishing between consensus message (emphasising the agreement), causes message (explaining the human causation and mechanisms), impacts message (focusing on the disparate effects of climate change), and solutions message (highlighting the actions taken) (Myers et al., 2023: 2). This draws attention to the role of human-caused messages in conveying the scientific consensus (in the setting of focusing on agreement, cause, impact, solutions).

7.3.2 Theory and method matter

Collecting the theoretical and strategic inputs from cognitive work on misinformation and climate change is challenging, even more so to connect and integrate it with extant theory. Its recommendations cannot easily be assembled. There is consistency in the focus on misinformation but some contradiction in the conclusions. For example, research focusing on the causal explanatory capacity of misinformation concludes that corrections do *not* eliminate the beliefs in and influences of misinformation (e.g. Lewandowsky et al., 2012). Other research, however, centres on the perception of the original source of misinformation and finds that corrections *do* reduce belief in misinformation and impact its continued influence (e.g. Westbrook et al., 2023). No joint theoretical framework keeps the multiple cognitive findings together or positions the differences, which may hinder their integration into a coherent body of literature on misinformation within the same discipline. This section takes up some debates on theory and methods to explore a few perspectives towards a more comprehensive set of approaches to misinformation. Though methods are an integral part of evolving and sustaining the scientific consensus, they have, to my knowledge, not explicitly been discussed as part of consensus communication and public support.

First, some comments on theory development could be useful. Most literature on climate misinformation comes from the cognitive and behavioural sciences (e.g. Samoilenko & Cook, 2023; Maertens et al., 2020; Cook, 2019; Cook et al., 2018). These sciences represent a wide variety of experts in cognition and memory, behaviour, the brain, language, and society, coming from the subdisciplines of psychology, sociology, communication sciences and more. In the area of misinformation, the principal contribution of this expertise is the application of largely the same type of quantitative experimental testing, data, methods, templates, and models, with almost similar ways of presenting the findings (Connor Desai & Reimers, 2023;

Sanderson et al., 2022; Swire-Thompson et al., 2021; Ecker et al., 2020; O'Rear & Radvansky, 2020). The tests have undergone additional refinement as tools, instruments or techniques of the correction approach itself (e.g. Ecker et al., 2010; Ecker et al., 2015). Of course, there always remain, as Mathew Vowels argues, problematic issues that relate to modelling, replication, extrapolation from data, measurement issues, or the risks of invalid inferences (Vowels, 2023: 507–508). However, as the experimental methods for studying misinformation further improve, the link between the multiple empirical findings and ongoing theory development may sometimes become lost.

The explanatory theory Johnson and Seifert derived from experiments in their seminal work (Johnson & Seifert, 1994) still stands out as a challenge for current research. Since then, various theoretical propositions have developed to understand the complexities of the continued influence effect of misinformation. However, there is also some fragmentation since testing such propositions is usually bound to the conditions of each specific study design that do not allow for comparisons or generalisations. In addition, there are specific requirements regarding which designs or evidence are suitable for generalisation (O'Keefe, 2015). More substantial reflection might be needed on how empirical findings from new experiments support or contest extant theories in the same field or how they challenge, for example, broader theories on climate change. After Johnson and Seifert, subsequent research mainly extended the experiments and consistently revisited, reassessed or replicated them (e.g. Laurent et al., 2023), while its contribution to the explanatory theoretical framework on CIE often remains unexplored. The limitations stand out vividly: cognitive science offers much empirical data on misinformation but finds no thorough systematic theoretical framework to further account for and interpret the contradictions and contributions the new data analyses and theoretical propositions bring. Is the acquisition of new knowledge and the further development of theory sufficiently related? What Paul Meehl noted in 1978 for some areas of psychology seems to be still relevant 45 years later: specification and testing of ever more elaborate and precise quantitative models, only occasionally addressing more substantive theory (Meehl, 1978).

Second, a few notes on experimental methods might be included. Can data and findings experimentally obtained from labs under controlled and regulated conditions inform theories and practical approaches for real-world contexts? What about experiments aimed at correcting false beliefs? How might this translate towards effective strategies in real-world contexts where the public domain is part of a complex information environment full of confusing events and political controversies? Experiments and simulations are long-standing scientific tools and widely accepted methods for research in psychology and much broader in social, natural, and data sciences involved in climate change. Such experimental research brings up results with robust *internal* validity. The use of standardised procedures for conducting experiments improves the reliability of methods and tests, thereby strengthening comparative advantages. However, the findings' *external* validity and generalisability are the subject of much broader debate and one of the complications. Victoria Westbrook and co-authors may be among the few exceptions who directly address the latter difficulties in the context of CIE research (Westbrook et al., 2023: 1327).

The experiments on misinformation measure the impacts of corrections on beliefs, reasoning and attitudes (i.e., Ecker & Ang, 2019; Swire-Thompson et al., 2021; O'Rear & Radvansky, 2020; Ecker & Antonio, 2021) or test broader effects of interventions designed to reduce the influence of misinformation and advance communication of the scientific consensus (e.g. Cook et al., 2017; van der Linden, 2021). The empirical data originates from lab exposure of individuals and groups to misinformation: CIE research encompasses, on average, 120 to 160 total participants (e.g. Westbrook et al., 2023: 1320; Walter & Tukachinsky, 2020; Ecker et al., 2015). Though some experiments extend the CIE to political challenges, focus on political misinformation (e.g. Ecker & Ang, 2019; Thorson, 2016), the effects of politically incorrect statements (Swire et al., 2017), or the correction of political misperceptions (Nyhan & Reifler, 2010, 2015; Flynn et al., 2017), in experimental settings, real-life contexts are commonly absent and irrelevant (Lebow, 2022: 17, 75–85). To reiterate, the cognitive preference for experiments, associated with certain fundamental assumptions, could restrict the variety, diversity and flexibility of the methods and methodologies used. It probably necessitates integrating complementary methods in inter- and transdisciplinary collaboration on misinformation.

Third, some observations on correlation-causation could be beneficial. Climate change is part of major power shifts in the international order, with changing security concerns, potentially internationalising wars, and political polarisation in Western democracies. Climate insecurity and political instability have uncertain effects on (inter)national policies and strategies of institutions and organisations, involving the complexity of climate change causes and consequences. In international relations, where causation is fundamental, ferocious debates surround causal analysis due to some underlying problematic assumptions (positivist, deterministic, mechanistic and empiricist) (Kurki, 2008). However, though Kurki ingeniously proposes to reclaim causal analysis in the social sciences and open it up for multi-causal and methodologically pluralist avenues, it may still run the risk that the same assumptions re-enter, but now under the label of pluralism. Alternatively stated, a pluralistic framework comprising several causal assumptions could permit their coexistence without requiring interactions.

Cognitive misinformation research presents potential hazards when its contribution to broader climate change debates is questioned. The correlational analyses based on experimental research are not entirely convincing. Such analyses clarify whether and how positive or negative correlations can be found and reveal important empirical regularities and patterns. They may clarify that X and Y covary, that X precedes Y, and find analytic descriptions for these associations (Bleske-Rechek et al., 2015: 49). However, these analyses often cannot explain and interpret the causal relations: correlational data do not allow for it. For example, a meta-analysis of the psychological efficacy of debunking found that a detailed message correlated positively with the debunking effect *and* the misinformation-persistence effect (Chan et al., 2017) but could not move further to *explain* causality in the regularities found. Whereas the analysis is most relevant to the field, the correlational approach limits further interpretation. Questions thus remain as to whether such correlations have causal properties.

Correlational analyses also prevail in climate science research, particularly concerning the relationships between the consequences of climate change, public perceptions, and support for climate policy. This research examines the environmental effects of climate change (such as global warming, sea level rise, and weather extremes) and questions to what extent it links with public perceptions of the consequences in terms of risks, threats, and security (such as increased flooding, conflict, and migration), and public endorsement of the climate agenda (e.g. Xia et al., 2022; Lacroix & Gifford, 2018; Hagen & Pijawka, 2015). The assumption underpinning such correlational approaches is that lower or higher-risk beliefs of the severe consequences would be associated with less or more active public support for the climate agenda. However, though such correlational analyses may reveal whether and to what extent positive or negative correlations exist, they cannot link the causal connections to convincing explanations or sometimes conflate correlation with causation.

Finally, the scientific climate consensus reaches over multiple disciplines with usually limited understanding of each other's research traditions. An inter- or transdisciplinary debate on consensus communication has not started. Open discussion about the underlying assumptions and methodologies is still absent, including those in experimental psychological studies on climate misinformation. If the study of climate misinformation and the scientific consensus compels inter- and transdisciplinary approaches to face the complex and multifaceted issues, it would require innovation and inventiveness. Rather than addressing the ever-continuing knowledge gaps and data pitfalls, greater transparency regarding research paradigms and methodologies necessitates innovation. It transcends applying the same methods to accommodate larger datasets or additional empirical realities. Innovation encompasses improvements across the different parts of the research process, including but not limited to data generation and data analysis. Furthermore, it exposes the various empirical and conceptual choices and clarifies the methodological assumptions that underpin the research design. Similarly, innovation would be demanded in creating partnerships with policymakers and practitioners to overcome methodological divides and link methodologies towards more thorough theoretical explanations and public communication.

7.3.3 Causal correction and a different concept of cause

When communicating the scientific consensus, the causal correction approach may become a feasible part of a more comprehensive set of strategies to counter misinformation. The strategic potential of this approach can be identified in *three central components* outlined below. They may support broader objectives and outcomes to counter misinformation when communicating the scientific climate consensus.

First, the alternative correction approach's foundation is the internal causal structure of misinformation. The persistent effect of misinformation, framed as the continued influence effect, is due to the 'causal gap' in perceptions after corrective information. Perceptions rely on an *initial cause* provided in the misinformation that explains and facilitates the integration of new events or stories. Corrections of misinformation are likely to be successful if the initial source of the misinformation is questioned (Johnson & Seifert, 1994: 1421–1433). Also, the internal coherence of the explanation provided in the misinformation determines the degree of influence it has. When the cause of the fire in a misinformed message offers a reasonable and logical explanation (e.g. how the fire was lit), the impact capacity of the misinformation is more long-lasting (Johnson & Seifert, 1994: 1431). Because the causal structure of misinformation allows it to be internalised, it is notoriously difficult to remove it from perceptions. The conclusion at this point is that changing the perception of the original source explanation, as the key internal to misinformation, reduces its continued influence effect.

Second, providing an *alternative* causal explanation has to be integral to correcting misinformation since it reduces the dependence on and confidence in the initial cause. Such an alternate causal explanation needs to add complementary information (e.g. an electrician noticed a short circuit, and the fire was not lit), which may transform the persistent impact of the original explanation in the misinformation (Nyhan & Reifler, 2015: 84). Third, the approach is *substitutive*: it replaces the initial causal explanation in the misinformation. The alternative corrective explanation substitutes the original cause provided by misinformation. In addition, by ousting and displacing the initial cause with a causal alternative *and* a new explanation, the strategy ultimately fills the gap left by the retracted misinformation (Johnson & Seifert, 1994: 1421, 1429, 1431), to the effect that it becomes less enduring.

As mentioned before, this approach has implications for how to regard the effectiveness of fact-checking in support of the scientific consensus. Corrections are less likely to be accepted when fact-checking opposes the misinformation and brands it as false. Upfront negation of misinformation does not address misinformation's perceived original value as true and accurate, neither does it explain where the rejection comes from (Seifert, 2002: 284). Misinformation even invalidates the acceptance of new facts. By contrast, the causal approach does not confront and oppose but substitutes the initial and original value perceived in misinformation. However, the concept of cause in this approach needs more attention since it mainly focuses on the initial and original explanation that misinformation provides.

There are compelling reasons for climate misinformation scholars from various disciplines to develop a concept of causality free from linear X-leads-to-Y conceptions. Such a concept should be able to connect different methods and methodologies against deterministic and other limiting understandings of cause (as 'necessary' or 'sufficient' to generate an outcome) and towards comprehensive strategies in support of scientific consensus. Jonathan Culler's deconstructive approach (Culler, 1982), inspired by Nietzsche's concept of causality (*The Will to Power*), could be beneficial since it opens ways for not just falling back on the option for a plurality of causal assumptions and arguments. Moreover, it draws attention to a distinction between a principled philosophical understanding of cause and how cause may be commonly perceived. Culler posits that it is taken for granted that a cause produces an effect: the cause is given the primary position in the conceptual pair cause-effect. Commonly, cause comes first and gets priority over the second, which accords to 'cause' the position of origin. However, the effect (e.g. of pain in the foot and not the pin) comes first in the experience and "the cause gets imagined after the effect has occurred" (Culler, 1982: 86). It is the effect (the pain) that makes a cause (the pin) receive the status of a cause. In the words of Culler: "If the effect is what causes the cause to become a cause, then the effect, not the cause, should be treated as the origin" (Culler, 1982: 88).

Culler's approach of cause has implications: first, if the perceived effect is the origin for a cause to get the position of a cause, it upsets the hierarchy and changes the properties attributed to cause and effect (Culler, 1982: 88). Second, when this notion of cause is applied to causation itself (Culler, 1982: 87), and the cause is not the origin of its effect, it has implications for causal statements and origins approaches, since what is secondary may well be primary. Though Culler reiterates that he does not reject causal thinking as such since the occurrence of the effect still sets the need for identification of its cause, two observations might be needed. First, Culler's strength is revealing the perceptual sequence of events regarding causes and causality. Once the pin cutting the foot is discovered, the perceptual order is reversed to produce the causal order (pin-pain). However, the problem with Culler is that he seems to state that the effect *produces* the cause instead of arguing that the pain causes the *discovery* of the cause (the pin), more closely following the example from Nietzsche. Second, for Culler, the "principle of causality asserts the logical and temporary priority of cause to effect" (Culler, 1982: 86). The point here is that he refers to the *principle* that a cause precedes effects, whereas it later seems as if Culler creates a new principle: that the effect precedes a cause, and only through the effects can a cause be known. What he actually means is Nietzsche's causal 'structure' of the temporal relationship, where causes precede effects in the temporal sequence of events.

Based on Culler's implicit distinction between a principled and a perceived understanding of cause, the concepts of cause and causation in misinformation studies might need a reassessment, which has potential implications for the causal correction approach and ways of communicating the scientific consensus. When talking about the CIE and the 'causal structure' (Johnson & Seifert, 1994: 1421, 1425, 1426–1427, 1429, 1431; Seifert, 2002: 285) of misinformation, Johnson and Seifert focus on how the initial causal explanation of an event influences later inferential reasoning and the continued influence. For them, the structural aspect of causality is its temporal priority in an event, story or message. Causal correction then primarily focuses on the original coherence of the causal explanation provided by misinformation. However, when the effect of misinformation at the level of perception occurs first, as in Culler's example (pain-pin), the effect is *perceived* as the origin: it may reverse prevailing approaches of causation, with potential practical implications for conveying public messages on the scientific consensus. Adopting Culler's view on cause might call for reorientating the primary emphasis on human causation of climate change towards highlighting its *perceived effects*: the consequences of anthropogenic global warming.

Advancing on these matters could be accomplished through interdisciplinary and transdisciplinary research. Because knowledge classifications into specialised domains and disciplinary systems tend to be inadequate when facing the complexity of global issues, inter- and transdisciplinary research has more generally been strengthened. The indispensability of transdisciplinary research in addressing contemporary climate-related challenges is acknowledged mainly for its integrative capacity (e.g. Vienni-Baptista et al., 2023; Butt & Dimitrijević, 2023). Transdisciplinary research traverses across and beyond scientific disciplines: it encompasses interdisciplinary research but goes beyond it by stakeholder involvement towards integrated knowledge for science and society. This research engages stakeholders such as policymakers and practitioners in the full research process of problem-setting, design, data, methods, and output (Mitchell et al., 2017). This inter- and transdisciplinary work constitutes a form of boundary crossing with academic researchers and stakeholders that may have different purposes, contexts, institutional structures, and degrees of integration and interaction. Emerging assessments in climate science illustrate the benefits of initiating such initiatives

(Mitchell et al., 2017). Others also argue that knowledge creation in collaborative efforts has intricate dynamics and is fraught with difficulties (e.g. Meehan et al., 2018). Although transdisciplinarity is gaining traction, it is yet to get its position in academia: the concepts, processes, relevance, and impacts keep developing.

7.4 Conclusions and General Discussion

Scholars from many academic disciplines investigate approaches to counter climate misinformation and increase public support for the climate agenda. The assumptions correspond to the extent and scope of misinformation and its capacity to have a persistent influence on reasoning, beliefs, and attitudes. In the search for effective strategies, improved public communication of the scientific climate consensus has garnered much attention recently. In this context, the present study contributed to climate misinformation research by arguing that the continued influence effect and the corresponding causal correction approach might become significant parts of a more comprehensive set of strategies to counter misinformation when publicly communicating the scientific climate consensus.

Regarding the main objective of this study, the continued influence of misinformation was studied both regarding the correction efforts and the theoretical explanations provided. It was shown that the cognitive sciences bring substantial novelty to the debate on climate change and the scientific consensus. A few key findings were identified as a niche. First, what drives the continued influence effect is the powerful causal explanation embedded in misinformation, which continues influencing reasoning even when it is known to be inaccurate. When a new event necessitates an explanation, the fallback on the initial cause provided by misinformation illustrates its power. Second, by revealing the causal structure of misinformation and the perception gap left by corrected information, research on the CIE has revealed the unique characteristics of misinformation and why it has such enduring effects on inferential reasoning. The explanatory coherence of misinformation also impacts its degree of influence, which is why a causal alternative explanation is required to correct it.

In communicating the scientific climate consensus on anthropogenic global warming, the public *acceptance* of human causation has emerged as a focal point of the recent debates on the most effective ways of publicly conveying the consensus. However, climate disinformation affects perceptions of climate change and precisely consists of the *denial* that humans are the cause of climate change while downplaying its severe consequences. Concerning this conundrum, the question became how much emphasis is placed on causal messages of climate change and what the position of cause is (in the setting of emphasising the agreement, cause, impact, or solutions).

In response, this study proposed reassessing the concepts of cause and causation. In cause-effect concepts in climate science and cognitive science, the cause is given the principled status of the origin that produces the effect. By contrast, when the effect at the level of the perception is occurring first, as in Culler's example (pain-pin), then the effect is *perceived* as the origin, the secondary gets the primary position, the properties attributed to cause and effect change, and the cause is not the origin of its effect. To put it succinctly, how a cause is *perceived* may have an impact distinct from that of cause as a philosophical principle, thereby subverting prevailing approaches to causation. It might have potential practical implications for publicly conveying the scientific consensus. Taking the proposed concept of cause would presumably shift the priority emphasis in consensus communication from the human causation of climate change, which is the core of the scientific climate consensus, to highlighting its *effects* in consensus messaging: the consequences of anthropogenic global warming. Evidently, questioning the notion of cause and causality by considering the possibility of another concept of cause-effect is novel to the debates on the continued influence of misinformation and scientific consensus communication and requires much further exploration.

The present study also responded to the central question posed at the outset. Strategies for communicating the consensus may take the causal correction approach as a feasible way to counter climate change misinformation. As explained before, this approach has much potential for integration into a more comprehensive set of strategies. However, it also brings up one of the limitations of this study. Such a broader set of strategies would involve political mechanisms, legal instruments, channels for financial transparency, educational approaches, and much more, which have remained outside the scope of this study. Subsequent research might concretely position the alternative causal correction approach in this broader setting.

Several other potential avenues have emerged that hold significance for follow-up research. It was shown that studies on the continuous influence effect have a vigorous empirical basis in experimental tests that produce consistent evidence. Based on such evidence, the cognitive sciences have generated original theoretical clarifications that may support more comprehensive strategies to respond to misinformation. However, some critical challenges surfaced regarding the empirical evidence and the theoretical contributions due to limitations inherent to the experimental methods and research designs.

The proposal was to take up such issues of method and theory, comparability and generalisability, in a wider setting of inter- and transdisciplinary approaches. Whereas interdisciplinary research fosters collaboration among scholars of different disciplines, transdisciplinary research expands the scope by opening scientific inquiry to involve policymakers, practitioners, and other stakeholders in knowledge creation. Such integration of knowledge facilitates the feedback effects of policies and practices on joint problem identification, research co-design, method re-invention, scope definition, strategic impact mapping, and joint implementation of knowledge beyond academia.

Finally, climate issues are discussed within complex global contexts with diverse publics. When information is uncertain, whether through the unreliability of sources, information manipulation, missing evidence, or complexity of the issues, it is difficult to collect information, opt between alternatives, judge and decide on the correct information. Public information processing, distinguishing and judging the possible alternatives, demands public partnerships and integrative approaches to the relationship between science and the public.

The climate change agenda necessitates such advanced public partnerships, requiring stakeholders to collaborate in knowledge discovery and shared decision-making. Accordingly, public communication on the scientific climate consensus is uniquely positioned to advance the climate agenda in meaningful and effective ways, with numerous opportunities, challenges, and complexities.

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CHAPTER 8

Towards a Sustainable Military Supply Chain: An Empirical Exploration of Defence Industry Codes of Conduct

Job Timmermans, Marion Bogers and Robert Beeres

Abstract

To be successful in meeting their environmental sustainability goals Ministries of Defence (MoDs) depend on their suppliers, the Defence Industry (DI). However, a comprehensive inquiry into the current state of affairs of the addressing of sustainability by the DI is still lacking. Following the literature, evidence of the interest in sustainability of DI companies can be found in their code of conduct (CoC). This chapter aims to make a first step towards closing this gap by empirically exploring to what extent and in what manner the CoCs of the top 18 contractors of the DI reflect the theme of sustainability. The insights gained support the identification of opportunities for MoDs' policymakers, especially in the areas of procurement and supply-chain management, as well as identify possible avenues for further research into this subject area. The results show that DI members differ in their approach to sustainability and the manner in which key values have been anchored in their CoCs. Some CoCs do not effectively address company expectations and standards on sustainability, which undermines CoC effectiveness.

Keywords: code of conduct, defence industry, environmental sustainability, supply chain management, military supply chain.

8.1 Introduction

Meeting the environmental sustainability challenges facing our world has become a pressing priority. As large consumers of fossil fuels and other resources, the Ministries of Defence (MoDs) are not an exception. Both in the literature and in policy documents, the importance of energy security and resilience and a reduction of the environmental footprint have been articulated (Brzoska, 2015; Crawford, 2019; Department of Defense, 2021; Global Military Advisory Council on Climate Change, 2021; Ministry of Defence, 2021; Scott & Khan, 2016; van Schaik et al., 2020).

To be successful in meeting their sustainability goals, MoDs depend on their partners, not least their business partners in the supply-chain (Erkul et al., 2015;

Gopalakrishnan et al., 2012; Rudnicka, 2016). The MoDs thus have an interest in their suppliers to make their business, products and services sustainable.

This is well recognised by both the defence industry (DI) (ASD, 2021) and four major consulting firms that are advising the industry (Dimitrova et al., 2023; EY, 2023; KPMG, 2023; McKinsey, 2022). Nevertheless, to the authors' knowledge, a comprehensive inquiry into the current state of affairs of the addressing of sustainability by the DI is still lacking. Insight into the DI's addressing of sustainability supports the identification of opportunities for MoDs' policymakers, especially in the areas of procurement and supply-chain management, as well as identifying possible avenues for further research into this subject area. This chapter aims to make a first step towards closing this gap by empirically exploring the codes of conduct (CoCs) of DI companies for evidence of the addressing of sustainability.

A code of conduct is 'a set of prescriptions developed by a company to guide the behaviour of managers and employees' (Kaptein, 2011). It is a commonly used management control instrument (Weber & Wasieleski, 2013) aimed at the outward responsibilities of companies to their external stakeholders as well as the inward responsibilities of their employees to display accepted behaviour (Kaptein & Wempe, 2002). The content of CoCs therefore can be expected to display consistency with stakeholder values and expectations (Garegnani et al., 2015; Kaptein & Schwartz, 2008; Mcdonald, 2009; J. M. Stevens et al., 2005; Weaver & Trevino, 1999; Webley & Werner, 2008). Consequently, evidence of whether the interest in sustainability has been carried over to the MoDs business partners can be found in the CoCs of these partners (Erkul et al., 2015; Gopalakrishnan et al., 2012; Rudnicka, 2016). And, indirectly, the attention to sustainability of CoCs of DI companies can also be considered a predictor of the interest in sustainability by their main stakeholders, the Ministries of Defence (MoDs).

Building on this thesis, this contribution qualitatively investigates to what extent and in what manner the CoCs of the top 18 contractors of the DI reflect the theme of sustainability. Moreover, to ascertain whether there have been any developments in this respect, the study offers a longitudinal approach comparing the CoCs of 5 years ago with the most recent editions. This way, the research provides insight into the development of the interest in sustainability by the MoDs' DI partners. Moreover, it offers an initial impulse to get a better understanding of the military supply chain and thereby ways of effectively managing it towards sustainability.

This chapter continues by outlining the qualitative method used for the content analysis of CoCs. In section three the findings are discussed according to the main themes that surfaced from the analysis. The last section offers a brief discussion of the results and some concluding remarks.

8.2 Method: Qualitative Content Analysis

In order to meet the aim, a qualitative content analysis of the CoCs of 18 of the largest multinational companies operating in the DI is conducted. This sample is based on the SIPRI top 25 largest DI companies in 2019 ranked according to their arms sales (SIPRI, 2019). However, seven (all non-western) companies are excluded because they do not have a publicly available CoC. Also, these companies do not conduct business with Western MoDs. The arms sales of 5 of the 18 remaining companies (italicised, see Table 8.1) amounts to less than 25% of their total annual sales. Because the absolute volume of their arms sales is still significant, these companies are nevertheless included in the sample. Moreover, it is warranted to limit ourselves to the largest companies, because earlier research has indicated that smaller companies tend to imitate those of the larger ones (Forster et al., 2009; Garegnani et al., 2015).

Table 8.1. SIPRI 2019 top 25 DI-companies excluding non-western companies. (Source: SIPRI Arms Industry Database, retrieved April 2021).

Rank	Company	Home-country	Arms sales ($MM)	% Arms sales	CoC 2019	Updated CoC 2023
1	Lockheed Martin Corp.	US	53,230	89	X	X
2	Boeing	US	33,580	44	X	X
3	Northrop Grumman Corp.	US	29,220	86	X	X
4	Raytheon	US	25,320	87	X	X
5	General Dynamics Corp.	US	24,500	62	X	-
7	BAE Systems	UK	22,240	95	X	X
10	L3Harris Technologies	US	13,920	77	X	-
11	*United Technologies Corp.*	US	13,100	*17*	X	-[1]
12	Leonardo	Italy	11,110	72	X	-
13	*Airbus*	EU	11,050	*14*	X	X
14	Thales	France	9,470	46	X	X
16	Huntington Ingalls Industries	US	7,740	87	X	-
17	Dassault Aviation Group	France	5,760	70	X	-
18	*Honeywell International*	US	5,330	*15*	X	X
19	Leidos	US	5,330	48	X	-
20	Booz Allen Hamilton	US	5,140	69	X	X
21	*General Electric*	US	4,760	*5*	X	X
23	*Rolls-Royce*	UK	4,710	*24*	X	X

[1] United Technologies merged with Raytheon in 2020 and operates under the new name Raytheon Technologies. Here we will retain Raytheon for the sake of simplicity.

For the time analysis, CoCs were collected online at two points in time, namely in 2019 and in 2023. Notably, 6 of the 18 companies have not published an updated CoC since 2019 (See Table 8.1). Consequently, to study the development over time of the CoC content regarding sustainability, for those companies the same CoC is considered for both measure points. Furthermore, because in 2020 United Technologies merged with Raytheon, there is no CoC of United Technologies in the 2023 sample.

The content of the CoC is analysed using thematic coding followed by a cross-source comparison. Thematic coding is a method for systematically identifying, organising, and offering insight into patterns of meaning (themes) across a data set (Braun & Clarke, 2012). It allows for a combination of inductive and deductive analyses.

In order to meet the aim of this research, the primary focus of the coding is on the addressing of the topic of sustainability in CoC content. Sustainability, here, is solely understood as environmental sustainability. So references to other types of sustainability, for example, sustaining an ethical culture, are excluded. Besides 'sustainability' and its derivatives such as 'sustainable', the related concepts 'environment', 'ecology' and 'recycling' are used to analyse the CoCs. The snippets of content thus singled out, such as a paragraph or a (subs)section of text that addresses sustainability for each CoC, are then further analysed. Deductively, because of the dependence on partnerships to meet sustainability goals, coding will focus on evidence for cooperation within (1) the supply chain and (2) horizontally with peer groups i.e. concerted practices between companies operating at the same level in the market.

Apart from these two themes, inductively, four additional themes arose during the analysis. These are added to the coding scheme, namely:

1) Type of CoC (sub)section in which the theme of sustainability is addressed;
2) Inclusion of 'guidelines for behaviour' as a manner to operationalise the theme;
3) Different types of motivation for addressing sustainability;
4) Reference to a policy document on sustainability.

The analysis was carried out by two people: each CoC was coded independently by one coder and then reviewed by the other coder.

Lastly, to corroborate the findings and put them in a broader context, they are tested against:

1) a purposive sample of five companies[1] from the 2021 nominees of Ethisphere's 2021 World's Most Ethical Companies (Ethisphere, 2021), and
2) a quick scan of the most recent sustainability reports (or equivalent reportages) of the companies in the sample.

8.3 Findings

The discussion of the findings starts by drawing an overall picture of the addressing of the theme of sustainability across the CoCs. Second, the inductive codes 'guidelines for behaviour' and 'reference to policy documents' the CoCs use to guide employee behaviour in relation to sustainability are discussed. Third, based on the code '(sub)sections of CoCs addressing sustainability' the conceptualisation of sustainability is analysed, followed by a discussion of the vertical and horizon cooperation with regard to sustainability based on the related deductive codes. Fifth, different types of motivation for sustainability are assessed based on the related inductive code. The section finishes by corroborating the results and then putting them in a broader context by comparing them with the quick scan of the benchmark and the sustainability reports.

8.3.1 Overall attention to sustainability

The research shows that the theme of sustainability is touched upon in all the sample's CoCs except for those by Boeing, whose 2019 CoC and 2023 update do not reference it. However, although sustainability is referred to across the CoCs, relatively little text is dedicated to it. Most of the CoCs spend just a few sentences or paragraphs on sustainability, whereas only a few have a dedicated (sub)section on the topic (see Table 8.A1 in the appendix). On average 8 lines are dedicated to the theme, ranging between 2 and 18 across both years. So, based on this metric alone, there is no indication of an increase in the companies' interest in sustainability.

A possible explanation of the number of lines dedicated to sustainability can be the overall size of the CoC. When comparing the number of lines to the overall size, this shows that more substantial CoCs do tend to spend the most lines on sustainability (see Table 8.A2 in the appendix). However, at the medium and lower end of the spectrum, size offers no clear predictor of the amount of text dedicated to sustainability.

Apart from Boeing, the least evidence is found in the CoCs by Leidos, L3, Huntington and Thales, of which only Thales updated theirs in 2023, and the 2019 CoCs of Raytheon and Rolls Royce. In these CoCs the attention to sustainability is limited to a statement of commitment to the protection of the environment.

On the other end of the spectrum, there are the CoCs by Leonardo, United Technology, Honeywell and the 2023 update by Rolls Royce that offer a more elaborate discussion of their sustainability goals and include practical guidance to their employees. In their CoCs Honeywell, for example, discusses how they '[…] identify, control, and endeavor to reduce emissions, waste and inefficient use of resources and energy.'(p.30) And, across different sections of their CoC Rolls Royce shows how they 'integrate sustainability considerations into decisionmaking at all levels of the organisation.' (p. 27)

In between these ends, the remaining CoCs are located. Lockheed Martin's and General Dynamics' CoCs, for instance, offer some elaboration on why sustainability is important to them, but lack any translation into practical guidance.

Over time, in those cases in which the companies updated it, their 2023 CoC shows little development. The only exception is Rolls Royce's[2], who went from very limited (2 lines) to integrating sustainability across many subsections of their CoC in 2023 (23 lines). That does not mean, however, that across the CoCs the discussion of sustainability underwent changes. The following paragraphs discuss in more depth the manner in which the theme of sustainability is being addressed.

8.3.2 Guidance of employees' behaviour

A CoC contains guidelines on the acceptable behaviour of employees in the organisation. There is no fixed and generally approved format for drawing up a code of conduct; consequently, companies use their own unique format. Table 8.A1 in the appendix shows that, in 2019 and 2023, 10 out of 18 and 9 out of 17 companies have a separate sustainability section in the CoC scoring well below average in comparison to the reference group. All companies use the CoC to express their core values and beliefs. The 2023 CoC of Lockheed Martin, for example, states that 'at Lockheed Martin, we believe in living our core values, to do what's right, respect others, and perform with excellence' (p.1). According to the President and Chief Executive Officer of Lockheed Martin 'the values serve as our North Star, enabling us to maintain operational excellence and cultivate innovation' (p.1). In addition to explaining the core values and beliefs the 2023 CoC of Airbus explains '[…] this CoC is designed to provide you with user-friendly and practical guidance on the proper conduct needed to build business relationships between Airbus and its stakeholders […]' (p.3). Therefore, Airbus' CoC provides a clear example of a guideline of expected behaviour in the workplace.

Like Airbus, four companies also include more detailed information about what is expected of their employees. To explain the desired behaviour to their employees the 2023 CoC of Rolls Royce uses different headings. Each page starts with 'our principles' followed by 'what this means for you' and 'where to go for help' (p.34). The CoC 2023 of Thales and Airbus translates companies' principles in a list of 'what employees must not do' and 'what employees should do'. For example, the 2023 CoC of Airbus explains '[…] employees should follow local rules that apply to the storage and use of chemicals and reducing company's environmental impact […]' but '[…] employees are not allowed to accept environmental practices in the supply chain that are not accepted in Airbus operations […]'. Even though both Thales' and Airbus' do's and don'ts-lists are not exhaustive, this approach gives an evident view of recommended behaviour and prohibitions. Companies that do not translate general rules into a more detailed set of behavioural rules may sometimes refer to their sustainability policy. In total, the study reveals that 6 out of 18 companies in 2019 and 6 out of 17 in 2023 included such a reference in their CoC.

8.3.3 The concept of sustainability in the defence industry

Corporations in the DI integrated sustainability in their CoC in a variety of ways. Inductive coding of the headings of the sustainability (sub)section found several key words that are listed in the left column of Table 8.2. A distinction is made between 2019 and 2023. Three types of distinct stakeholder groups came to the fore: [1] employees, [2] communities and [3] global. Some CoCs focus on one stakeholder group while others have a multiple stakeholder focus.

Table 8.2. Keywords used in the heading of (sub)sections featuring sustainability classified by targeted stakeholder.

Keywords	Focus	Stakeholder	2019	2023
1) Good corporate citizen 2) Committed to sustainability 3) How we treat our world 4) Responsible corporate citizen	Protecting the world/planet	Global	5	4
5) Environmental protection 6) Engaged in our communities 7) Commitment to our community 8) Respecting our environment 9) Community investment	Environmental protection	Communities	12	11
10) Health, safety 11) Workplace responsibilities 12) Safe workplace 13) Keeping everyone safe and well	Health and Safety	Employees	6	5

Table 8.2 shows that most CoCs focus on the protection of the immediate environment. These CoCs advise the employees to show commitment to their community as the sustainability section deals specifically with ‘respecting the direct environment’ and ‘community investments’. For example, the 2019 CoC of United Technologies, states ‘We are engaged in our communities’, ‘[…] we protect the environment we share and seek out sustainable ways to create value’ (p.48). While the 2019 CoC of General Dynamics explains ‘[…] We protect the environment of the communities in which we work. In all jurisdictions where we do business, we comply with environmental protection laws and regulations, including recycling and waste disposal requirements’ (p.16). There are fewer CoCs that have a ‘health and safety’ or ‘protecting the planet’-approach. When a health and safety-approach has been adopted, the

sustainability section in the CoC is mainly concerned with 'keeping everyone safe and well'. The 2019 CoC of Raytheon, for instance, states that '[t]he company ensures compliance with applicable environmental laws and regulations and provides a safe and healthy workplace for our employees' (p.9). When companies adopt a protecting the planet-approach, the CoC uses terms such as 'good corporate citizen' and 'how to treat the world' to explain to the employees the importance of sustainable enterprise and the role the industry can and wants to play in this respect. The 2023 CoC of Airbus is illustrative of such an approach, by using the following sentence 'We have a responsibility to the global community to protect the environment in our operations and throughout our value chain' (p.46). These companies often have a broader view on sustainability that goes beyond their own business activities.

8.3.4 Supply-chain approach and horizontal cooperation

A few companies notice in their CoC that the environmental impact of the DI is intricately linked to their supply chain. Six companies, for example, underline the importance of a responsible supply chain while some expect key suppliers to increasingly employ sustainable practices. The 2019 Coc of United Technologies, for example, states 'We expect our key suppliers to increasingly employ sustainable practices' and 'we set goals that motivate us and our key suppliers to seek out constant improvement in conservation and sustainability' (p.48). Sometimes suppliers are even asked to provide evidence for their environmental responsible behaviour. This is illustrated by the 2019 CoC of Airbus in which the company asks its employees to conduct responsible sourcing and when needed suggests employees to ask suppliers to provide evidence of the application of sustainability principles (p.24). In contrast, other companies do not express such expectations in their CoC. This does not have to mean that there are no requirements as some companies refer to a separate, dedicated supplier code of conduct in their CoC. While these documents are of interest, they are not always publicly available and beyond the scope of the present exploration and therefore left out.

Horizontal cooperation is understood here as the concerted practices between companies operating at the same level in the defence market. Across the CoCs included in the sample, three mentioned engagement with peer groups to reduce the environmental footprint. The 2019 CoC of United Technologies Corp., for example, states '[...] we are not content to simply meet our legal obligations when it comes to environmental standards. We want to be a catalyst of positive change, making progress though innovation and showing our peers and our communities that reducing your environmental footprint is not only good for the world, it's good for business' (p.48). Likewise, the 2023 Airbus CoC explains '[...] we engage with companies throughout the aerospace sector to reduce the environmental footprint' (p.46). Apart from the limited references to horizontal cooperation concerning sustainability, these engagements with peer groups concern in particular the development of new technologies.

8.3.5 Corporate motivation for sustainability

Across the CoCs, evidence emerged for different motivations to address the topic of sustainability. Broadly, three types of motivation can be discerned: (1) Social Responsibility, (2) Economic, and (3) Juridical/Legal (see Table 8.3).

The 2019 CoC of Booz Hamilton, for example, states that the company has '[…] a responsibility as a corporate citizen to make a positive impact on building a more sustainable society.' (p.31). In turn, the 2023 Lockheed Martin CoC links their commitment to sustainability to '[…] ensure long-term competitiveness of our business.' (p. 34), while the 2019 CoC by General Dynamics explains that they '[…] comply with environmental protection laws and regulations, including recycling and waste disposal requirements.' (p.16).

Table 8.3 Different types of motivation for sustainability in the 2019 and 2023 CoCs.

Type of Motivation	**2019 (18 CoCs)**	**2023 (17 CoCs)**
None	2	2
Social Responsibility (R)	11	11
Economical (E)	4	5
Juridical/Legal (J)	11	12

The motivations, however, are not mutually exclusive. In the majority of the CoCs, different types of motivations are provided alongside each other. For both years, two companies combined economic and social responsibility and five juridical and social responsibility motivations, while in 2019 two and in 2023 three companies included all three types.

For instance, the United Technologies 2019 CoC states that '[…] we respect all environmental laws and regulations that apply to us' (p. 48), but also asserts that for social reasons 'we are not content to simply meet our legal obligations when it comes to environmental standards.' (p. 48). At the same time their CoC claims that meeting sustainability goals 'is not only good for the world, it's good for business' (p 48).

Over time, there has been little development in terms of the types of motivation provided by the CoCs. The differences between the two columns of Table 8.12 are accounted for by only one company. Of the eleven companies that updated their CoC in 2023, nine provide a motivation for sustainability that is similar to that of their 2019 CoC. And, although Raytheon went from providing solely a legal motivation in 2019 to including all three types in 2023, this can be explained by the CoC of their merger partner United Technologies, in which the 2019 CoC also mentioned all three motivations. That only leaves Rolls Royce, in which the 2019 CoC referred only to social responsibility, while in 2023 it mentioned all three types of motivation.

8.3.6 Corroboration of the findings

This research confirmed that the DI has placed sustainability on its agenda, as almost all companies included sustainability in their CoC. Evidence emerged for different motivations to address the topic of sustainability. Broadly, three types of motivation were discerned; (1) Social Responsibility, (2) Economic, and (3) Legal. In the majority of the CoCs different types of motivations are provided alongside each other. The way companies include sustainability in their CoC differs. Some CoCs focus on the protection of the immediate environment and safety of personnel, other CoCs have a much broader view on sustainability and show responsibility for the whole planet. On the one hand, this can be explained by companies' narrow or broad approach to sustainability, on the other hand by the manner in which key values have been anchored in the CoC.

The findings were tested against a purposive sample of five companies from the 2021 nominees of Ethisphere's 2021 World's Most Ethical Companies. This comparison showed that the CoCs of the reference group all contain a separate sustainability section and four of the five CoCs provide all three motivations to address the topic of sustainability. Three out of five of the reference group CoCs underline the importance of a responsible supply chain and two out of five CoCs mentioned engagement with peer groups to reduce the environmental footprint. Compared to the reference group, the CoCs of the defence industry score below average on multiple parameters.

A comparison with the most recent sustainability reports of the companies in the sample shows a different picture (see Table 8.A1 and Table 8.A2 in the appendix). Fifteen sustainability reports pay attention to a sustainable supply chain against four CoCs. The analysis of the sustainability reports also shows thirteen companies that combine their knowledge and skills with peers against only one CoC. There appears to be a difference between the information included in both documents. This difference becomes particularly evident when comparing the CoC and sustainability report of Boeing. The Boeing CoC does not include a separate sustainability section or a motivation for sustainability. It also does not make reference to a supply chain approach or horizontal cooperation with peers. Surprisingly, the Boeing sustainability report incorporates all three motivations to address the topic of sustainability and makes reference to both the supply chain approach and horizontal cooperation. This raises the question of to what extent the CoC is the commonly used management control instrument to display the variety of sustainability responsibilities of companies and their stakeholders. This question is further touched upon in the discussion section.

8.4 Discussion

A CoC provides an understanding of expectations and standards for ethical behaviour and responsible business practices (Erwin, 2011; Stevens, 2008). Compliance with laws and high standards of behaviour are important to protect the reputation and long-term success of a company (Babri et al., 2019). It seems therefore logical to include sustainability in the CoC since not complying with environmental legislation, energy- and climate targets can have a considerable impact on a company's reputation. This research confirms that all companies except one included sustainability in their CoC.

8.4.1 Staff versus wider stakeholder-groups

However, the way companies have included sustainability in their CoC varies widely. This can be explained by the way companies pursue sustainability, but also by how key values have been anchored in the CoC. To start with the latter, current research examined how companies use the CoC. It found companies that use the CoC to express their core values and beliefs and companies that use the CoC more as a guide on how to conduct business. A combination of both can also occur. It depends to whom the code of conduct applies. In some cases, the code of conduct only applies to staff members; in other cases, it also promotes the adaptation of sustainability standards by multiple stakeholders in the supply chain (customers, suppliers, partners, contractors). In the latter case, companies sometimes refer in the CoC to a 'responsible supply chain' and 'horizontal cooperation'.

This ties in with the different uses of CoCs described by the literature, which can be focused on external and/or internal stakeholders (e.g. Kaptein & Wempe, 2002; Weber & Wasieleski, 2013). In both cases, a CoC may reflect the importance of sustainability to the company. Nevertheless, except for a small group of companies that integrated the theme across their CoC, the DI CoCs are below that of the level of addressing found across the five companies of the benchmark at both measure points.

8.4.2 Broad versus narrow view of sustainability responsibility

Getting back to the question posed in the previous section 'to what extent is the CoC the commonly used management control instrument to display the variety of sustainability responsibilities of companies and their stakeholders', the results show that this is not always the case. Some companies solely discuss sustainability in their CoC concerning the health and safety of their employees and/or on impacts on the communities and direct surroundings in which they are located (see Table8.11). Consequently, there is less chance of a trickling-down effect towards partners in the supply chain such as suppliers as well as a trickling-up effect towards customers such as MoDs.

This can, therefore, be qualified as a ‘narrow’ view of sustainability responsibility. In contrast, there are also companies that discuss sustainability in terms of protecting the world and planet. Moving beyond their local interests this ‘broad’ of sustainability responsibility also takes into account the impact on the environment and planet as a whole. When taken seriously, this should carry over to the companies’ products and services and hence make trickling up and down more likely. Moreover, it can be seen as evidence of the companies taking the interests of their customers such as MoDs seriously.

8.4.3 Compliance versus integrity strategy

This distinction resonates with three types of motivation for pursuing sustainability that emerged from the results (Table 8.12).

On the one hand, a large group of companies mention legal and economic motives to address the theme of sustainability. This conforms to the (neo)classic economic paradigm that suggests companies pursue their self-interest within the legal boundaries set by the state (or other types of standards of regulations within an organisation). Accordingly, companies will follow a strategy that is limited to complying with legal and other regulatory requirements (Paine, 1994, p. 19; Silverman, 2008; Timmermans, 2022).

On the other hand, a large group of CoCs (also) mentioned social responsibility as their motivation. This suggests that these companies go beyond compliance and pursue a so-called integrity strategy, which aspires to contribute to what is deemed socially and ethically desirable as well (Paine, 1994, p. 19; Silverman, 2008; Timmermans, 2022).

Although pursuing an integrity strategy does not rule out that companies exclusively have a narrow view of sustainability responsibility, companies with such a strategy seem to be more likely to have a broad view of sustainability responsibility. And vice versa, adhering to a compliance strategy may not necessarily preclude concern for sustainability in products and services. At the same time, however, it is unlikely that these concerns will go beyond regulatory and legal requirements.

8.5 Conclusion

This research set out to make a first step towards a better understanding of the current state of affairs of the addressing of environmental sustainability by the DI. Overall, it shows that, although all companies except one have addressed sustainability in their CoC, the integration of the theme is rather shallow. Most of the CoCs spend only a limited number of lines on it across one or two subsections, while targeting a limited number of stakeholders. Furthermore, this is coupled with a predominantly narrow view of sustainability responsibility that oftentimes is linked to a compliance strategy. Few companies integrate the theme throughout their CoC coupled with a broad view of sustainability responsibility while pursuing an integrity strategy. Moreover, the increase in prominence of sustainability in recent years is also not reflected in the development of the CoCs over the two measurement points: the overall picture has not altered much, despite 12 companies having updated their CoC in the meantime.

When comparing these findings to those of the companies in the benchmark, the snapshot of the DI looks rather bleak. Based on this, the conclusion can be drawn that the interests of the MoDs do not trickle down to their suppliers. This may be due to a reluctance of the suppliers or to the MoDs not yet prioritising sustainability in their dealing with the DI or failing to communicate that interest effectively to their suppliers. In any case, this indicated that there is still much room for improvement for both the suppliers and the MoDs.

Yet, when the sustainability reports of the DI companies are taken into account this conclusion needs nuancing. In most of the reports more attention is given to the theme, multiple stakeholders beyond the community and employees are targeted, and the companies seem to have a broad view of sustainability.

This seems to imply that companies use accountability reporting for sustainability goals rather than their CoCs. However, none of the sustainability reports provide practical guidance to the staff and/or other stakeholders. Instead, in line with their function, the sustainability reports' focus is solely external, namely raising awareness and being accountable to the stakeholders. And, because most of the companies, unlike most companies in the benchmark and a small group of their DI peers, do not use their CoCs to provide guidance instead, there seems to be a gap between the overarching sustainability strategies and operations within the company and towards their supply-chain partners. This highlights a huge opportunity for the companies to take advantage of the main function of CoCs, namely to guide the behaviour of the individual members of their staff.

Besides opening up opportunities for the further addressing of sustainability throughout the supply chain, this research also signals further avenues of inquiry. The limited use of CoCs to address sustainability by the DI highlights a need to look further into the (alleged) functioning and effectiveness of CoCs concerning that theme. As a part of this, the relationship and differences between CoCs and other tools such as sustainability reports and corporate websites should be taken into account, all the more, because present research has shown that sustainability reports evidenced sustainability much more extensively.

Appendix

Table 8.A1. Results of Analysis on Code of Conduct and Sustainability Report.

	Code of Conduct 2019						Code of Conduct 2023						Sustainability Report 2023			
	Sustainability Section in CoC	Reference sustainability policy	Guidelines for behaviour	Supply chain approach	Horizontal cooperation	Motivation for sustainability[2]	Sustainability Section in CoC	Reference sustainability policy	Guidelines for behaviour	Supply chain approach	Horizontal cooperation	Motivation for sustainability	Guidelines for behaviour	Supply chain approach	Horizontal cooperation	Motivation for sustainability
1. Lockheed Martin	Yes	Yes	No	No	No	RE	Yes	Yes	No	No	No	RE	No	Yes	No	R
2. Boeing	No	No	No	No	No	N	No	No	No	No	No	No	No	Yes	Yes	ERJ
3. Northrop Grumman Corp.	Yes	No	No	No	No	R	Yes	No	No	No	No	R	No	Yes	Yes	R
4. Raytheon	No	No	No	No	No	J	No	No	No	Yes	No	JRE	No	Yes	Yes	ERJ
5. General Dynamics Corp.	No	No	No	No	No	J	No	No	No	No	No	J	No	Yes	No	R
6. BAE Systems*	Yes	Yes	Yes	No	No	JR	Yes	Yes	Yes	No	No	JR	No	Yes	Yes	ERJ
7. L3Harris Technologies	No	No	No	No	No	J	No	No	No	No	No	J	No	Yes	Yes	ERJ
8. United Technologies Corp.***	Yes	No	No	Yes	Yes	REJ	Not Applicable									

[2] Motivation for sustainability: J = Juridical/legal; R = Social Responsibility; E = Economical.

9. Leonardo*	Yes	Yes	Yes	No	No	JRE	Yes	Yes	Yes	No	No	JRE	No	Yes	Yes	ERJ
10. Airbus**	Yes	Yes	No	Yes	No	RJ	Yes	Yes	Yes	Yes	Yes	RJ	No	Yes	Yes	R
11. Thales	No	No	No	No	No	N	No	No	No	No	No	No	Yes	Yes	Yes	ERJ
12. Huntington Ingalls Industries	Yes	No	No	Yes	No	RJ	Yes	No	No	Yes	No	RJ	No	No	No	RJ
13. Dassault**	No	No	No	No	No	RE	No	No	No	No	No	RE	No	No	Yes	RJ
14. Honeywell International	Yes	No	No	No	No	RJ	Yes	No	No	No	No	RJ	No	Yes	Yes	R
15. Leidos	No	No	No	No	No	J	No	No	No	No	No	J	No	Yes	No	RJ
16. Booz Allen Hamilton**	Yes	Yes	No	No	No	RJ	Yes	Yes	No	No	No	RJ	No	Yes	Yes	R
17. General Electric	No	No	Yes	Yes	No	J	No	No	No	Yes	No	J	Yes	Yes	Yes	RJ
18. Rolls-Royce**	Yes	Yes	Yes	No	No	R	Yes	Yes	Yes	Yes	Yes	JRE	No	Yes	Yes	R
In sum	10	6	4	4	1		9	6	4	5	2		2	15	12	

Reference Group CoC 2019 Scores						
	Code of Conduct 2019					
1. Arm	Y	Y	N	Y	Y	JRE
2. Schneider Electric	Y	Y	Y	Y	Y	JRE
3. Schnitzer	Y	Y	Y	Y	N	JRE
4. Cummings	Y	Y	Y	N	N	JRE
5. Illy	Y	N	N	N	N	JE
In Sum:	5	3	3	3	2	

Table 8.A2. Results of Analysis on sustainability content in Codes of Conduct.

	Lines addressing sustainability[3]		Overall number of Pages of CoC[4]	
Company[5]	**2019**	**2023**	**2019**	**2023**
1.Lockheed Martin Corp.	7	7	38	38
2.Boeing	0	0	21	27
3.Northrop Grumman Corp.	5	5	47	45
4.Raytheon	3	8	36	50
5.General Dynamics Corp.	6		21	
6.BAE Systems	12	8	63	89
7.L3Harris Technologies	2		35	
8.United Technologies Corp.	16	N/A	50	
9.Leonardo	18		31	
10.Airbus	8	5	29	55
11.Thales	2	2	12	46
12.Huntington Ingalls Industries	2		36	
13.Dassault Aviation Group	6		9	
14.Honeywell International	14	14	54	56
15.Leidos	3		43	
16.Booz Allen Hamiliton	6	6	35	43
17.General Electric	4	4	20	27
18.Rolls-Royce	2	23	33	55
AVERAGE	6.4	7.0	34.1	48.3

[3] Colouring of cells: Red = low (i.e. a relatively low number of lines); blue = average; Green = high

[4] Colouring of cells: Ranging from green (a relatively high number of pages) to red (a relatively low number of pages)

[5] A company name displayed in italics indicates that the company has not updated its CoC after 2019.

Notes

1 The CoCs of five companies headquartered in different countries, with an industrial or technical background matching that of the DI sample and with a number of employees comparable to that of the DI sample were selected from five different industries: ARM (UK), Cummins (US), Illy (Italy), Schnitzer (US), and Schneider Electric (France).

2 As discussed before, the developments of the Raytheon CoC can be accounted for by its merger with United Technologies, whose CoC paid even more attention to sustainability than the CoC of the merged company.

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CHAPTER 9

Uphill Battle: Military Organisations' Reporting on Environmental Sustainability Performance

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'We need to climate-proof our organizations, our policies, and our equipment'
—General Middendorp[1]

Abstract
This chapter investigates the issues the military need to address when reporting to internal and external stakeholders on its environmental sustainability performance. We propose a conceptual model to identify the most important decisions to be made. Empirically, we provide an overview of recent developments in reporting on environmental sustainability by the MODs of Australia, Canada, the United Kingdom, the United States, and the Netherlands. In doing so, we identify two main decisions to operationalise environmental sustainability performance and its reporting.

Keywords: operational sustainability performance, environmental sustainability performance, secrecy, defense, internal and external reporting.

9.1 Introduction

Sustainability entails more than a reduction of footprints. In the military, the concept is applied in several contexts and is understood in several ways. The NATO Logistics Handbook defines sustainability as "the ability of a force to maintain the necessary level of combat power for the duration required to achieve its objectives".[2] Regarding this definition, the European Defense Agency (EDA, 2017) annually reported from 2007 until 2017 on sustainability, concerning 27 European Union (EU) member states. During this period, typically, sustainability would be derived from the armed forces' deployability, defined as the number of national (land)forces that could be deployed immediately by a member state. Deployability was measured both as an absolute number of military men and women, as well as a percentage of the sum total of the nation's military. Regarded as a derivate of deployability, sustainability was defined to equal the number of (land)forces a nation can deploy in the longer term. In line with deployability, sustainability also would be expressed as both an absolute number of military as well as a percentage of the sum total of the nation's deployable military (Beeres, Bollen, and Bogers, 2023, Beeres and Bollen, 2017). From 2005–2017, based on a mean of 1,580,614 military annually, the 27 EU member states reached a deployability percentage of 27.3%. During the same period, the mean sustainability percentage reached 23.3%. Thus, out of a European total of 1,580,614 military, annually 99,612 military could be deployed on missions in the long term.

Recently, in literature, military sustainability has been operationalised quite differently than described above, referring to issues pertaining to the social (e.g. social safety), environmental (e.g. CO_2 emissions), and economic (i.e. cost-effectiveness) behaviour of defense forces (Atlason and Gerstlberger, 2017, Holcner and Smiljanic, 2018, Smaliukiene, 2018). Intra-military environmental sustainability discourses focus both on sustainable energy consumption and additional environmental issues, traditionally connected with the armed forces, such as soil contamination at military bases, pit burns, water extraction in mission areas, noise levels caused by fighter jets, and use and storage of dangerous substances (Smaliukiene, 2018). According to a report by Kearney, a drastic shift in the global supply of energy is expected in the next 25 years as supplies of non-renewable energy decline, which will affect a nation's ability to deploy its armed forces (Boladian et al., 2023). This means that military organisations should have a focus on military effectiveness in a world that is changing due to investments in sustainability, but also a focus on social responsibility to contribute where they can to sustainability. One would expect that designed measures would support awareness and would support defined desired outcomes for future-proof military effectiveness and military sustainability.

In the private sector we see quite a similar shift. The *Corporate Sustainability Reporting Directive* (CSRD) of the European Union (EU) introduces detailed sustainability reporting requirements for large EU corporations. CSRD is a core element in the EU's ambitious focus on corporate sustainability and entered into force on January 5, 2023. On one hand, companies are required to disclose information on how sustainability-related factors affect their operations and the business (outside-in). On the other hand, companies must inform how their business model impacts sustainability factors (inside-out). The scope of required reporting covers environmental, social, and human rights and governance factors. Developments such as the establishment of CSRD in the EU are paralleled by similar developments in the United States (US) and the United Kingdom (UK). In March 2022, the US Securities and Exchange Commission proposed expansive climate related disclosure rules. Likewise, the UK is developing its own broader corporate sustainability reporting standards. Moreover, the International Sustainability Standards Board (ISSB) has produced a comprehensive global baseline of sustainability-related disclosure standards.

Zooming in on the industry providing major military systems, we note that compared to most other sectors, the global defense industry is challenged regarding environmental sustainability, for example in reducing greenhouse gas emissions. This is not entirely surprising: safety, reliability, and performance have been and will continue to be the paramount requirements of customers in the armed forces. Many defense systems and supporting infrastructure are also inherently more difficult to decarbonise than in most other sectors (Dimitrova et al., 2021). It is stated that decarbonising efficiently will require a holistic approach. Defense contractors and the sector as a whole need to get a clear picture of their current emissions to establish a baseline, define firm targets and strategic roadmaps for each business unit, and start implementing emission reduction initiatives. These initiatives will vary by company and business unit, but they should include procuring greener inputs and assemblies from suppliers, accelerating R&D programs to develop new generations of carbon-efficient products, and coordinating with other players to create green solutions at scale.

Depending on the specific situation of a public organisation, a performance measurement instrument is designed and geared towards effectiveness, efficiency, or fairness. Because of its relatively large footprint as a public organisation, environmental sustainability is to be added to the existing performance measurement instruments in the Defense public sector. To this end, the traditional sustainability context needs to be operationalised concerning other performance elements. As large corporations do, the military is also confronted with some level of public pressure to organise their operations sustainably and to report on what they are doing in this regard. Current research on this topic in a military context is limited. It represents a specific domain of research adjacent to military studies, public management (e.g. procurement) and sustainability as a broader topic.

Our chapter offers a strategic, qualitative reflection on sustainability reporting by military organisations of several countries. Hence, to limit the scope our research, we do not design a roadmap for sustainability reporting by military organisations, recommend improvements on sustainability reporting by military organisations or quantitatively measure sustainability performance of military organisations. Instead, our research questions include:

(1) How do we position environmental sustainability in the notion of sustainability?

(2) How do military organisations report on environmental sustainability?

To do so, first, we present our theoretical framework to enable us to think conceptually about the design of performance management systems for public and non-profit organisations. We then identify major decisions to be made for both internal and external reports on environmentally sustainable performance. Next, we discuss the ways in which the MODs of The Netherlands, Australia, Canada, the UK, and the US currently report on environmental sustainability. Finally, we reflect upon sustainability policies and reporting across international cases of military organisations and identify two main decisions to operationalise environmental sustainability performance and its reporting.

9.2 Positioning Environmental Sustainability

What is the scope of environmental sustainability (performance)? According to Dathe et al. (2022), Environmental Social Governance (ESG) is defined as "the operationalization of sustainability management by means of the process of Environmental Social Governance" (Dathe et al., 2022). So, being successful in sustainability needs managing these three dimensions. Furthermore, the successful application of ESG requires smooth cooperation between a variety of stakeholders, good quality reported data (Cort and Esty, 2020), and decent underlying concepts to ensure this quality. Let us first describe the three dimensions of ESG.

First, according to Bradley (2021), the main ESG ***environmental factors*** relate to the (re)use of natural resources. That is a company's stewardship obligations which can be outlined in practices as:
- Protecting the natural environment, and
- Using natural resources throughout the logistics process and product lifecycle in a responsible manner (i.e., from product design, purchasing, production, assembly, warehousing to transportation, and recycling) (Uemura Reche et al., 2022), thus
- Promoting a circular economy, preventing pollution, and stimulating biodiversity (Bradley, 2021).

These practices usually involve matters such as confronting greenhouse gas and carbon emissions, adopting clean energy sources, optimising energy usage, and conserving water.

Second, important ESG ***social factors,*** identified by Bradley (2021), are social trends and conditions related to how a company's social performance impacts human well-being. This varies from the life quality of employees and dealing with social communities, to applying social standards regarding the supply chain. Examples of topics frequently dealt with are gender and diversity (so the reduction or elimination of inequalities), data protection and privacy, employee engagement, community relations, human rights, and labour standards.

Third and finally, ***governance*** is a mandatory element in any due diligence process, directing and dictating the environmental and social elements of ESG. It comprises four factors: organisational leadership, its management; the internal auditors and the external auditors. As stated by Bradley (2021, p. 83) “In total, it safeguards appropriate oversight aimed at ensuring long-term, sustainable value creation with due regard for all stakeholders.”

Although environmental sustainability is mostly dealt with in combination with social and governance sustainability, we focus mainly on the first one. It is this field that has seen the most turbulent developments in recent years, with the 2015 Paris Agreement on climate change, assessment reports of the Intergovernmental Panel on Climate Change (IPCC), and a continuous stream of media messages on climate change and its imminent effects, which urge organisations, both public and private, to act.

9.3 Reporting on Environmental Sustainability

For the private sector there are multiple frameworks developed that cover sustainability performance reporting. Examples of these frameworks are the Global Reporting Initiative (GRI), the Task Force on Climate Related Financial Disclosures (TCFD), the World Economic Forum (WEF), the International Integrated Reporting Council (IIRC), the International Sustainability Standards Board (ISSB), and the European Financial Reporting Advisory Group (EFRAG). Each of the aforementioned reporting frameworks may cover environmental, social, and human rights, governance, and other factors. In general, they all strive for integrated reporting. However, these reporting frameworks vary substantially in terms of for instance the scope of the framework, disclosure requirements, sector applicability, the effective date of the standards, and the interoperability with other frameworks.

We see similar developments in the public sector, although it is lagging a little behind. On May 9, 2022, the International Public Sector Accounting Standards Board published its consultation paper, Advancing Public Sector Sustainability Reporting (IPSASB, 2022). This paper identifies the following factors driving the need for public sector-specific sustainability reporting:

– Global public interest;
– Major economic, environmental, social and governance impact;
– Capital markets significance.

IPSAS proposes a public sector-specific sustainability reporting framework. After reviewing the responses in the last quarter of 2022, IPSAS decided to establish a Sustainability Task Force for further research and scoping. The prioritised research topics of the Task Force are:

- General requirements for disclosure of sustainability-related financial information;
- Climate-related disclosures;
- Natural resources – non-financial disclosures.

Especially in the research topics we see the main focus is on environmental sustainability. However, in the current situation the public sector has not established standards on sustainability reporting, nor on topics that are mandatory to report on. So how and what to report on concerning environmental sustainability is still unclear.

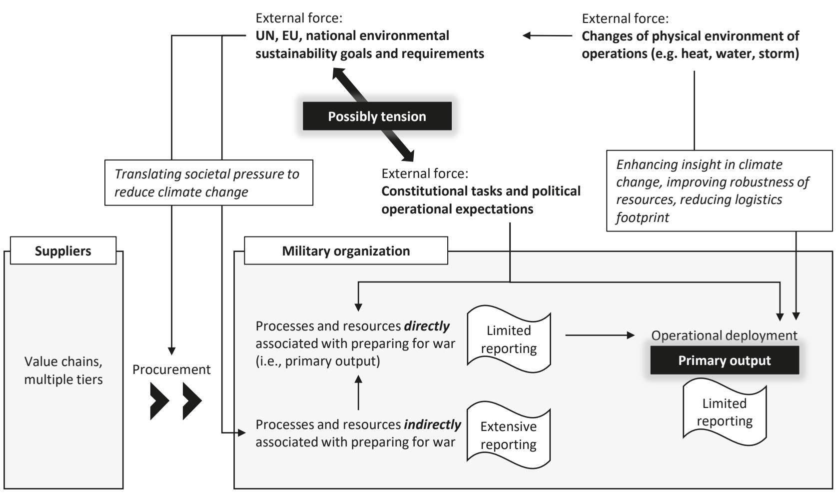
After discussing private and public sector reporting we looked for guidance in the (international) military scope (e.g. NATO). We find no established guidance on reporting. However, we notice military organisations are still probing sustainability reporting on national level. Because of this we need to explore reporting possibilities further, which is done in the next section.

9.4 Military Organisations: External Influences and Organisational Reporting

Non-financial external reporting is an emerging phenomenon that asks organisations to develop and embrace new organisational practices (O'Dwyer and Unerman, 2020). When military organisations need to account for their policy, actions and results achieved in the field of environmental sustainability this is covered by non-financial reporting. Non-financial external reporting is relatively new. This contrasts with the long-standing, institutionalised rules and practices concerning financial external reporting (Lahouirich et al., 2022). To relate external reporting to an organisation, internal reporting is a necessary precondition. As a starting point, we can distinguish internal reporting as a counter-phenomenon within the organisation (Jones and Ratnatunga, 2012). Internal reporting stimulates organisations to be adaptive to external developments; it preludes pending changes to transform the fabric of organisations. It implies more than just reporting within the organisation, involving a range of intervention opportunities like the development of strategies and policies, performance management, technology, controls, change management and audit readiness. Research has been emerging on these intervention opportunities to enable sustainability transformation in organisations (Romero, Jeffers, and DeGaetano, 2014).

Figure 9.1 provides a framework for contextualising these opportunities for sustainability reporting interventions. First, internal goals and indicators enable reporting on internal/external environmental sustainability performance. Mirroring external goals and indicators, the internal side also requires political and conceptualisation (operationalisation) processes. The relationship between environmental sustainability and other aspects of organisational functioning tends to be complex. Second, internal reporting requires information on activities and resources being the object of measurement. This is where internal reporting proceeds to the micro realities of organisations. For military organisations we distinguish on the one hand the standing organisation and peacetime operations, and on the other hand the mission-oriented operations (de Bakker and Beeres, 2016). And third, a military organisation's activities and resources relate on the input side to suppliers and on the output side to external partners and contexts. Both generate information that is used in internal reporting.

Figure 9.1. Military organisations and reporting on environmental sustainability.



Conceptually, the internal organisation can be understood as a cybernetic information processing system that includes goals, operationalisation of goals (indicators), measurement systems, and actual information processing (Galbraith, 1981). An integrated theory of organisations as cybernetic information processing systems encompasses, for instance, the Viable Systems model and the (increasingly sustainability oriented) Business Model approach (Espejo et al., 1996, Freudenreich, Lüdeke-Freund, and Schaltegger, 2020). The extant cybernetic system must be enriched and transformed by environmental sustainability, i.e. changes to goals and policies (Greve and Teh, 2018), capabilities (Silva, Rodrigues, and Ferreira Alves, 2022), and reporting. Organisations increasingly face the challenge of such 'deeper change' and entering the 'decade of action' (van Tulder et al., 2021), i.e. to institutionalise sustainability in their strategic control and operations. This will help them address external criticism of merely pursuing superficial change like greenwashing (de Freitas Netto et al., 2020). Instead, stemming from fundamentally new ideas on sustainability and circularity, organisations would rethink their stakeholder management, business/ organisational models, structure, culture, and product/ service chains (Bansal et al., 2022). In other words, a more fundamental challenge needs to be addressed in transforming an organisation's cybernetic system to avoid remaining stuck in greenwashing.

While presently existing business models are extended with 'eco-social costs' and 'eco-social benefits,' rethinking strategies and performance measures is required to meet rapidly changing external expectations (Medne, Lapiņa, and Zeps, 2022). Some sectors spearhead this trend due to their impact on the environment (e.g. construction and agriculture). For military organisations, rethinking strategies and measures will stem from dealing with new and increasingly enforced societal-public and industry standards as well as expectations and requirements pertaining to military operations and their contextual properties (like climate change). Internal reporting tends to start with high level domains that express an organisation's mission and can be operationalised towards the internal organisation and its activities/ resources. For instance, Novo Nordisk, a global healthcare company, uses *Living our values, Access to health, Our employees, Our use of animals, Eco-efficiency and compliance, and Economic contribution* (Morsing, Oswald, and Stormer, 2018). Military organisations operating in a different context will need to rearticulate their high-level domains and re-operationalise these. Several domains prove relevant to military organisations and lead to initiatives to restructure internal reporting with environmental sustainability in mind.

- Overall, procurement and life cycle management of technologies increasingly incorporate environmental aspects (Hastings, 2015). Suppliers of weapon systems and other technologies like general purpose vehicles and services must report towards customer organisations on their sustainability scores, which directly leads to internal reporting (Hafsa, Darnall, and Bretschneider, 2021).
- Concerning the military organisation as a standing organisation – including its peacetime operations – attention is paid to mobility (reducing travel, opting for low-pollution modalities) and energy (shift towards new technologies such as used in buildings, e.g. solar panels).
- For mission-oriented operations, military organisations seek to reduce the logistics footprint of transportation and compounds (energy, water, waste), in part to improve environmental sustainability.

Internal reporting, to conclude, will not be easy. While initiatives are taken to reduce for instance CO_2 (e.g. 50% by 2030), implementation of these often-separate initiatives does not yet guarantee better overall environmental sustainability performance and achievement of organisational objectives in a broader sense. In fact, across all levels of organisations, a combination of indicators and reporting information must be considered to identify and manage tension between environmental sustainability approaches and 'other' approaches emphasising business, power, and finance. This pertains in a context-dependent manner to multinational corporations like Unilever as well as public and military organisations (Hahn et al., 2014). A clear example of this struggle is the steel industry, the centre of major political and public attention (and very important for the military as well) (Choudhury, 2022). As our model in Figure 9.1 illustrates, organisations are open systems on the input and output sides. Hence, internal reporting will embark on a journey to combine information on their purely internal activities and resources with information on external dependencies. This includes information from value/ supply chains (input) and information on operational settings (output). As mentioned in the introduction, sustainability encompasses both inside-out and outside-in dimensions. Moreover, tensions arise as shown in Figure 9.1. Combined, internal reporting information will contribute to the organisation's environmental sustainability insights, innovations, interventions, and performance, and in the end to external reporting.

Finally, we need to describe one specific caveat for military organisations, when it comes to external reporting. In general, transparency is what organisations strive for. However, precisely military organisations need to uphold a certain level of confidentiality because not everything is for the external world to know. While private businesses like Tony Chocolonely strongly focus on transparency, this is not what the military always would – or even should – do, because providing specific information might be detrimental to military interests. To find out what practices there are, in the next sections we discuss how other MODs – internationally and in the Netherlands – report on environmental sustainability.

9.5 Concepts for Comparing Countries

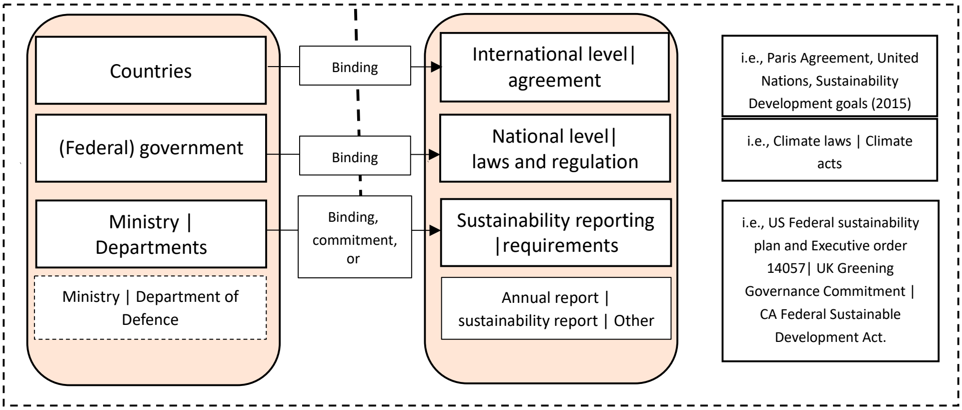
We now focus on the aspects that are important in shaping the way both internal and external reporting on environmentally sustainable performance is done in different countries. First, we explain our research method. Next, we discuss the ways in which the MODs of the Netherlands, Australia, Canada, the UK, and the US currently report on environmental sustainability.

When analysing the different countries reporting, the following aspects were considered:

- What is the relevant international, institutional context for national government and MOD;
- How is the MOD embedded in national government, and its reporting structures;
- What are the main policies for the MOD with respect to environmental sustainability in the different countries;
- What is the main orientation of and stakeholders in sustainability reporting in the different countries.

Our empirics consist of multiple case studies and our approach is inductive. We investigated five countries, the United Kingdom, the United States of America, Canada, Australia, and the Netherlands. The criterion for inclusion is that the Netherlands has worked closely with these countries for many years and in many ways, they organise and operate in a manner comparable to our MOD. We research the environmental sustainability and climate change policy and subsequently the reporting for each of these countries, focusing on the aspects described above. As stated earlier, on an international level the public sector has not established standards on sustainability reporting, nor on topics that are mandatory to report on. Therefore, we must look at the national regulatory items covered. There are however sustainability goals set in international agreements that translate into national law. An overview of sustainability regulation is given in Figure 9.2 below.

Figure 9.2. General overview of world-wide sustainability regulations for Defense.



When looking at the current situation in the five countries we included in our research, we see they diverge on sustainability reporting requirements (Table 9.1). Some do and others do not have formal sustainability reporting requirements. Consequently, form and substance of sustainability reporting differ depending on countries' and defense organisations' orientation.

Table 9.1. Overview table of sustainability reporting regulation.

Country	**Sustainability reporting requirements**	**Reference**
The Netherlands	No formal sustainability reporting regulation. The government commits to the sustainability targets by the United Nations. The Ministry of Defense developed goals and targets for sustainability and reporting.	Klimaatwet [Climate law], Uitvoeringsagenda Duurzaamheid [sustainability implementation agenda]
United States of America	Formal regulation for sustainability reporting at the federal level. The Department of Defense is required to develop plans and report on a regular basis with score cards.	United States federal sustainability plan and executive order 14057
Australia	No formal sustainability reporting requirements for the Department of Defense.	Public Governance, Performance and Accountability [PGPA] act/rule
United Kingdom	No formal sustainability reporting regulation. The governance commits to the sustainability targets by the United Nations. The Ministry of Defense developed goals and targets for sustainability and reporting.	Greening Governance Commitments (GCC), Ministry of Defense Climate Change and Sustainability Strategic Approach
Canada	Formal regulation for sustainability reporting on federal level [FSDA]. The Department of Defense is required to develop plans and report on a regular basis.	Federal Sustainable Development Act, Greening Government Strategy [GGS].

9.6 Results: Military Organisations and Sustainability Reporting

In this section we analyse the actual situation on sustainability reporting in the different countries, starting with the Netherlands.

9.6.1 The Netherlands

9.6.1.1 The Netherlands sustainability policy

The Netherlands MOD is focusing on environmental responsibility. The origin is found in the 2015 Paris Agreement on climate change. The Netherlands government implemented the measures of the Paris Agreement in 2018. At the national level there is a Netherlands Global Climate Strategy (2022) and a Climate Act from 2019 and 2023. This act and strategy should lead to a reduction in CO_2 emissions of 30% in 2030, and by 2050 the reduction must be 95%. Furthermore, a circular economy needs to be in place by 2050. The Dutch MOD has committed itself to a reduction of the environmental footprint too. Its efforts resulted in the *Defense Energy and Environment Strategy* (Tweede Kamer, 2019). Research shows that there is not a clear relation between the national targets and the MOD sustainability targets. An important reason for that lies in the fact that, from an outside-in perspective, the Dutch MOD needs to be able to operate under all circumstances. Climate change and energy transition influence the security of the world and the ability to operate as a military organisation. They, therefore, have an impact on personnel of the Dutch MOD and its means. Natural resources are getting scarcer; gaining resources and having access to resources are a risk for global security. Moreover, usage of natural resources affects the environment (inside-out perspective). It is clear that military organisations need to reduce their footprints as well, as part of society, but also to be able to operate.

The *Defense Energy and Environment Strategy* describes the focus to work towards sustainable and environmentally aware armed forces that are less dependent on fossil fuels, with a reduced ecological footprint and reduced negative consequences for the environment. The Dutch MOD focuses on taking reduction measures concerning real estate and reduction of fuel consumption in peacetime (Tweede Kamer 2019–2020). Therefore, a baseline measurement has been performed to determine the position of the Dutch MOD before the implementation of reduction measures. With the help of this baseline measurement, structural monitoring of consumption of energy and fuel has started to provide insights into the amount of reduction that is established now and in the future.

Dutch MOD policy is trying to ensure sustainability through cooperation, innovation, awareness, and behaviour, allocating responsibilities and working towards specified goals, strengthening government-wide initiatives, and stimulating sustainability in procurement procedures. Therefore, the Dutch MOD has formulated three primary objectives (Tweede Kamer, 2022–2023: 2):

- Dutch MOD adapts to the effects of climate change;
- Reduction of dependency on fossil fuels;
- Dutch MOD works where possible on a circular basis.

Internally the Dutch MOD is using information to refine more specific actions in the categories (note the link to processes and resources that are in/directly related to operational deployment, Figure 9.1):

- Operational material, military weapon systems like planes, ships, and vehicles (including encampments);
- Real estate, like terrains and buildings;
- Sustainable mobility, like daily commuting and business travelling;
- Non-operational equipment and consumables (Tweede Kamer, 2022–2023: 2–3).

9.6.1.2 The Netherlands sustainability reporting

The categories mentioned above are further divided into specific subjects which can be monitored individually and should be the basis for a dashboard capturing sustainability at the Dutch MOD. This dashboard is not yet in use, it is still being developed.

Currently the Dutch MOD reports the following performance measures concerning sustainability: 1) the total amount of CO_2 emission and 2) the percentage of used biofuels. The percentages for used renewable energy and for sustainable procurement are under construction (Tweede Kamer, 2022–2023). This information is being prepared for internal and external reporting.

Through external reporting, the Dutch MOD expresses its responsibility for climate change and its role in this respect. In short, sustainability within the Dutch MOD is still developing and is expected to become more part of day-to-day business. Current developments show that the Dutch MOD recognises the need for climate change and therefore plans are made. Moreover, the first elements of reporting on progress can be found in external communication. On a normative note, it seems crucial now to proceed from planning to execution and to show how closely the MOD moves towards reaching these goals. One of the first actions needed will be to establish a more complete set of performance measures and associated reporting routines.

9.6.2 United Kingdom

9.6.2.1 United Kingdom sustainability policy

The sustainability policy of the MOD of the United Kingdom is driven by climate change (MoD 2015–2025). The UK MOD conforms as much as possible to national policy on environmental sustainability. It also considers what climate change means for operational deployability, in particular to operating in mission areas, specifically aimed at logistical support, and adapting to new circumstances. As a first response to these challenges, the Sustainable Support Strategy has been developed, based on the policy for the coming years. Emerging green technology helps defense for the future in agility, resilience and increased operational pace. It also includes how the results of this strategy are monitored. This strategy is derived from a larger, national plan "Net Zero Economy 2050" (BCG, 2022). Examples of performance measures include CO_2 emissions (related to estates, travel, domestic flights), total waste (related to waste to landfill, waste to recycle), water use, paper use, international flights.

9.6.2.2 United Kingdom sustainability reporting

In the UK Ministry of Defense Annual Report and Accounts 2021–22, sustainability results achieved are reported in accordance with the provisions of the Sustainable Support Strategy, in addition to financial, personnel and operational data (MoD, 2021). These are limited to plain numbers/percentages regarding CO_2 emissions, water consumption and waste processing. A visualisation of CO_2 emissions' development is included in the report. The progress of other sustainability results is explained in more general terms, such as socially responsible procurement, nature restoration and sustainable infrastructure.

9.6.3 United States

9.6.3.1 United States sustainability policy

Within the US Department of Defense (DOD), the focus is on climate change and its impact on the armed forces. In addition, the DOD conforms as much as possible to national policy on environmental sustainability. It also considers what climate change means for operational deployability and national security. It focuses on how to guarantee safety in changing circumstances and how to adapt to it. At the strategic level, the *DOD Climate Adaptation Plan* was released. It states: "The Department must take bold steps to accelerate adaptation to reduce the adverse impacts of climate change. These adaptation efforts must align with our strategic objectives and mission requirements, ensuring that our military can deter aggression and defend the nation under all conditions. The Department is responding to climate change in two ways: adaptation to enhance resilience to the effects of climate change; and mitigation to reduce greenhouse gas emissions" (DOD, 2021). In addition, "In all cases, both within large corporations and militaries, the environmental and social effects of solutions are considered secondary to the operational benefits that a given solution brings." The initial 'drive' is therefore dictated by operational deployability, with environmental sustainability coming second. In the *Department of Defense Sustainability Plan 2022*, attention is paid to reducing waste and environmental pollution, promoting circularity, and using sustainable materials. In addition, various programs have been set up with training courses for staff to enhance awareness in the field of sustainability (DOD, 2022b). A scorecard has been developed which reports on energy use, water use, renewable energy use, facility efficiency investments, high performance, sustainable buildings, fleet petroleum and alternative fuel, and greenhouse gas emissions.

9.6.3.2 United States sustainability reporting

The US DOD reporting on 'performance metrics' related to climate change is linked to the *Lines of Effort (LOE).* US DOD describes some of the recent efforts to respond to the climate crisis, but it is stated not to be complete, and it is recognised that there is much more work to be done (DOD, 2022a). It also states that in the years ahead, the countries that are the most resilient and best prepared to manage the effects of climate change will gain significant security advantages (Atlason and Gerstlberger, 2017). One could consider the progress report as a form of integrated reporting. At the same time, the adjective 'integrated' could be further scrutinised. It should be noted that progress often consists of making separate plans regarding the LOEs, supported by a few examples of related activities and new initiatives. In addition, a Climate Assessment Tool has been developed that collects climate-oriented scientific data to support research, analysis, and decision-making regarding future climate impacts. This helps the DOD to determine how to adapt and protect their assets and installations in the US to be sufficiently resilient.

In addition to the aforementioned progress reporting, there is also an annual report in the form of a 'scorecard', aimed at 'metrics' in the field of emissions, energy consumption/ reuse, water consumption, buildings, vehicle fuel consumption and socially responsible procurement. These results are compared to those of former years and explained in the annual Sustainability Report & Implementation Plan. The goals (sometimes in numbers or percentages) are also displayed for the following year. It is sometimes difficult to assess whether the reports referred to serve as external accountability documents or as internal reports. The impression is that, given some titles, external accountability to Congress or other government agencies prevails.

9.6.4 Canada

9.6.4.1 Canada sustainability policy

In Canada, an Act has existed since 2018, prescribing that each federal organisation, including the MOD, is required to contribute to the *Federal Sustainable Development Strategy* (GoC, 2021). This enables the Minister of Environment and Climate Change to report on this strategy every three years. Each federal organisation must prepare and execute its own departmental environmentally sustainable development strategy. These strategies complement the federal strategy by listing their own targets and goals. *The Departmental Sustainable Development Strategies* provide detailed information on what individual departments and agencies are working on to help meet the aspirational goals of the Federal Sustainable Development Strategy (GoC, 2021).

The *Defense Energy and Environment Strategy* sets out the direction to evolve as an environmentally sustainable organisation, better manage energy use, and minimise the environmental footprint across a broad spectrum of activities (CAF, 2017). The Canadian Department of National Defense continues to focus on four key themes: improving energy efficiency, integrating climate change adaptation into their programs, maintaining sustainable real property, and strengthening Defense's green procurement processes.

9.6.4.2 Canada sustainability reporting

The Canadian Department of National Defense annually reports on their sustainability goals separately. Being the results of government policy – the underlying sustainability strategies and reporting are laid down in legislation – a review of the *Defense Energy and Environment* shows there is room for improvement (Sultana, 2019). The implementation of the policy lacks potency as it fails to assign sufficient targets which would decrease greenhouse gas emissions on deployed operations and in military fleet vehicles (Sultana, 2019).

9.6.5 Australia

9.6.5.1 Australia sustainability policy

Globally, Australia is one of the largest contributors to negative climate impact. In 2021, the United Nations generated a report on positive climate action of its 193 member states, and Australia was ranked last (Mazengarb, 2021). It is expected that from May 2022 onwards, under the leadership of a new Federal Government, after years of natural disasters, Australia will finally pay more attention to environmental sustainability and climate change. Butlers (2022) states that on June 12, 2019, the Chief of the Australian Defense Force made a speech to the National Security Management Symposium in which he made a statement towards "*securitizing the issue of climate change*" (Bulters 2022). This was done to get more and adequate resources for realising a proper sustainability and climate change policy. The *Royal Australian Forces Defense Environmental Strategy* (2016–2036) is structured according to four pillars: Compliance, Efficiency, Trust, and Accountability (ADF, 2016). These pillars underpin Defense activities, guide decisions, and align behaviours when managing environmental challenges and opportunities. The Defense mission is to defend Australia and its national interests. The Defense Environmental Policy is supported by the Defense Environmental Strategy and the Defense Environmental Plan (ADF, 2016). The Defense Environmental Strategy articulates how Defense will achieve its environmental vision, while the Defense Environmental Plan outlines specific actions, timeframes, and responsibilities for implementing the strategy and reporting on achievements.

9.6.5.2 Australia sustainability reporting

The Governmental Committee on Foreign Affairs, Defense and Trade (2018) advised that Defense must "follow their strategic allies and increase military preparedness and resilience in the face of growing climate risks" (GCFA, 2018). In line with the Australian Climate Change Act 2022, the Climate Change Authority sent the first annual progress report on Climate Change to Parliament in November 2022. In this report, the Australian MOD was not mentioned. The Royal Australian Forces report on their goals as mentioned in their Environmental Strategy as part of their annual Defense Report (ADF 2016). Topics that are addressed are its environmental performance on topics like waste management, land and water management, climate, disaster resilience and sustainability on the Defense Estate. The statements made have not yet been translated to targets and key performance indicators on all topics.

9.7 Conclusion

This chapter has investigated the issues the military will have to address when reporting both to internal and external stakeholders on its environmental sustainability performance. In doing so, we have identified two major decisions to enable the military to operationalise environmental sustainability performance and its reporting.

First, it is generally acknowledged that the armed forces' raison d'être is to fight when necessary to protect all that is dear to us. In line with this paramount goal people are educated and trained to be deployed during crises. All means to support the military in their job must be robust for soldiers to trust the quality and deployability of their materiel. Sustainability of materiel is therefore not a priority per se. However, on the flipside, the military, are also morally and legally obliged to achieve various sustainability objectives. This presents contradictory requirements, i.e. a paradox, making for a challenging process to achieve an equilibrium (Smith and Lewis, 2011). Moreover, climate change may very well induce operational changes although it is not yet clear which adaptations are to be made. It may become harder to achieve 24/7 deployability across the globe as the conditions may deteriorate due to climate change. Therefore, we will have to understand **what matters most** to the military regarding sustainability and, in its slipstream, which goals we will have to strive for, and how multiple goals can be combined. This requires a perspective on how operational deployability, sustainability and environmental sustainability performance are related. As there may exist tension between these three concepts, this new perspective, or vision, will have to be clear on the conditions under which one or the other concept will be prioritised. From our empirical investigation we conclude that our most important defense allies have more or less the same focus on environmental sustainability as the Dutch MOD, although they might have different motivations for introducing policies and measures in the field of environmental sustainability and climate change. On one hand, attention is paid to environmental sustainability and climate change, and issues related to economic, planet and people aspects. On the other hand, especially in the UK and US, we also see palpable attention for the consequences of sustainability-inspired interventions for performance (the deployment) of the armed forces. Presently, the degree of embedding and the translation of policy into measures and measurable objectives and also the reporting on these topics is not always clear within the different MODs. Furthermore, environmental sustainability is primarily managed in peacetime operations and less in situations of military deployment. An attractive area of innovation is reduction of logistics footprint; this may serve both operational and sustainablity-related objectives. Reverting to policy, we conclude that reporting on environmental sustainability and climate change differs between the four researched MODs. It is strongly related to the way the MOD is subject to a larger agreement (e.g. an Act) or is just realising its own self-imposed targets. Although reporting should be closely related to the way an organisation is managing and realising its environmental sustainability and climate change goals, we do not see a common pattern or a best practice for reporting.

Second, being a national security organisation, it seems unlikely that all information will be shared. The current security era will probably require even more scrutiny. The new vision will have to offer clarity on what (sections of) information can be shared externally, i.e. information governance (Szczepaniuk et al., 2020). After all, the more detailed the reporting that takes place, the more information potential opponents may obtain. As discussed in the introduction of this chapter, the development of such visions may be one reason to stop reporting on operational performance on deployability, sustainability and deployment by the European Defense Agency. EDA does not provide any straightforward comments regarding this assumption.

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Notes

1 https://www.mckinsey.com/industries/aerospace-and-defense/our-insights/the-link-between-climate-and-national-security
2 https://www.nato.int/docu/logi-en/1997/defini.htm

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PART 3
Adaptation

CHAPTER 10

Climate Change and the Role of the Military in Crisis Management and Disaster Response

Jori Pascal Kalkman and Myriame Bollen

Abstract

Armed forces have long played a role in crisis management and disaster response. Yet, as the effects of climate change become increasingly widespread and disruptive, civilian authorities are more likely to be overwhelmed by the impact of these events and request military support. This chapter proposes three changes in military contributions as it takes on a larger role in responding to crises and disasters. The military needs to shift from a security to a humanitarian mindset, from autonomous to civil-military operations, and from crisis response to improving resilience. The concluding sections reflect on the normative and practical implications of the proposed changes and offer a research agenda.

Keywords: crisis management, disaster response, climate change, security, military, humanitarian aid.

10.1 Introduction

Climate change poses one of the greatest challenges of our times. The global rise in temperatures has far-reaching consequences for the natural equilibrium and, by extension, for human welfare. One of the most disconcerting consequences of climate change is that natural hazards will continue to increase in scale and frequency, making crises and disasters more likely. Catastrophic wildfires and extreme rainfall, for instance, are becoming more common and cause ever more damage. Coastal and inland floods are also intensified by climate change and are now increasingly severe (IPCC, 2022). And even though tropical cyclones may reduce in number, they are increasingly powerful and have potentially devastating effects, as storm surge risks are on the rise (Walsh et al., 2016).

Natural hazards, however, do not cause crises and disasters on their own. Hazards only turn into crises or disasters when communities are vulnerable to their impact. The main cause of a crisis is therefore not the natural event, but the social structures and political decisions that have rendered people vulnerable to those events in the first place. By extension, climate change does not cause disasters, but poor preparation, societal marginalisation, and widespread poverty do (Chmutina & Von Meding, 2019; Kelman, 2020; O'Keefe et al., 1976; Raju et al., 2022). Such social processes render people more exposed to the impact of climate change effects and less able 'to anticipate, cope with, resist and recover from the impact of a natural hazard' (Wisner et al., 2004, p. 11).

In response to the disastrous effects of human-induced climate change on vulnerable communities, countries are increasingly deploying their armed forces (Brzoska, 2015). Armed forces bring several capabilities that are complementary to those of civilian crisis organisations and that have proven useful in the aftermath of disasters. Navy ships have transferred large quantities of goods to hurricane-struck areas, the Army has activated its personnel to reinforce dykes and evacuate communities at risk of flooding, and Air Force helicopters are crucial for gaining an informational picture of a disaster's impact (Canyon et al., 2017; Kalkman, 2023; McGrady et al., 2010). There is therefore clearly a functional need for military contributions, because civilian crisis organisations often lack the required capacities, particularly in large-scale disaster events. In addition, there are good reasons for armed forces to get involved as well. Crisis management activities, including humanitarian aid and disaster relief (HADR) missions, boost the military image in the public eye and are generally good for personnel morale. Such civil support operations clearly are in the interest of military organisations too (Edmunds, 2006; Malešič, 2015). Thus, it should come as no surprise that armed forces have recently played a crucial role in the response to various major crises and disasters, including tropical cyclones, floods, and wildfires (Botha, 2018; Canyon et al., 2017; Moynihan, 2012). Armed forces are even deployed in response to the rise of climate refugees, either to search and rescue those at risk or to fortify and enforce border control measures (Smith, 2007).

As of yet, the military literature seems primarily preoccupied with the geopolitical and security implications of climate change, while the consequences for civil support operations by armed forces have received only limited attention. Instead, we explore the evolving role of armed forces in crisis management and disaster response, as human-induced climate change continues to wreak havoc on vulnerable communities. Rather than a comprehensive literature review, this chapter aims to explore these changing roles and contributions of armed forces in a climate changed world on the basis of a selection of relevant publications.

This chapter proceeds with a discussion of the current roles of armed forces in crisis management and disaster response, before exploring potential future roles and contributions. In the main section, we argue for three changes in military contributions, stating that the organisation needs to shift from a security to a humanitarian mindset, from autonomous to civil-military operations, and from crisis response to improving resilience. The following section offers some reflections and practical implications of the ideas in this chapter, while a final section provides a research agenda.

10.2 Roles of Armed Forces in Crisis Management and Disaster Response

Over the last few decades, the role of armed forces in responding to crises and disasters has increased significantly. While military deployments in this domain used to be exceptional, there has been a noticeable rise since the end of the Cold War with countries deploying their armed forces for a range of new activities, reflecting a shift away from territorial defense towards civil support operations (Clarke, 2013; Edmunds, 2006). Of late, military personnel, logistics, and information-gathering capacities have frequently been requested by civilian authorities in times of need and are often both available and of high quality (Kapucu, 2011; Osborne, 2006). There have even been calls to give armed forces a leading position during large-scale emergencies out of a presumption of superior leadership skills (Banks, 2006), although this remains contentious.

In practice, a large variety of tasks may be allocated to armed forces in times of emergency (Schnabel & Krupanski, 2012), such as the responsibility to evacuate (soon to be) affected areas, search and rescue duties, the provision of relief goods, or maintaining public order. Covid-19 also triggered novel military contributions, including the deployment of military medical personnel to serve in public healthcare, the creation of new medical facilities, and the enforcement of lockdowns (Kalkman, 2021). Military activities during crises and disasters, clearly, are diverse and often substantial.

The military role in times of emergency is expected to increase, as climate change leads to increased risks of destructive disasters (IPCC, 2022). Civilian crisis organisations are more likely to become overwhelmed by the impact of these disastrous events and request military support, particularly when repeated disasters (e.g. recurring extreme weather events, rising sea levels) progressively erode the civilian response capacities in communities. Thus, a core assumption in this chapter is that civilian and military organisations need to coordinate in responding to this global challenge, and that civil-military interactions are therefore key to effective crisis management and disaster response.

It is important to note that a greater role for armed forces in responding to crises and disasters is not always broadly supported. Military organisations, in fact, are not necessarily (perceived as) impartial organisations and their participation in humanitarian relief operations may well be met with skepticism in various contexts. In countries like Haiti and Zimbabwe, people have good reasons to be mistrustful of their armed forces, because their interventions may primarily serve the purpose of suppressing social movements or silencing opposition candidates rather than providing relief to those in need (Hilhorst & Mena, 2021). Clearly, when there is general distrust towards the central government in a society, military contributions to crisis management and disaster response will be of limited use or may be altogether rejected by intended clients. Still, in many countries, armed forces can and do offer important capabilities for managing crises and responding to disasters.

In the remainder of this chapter, we focus specifically on armed forces and their role in mitigating the adverse effects of climate change-related crises and disasters. For military contributions to remain successful in this domain, the organisation would do well to start reviewing and revising its crisis mindset, operations, and approach.

10.3 The Need for Changing Military Contributions in Response to Climate Change

10.3.1 From a security to a humanitarian mindset

The armed forces are a security-oriented organisation. Being the primary organisation for the protection of territorial integrity and the international rule of law, armed forces are equipped and prepared for interventions that aim to counter security threats and defend their country's vested interests. By extension, new recruits are socialised and trained to develop security mindsets, making them conscious and aware of security risks as well as able to neutralise threats swiftly when necessary. This mindset is of instrumental importance in times of war and armed conflict, but may be an obstacle when the crisis is of a humanitarian nature. Since climate change primarily creates the conditions for humanitarian emergencies, effective military interventions will require a shift away from the familiar security mindset.

Difficulties in switching from a security to a humanitarian mindset have been reported during various disasters. Over a century ago, when San Francisco was consumed by earthquake-induced fires, the inhabitants were trying to fight the fires to save what remained of their city, but were seen as looters and security threats by deployed military personnel, who even went so far as to shoot innocent civilians in their desperate, misguided attempt to quell what they perceived as social unrest (Solnit, 2010). One hundred years later, the US military and the US government at large repeated this mistake after Hurricane Katrina struck New Orleans. Again, the disaster area was viewed from a security perspective with one general infamously likening New Orleans to Somalia and announcing a 'combat operation' to retake the city, even as thousands of disaster victims remained without water, food, medicine, and electricity (Chenelly, 2005).

The above examples reflect a 'securitisation' of the disasters, induced by the military using their security mindset to act in a disaster context. This is problematic, because armed forces may inadvertently end up doing more harm than good if they mistake a disaster for a security threat. Rather than providing much-needed first aid, overburdened supply lines serve to ship in security personnel and consume scarce resources needed by the local population. As a result, communities are likely to resent the armed forces or the government in general. For one, they feel treated as criminals rather than victims, and, even worse, they do not receive the most basic goods for survival (Tierney et al., 2006).

For effective military interventions in climate-change related crises and disasters, military personnel must be able to switch to a more humanitarian mindset. This requires a certain adaptive flexibility on the part of armed forces. Rather than extensive planning and intelligence-gathering, they need to assume that security risks after major emergencies are minimal, as confirmed in previous studies (Heide, 2004), and improvise a humanitarian response. The fact that this does not come easy to armed forces is reflected in the derogatory reference to 'the military approach' in disaster literature as representing an overly rigid and hierarchical way of responding to disasters (Dynes, 1994), but fortunately there are also more successful examples of military adaptive capacity enabling humanitarian relief operations in the aftermath of crises and disasters (Kalkman, 2023; Zijderveld & Kalkman, 2023). Generally, it may be advisable to follow the example of humanitarian organisations in these situations: non-governmental organisations have more experience with operating in disaster-struck areas and are well aware of the merits (and limitations) of a humanitarian mindset when operating in an affected area.

10.3.2 From autonomous to civil-military operations

In many missions and operations, armed forces operate autonomously. The military actively tries to avoid being dependent on other organisations to maintain its ability to choose its own course and to adapt quickly when the environment has changed. In expeditionary contexts particularly, the reliability and trustworthiness of civilian agencies have been questioned, resulting in a preference for autonomous military operations. But armed forces are usually not allowed to operate by themselves in crisis and disaster areas. Only after a formal request for military assistance by civilian authorities, may troops be deployed. Even when deployed, military personnel typically remain subordinate to civilian authorities for as long as the response lasts. This means that civil-military collaboration is crucial to managing a disaster after a natural hazard, intensified by climate change, has struck a vulnerable population (Bollen & Kalkman, 2022).

Albeit crucial, civil-military cooperation is not an easy endeavour. Earlier research shows recurrent obstacles to the partnership. Civilian and military organisations differ in some important ways. The organisations feature different operational styles, organisational principles, and normative values that create a gap between them, which may sometimes appear unbridgeable (Franke, 2006). When there is a need for urgency and partners lack familiarity, collaboration is particularly problematic and prone to produce suboptimal results (Rietjens & Bollen, 2008). To complicate matters even more, organisations may hold competing interests, which hinders communication and coordination, in particular when there is a lot of public attention for the response and there is much at stake (Keane & Wood, 2016)

Yet, the majority of studies focus on civil-military collaboration in expeditionary contexts which may differ considerably from civil-military responses to crises and disasters (Bakx et al., 2021). The few studies on this latter type of civil-military cooperation offer mixed results. In a domestic context, civilian and military liaisons may collaborate on a daily basis in crisis prevention and preparation, fostering a bond of inter-personal trust that facilitates effective collective action in response to small-scale crisis incidents and emergencies (Kalkman & de Waard, 2017). Research on civil-military collaboration during infectious disease outbreaks, however, demonstrates persistent problems in creating adequate framework conditions, maintaining strong relations over time, and integrating civilian and military activities (Janse et al., 2022). Finally, responses to large-scale disasters, such as hurricanes, show that civil-military cooperation experiences can go either way, with interactions ranging from highly successful to deeply problematic (Kalkman, 2023; Samaan & Verneuil, 2009).

As of yet, there is no clear pattern to be distinguished. Civil-military collaboration in response to climate change effects may benefit from the (temporarily) shared objective of reducing the impact of emergencies as well as the awareness among partner organisations of their interdependency to reach this objective (Bollen, 2002). When collaboration is lasting, civilian and military personnel may also build more trusting relations and develop confidence in one another (Alvinius et al., 2014). However, civilian and military organisations will still have their organisational differences and competing priorities complicating their cooperation. In general, it is clear that, just like in other civil support missions, armed forces will depend heavily on civilian institutions and authorities when responding to the emergencies that climate change renders more likely. Investments in civil-military partnerships appear therefore indispensable to deliver effective military contributions to future crisis management and disaster response.

10.3.3 From crisis response to improving resilience

Currently, armed forces are often operating as a 'last resort' during crises and disasters, which means that they are called to intervene when no other options are available. This may partly be explained by the fact that military organisations are not always eager to take up this new role, as some personnel view it as a distraction from the organisation's main task to fight wars and intervene in armed conflicts (Forster, 2005). Yet, the 'last resort' approach also restricts potential military contributions to a late phase in emergency management, even though such support could have contributed to improving resilience before a situation escalated.

To reflect on how the armed forces can contribute to more resilient societies in the face of climate change, it is important to zoom in on the vulnerabilities of affected people. In particular, marginalised groups (e.g. women, minorities, lower socioeconomic classes) are consistently hit harder than others (Kalkman, 2024). These groups are more vulnerable, because they tend to live in areas that experience the brunt of climate change effects while having fewer resources to save themselves. In the aftermath of hurricane Katrina, for instance, it was the poor, black population in New Orleans that faced the worst effects (Bolin & Kurtz, 2018). Similarly, after the 2004 Indian Ocean tsunami, women and certain ethnic groups were worse off than groups that were relatively privileged (Amarasiri de Silva, 2009). This unequal impact of disasters among communities is found time and again. The problem with climate change is that rising sea levels and recurring extreme weather events may continuously undermine the resilience of the most vulnerable communities, resulting in ever-worsening vulnerability.

It is not up to the armed forces to make public policy, but military actions may undermine or contribute to community resilience in various ways. One way is to assess the impact of crisis management and disaster response activities by not only looking at speed and size of the operations, but also by taking into account the impact on affected communities. At the moment, public emergency responses may unintentionally reinforce marginalisation of vulnerable groups. Public authorities are often unaware of the specific needs of particular vulnerable groups or focus activities on easy-to-reach (but relatively well-off) victims of a disaster, exacerbating inequalities in a society (e.g. Akerkar, 2007; Amarasiri de Silva, 2009). Increased awareness may help armed forces to avoid accidental erosion of community resilience. Military organisations can also decide to be more ambitious and actively correct societal discrimination through their response activities by prioritising aid to the most marginalised, challenging historical inequalities and contributing to societal change that makes the most vulnerable more resilient (Branicki, 2020).

Military involvement in the early stages of crisis management and disaster response may further improve societal resilience to climate change in another way.

Armed forces usually need some time to activate resources to commence relief operations, so are sometimes criticised for being slow responders (Moynihan, 2012). If military partners are involved in the preparation through planning sessions, training, and exercises, it will be easier to anticipate requests, enabling faster responses and reducing the impact of extreme events. By extension, military expertise might come in useful in thinking about preventing and preparing for crises and disasters (Kalkman & de Waard, 2017). As such, when military contributions shift from a reactive to proactive approach, they have the potential to increase community resilience and thereby mitigate the worst effects of climate change.

10.4 Reflections and Implications

Climate change is creating the conditions for increasingly disruptive crises and disasters, and civil authorities are likely to increasingly call for military support to respond to these extreme situations as a result. For effective interventions, three changes are required from the armed forces. The organisation needs to shift from a security to a humanitarian mindset, from autonomous to civil-military operations, and from crisis response to improving resilience.

It is worthwhile reflecting on the normative implications of these changes. These changes facilitate more effective military contributions, but there are also some potential downsides to consider (Head & Mann, 2016; Malešič, 2015). First, there is the risk of a militarisation of society, particularly when a growing military role comes at the cost of civilian organisations, eroding their funding or capacities. Equally worrisome is the possibility of military personnel being unaware of the operational restrictions during these missions and treating a disaster zone as a warzone, failing to abide by the rule of law or legislation that protects certain rights, such as the right to assembly. There are also implications for armed forces to take into account, since a larger role in responding to the worst effects of climate change may interfere with exercises or other missions and require the acquisition of new or dual-purpose capabilities. It is therefore of crucial importance that (new) positions and roles of armed forces are legally justified, politically mandated, and broadly supported. Still, climate change is commonly believed to pose one of the greatest threats to vulnerable societies across the globe and armed forces cannot stand aside idle.

Finally, there are some practical implications that can be drawn from the three proposed shifts. Military personnel need training for humanitarian interventions in order to enable switching from a security mindset to a humanitarian mindset, preferably together with civilian partner organisations who have more experience with operating in these contexts and know best what people will need after a devastating crisis or disaster. There is also a need for giving more prominence to partnering across civil-military boundaries by training dedicated liaisons in both organisations for this task. This will increase mutual understanding and collective problem-solving when disaster strikes. By extension, these liaisons need to be granted discretionary powers as well as influence in their respective organisations to ensure that they can effectively fulfill their role as inter-organisational boundary-spanners. Moreover, military units would do well to start collaboration with intended civilian partners from the pre-emergency stage onward. And after interventions, they should collaborate with civilian partners and affected communities to explore the impact of the response operations on community resilience. If these proposed changes are considered and incorporated, the armed forces will likely play both a crucial and sustainable role in responding to the potentially disastrous effects of climate change.

10.5 A Research Agenda

In this chapter, we have focused primarily on the required changes in the armed forces to become better prepared for responding to the dramatic effects of human-induced climate change on vulnerable communities, but civilian organisations might also need to undergo changes. Non-governmental organisations, for instance, will play a key role in responding to future crises and disasters, but may not always be able to reallocate funding rapidly in reaction to unanticipated disaster relief projects. Vice versa, military organisations can be very decisive in crisis situations and set aside inhibiting rules and procedures in the interest of the mission. We need more research on what civilians can learn from the military too, as we prepare for a climate-changed future. Next, as we argue for changes in the armed forces, it is important to acknowledge that change in the military is not always easy (Holmberg & Alvinius, 2019). Successful examples need to be treasured, studied, and analysed for generalisable lessons. Moreover, since armed forces are bound to play a greater role in a climate-changed future, concerns have been raised about the societal and organisational effects of the larger domestic military presence. Most of it, however, is speculation and empirical studies on these effects are virtually absent but much needed. Finally, civil-military cooperation is crucial for effective missions and operations in the future. There have been positive experiences with such partnerships in earlier cases (e.g. HADR, Covid-19), so it is worthwhile exploring what lessons can be drawn from these positive experiences that can be used by armed forces and civilian organisations in the future as they collectively prepare for mitigating the potentially disastrous effects of climate change.

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CHAPTER 11

Novel Emergency Response Interventions for Flood Resilience

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Abstract
Worldwide, climate change is expected to lead to increased probability of severe weather conditions and therefore an increased probability of flood events. Therefore, within the Netherlands, authorities have adopted several long-term programmes to secure flood resilience of the densely urbanised Dutch delta areas. Here, we focus on one of the strategies to mitigate the effects of flooding: emergency response interventions. The latter constitute an important aspect of the strategic approach towards flood resilience. Emergency response is also the adaptive measure in which civil authorities collaborate with the military. They bring in personnel, logistic capacities and are also at the frontline when such measures are deployed. Therefore, we focus on the role of the military in emergency response and present the results of large-scale experiments under artificial high-water conditions. These experiments, a joint effort of military, academic and flood risk professionals, are aimed at developing novel methods that can be employed by the military during future flood crises.

Keywords: climate resilience, critical infrastructures, emergency response, flooding, explosive breach initiation, waterborne emergency interventions, civil-military interaction

11.1 Introduction

It is now commonly believed that climate change is leading to an increased likelihood of unpredicted and severe weather conditions. Think of the extreme precipitation events as experienced in Western Europe in the summer of 2021. A major consequence is an increased probability of floods, threatening human lives, disrupting economic activities and the environment. In climate change research, the concept of such risk is usually defined as the combination of hazard, exposure, and vulnerability (Parry, 2007). This definition is currently universally accepted by policy makers and the public at large. Interestingly, some natural disaster historians argue that this perception of risk is for a large part a “physical construct, with the degree of environmental exposure and the nature of hazard often overshadowing social vulnerability” (van Bavel, et al., 2020). In short, these authors show how in the past, communities had developed resilient lifestyles: hazard and vulnerability were part of daily life. And preparedness consisted of “… ‘traditional’ coping mechanisms: strongly localized ‘indigenous’ knowledge on disaster prevention and mitigation, which was often passed from generation to generation, and might be ‘reactivated’ to complement ‘modern’ disaster prevention or relief mechanisms.” With respect to flood resilience, Soens mentioned these resilient practices as ‘amphibious communities’ (Soens, 2023). Widespread public engagement, when dealing with risks associated with climate change, has been neglected for a long time. Risk mitigation and disaster relief became primarily the responsibility of authorities and dedicated government agencies. Although the focus of this work is merely on centralised response strategies to flooding, it should be emphasised that when dealing with the unexpected, improvisation and public engagement are to be incorporated as important aspects of societal resilience to effects of climate change.

Traditionally, flood risk has been anticipated by flood prevention strategies e.g. by reinforcing and raising existing flood defences such as levees. The history of the Dutch Delta program offers a good example of how the Dutch approach to water security has changed throughout the years (Expertise Network for Flood Protection, 2017). The first initiatives and efforts, after the North Sea flood of 1953, were based on calculated flood risks. After river floods in 1993 and 1995, a risk-based approach was introduced. Instead of merely focusing on reinforcement of the levee-system, a more integral approach, “room for the river”, was adopted, in which a widening of the floodplain of rivers was promoted (Slomp, 2015). In the Netherlands, the flood mitigation approach has recently shifted from flood prevention to the more integral approach of flood risk management. This so-called multi-layer safety model (STOWA, 2017) intends to reduce flood risk by integrating defensive measures against floods (layer 1), resilient spatial planning (layer 2), and effective crisis management measures (layer 3). Within layer 3, effective emergency response methods are an important means of managing and preventing the consequences of flooding.

A recent example of the layer of spatial adaptation is the transformation of the Dutch Hedwigepolder and the Belgian Prosperpolder into new tidal nature. This has offered the opportunity of using an existing levee for strength and emergency response tests: the Living Lab Hedwige-Prosperpolder. For this, a multinational consortium from the 2 Seas Region was founded to join efforts in the European Union funded programme Polder2C’s. The Dutch Ministry of Defence (MoD) was a leading member of this consortium. Within this project the MoD’s main tasks were the development and testing of novel and effective emergency response methods for flood resilience. Two means of emergency response have been considered more closely. Firstly, interventions that preserve the water-retaining function of a levee exposed to extreme high-water conditions. Secondly, means to reduce the water-load on segments of the levee-system. This can be achieved by dedicated breach-initiation upstream from the endangered levee segment, followed by peak water storage in temporary inundation areas. In this chapter, we present the results of large-scale experiments on the feasibility of these emergency response methods. Eventually, this may lead to a new set of effective response concepts, to be utilised and employed by the military in case of imminent flooding disasters.

Finally, it should be emphasized that current (summer 2023) geopolitical developments, especially the war of the Russian Federation against Ukraine, have led to a drastic shift of scope of the Dutch military. A shift is being made towards the first of its three main tasks i.e., defending its own territory and that of its allies. From a water resilience perspective, the war in Ukraine has emphasized the importance of hydraulic warfare. In a way, this is the mirror image of the research presented here. Breach initiation and inundation were tactically employed by the Ukrainians during the Battle of Kyiv, recalling the traditional Dutch approach to water as a means of defence (Bruijstens, 2023). Another infamous example is the destruction of the Kakhovka dam by the Russians. While the need for improvised reinforcement of damaged infrastructure, e.g. the Antonivka road bridge (Persson & Verwiel, 2022), echoes the damage mitigation approach presented in the next paragraphs of this chapter. Specifically, application of a floating pontoon, the BresDefender, in the case of stability criticality of levees under high-water conditions.

11.2 Emergency Response Interventions in Flood Disasters

As the Netherlands is a delta area where more than half of the land and population and two-thirds of the economic activity are flood-prone, flood resilience is really an issue of national security. Given the prospects of climate change and the related increase of frequency and severity of high-water events, solutions from a singular perspective i.e., the strengthening of the levee-system by merely technical-engineering solutions, is not sustainable. Integral methods, such as the multi-level safety approach, are required to meet challenges that cannot be addressed by other means.

When water defences happen to not function as expected, appropriate measures should be taken to prevent flooding of valuable areas. These are the emergency response interventions – as mentioned before – that constitute the third layer in the multi-level water safety philosophy. Here, emergency response is defined as "the systematic response to an unexpected or dangerous occurrence, which goal it is to mitigate the impact of the event on people and the environment" ("Safeopedia", 2023). Contingency measures and emergency interventions must be called by the responsible authorities within the water chain: water boards, regional safety authorities and dedicated crisis task forces. At this stage also the military – here the Dutch Ministry of Defence (MoD) – become involved, through invoking its third main task: support the government with law enforcement, disaster relief and humanitarian aid, nationally and internationally. Then, other contingency options have been exhausted, and the military is called to provide personnel, logistics, robust command and control structures, perseverance, and equipment. To guarantee optimal performance of the military operations during actual crises ("the warm phase"), it is necessary that the military is already involved in planning and preparation with respect to future flood events ("the cold phase"). In the cold phase, water safety professionals and military personnel collaborate in emergency exercises and jointly develop tools and strategies to assure optimal joint disaster prevention or mitigation operations during actual crises.

11.2.1 Means of physical emergency intervention

It is the cold phase in flood risk management that justifies the involvement of the Ministry of Defence in the Polder2C's project. The Ministry of Defence was involved through various internal stakeholders, including operational units (e.g. 105th Hydraulic Engineers Company) and Knowledge Centres and institutes (Knowledge Centre Military Engineering and Netherlands Defence Academy). The MoD's role within Polder2C's was in the areas of emergency response and disaster relief, both at the level of scientific research and practical training. The collaboration with external stakeholders, as well as training and knowledge exchange, are considered key enablers to the final layer of climate adaptation i.e., through emergency response.

When it comes to physical emergency response interventions, one may distinguish two fundamentally distinct strategies:

i. Prevent structural failure of the levee or the levee system. This can be achieved through reinforcement of levee segments, emergency repairs or temporary increase of the levee's crest height.
ii. Reduce the hydraulic loading on the levee.

These approaches will be detailed in the forthcoming paragraphs.

11.2.2 Interventions to prevent structural failure of levees

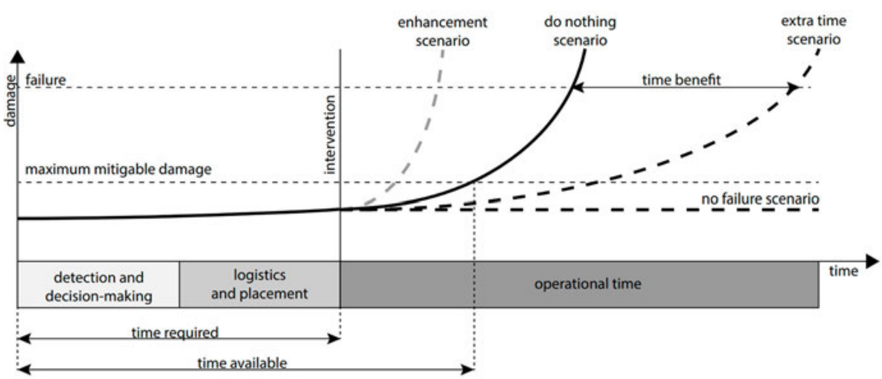
Interventions to prevent structural failure of levees aim to preserve the water-retaining function of a levee. This has for long been the traditional means of flood-crisis support by the military (Leger verhoogt dijk in Roermond met zandzakken, 2021; Vossers, 2013). These relief operations can be deployed from the land (land-borne) such as the placement of sandbags or other mobile barrier systems. However, during a water crisis it can be undesirable – and difficult – to approach a saturated levee from the landside. In that case water-borne interventions are to be preferred.

Land-borne emergency response measures have been evaluated to study the performance of novel mobile barrier solutions (van Duinkerken, 2022). An important benefit of these mobile barrier systems is that they use the water, which is always abundantly available at a potential flood-endangered location, as the substance that provides weight and stability to the temporary protective structure. Of course, such novel solutions should at least provide the same amount of protection and performance as the traditional sandbag. Also, the ease of placement and logistical issues should be addressed, before implementing these systems in real crisis circumstances.

Another concept is the deployment of preventive measures from the riverside: waterborne emergency response measures. One possibility is the use of military pontoons, which are commonly used to construct temporal floating bridges. Initially this concept was successfully tested (proof of concept) by military engineers in collaboration with water authorities during the exercise Alert 2015. This waterborne intervention method is referred to as BresDefender. The BresDefender concept can be considered as an example of an adaptive military (Dutch: *adaptieve krijgsmacht*), as it utilises existing military equipment in an alternative manner.

To describe the deployment of the BresDefender intervention method – and actually any means of levee reinforcement – with respect to decision processes, logistics and its actual performance as an emergency intervention method, a conceptual framework (Janssen, Schmets, Hofland, Dado, & Jonkman, 2020) has been developed, see Figure 11.1.

Figure 11.1. Effect of emergency response intervention scenarios on time to failure (Janssen, Schmets, Hofland, Dado, & Jonkman, 2020).

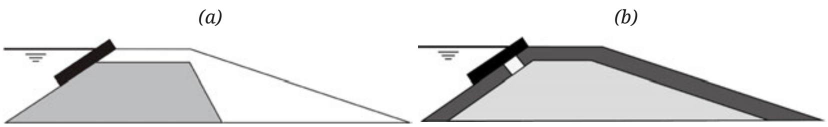


Within this framework time is displayed at the horizontal axis against a parameter that represents the level of structural damage of a levee section. Two special damage levels are to be considered with respect to eventual intervention actions. Firstly, the damage level that represents complete functional failure, i.e., the water retaining function of the levee cannot be maintained; neither autonomously nor by any sort of external intervention. This damage level is represented in Figure 11.1 by the upper, horizontal dotted line labelled 'failure'. Secondly, the maximum damage level that would still allow for successful emergency intervention; the maximum mitigatable damage, represented by the lower, horizontal dotted line in Figure 11.1. Then, the solid line in Figure 11.1 represents a possible trajectory of structural damage development over time. During periods of high-water in a river, the weaker sections of a levee will be most susceptible to dynamic damage processes. At these locations, damage could initiate and start developing. Initially, damage will increase slowly with time, and eventually accelerate to reach structural failure. Failure of large-scale structures such as levees are often found to follow this type of 'power law' pattern (Bažant & Chen, 1997). Thus, the solid line identifies the time to failure in case no emergency intervention is to be employed: the do-nothing-scenario. Then, the various dashed lines in Figure 11.1 correspond to the possible effect of various intervention scenarios on the damage growth process. Obviously, the ideal case of a perfect intervention is represented by the no-failure-scenario. The enhancement-scenario illustrates a situation where it would be unwise to intervene at all. The most desirable effect of an intervention is illustrated by the extra-time-scenario in Figure 11.1. In the latter scenario, the time to failure increases the time benefit. This time benefit serves as a measure for the effectiveness of an emergency intervention.

Any intervention is triggered by the detection of damage at its early stages. Detection is usually achieved by intensified levee inspections or by remote methods using drones. Drones equipped with Lidar (Light Detection and Ranging) sensors allow for the detection of tiny movements of landmasses, pinpointing regions where structural damage of a levee may develop. After initial damage detection, crisis managers decide which response actions are to be launched, and whether military assistance should be called in. In the latter case, the military chain of command must be activated, and the deployment process starts (Kalkman, 2021). In case of employment of the BresDefender, a pontoon is to be shipped to the desired location, followed by the onsite placement (van Veelen, 2021) of the system. The complete intervention process, from detection through decision-making and up to physical placement of a structure, requires optimisation. Such optimisation will shorten the time required and hence increase the probability that the levee will hold during a high-water event (van de Velde, 2022).

Of course, interventions only add value when they perform according to an intended effect. This requires a priori knowledge about the physical damage processes that are to be mitigated by an emergency measure (Elsing, 2018). In the case of the BresDefender, two primary damage mechanisms have been identified which can be slowed down or stopped. Firstly, it can arrest the breach initiation process (Figure 11.2a). This is achieved either by a temporary increase of crest height, to prevent the erosive forces associated with wave overtopping, or by blocking the water flow into an already existing breach (Janssen, Hofland, Schmets, Dado, & Jonkman, 2023), inhibiting imminent breach growth.

Figure 11.2. Scenarios for deployment of BresDefender: (a) stop overflow and arrest breach growth, and (b) reduce stability reduction by blocking infiltration of water at damaged levee sections (Janssen, Schmets, Hofland, Dado, & Jonkman, 2020).



Secondly, the method can provide a water-impermeable seal covering the outer slope of the levee. In this way the development of the phreatic surface (water level) in the levee is expected to increase slower and to lower equilibrium levels (van de Wilt, 2020). Controlling the phreatic surface in a levee is a particularly important addition to traditional methods, as it interacts with an invisible damage pathway, that usually ends in sudden slip failure of the complete structure. Lab-scale and real-scale experiments, supported by numerical calculations, hint that application of an impermeable seal does extend the time to failure at least by one hour (Janssen, et al., 2023; Hommes, 2022). The overall effectiveness and operational reliability of the BresDefender methodology for some river flooding scenarios are presented elsewhere (Janssen, Jonkman, Schmets, Hofland, & Dado, 2023).

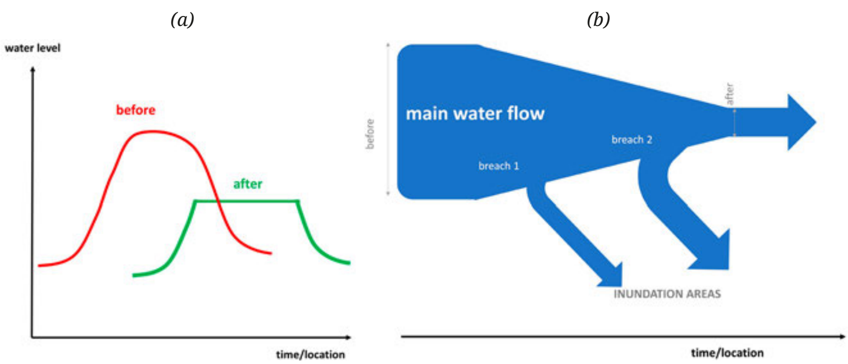
11.2.3 Interventions to reduce hydraulic loading on levees

In contrast to levee reinforcement as a method of emergency intervention, one can also consider reducing the hydraulic load at a designated levee segment during a high-water crisis. This would require decreasing the water level in a river at the site of a vulnerable levee segment. This can be achieved by topping off the high-water peak (Figure 11.3a), through deviating excess water to areas where temporary flooding would have lesser impact on human life, infrastructure, and economic development (Figure 11.3b). In case constructions that allow for inundation, such as inlets, are absent, the method of choice would be to intentionally initiate a levee breach by pyrotechnic means. It is anticipated that after initiating a breach, the water flow into the inundation area will start eroding the breach, i.e., a breach growth process will develop.

In the past, large scale breach growth experiments have been conducted on a large scale, homogeneous sand dike at Het Zwin (Bakker, et al., 1996). Here, two successive tests were conducted with artificially created, 2.5-metre-wide initial breaches, while the outer water level was about +0.25–0.50 metres relative to the bottom of the artificial gully. Within an hour, equilibrium breach widths of 13 and 41 metres were measured, respectively. Moreover, model calculations have demonstrated that breach widening rates at constant flow velocities through the breach, are most sensitive to soil erodibility and the shear strength of the soil mass (Robbins, 2022).

Certainly, the total available volumetric capacity of the inundation area should be sufficient to achieve the desired reduction of peak discharge. Another critical factor is the precise timing of the (explosive) breach initiation. Too early breach initiation will cause the inundation area to be filled up before the peak discharge has passed the breaching location, which will leave the peak discharge, and consequently the water level, of the river largely unaltered at the levee section to be protected.

Figure 11.3. (a) The concept of reduction of river discharge (water levels), by (b) deviating part of the flow by intentional levee breaches and inundation of designated areas. The width of the arrow represents the flow rate. Figure source: the authors.



To achieve a desired decrease of water level in a specific river, details of the discharge characteristics of such a river are required. For instance, based on data from the department of waterways and public works in the Netherlands, it is known that rivers Waal and IJssel may accommodate peak discharges of 10.500 m^3/s and 2400 m^3/s respectively. As a rule of thumb, to achieve a 1 cm decrease in water level at peak discharge conditions, one should deviate 25 m^3/s for the river Waal and 10 m^3/s for the river IJssel (van der Nat, 2023). The data allows for estimating the minimum discharge a breach – or multiple breaches – should be able to deviate eventually.

A helpful method to estimate the discharge through a breach of known geometry is due to Visser (Visser, 1998). The method derives from the theory of open channel flow through a breach, with the assumption of critical water flow conditions, i.e., that the Froude number $Fr = 1$. For the specific condition of critical flow, the discharge through a breach happens to be a function of just a few geometric parameters, such as the wet cross-sectional area, the water depth in the breach and the average flow velocity. Then, the discharge through a levee breach is given by,

$$Q = m \left(\frac{2}{3}\right)^{\frac{3}{2}} \sqrt{g}\, B \left(H_w - Z_{br}\right)^{\frac{3}{2}}, \tag{1}$$

with Q [m^3/s] the flow rate through the breach, m [-] a breach-inflow factor, g [m^2/s] the acceleration of gravity, B [m] the average width of the wet cross-section of the breach, H_w [m] the riverside water level, and Z_{br} $[m]$ the height of the bottom of the breach relative to an arbitrary reference level. Moreover, equation (1) can also be used to calculate the leakage discharges, and reduction thereof, when employing intervention measures like BresDefender.

In preparation for the real scale explosive breach initiation experiments, the parameters that govern the breach initiation and subsequent breach growth processes needed to be established. First, details of craters due to subsoil detonations were studied for dry and saturated sand bodies (Zoomers, 2019). Next the same was studied, but now the sand was covered by a layer of clay, mimicking the typical layout of a Dutch river levee (Mekenkamp, 2022). Next, the breach growth process after pyrotechnic breach initiation was studied (Steneker, 2022), and at last the concept was tested through real scale experiments (Mossinkoff, 2023).

Finally, the method of explosive breach initiation is by no means an unexplored topic. It was used to liberate the Dutch town of Alkmaar in 1583 from Spanish troops by flooding the enemy positions. In the Second World War the Royal Airforce had to spend significant effort to breach the sea dike at Westkapelle (Zeeland, the Netherlands) from the air. In the USA, embankments of the Mississippi river were breached in 2011 to achieve the same effect as mentioned earlier: decrease the river's water level to safeguard levee systems protecting densely populated areas.

11.3 Large, Real-Scale Emergency Response Experiments

The Living Lab Hedwige-Prosperpolder offered an excellent environment to study real scale flood defences and emergency response actions under controlled, but realistic conditions. By a treaty between Belgium and Netherlands, the Belgian Prosperpolder and the adjacent Dutch Hedwigepolder was to be depoldered to create natural qualities, such as tidal marshes. The depoldering was also part of a Belgian flood protection plan, for which it is to serve as a natural flood control area. In late 2022 the sea water finally flooded the polders at high tide. Interestingly, an adjacent former polder known as the Drowned Land of Saeftinghe, was inundated by breaching the sea dikes in 1584 during the Eighty Years' War by Dutch troops, drowning the small town of Saeftinghe.

After a new dike was built inland, and the hinterland was protected, the sea dike at the Western Scheldt, and the polders behind it, became available for the living lab. The consortium undertook many separate tests, ranging from nightly civil-military levee-guard exercises with up-to-date tools (damage-locator app with GPS and handheld IR-cameras) to extensive destructive overflow tests (Polder2C's, 2020–2023). Other activities within the programme were extensive wave-overtopping and wave-impact tests, emergency response exercises, breach initiation tests, etc.

In the following, the focus will be on the design and construction of experiments within the living lab environment, to assess water-borne interventions (BresDefender) for reinforcing a levee at emergency, high-water conditions.

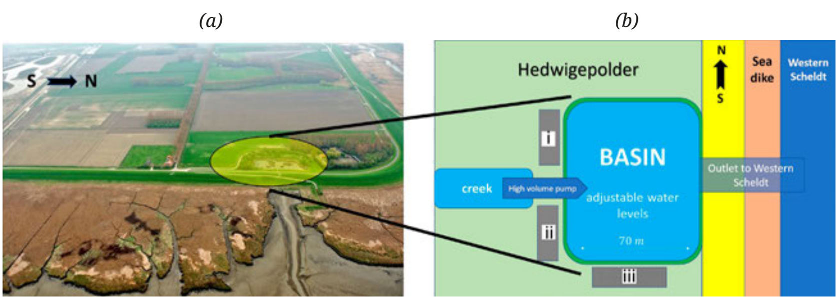
11.3.1 Real scale experiments for reinforcing the water retaining function of a levee

11.3.1.1 Design of a real-scale test setup for levee stabilisation experiments

To test emergency interventions, the minimal requirement is the availability of a levee with the outer water at very high levels, i.e., the outer water level should be at least 0.5 *m* below the crest, preferably even closer (artificially created emergency conditions). Even at spring tide this condition would never be reached at the sea dike of the Western Scheldt. Hence, designing tests to be deployed at the sea dike proved to be impossible. Then, it was decided to use an existing retention basin, and redesign the levee surrounding it to purpose (Schmets, Dado, Leertouwer, de Rijke, & Postma, 2021), see Figure 11.4. The basin had dimensions of 100 by 50 metres and was specifically designed to simulate high water conditions in a river. When filled with water to 0.1 m beneath crest level, the basin held about 20000 m 3 water, almost 10 Olympic swimming pools. High-capacity pumps (up to 10.000 m 3/hour) were installed to fill the basin to emergency water levels. An existing unidirectional (because of PFAS) outlet was used to flush water from the basin to the Western Scheldt at the end of an experimental session.

The levee was designed to resemble an average Dutch river levee (Technische Adviescommissie voor de Waterkeringen, 2001). The levee consisted of a permeable, sandy core, covered with a 0.5 m clay layer. The outer slope of the levee was according to standard practice 1:3. Three test areas were assigned to separate locations on the 5m-wide crest, Figure 11.4(b). At location (i), where the BresDefender was to be deployed, the outer slope was covered with sods, to closely mimic a typical Dutch grass covered levee.

Figure 11.4. (a) Overview of the (once) existing retention pool in the former Hedwigepolder. (b) Sketch of the design of the basin, with new levees, water supply from an existing creek, and water outlet to Western Scheldt. The sites i, ii, and iii indicate the dedicated test areas for BresDefender, mobile barriers and (intended) breach initiation, respectively. Figure source: the authors.



11.3.1.2 Results of levee stabilisation experiments using the BresDefender

In the period November 2021 to January 2022 the basin was built, and pumps and measurement equipment were installed. A section of military engineers from 105 Geniecompagnie Waterbouw moored a pusher boat and floating pontoons in the basin, Figure 11.5(a). For the experimental scenario which intended to reduce the water flow through a breach, see Figure 11.2(a), an artificial breach was purposely created. Within the artificial breach a hatch was installed, Figure 11.5(b), and a flow rate measurement box was placed at the landside of the artificial breach.

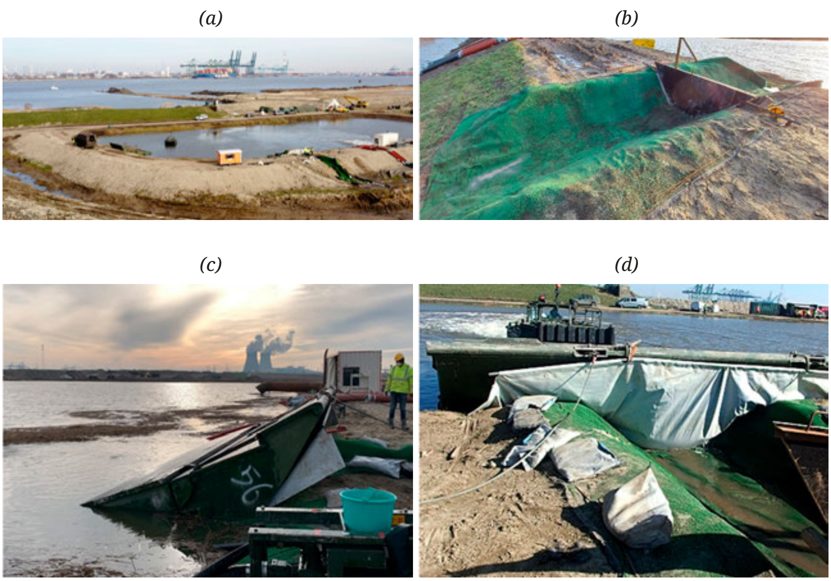
Actual experiments were performed during February-March 2022 (Rozendaal, 2022). Two different scenarios were assessed. The first test scenario involved an unmodified pontoon, while the second scenario used a pontoon with a flexible plastic sheet (tarpaulin) attached to the bottom, Figure 11.5(c,d). After minor adjustments to the original pontoon, it could be sunk in front of the weakened levee section, i.e., the artificial breach, to reduce the discharge over or through the levee. The discharge reduction for the first scenario was found to be insignificant.

However, for the second scenario, with the tarpaulin applied, the discharge through the breach was measured to decrease more than 99% compared to the situation without an intervention installed (Janssen, Hofland, Schmets, Dado, & Jonkman, 2023). Also in this scenario, the measured discharges might still lead to erosion of dike core material. But now at erosion rates which are a few orders of magnitude lower compared to the situation without an emergency measure installed.

Altogether, application of the BresDefender can achieve a time benefit as sketched in Figure 11.1. Also, a substantiated estimate of this benefit can be found from physical models (Janssen, Hofland, Schmets, Dado, & Jonkman, 2023). Breach growth happens to be arrested, which allows time for evacuation of people and livestock from the hinterland.

Parameters related to the other anticipated effect of BresDefender, reduction of the water flow into the levee leading to a decrease of phreatic surface level, could not be obtained from these large-scale experiments. But dedicated lab-scale and intermediate-scale experiments elsewhere have demonstrated that also this effect offers a time benefit, i.e., a prolonged time to failure (van de Wilt, 2020; Janssen, et al., 2023).

Figure 11.5. (a) The purposely build test facility in the former Hedwigepolder. (b) Artificial breach with hatch for BresDefender experiments. (c) Pontoon covered with flexible sheet placed in front of breach. (d) Flow reduction through breach after application of pontoon. All images from February/March 2022. Figure source: Bureau Multimedia, Den Helder.



11.3.2 Real-scale breach initiation experiments

11.3.2.1 Design of a real-scale test setup for breach initiation experiments

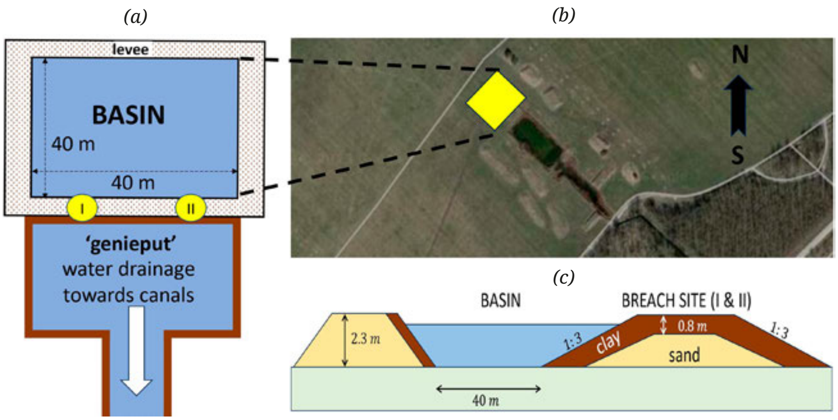
Initially, the basin in the Hedwigepolder was also intended for explosive breach initiation experiments. These experiments would involve the use of explosive charges applied to the levee. However, the Hedwigepolder is located close to a very busy waterway and high-pressure pipelines transporting chemicals to and from the nearby chemical industry. Also, the nuclear powerplant of Doel (Belgium) is at less than 2 kilometres from the basin. Therefore, first an assessment of the seismic consequences of levee breaching by detonation had to be made. Large impact tests were performed at the levee, creating, after appropriate scaling, seismic effects like those expected from a detonation (de Graaf, 2022). In this way, it could be predicted that the seismic effect of explosive breach initiation would stay well below the norm value of 3 mm/s (peak particle velocity) for nuclear installations. The predicted soil velocity at the location of the nuclear powerplant caused by detonation was found to be less than 0.1 mm/s. However, by the time this result was established, the decommissioning of the basin had already been planned. The time it would have taken to convince the stakeholders in the Antwerp-harbour area was unfortunately not favourable for timely execution of the breach initiation experiments at the dedicated site in the Hedwige-Prosperpolder Living Lab.

Therefore, breach initiation experiments had to be conducted elsewhere. At the military training grounds in Marnewaard a facility resembling the basin in the Hedwigepolder, though smaller, was built in the autumn of 2022, Figure 11.6a. Also, this basin was surrounded by levees, which were designed according to the specifications of an average Dutch river dike, Figure 11.6c. Once more, large pumps were installed to raise the water in the basin to emergency levels. Here, emergency level refers to almost-flooding conditions, with river levels close to the crest of the levee. After creation of a breach, water could flow through the breach into an already existing pond (*geniepu*t).

Breach initiation tests, operation name Breaching Beaver, were conducted at two different days in 2023, at two different breaching sites at the levee, indicated as I and II in Figure 11.6(b,c). Apart from the water retaining levee of the basin, a purposely built levee section not retaining water, indicated as dry levee, was built near the basin. It served as a physical twin structure of the basin's levee. For every breach experiment, the dry levee was subjected to the same breaching procedure as the basin's levee. The explosive breaching experiment of the physical twin levee was meant to obtain data on the size and velocity distribution of ejected soil fragments, which is important for the determination of safety distances for personnel involved in the breaching procedure. Moreover, the breach in the dry levee will have an almost similar breach geometry as the breach in the basin's levee. This guarantees a precise definition of the breach geometry at the start of the dynamic breach growth process.

The first experiment, Breaching Beaver I, was conducted for a water-filled basin, to study the effect of breaching on a hydraulically loaded levee. However, the subsequent breach growth process, caused by the outflow of water, was not representative for a river breach due to the decreasing basin water level over time. Therefore, in the follow-up experiment (Breaching Beaver II), water was continuously pumped back into the basin, maintaining the basin water at emergency levels for a period as long as was achievable.

Figure 11.6. (a) The existing site at Marnewaard with the projected (yellow) location of the basin. (b) Sketch of the design of the basin, the new levee, and breach sites I (January 24th, 2023) and II (February 28th, 2023). (c) Cross section and dimensions of the basin, and design details of the levee. Figure source: the authors.



11.3.2.2 Results of breach initiation experiments

Using explosives to initiate a breach has advantages over traditional methods, i.e., using heavy equipment such as excavators. Apart from not having heavy equipment on a potentially unstable levee, explosive breach initiation is also a flexible and fast method: a group of combat engineers can be deployed by boat, over land and even through the air. All necessary tools and the explosives can be easily brought to the detonation site by backpack. However, it is especially important to precisely time the moment of breach initiation in relation to the passing of the discharge peak in a river, see Figure 11.3. Only then can the intended reduction of hydraulic loads on levee segments downstream be achieved.

The pyrotechnic breaching experiments were conducted on two days, in January and February 2023 (Dekker, 2023). The principle of the explosive breach initiation procedure is as follows. By precise positioning of explosive charges at the levee, and their subsequent simultaneous detonation, the erosion resistant clay layer is removed. This starts off the discharge of basin water through the breach, accompanied by erosion of the levee's sandy core. In this way, a breach growth process is triggered, leading to breach widening and increased water discharge rates.

Figure 11.7. (a) The purposely built test basin facility at Marnewaard, with the test levee prepared for detonation at location II, visible in the foreground. (b) Explosive breaching of the test levee. (c) Initial breach and water outflow immediately after detonation. (d) Final equilibrium state of the breach. Figure source: the authors, February 28th, 2023.

(a)

(b)

(c)

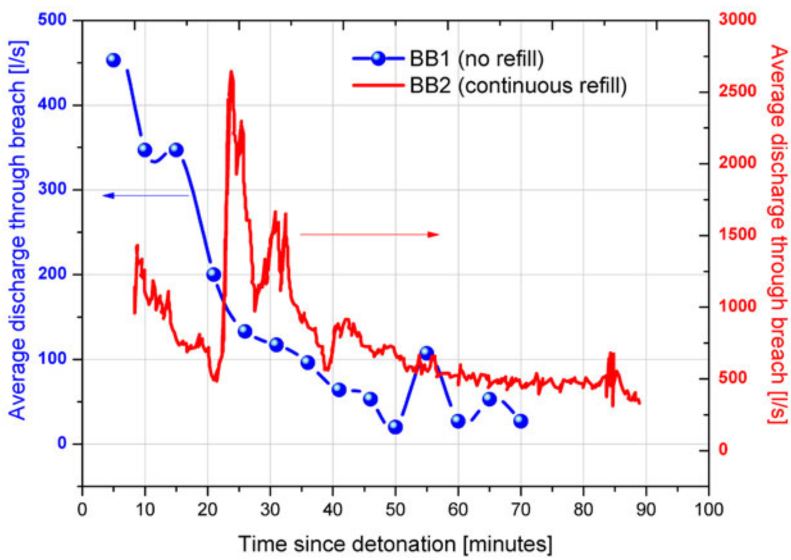
(d)

At the time of detonation, the basin water level was at approximately 20 cm below the crest. Multiple, standard military grade, plastic explosive charges were buried inside the levee, using a soil auger. The charges were placed in a string-like fashion across the levee. The tests allowed for evaluating and improving on earlier established estimates of breach parameters (Zoomers, 2019; Mekenkamp, 2022). These parameters included the depth of burial of the charges, the number of charges required, the amount of explosive to be used for each charge location and the precise position of each charge on the levee, Figure 11.7(a). The order of events during Breaching Beaver II is presented in Figure 11.7.

To monitor details of the explosive effects in general, and the breaching process in particular, various measurement systems were put in place. From the air, sensor-equipped drones collected multispectral and lidar data over time. In this way the geometry changes of the levee, the initial breach as well as the soil and water surfaces were recorded over time. A series of electronic pressure sensors installed in the basin allowed for measuring the discharge through the breach. High-definition photography and high-speed cameras imaged the various stages of the process, including the size and velocity distribution of soil fragments ejected from the breach site. The latter has provided unique data for estimating safety distances for this type of operation.

In Figure 11.8 the experimentally obtained discharge through the breach as a function of time is presented for both experiments. The measured peak discharges are found to differ significantly between both experiments. Peak discharges of almost 500 l/s and 2500 l/s were measured for Breaching Beaver I (BB1) and Breaching Beaver II (BB2) respectively. The observed difference originates from variations in experimental setup between the two tests. In BB1 the basin level decreased over time, while for BB2 a constant water level could be maintained for a longer time after detonation by synchronous refilling the basin with large pumps. Another reason for the observed discharge differences was an improved explosive charge geometry. The improved geometry was inspired by the result of the earlier experiment, BB1.

Figure 11.8. Measured discharges through breach as function of time after breach initiation event for Breaching Beaver I (BB1, constant volume basin) and II (BB2, constant backflow into basin). Figure source: the authors.



Remarkably though, the final breach width was found to be four metres in both experiments. This is small compared to the final breach dimensions of the Zwin experiments (Bakker, et al., 1996), possibly due to a higher value of the driving potential of the water flow, i.e., the factor $(H_w - Z_{br})$ in equation 1. Another remarkable finding is that the time for the breach growth process to stop is found to be between 40–50 minutes, for both Marnewaard experiments as well as for the Zwin experiments. Whether this is only a coincidence is to be subject of further research.

These initial results suggest that the method can be used in smaller, almost stagnant water systems, such as lakes, basins, and canals, with relative ease. This is because the effect of the breach is easily predicted, given the desired water volume to be deviated and the size of the retention area. However, application of this method in the case of rivers will be more involved. For rivers proper timing of the breach creation – relative to the passage of the discharge peak – as well as the size of the breach are essential for the method to be effective. Further analysis of the results (Mossinkoff, 2023), extrapolating to the boundary conditions set by river levees, indicates that implementation of the same method will lead to deviation discharges up to 20 m^3/s. This estimation assumes that real rivers allow for complete development of the breach growth process, because of abundant availability of water. Overall, the method has been proven to work, but waits for testing on real river systems. Also, development of computational models could guide the future selection of the various parameters involved.

Finally, the experiments presented here demonstrate that military engineering service men are already sufficiently trained to successfully execute a breach initiation as an operational task under emergency conditions. However, it is particularly important that they receive accurate instructions, in which also the aims of the breach and the importance of accurate timing of the action are explained. The desired technical information required involves the coordinates of the desired breach site, accurate predictions of the moment of breach initiation, and details about the cross-sectional properties of the levee, i.e., layer thicknesses, crest cover material (grass or asphalt), etc. The latter information should be supplied by the water authorities, otherwise it should be gathered by a separate intelligence harvesting mission prior to deployment of the breachers team.

11.4 Conclusions

Here we have presented novel methods for military led emergency response interventions during river flood crises. River flooding is expected to occur more often, and with more severe consequences, due to climate change. Two principally different emergency intervention strategies were presented. Firstly, the temporary strengthening of the levee's water retaining function by waterborne deployment of a seal: the BresDefender. Secondly, the local reduction of the hydraulic loading on a selected levee section by partly deviating the river's discharge to an inundation area upstream. This inundation is achieved by localised, explosively initiated breaching of upstream levees.

These techniques were developed and evaluated using large scale facilities (basins) in Hedwigepolder and Marnewaard. These facilities were designed to resemble Dutch river settings and to allow for emergency-like water levels by application of large pumps.

BresDefender's effectiveness as a waterborne, levee reinforcement technique, and its potential for use in real emergency response situations, was studied under realistic environmental conditions. The primary aim of the experiments was to evaluate the applicability and effectiveness of a stiff structure positioned in front of a locally reduced crest, in minimising the total discharge through the breach. In addition, the placement procedure of the pontoon was assessed. The application of a flexible sheet or tarpaulin between the stiff structure and the levee proved to be crucial for the effectiveness of this method. It was demonstrated that deployment of the BresDefender emergency response measure has several advantages over the application of traditional measures to stop a breach in its early stages:

– It makes up the only theoretical underpinned solution to avoid or arrest the breach initiation process in its early stages.
– The method leads to a significant reduction of water flow to the hinterland. It also arrests the growth of the breach because reduced flow rates lead to decrease of soil erosion rates.
– Altogether, the method delivers with respect to the aspect of creating a time benefit (Figure 11.1). This time benefit can be required for evacuation, but it could ideally make the levee survive the flood.
– The method has been demonstrated to work when applied to overflow in case failure of a levee has led to local decrease of crest height.
– The method can also be applied when the outer slope, or its protective cover layer, is damaged. The method is found to significantly slow down the ingress of water into the levee and prevents shear failure due to increased loading by the increased outer water level.

Explosive breach initiation and subsequent breach growth were studied experimentally, aiming at developing best practices for future use during high water events. This emergency intervention method intends to reduce hydraulic loads on critical levee segments. The method has been proven to work and may also be applicable in a military context for counter mobility or other defensive purposes.

The main findings of the breach initiation and growth experiments can be summarised as:

– Levee dimensions, soil stratification and composition are required to properly design a charge geometry for effective breach initiation.
– Breach growth has been observed, and final breach widths up to 4 metres were obtained. Experiments at real rivers should be conducted to assess the extrapolation-based assumption of achievable deviation volumes.
– Small military teams equipped only with backpacks, deployed by either land, water or air, can achieve deviation discharges of 20 m^3/s per breach, for a typical Dutch river levee.
– Further research should lead to charge configurations that allow for optimal breach growth and breach growth velocities. This would make the method more useful for practical application, as precise timing with respect to the approaching discharge peak becomes possible.
– More studies are advised to make the method more versatile. The procedure should be evaluated for diverse types of levees (clay, sand, peat, roads on top, stone, or asphalt revetment, etc.). Also, the decision-making process by water managers and civil administrators, during an actual crisis, leading up to a breach creation by the military, should be examined.

Overall, novel emergency response intervention techniques have been presented. Both, the BresDefender technology and the explosive breach initiation technologies are, or will be, added to the International Handbook of Emergency Response, a document with similar aims as the International Levee Handbook (Sharp, et al., 2013). The next step would be for the water-safety authorities to weigh its usefulness, and then request the military and/or civil authorities to develop the proposed techniques for tools which could be embedded in the regular military training programs. As disaster events and circumstances are always unpredictable, emergency measures should lean on proper preparation by training. Here, training means not only following procedures, but also using the trained skills to improvise successfully in all sorts of environments under extreme circumstantial conditions.

Finally, the project and its deliverables result from a collaboration between military, national partners in the water safety chain and international partners. It was a learning environment for all, and a fruitful experience in international civil-military interaction. Such longer term, cold phase collaborations have proven to deliver a lot, not least mutual understanding, a critical requirement for effective emergency response. Finally, ‘playgrounds’ like Hedwige-Prosperpolder prove to be important triggers for collaboration and testing desktop ideas in the field.

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CHAPTER 12

Prevention and Detection of Adversarial Threats to Vital Infrastructure at Sea: An Operational Analysis Approach

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Abstract

Climate change has given impetus to the task of reducing the fossil footprint. This has led to major investments in offshore wind farms. Sabotaging this vital infrastructure, including the cables connecting them to the mainland, can cause significant damage with immense consequences. It has resulted in a new homeland defense task for the Netherlands Coast Guard: maritime security. The recent acknowledgment by NATO and the EU that enemy states can use deliberate attacks on vital (military) infrastructure has sparked new interest in the analysis of these kinds of security threats. By using the quantitative operational analysis approach presented and promoted in this article, insight can be gained into the structure of optimal surveillance patrols of vital (military) infrastructure. These patrols by Coast Guard platforms, unmanned and manned, contribute to operational climate security strategies with regard to prevention and detection. The analysis can also support procurement and development policies. To identify optimal surveillance patrols (given the cable networks, limited security resources, intelligent and adaptive behaviour of the adversary, etc.), we focus on maximising the protection time (the amount of time the attacker needs to execute its task successfully) and minimising the detection time (required time for the defender to detect that the infrastructure is compromised and degraded). In our models we use network science (the topology of the cable network), game theory and optimisation theory (the strategic interaction between Coast Guard maritime patrols and its adversaries, and optimal allocation of limited security resources), and probability theory and machine learning (detection of anomalous behaviour). We illustrate our approach using two illustrative examples, which also underpin the added value of including the reaction of adversaries into our models.

Keywords: critical infrastructure security and resilience, maritime security, rural postman problem, game theory, climate change

12.1 Introduction

The main consequence of climate change is global warming, causing irreversible disruption to global weather systems and the entire water cycle. As a result, more extreme weather types will exacerbate water-related hazards such as extreme droughts and major floods. The first main consequence of climate change therefore is the scarcity of drinking water, food, and a safe living environment. Subsequently, this results in a scarcity of energy and raw materials that are necessary to adapt to these changing preconditions. Secondly, scarcity leads to further weakening of fragile states, but also to opportunities for powers seeking expansion or disruption, which will ultimately result in conflict and strife (Houben, 2017).

Society's response to climate change is twofold. First, strengthening resilience to cope with the far-reaching consequences of climate change and the resulting scarcity and safety issues (for example through the involvement of the Royal Netherlands Navy at St. Maarten after the hurricane Irma in 2017), i.e., making society shock-resistant. Second, tackling the causes of climate change for instance, by accelerating the energy transition. The construction of large offshore wind farms is an example of how this policy of generating energy security can be put into practice.

One aspect that is often overlooked is that the energy transition is occurring amidst increasing conflicts and strife. For instance, between 1970 and 2018, there were nearly 2,000 terrorist incidents targeting gas or oil facilities (Lee, 2022). The economic globalisation of recent decades has primarily been driven by cost considerations, causing aspects such as security and autonomy to gradually receive less attention. The latter is reinforced by the fact that there is often not one authority responsible for setting up facilities at sea (Bekker et al., 2021). It has become evident that not all participants in the field are as reliable as assumed or hoped. The recent conflict in Ukraine has served as a stark reminder of how economic interdependence with malicious powers can significantly disrupt the world order in terms of energy and food supplies. The sabotage of the Nord Stream 1 and 2 gas pipelines exposed the vulnerability of both energy and information infrastructure in a resounding manner. Power cables connecting offshore wind turbines to the mainland, global information networks, and pipelines are susceptible to sabotage by terrorist groups or hostile powers. Alternative approaches, such as converting wind energy into liquefied ammonia for easier transportation and storage, bring about potential safety and environmental risks for the transport network.

Disruption of these networks can have significant consequences for both energy and information supply. Climate change acts as a threat multiplier, impacting security, critical infrastructure, and military operations. NATO's role in energy security was defined at the Bucharest Summit in 2008, recognising that disruptions in energy supplies have a substantial impact on the safety of NATO members and can affect military operations (Olech, 2022). More recently, in January 2023, NATO and the EU agreed to establish a joint task force on resilience and critical infrastructure. The task force aims to enhance the resilience of critical infrastructure, technology, and supply chains against potential threats, and take action to mitigate vulnerabilities (European Commission, 2023).

In the North Sea, sea-based economic activities are rapidly expanding in size and complexity. These activities offer opportunities for malicious actors, as highlighted by The Hague Centre for Strategic Studies (Bekker et al., 2021). Their report analysed the associated consequences for the Netherlands Coast Guard (NLCG) and the Royal Netherlands Navy (RNLN). The report emphasised the need to integrate information from various sources to establish comprehensive maritime situational awareness and understanding. Permanent sensors to monitor large sea areas, including surveillance drones, are valuable assets for enhancing situational awareness. The NLCG is leading efforts to protect wind farms, pipelines, and communication cables at sea within the context of maritime security. Ensuring the security of these cables and wind farms remains a critical concern.

Our article serves as a plea to approach maritime security and the challenges posed by climate change in the context of adversaries or opponents, utilising a quantitative operational analysis approach. The ultimate goal is to create a safer living environment. Designing solutions to the multifaceted challenges of climate change involves numerous considerations that often conflict with each other, such as efficiency, effectiveness, cost, scarcity, security, risk management, and hostile interventions. Quantitative risk-informed decision-support models derived from operational analysis offer a natural framework to substantiate these efforts. They can assist in prioritising infrastructure investments based on quantitative risk assessments.

The general methodology of quantitative operational analysis is as follows. First, all relevant aspects, including desired objectives and imposed limitations of the problem, are incorporated into a mathematical model. The model, along with the experiences of the user, forms a system. In other words, the model functions as a link or moderator between observed reality and the model's designer/user/client (De Regt, 2017). By applying the model to the field of protection, calculations can provide insights into optimal inspection routines for wind farms and cabling, maximising protection time while minimising detection time. The model can also help determine the required military capabilities and doctrines. Theoretical concepts can be applied within the model to gain insights, which then serve as a platform for discussions with military experts. It is important to note that the model is not an endpoint but rather a starting point for discussion. Through this iterative process, one can identify the relevant parameters of the system and refine the model (also see Jacobs and Meester, 2023).

Although legal experts, maritime safety- and security professionals, government policy makers and the private sector alike, should expedite their efforts to deal with the increasing demand for maritime security, we focus on surveillance patrols only. To identify optimal surveillance patrols (given the cable networks, limited security resources, intelligent and adaptive behaviour of the adversary, etc.), we focus on maximising the protection time (the amount of time the attacker needs to execute its task successfully) and minimising the detection time (required time for the defender to detect that the infrastructure is compromised and degraded). Catching an adversary red-handed contributes to securing evidence, while pre-positioning other assets improves the time to recreate a safe system state. This means that surveillance of the network also contributes to minimising the reaction time (the time to recreate a safe system state and/or secure evidence); we will not elaborate on that in our contribution. The results are used for quantitative risk management and risk-informed decision-making, ultimately contributing to a safer, stable, and resilient (economic, social, and environmental) living environment.

In the next section, we introduce the protection, detection and reaction time in a general framework of Time-Based Security. In Section 3, using a few illustrative examples, we discuss models that focus on optimising the protection time. As adversaries introduce uncertainty regarding when and where they will attack a network of cables, we show the necessity and profitability of introducing randomness into our modus operandi. It shows how to manage adversarial risk. Section 4 summarises our approach and results.

12.2 Relevant Parameters in Critical Infrastructure Security and Resilience

Our aim is to model the security situations involved with offshore windmill parks with a model of Time-Based Security, (following Farhang & Grossklags, 2017). We will not elaborate on the details of the game-theoretical description of this model, but emphasise the three important parameters the model is based on: protection time, detection time, and reaction time (also called response time). Applied to our situation, they can be explained as follows.

12.2.1 Protection time

In general, the *protection time* represents the amount of time the attacker needs to execute its attack. For an offshore wind farm, this is a combination of the time needed to physically get to the desired location, added to the time needed for sabotage. Naturally, the aim is to design a system such that this time is as long as possible. This can be done by building resilience into the system. In case of an offshore wind farm, one can think of placing the transformation station in a secure place: hiding its location, or guarding it with a lock. The cables can be protected by placing them in pipes, ensuring also protection against natural influences like sea life and corrosion. Note that there is a trade-off between these security measures and how easy it is to do maintenance on the system.

An interesting way to increase the protection time is by patrolling the wind farm. If an attacker needs to hide from time to time to stay out of sight of the patrol, it will take longer to finalise an attack.

12.2.2 Detection time

It can take a long time before an attack is noticed in practice: think for example about infiltrating a secure cyber environment. And the longer it takes to detect an attack, the more harm can be done. Therefore, the goal of the designer of a system will be to decrease the *detection time*. Detecting an attack on an offshore wind farm consists of two phases: first, one detects that there has been an attack. Since the goal of an attack can be assumed to be a loss of power from the park, the detection of an attack is almost immediate. On the other hand, it is much harder to detect where in the park the problem exactly is and what this problem is (is one of the mills out of order, is it the transformation station, is it a cable?). One of the directions to tackle this problem is to use many sensors in the area. Power can be measured at multiple places in the park and this data can be monitored constantly. Video surveillance from the park itself can be captured, and there might be ships nearby whose location data can indicate suspicious behaviour.

However, this direction is expensive (many sensors needed), not failure proof (communication between sensors and observers can be attacked as well) and has several privacy issues (video surveillance, ship location data). This is why we argue that until this way of detecting is implemented, another way to decrease detection time is needed. Again, patrolling can be a very effective way to determine the exact location of an attack.

12.2.3 Reaction time

The *reaction time* is the time between the detection of the attack and the moment that the system is operational again. It is not necessary that the system is fully operational and in its original state: it can be that a backup is running, allowing for more time to repair the system in total. This time includes the time needed for repairs, but also travelling to the location of the attack. The first type of time can be shortened by the design of the system. In the case of a windmill park, there can be several cables connecting it to the coast. Inside the park, redundancy can be built in. This is closely related to the improvement of protection time, as discussed before: redundancy will both improve the resilience of a park against attacks, as well as improve the reaction time once an attack has occurred. Optimising the time needed to get to the place where repairs need to happen, in this case the wind farm, can be done for example by placing repair teams at strategic places.

12.2.4 Improving the protection and detection time using patrols

We have discussed the three parameters from the general Time-Based Security model, and illustrated their meaning for the security of an offshore wind farm: protection time, detection time, and reaction time. The NLCG traditionally focuses on shortening the reaction time: if a distress call from the sea comes in, they are well prepared to get there as fast as possible. Dealing with protection and detection of attacks on wind farms is a new task for the NLCG. As seen, effective patrolling can be used to improve both these parameters. In the following section we will discuss several techniques to optimise surveillance, by means of examples.

12.3 Maritime Security: Wind Farms and Seabed Warfare

In this section, we introduce our two illustrative cases in the first subsection. In the second subsection, we show how to determine and improve the maximum time between two surveillance visits along the network, which will be called the inter-arrival time. It shows that maintaining acceptable inter-arrival times necessitates a large fleet of UUvs (unmanned/autonomous underwater vehicles), which may not be available. In addition to that, another challenge arises as adversaries may observe the defensive surveillance patterns to estimate the inter-arrival time, allowing them to plan their attacks accordingly. A way out, tackling both scarcity of resources and the issue of an intelligent and adaptive adversary, is to introduce randomness in the modus operandi in an optimal way: game-theoretic risk management. This is discussed in the third subsection.

12.3.1 Description of the two cases

In this section, we illustrate the application of operational analysis to optimise the surveillance of underwater cables of wind farms and oil or gas pipelines using two examples. The first case resembles part of a network of oil pipelines near the isle of Ameland in the Netherlands, containing 98.5 NM pipelines connecting (underwater) platforms 1, 2, 6, 7, 8, and 9 with a through pipeline 3-2-4-5 (Figure 12.1). The second case is a network of underwater cables from the Luchterduinen wind farm in the Netherlands, containing 15 NM cables connecting 43 wind turbines to the transformation station (Figure 12.2). We assume we can use unmanned/autonomous underwater vehicles (UUVs/AUVs) that can detect anomalies while travelling along a cable or pipeline. For our computations, we assume a cruising speed of 2 knots. To impede sabotage of our network, our goal will be to design surveillance routes that cover every cable or pipeline, while minimising the maximum time between two surveillance visits (inter-arrival time) along the network.

Minimising the maximum time between two surveillance visits contributes to the task of improving the protection time (and detection time as well). If the inter-arrival time along the cables is small, an attacker is faced with the problem of executing its malicious task within that small time-frame. If the time needed to interrupt the operation of the network is larger than this inter-arrival time, the action surely will be detected, and also possibly prevented. We will consider this protection time given the technical parameters of the UUV and the number of UUVs available for the surveillance. This problem of minimising the inter-arrival time is related to the so-called *periodic latency problem* (Coene et al., 2011). It describes the problem during the reign of Charlemagne (768–814 AD). Counts had been appointed to govern different pieces of Charlemagne's empire, called counties. Charlemagne's challenge was to find a visiting sequence of his counts so that the time elapsed between two consecutive visits to a count would not exceed the "loyalty period" of that count. Not visiting a count for a certain period imposed a risk regarding the obedience to Charlemagne.

Figure 12.1. Network of oil pipelines near Ameland.

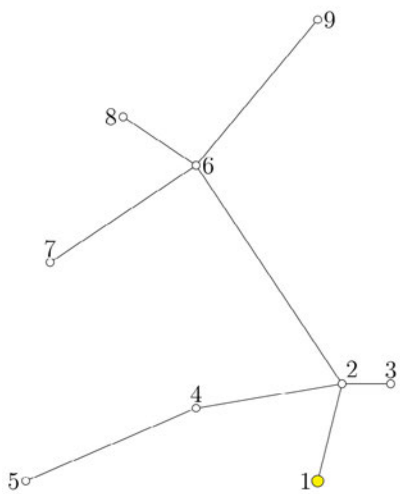
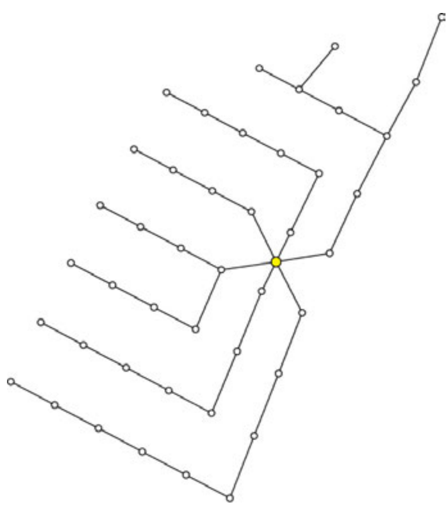


Figure 12.2. Luchterduinen wind farm.

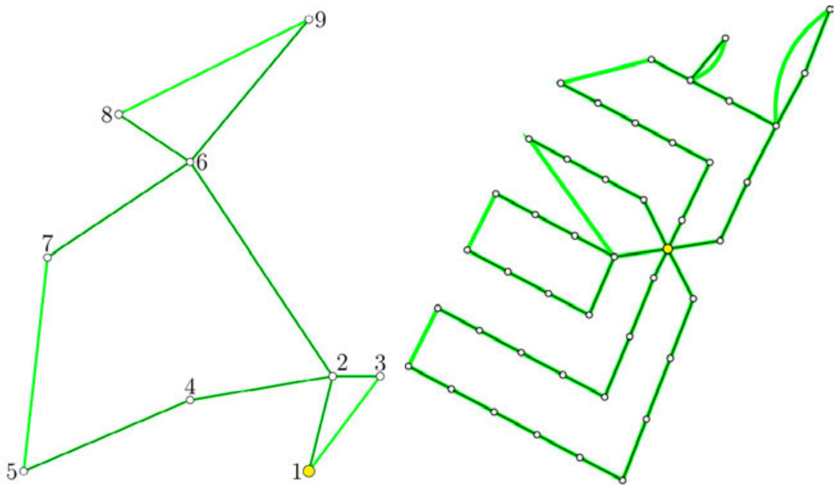


12.3.2 Modelling for risk informed decision making: output of models and discussion

Initially, we assume that we can deploy one operational UUV without range limitation that is restricted to move along the cables or pipelines. Since our networks are so-called trees, i.e., there are no cycles in the network, the optimal tours can be found by tracing the outside of the network, leading to solutions that visit each edge (pipeline or cable) in the network exactly twice, starting and ending at the yellow nodes. We note that this optimisation problem, known as the Chinese postman problem (Edmonds & Johnson, 1973), can also be efficiently solved when the network is not a tree. The total distance travelled in our first case study is 197 NM, which will take the UUV 98.5 hours. In the second case, the total distance travelled is 30 NM requiring 15 hours of surveillance time. Apart from range considerations of our UUV, the time between two visits at any position along the network is large. Therefore, we will relax the condition that the UUV can only travel along the edges of the network.

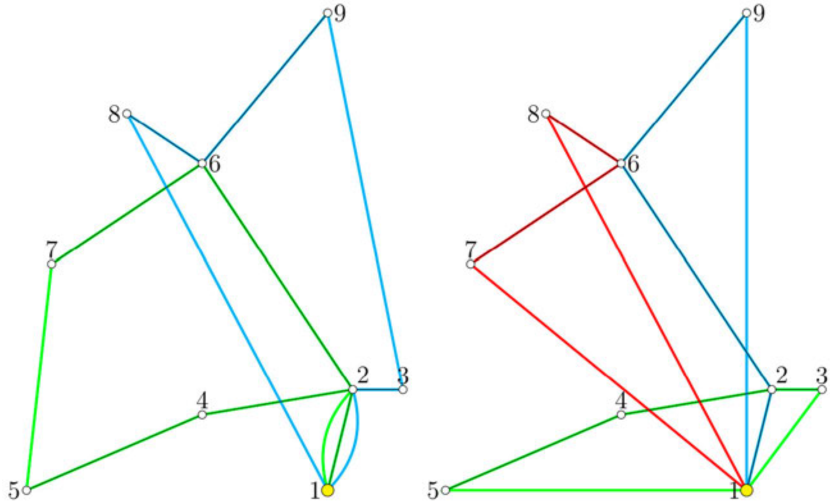
In our next problem setting, which is called the rural postman problem (Eiselt et al., 1995), we need to visit every edge at least once, where travel along non-edges is also permitted, and our goal is to find the shortest tour. In general, the rural postman problem is a computationally challenging problem, i.e., an NP-hard problem (Lenstra & Rinnooy Kan, 1976), but since our networks are connected, i.e., between any two points on the network there is a route using only cables or pipelines, the problem can be solved efficiently (Brandão & Eglese, 2008). To see this, note that the edges and non-edges used in the tour form a connected network, where the total number of edges and non-edges that are attached to any node is even. Since the edges that need to be visited already form a connected network, we only have to add non-edges in the cheapest possible way such that the nodes with an odd number of edges attached to it get a non-edge attached to it. This is done by introducing extra non-edges pairing nodes with an odd number of edges attached to it, minimising the overall length of these pairing edges. The original network, together with these pairing edges forms a minimal length tour covering the network. The resulting tours are depicted in Figure 12.3. In the first case, the total distance travelled reduces from 197 NM to 146 NM, which requires 73 operational hours. In the second case, the total distance travelled is reduced from 30 NM to 18.8 NM, which will take 9 hours and 24 minutes.

Figure 12.3. Optimal solution of the rural postman for the first case (left part), and optimal solution for the second case (right part).



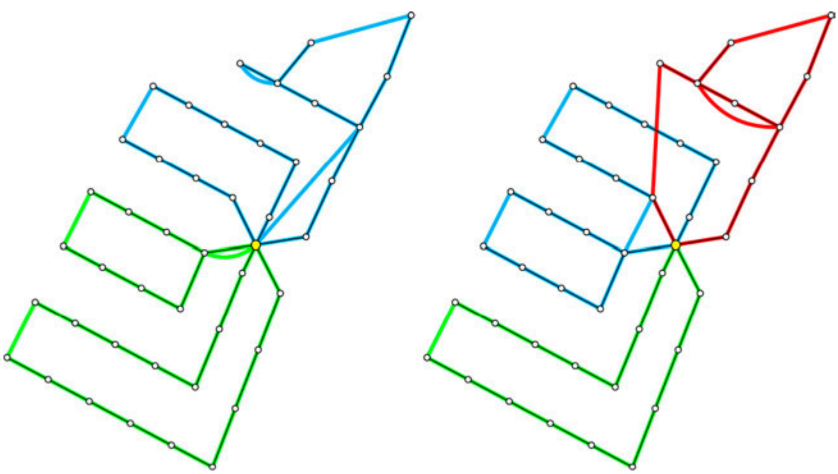
Since the inter-arrival times are equal to the total surveillance time of the tour, they are still quite large; we could deploy more UUVs to reduce the inter-arrival times. We now make a distinction between cases where the UUVs have a restricted range or an unrestricted range. If the range of the UUVs is unrestricted (or more than the length of the optimal tour for one vehicle), we can achieve an inter-arrival time which is equal to the original inter-arrival time divided by the number of UUVs. This is obtained by assigning the original tour to each UUV, where the starting locations of the UUVs are distributed uniformly along the tour. It is the best inter-arrival time obtainable given the number of UUVs. However, if the range of the UUVs is restricted, it might not be feasible that each UUV visits every edge. In that case UUVs possibly get different tours assigned, which will also result in reduced inter-arrival times. Since we aim for a low inter-arrival time at each position in the network, our objective becomes to minimise the largest tour length across all UUVs. For simplicity, we assume that each edge in the network is visited by exactly one of the UUVs. These problems can be solved using integer linear programming methods (Wolsey, 2020). The results for the first case are depicted in Figure 12.4, using two and three UUVs, respectively. It is assumed that all UUVs need to recharge at Node 1. Inter-arrival times are reduced to 49 hours and 51 minutes, and 42 hours and 2 minutes, respectively. If these inter-arrival times still exceed the range of the UUVs, more UUVs are needed for a feasible solution.

Figure 12.4: Routes for two (left part) and three (right part) UVVs for case 1.



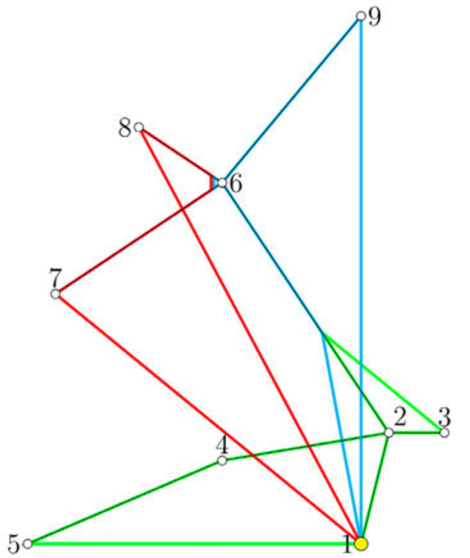
The results for the second case are depicted in Figure 12.5. Here, the inter-arrival times reduce to 4 hours and 52 minutes, and 3 hours and 21 minutes, respectively.

Figure 12.5. Routes for two (left part) and three (right part) UUVs for case 2.



We note that the used models are basic. However, they can easily be modified to include other real-life considerations. For example, if the endurance of the UUVs depends on the speed that is used, we could include the possibility of varying the speed along the tour and keeping track of the remaining range. Finally, we note that the objective can be slightly improved by relaxing the requirement that each edge is visited by exactly one UUV. An illustration of this phenomenon can be found in Figure 12.6 where UUVs with slack operating time take over parts of the pipelines from the critical UUV, thus reducing the inter-arrival time slightly to 41 hours and 51 minutes. It might also be better to let certain edges be visited by multiple UUVs, like in the case with unrestricted range. Coordination between the different UUVs will be vital to employ such a strategy. Therefore, we think it is an interesting problem for further research.

Figure 12.6. Alternative solution utilising slack operating time of other UUVs.



So far, we have shown how techniques from operations research can be used to design surveillance routes that curtail the operational time of adversaries seeking to damage our networks. We will now discuss possible directions for further research.

Until now we have implicitly assumed that every cable or pipe is equally important. In reality, some parts of the network may represent a higher risk than others. Damage to cables closer to the transformation station will have a greater impact on energy production, so these cables will have to be scanned more often. Also, given the shipping routes in the North Sea and, in addition, competing interests, various risk and threat scenarios may emerge. In that case, desired inter-arrival times may differ from one location to the other. Compare Gabriel et al. (2022), who use Bayesian

Networks to assess the risk, incorporating modern data science techniques. Given the desired inter-arrival time per edge and range per UUV, the minimum number of UUVs to be deployed could be calculated. This leads to a problem related to the periodic latency problem (Coene et al., 2011, Sanchez, 2013). Other variants related to desired inter-arrival times are the window scheduling problem (Bar-Noy et al., 2012), as well as other similar problems from literature (Holte et al., 1989, Bosman et al., 2022, Gąsieniec et al., 2017, Van Ee, 2021, Evers et al., 2014).

12.3.3 Introducing uncertainty for the adversary: a game-theoretic approach

As mentioned earlier, given the desired inter-arrival time per edge, and the range per UUV, one may determine the minimum number of UUVs required. Our examples have shown that maintaining small inter-arrival times necessitates a large fleet of UUVs. However, when such a large fleet is not available, this leads to the problem of resource scarcity. Another challenge arises from intelligent adversaries who may observe the defensive surveillance pattern to estimate the inter-arrival time, allowing them to plan their attacks accordingly.

To address these issues, one possible solution is to introduce randomisation of routes or patrols in an optimal manner. This introduces uncertainty and helps counteract the problem of scarcity. One approach to introducing this uncertainty while considering adversary observation is the game-theoretic approach. Game theory has been extensively studied in the field of security games, as seen in the literature (Tambe, 2012). Defensive procedures based on these games have been implemented at locations such as LAX airport and by the US Coast Guard. By employing random patrols, these procedures maximise unpredictability for the adversary while maintaining a high probability of detecting them. For an application related to border security, involving partial information on the state of the game for both players, see Laan et al. (2019).

In this contribution, we again restrict ourselves to the network of cables. To this end, we divide the edges into smaller ones, such that traversing each edge takes one time-step. A patrol on the original network of cables then corresponds to a patrol of adjacent edges, where each edge takes one time-step. But our class of patrols is larger than before: patrols may change direction, for example halfway on an original edge. In addition, we also consider patrols that do not visit each edge, and patrols that stay at an edge for more than one time step, i.e., wait at that edge hoping to interdict the adversary.

We further assume that the adversary needs m time-steps to perform the attack on any edge: this is part of the protection time discussed in section 2.1. If it performs its attack at time t, it is present at the edge at time-steps t, $t+1$, …, $t+m-1$. The patrol catches the intruder in the act if it visits this particular edge at some time between

t and $t+m-1$. Indeed, the game between the patrol and the adversary involves strategic choices for both players. The adversary must select which edge to attack and when to initiate the attack, while the patrol needs to determine its route and the timing of its patrol. Both players strive to optimise their strategies.

The probability of detecting the adversary is at least $1/n$, where n represents the total number of edges: the patrol can choose to stay at a uniformly randomly selected edge. To achieve stronger results, the concept of intercepting strategies can be introduced. An intercepting strategy for a given edge is a patrol that ensures the inter-arrival time for that edge is no greater than m. However, such a patrol may not visit all edges. A covering set refers to a collection of intercepting strategies where each edge is included in at least one intercepting strategy. If the number of these strategies is denoted as C, then the probability of detection is guaranteed to be at least $1/C$ by randomly selecting one of these intercepting strategies. Considering these factors, it is indeed desirable to design wind farms and the topology of their connecting cables in a way that minimises the number of required intercepting patrols (C). This contributes to the resilience of the system and strengthens its ability to withstand potential attacks.

12.4 Conclusion

In this contribution, we have presented our quantitative operational analysis approach for determining optimal surveillance patrols for seabed cables and offshore wind farms, with a specific focus on optimising protection and detection time. Our approach and the resulting insight can also be applied to the issue of how to strategically position NLCG assets at sea, enabling threat deterrence, optimal protection time, quick response time, and optimising reaction capabilities.

The theory presented here is part of the broader field of search and detection theory. Typically, the sea is divided into sectors, with each sector assigned a probability of containing the target or adversary being sought. Well-known formulas, such as the random search formula, can be utilised to calculate the probability of detection (Washburn, 2002). These formulas have been employed in various studies. This includes the optimal search for intruders in the Port of Rotterdam (Zijlstra, 2019) after initial detection of intrusion, enabling securing of evidence. Another example is the coordination of cooperative drones during area search (Zijlstra, 2022).

In this chapter, we adopted a different approach by focusing solely on patrolling the network (including hypothetical edges between nodes), as we were aware that an attacker needs to attack an edge of the network. Our objective was (1) to reduce the inter-arrival time, consequently improving the probability of detecting an attacker, and (2) introduce randomness in the patrols in an optimal way. Our models provide insight into assumptions and give suggestions for the deployment of available resources. This hopefully supports our plea to incorporate a quantitative OA approach into the analysis of information-driven operations for maritime security. The models and the insight they provide may serve as a platform for discussions with experts in critical infrastructure security and resilience, and more specific maritime safety and security, ensuring that the maritime environment is resilient enough to facilitate the growing demand in a sustainable manner.

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PART 4

Mitigation

CHAPTER 13

Cleaner Conflicts? Energy Transition and Green Innovation in the Dutch Army

Thijs Jeursen and Bart Hollants

Abstract

Military actors increasingly view climate change as a challenge to international security and peacekeeping operations. But these same armed forces also produce environmental harm themselves: their operations, supply chains, and bases damage local ecosystems and generate significant greenhouse gas emissions. The Dutch Army is currently looking to combine adaptive military strategies and operations with more sustainable solutions. Focusing on energy transition and dual-use technologies, this chapter investigates how the Dutch Army integrates environmental goals, scientific expertise, and industry innovations in military operations. By extension, this work contributes to mitigating the environmental harm that military strategies pose to civilians and ecosystems in conflict zones. In our conclusion, we critically assess the greening of the military in mitigating climate change and environmental harm.

Keywords: energy transition, security, peacekeeping, military, civilian, innovation, operations

13.1 Introduction

War and military operations have always been particularly destructive to the environment (Depledge, 2023; Gould, 2007). In the first place, they directly damage and destroy the environment and contaminate water, land, and air (Jorgenson et al., 2012). Ever since the Russian invasion in 2022, the Ukrainian government and the United Nations Environmental Program (UNEP) have carefully registered environmental damage and risks. These reports demonstrate that Ukraine's government and society are grappling with multiple crises associated with chemicals, munitions, and military equipment, the presence of a range of pollutants continuing to be released during the active phase of the conflict, the damage inflicted on fuel storage facilities, industrial infrastructure, key infrastructure such as water, energy, and waste management systems, urban areas, agricultural and natural areas. Assessing such damage will require a multitude of complex methods to establish the impacts and plan recovery activities. It is also important to emphasise that the effects war has on the environment go beyond borders, impacting, for example, maritime life and ocean ecosystems. Effects hereof have been called a form of "slow violence" (Nixon, 2011): one that is less visible and one of delayed destruction.

In addition to the environmental harm of warfare, the energy consumption of military actors is also under increased scrutiny. The military consumption of fossil fuels has increased immensely over the past decades, and estimates suggest that they account for 5.5% of the total amount of greenhouse gas emissions (Parkinson & Cottrell, 2022). Several factors complicate monitoring the carbon foot or boot–print of state armed forces, one being that governments do not have to register and account for their emissions (Ambrose, 2021). At the same time, many other (indirect) effects of military activities are often unaccounted for, including those of military bases and militarised environments (Woodward, 2004). For example, a journalist pointed out that many of the Dutch Ministry of Defense (MoD) sites are heavily contaminated (Kuijpers, 2023). Researchers and policymakers advocate for the development of international reporting requirements and accurate methodologies to calculate military emissions. While the analysis of a military's fossil fuel consumption, Mohammed Ali Rajaeifar and colleagues (2022) point out, would always be complicated due to a variety of reasons, it remains essential to break down targets and policy priorities that aim to reduce the ecological impact of military activities.

Military actors increasingly recognise their role as climate actors. They explore how they can lower their emissions and use of fossil fuels while maintaining, or even improving, operational effectiveness (Middendorp, 2022). So far, military actors seem particularly interested in energy transition and consider the innovation and development of new technologies essential to realise a shift away from costly fossil fuels while also lowering risks and vulnerability. For example, in 2022, NATO stated that it wanted to reduce the gas emissions by armed forces of member states by at least 45% by 2030 (Kõrts, 2022). A goal mirrored by the Dutch government in their military sustainability strategy, striving for a reduction in fossil fuel consumption of 20% by 2023, and 70% by 2050 (Defensie, 2021). Such goals, however, require ambitious and long-term projects and strategies that reduce operational demands and make available alternative energy sources (Erdogan et al., 2022)

There are many opportunities for the Dutch Army to reduce its environmental impact while also fulfilling its mandate and national responsibilities. Moreover, a transition to alternative energy sources could also make the Army more independent and self-reliant; contributing to its overall effectiveness and lowering costs rather than negatively impacting its activities. In this chapter, we examine how the Dutch Army integrates environmental goals, scientific expertise, and industry innovations in a military capacity and, potentially, in future operations. We are specifically interested in the Army's transition to more sustainable energy sources and how this shapes operational capacity and strategy. How is the societal challenge of sustainability and the threat of climate change translated into military capability development and practice? In answering this question, we analyse policy documents, and public statements, as well as draw on the experiences and insights of the second author, who works at the Innovation Branch of the Dutch Army. This offers an insider account and perspective on the processes and decisions that shape the energy transition and innovation efforts of the Dutch Army.

We found that the Army is rapidly expanding its network and collaborations, efforts that increasingly involve business-like and societal partnerships. Indeed, there is a growing realisation that there is much to learn from research centres, policymakers, and corporations when it comes to transitioning to alternative energy infrastructure and low-carbon warfare. New and creative innovations are developed and “dual-use” technology is tested to understand how and where the Army can lower its carbon footprint. The term “dual use” in this sense refers to technologies that can both be used in military and civilian settings (Forge, 2010). This also recognises that civilian industries have become highly innovative, while military actors have seen declining budgets in the past decade (Mowery, 2012; Torres, 2018). While the Dutch Army values the potential and opportunities of civilian industries and innovations for military development, they also become increasingly dependent on corporations and commercial technologies in any attempt to transition to low-carbon operations and strategies. This also means that market dynamics and governmental policies surrounding the development and purchase of new materials and technologies shape the future of military operations in an era affected by climate change.

In the next section, we discuss in more detail the relationships between energy, conflict, and the military. Our focus on energy transition and the Dutch Army also necessitates the introduction of a Green Conflict Studies agenda: centring the question of how environmental issues and challenges impact or are impacted by conflict and warfare. This also means recognising the military as a climate actor and driver of other industries, societal processes, and producers of scientific research, technologies, and knowledge surrounding climate change and ecological damage. Next, two more empirical sections will discuss the role of dual-use technology in the Dutch Army and the practicalities underlying the energy transition. In our conclusion, we critically assess the greening of the Army in mitigating climate change and environmental harm.

13.2 Energy, Conflict, and the Military

Many nation-states have used military power and violence to ensure or expand their domination of fossil fuels and support national economies (Gould 2007). This ecological imperialism has led to much violence and conflict, ranging from the

Iran-Iraq War of 1980–1988, or the Gulf War of 1990–1991. But also, beyond these more "renowned" fuel conflicts, military missions and operations have strong yet more implicit connections to oil and gas. According to Greenpeace (2021), "Almost two-thirds of all EU military missions monitor and secure the production and transport of oil and gas to Europe".

While alternative energy sources and systems are necessary to lower greenhouse gas emissions, it is important to recognise the broader levels of power and domination intrinsic to energy itself. Cara Daggett (2020) critiques a narrow focus on more sustainable energy sources and technologies. Reflecting on earlier energy transitions (the rise of agriculture and steam engines), Daggett argues that energy transitions are inherently a political innovation – not an outcome of more efficient or sustainable technology. "Those seeking just transitions," she writes, "go beyond asking which fuel technologies are used, and pay attention to which groups and interests control and benefit from energy systems" (2020, 646). Political will and domination make energy transitions possible, regardless of whether new technologies are inferior or suboptimal in terms of human well-being, quality, and economic efficiency. It is no surprise that the current widespread interest in more sustainable energy sources and independent infrastructures occurs parallel to a ravaging war – in which one party is an important provider of gas – and increased political tensions on an international stage. That means that studying energy is ultimately about the relationships between humans and their desire for energy.

Understanding the relationship between energy, conflict, and the military also requires us to look beyond the dichotomies of peace and war. Militaries act as major climate actors also because of the production of military weapons and materials, as well as the "logistical supply chain that makes its acquisition and consumption of hydrocarbon-based fuels possible" (Belcher et al., 2020, p. 65). This seems particularly urgent in light of what scholars have called the "everywhere war": an intensifying imperative for military responses and readiness across a multitude of converging dimensions and geographies (Gregory, 2011). Instead of delineating where military operations and warfare begin and end, then, it is necessary to recognise the role of state armed forces in climate change as a political actor and consumer of fossil fuels, much like any other industry.

Unlike other industries, however, military activities are often exempt from environmental regulations and protection in the name of national security. "That exemption," Kenneth A. Gould writes, "has made military production facilities the most ecologically devasted locations on Earth" (Gould, 2007, p. 331). This also relates to the entanglements between corporate industries and military operations: the so-called military-industrial complex. The production, storage, transport, and use of military equipment are inherently connected, which means that the military's environmental impact cannot be separated from the corporate dimension.

Since it is unlikely that military actors will rely completely on sustainable energy sources soon, Duncan Depledge (2023) uses the term "low-carbon warfare" to capture what a shift away from fossil fuels might mean for military activities in practice. These activities are not limited to actual combat encounters: they also relate to training and the development and maintenance of military bases and equipment. Aspirations and attempts to decarbonise state armed forces and warfare are likely to affect the character of military operations in various ways. This is first and foremost because military activities heavily rely on the supply, transport, and consumption of fossil fuels. Yet the use and costs of oil have increased enormously over the past decades. In addition, military forces suffer additional casualties in attempts to protect their fuel convoys (Depledge 2023), which also add to the costs of military activities and combat missions. This eventually accumulated growing pressure on NATO and Western forces to reduce energy consumption and transition to alternative and sustainable sources that, importantly, also improve the operational capacities of these units and lower their vulnerability. Decarbonisation and the transitions towards more sustainable sources, in other words, are interpreted through military goals and activities.

While lowering the emissions of greenhouse gases would be admirable and desirable, it is second to operational imperatives and military doctrine developed to defend national interests. Indeed, to military actors, the idea of energy security is somewhat different from the more conventional use in terms of economic and political independence. "Defense energy and security efforts are more directed at achieving military missions and strategic objectives" (Samaras et al., 2019, p. 1). Military actors are primarily interested in energy transition when it also reduces the vulnerability of its operations, and the research and development of new technologies to realise and implement new energy systems should be understood in this light. At the same time, we would like to downplay a claim of "defense exceptionalism" and point out how military energy concerns often collide and shape civilian energy needs and industries.

Especially in times of conflict, military energy needs often prevail over civilian needs, where "the military would be the first buyer of any domestically produced fuels, and the US Defense Production Act enables the President to prioritise energy procurement for national security" (Samaras et al., 2019, p. 2). Academics and policymakers even identify the economic opportunity and political incentive to increase military-civilian collaborations in this regard, "especially as one considers the greening of the military operations" (Samaras et al., 2019, p. 9).

Focusing on the US military's supply chains, Oliver Belcher and colleagues (Belcher et al., 2020) investigate various sub-agencies of the US military, documenting how energy, services, and munitions are delivered. Uncovering the US military self-provisioning of infrastructure and material resources, the authors document the conditions under which these armed forces have operated over the past 20 years. These "military doctrines", or "combat paradigms", have significantly altered its hydrocarbon infrastructure. For example, the contemporary form of "hybrid warfare" involves the use of information-based technologies and drone warfare, as well as an energy system that enables it. Studying this overlooked section of the military apparatus, the authors point out, "is important to expose the oft-overlooked aspects of the military's ability to wage the everywhere war" (Belcher et al., 2020, p. 67). What is particularly insightful here is that they demonstrate how military operations are ultimately embedded and enabled by political choices and economic interests made in the past.

Innovation, not just in the context of climate change, has increasingly become the main strategy for militaries across the world to respond to a range of identified threats. As part of this development, warfare and armed conflict became an opportunity to experiment. Marijn Hoijtink (2022) points out that wars are endless and everywhere, not because of the representation of the enemy, but exactly because of the broader experimental infrastructure that is created and that needs to be maintained. This emerging interest in low-carbon warfare is not new from a Western perspective and could be aligned with a military doctrine that aims to "conduct the business of war through a combination of self-restraint, risk transference and a reliance on technological 'fixes', all girded by a persistent belief in the utility of force to as a means to securing political ends" (Depledge, 2023, p. 677)

Until more recently, political choices have always perpetuated and intensified hydrocarbon-based path dependencies. Several military actors increasingly experiment and develop new military hardware and supply chains. The United States military has become a prominent case in point. In 2012, the US Navy demonstrated its latest naval strike force, the "Great Green Fleet" (GGF). The GGF is exemplary of a broader, yet often discursive, attempt to change the military's "long-standing and complicated logistical relationships with fossil-fuel infrastructures in light of emerging geopolitical entanglements influenced by climate change" (Bigger & Neimark, 2017, pp. 13-14). This is not a form of "greenwashing"; a way of marketing and otherwise publicising sustainability efforts that are marginal at best, and non-existent or counterproductive at worst. "The Navy's move toward biofuels is framed as a 'win-win-win'", Patrick Bigger and Benjamin D. Neimark argue, "as it looks to deliver positive environmental outcomes, while also furthering national security priorities and subsidizing a new US industry. These three aims are coincident with the analytical outlook of geopolitical ecology, encompassing geopolitics and political ecology, which in turn integrates political economy with environmental change" (Belcher et al., 2020, p. 14)

With climate change as a major factor for contemporary preparations for future conflict, the GGF is about building "infrastructure capacity and changing material provision, including US unconventional fuel refining and distribution capacity" (Bigger & Neimark, 2017, p. 14). Critical of the military's environmental projects and ambitions, the authors warn that militaries might mobilise specific projections of future threats in which the military itself is essential for responses to these impending dangers. Breaking away from fossil fuel infrastructures, then, is about enabling more military flexibility and capacity to respond to these threats. Consequently, the alignment of goals between civilian and military actors, particularly in the domain of energy, provides an intriguing subject for study. In the next section, we introduce the underlying notions of the Dutch Army's attempt to materialise a future base of military operations.

13.3 Energy Transition in the Dutch Army

The civilian industry has traditionally functioned as a customer-supplier relationship for the military. In recent times, however, there has been a transition towards working with civilian partners more collaboratively. The military is now seeking to address societal challenges by embracing an open innovation approach, where cooperation partners play a more significant and transparent role. This departure from the conventional technology-driven approach to weapons production signifies a willingness to innovate in response to societal concerns. We identify two main dimensions through which the Dutch Army seeks to transition to alternative energy sources and systems: (1) the development and implementation of Dual-Use Technology, and (2) the innovation within the experimental platform of the FieldLab SmartBase.

13.3.1 Dual-use technology

When it comes to transitioning to alternative energy infrastructure and low-carbon warfare, the Dutch Army's primary motivator is to reduce exposure to uncertainty and vulnerability. This includes strategic autonomy (e.g. no Russian oil and gas), less dangerous logistics (i.e., transporting fossil fuels through areas of conflict), and increasing self-sufficiency in the field. With mounting pressure from political and societal actors, the Dutch Army considers "dual-use" technology to be key in addressing the challenge of lowering their carbon footprint. Energy transition in the Dutch Army holds significant importance within the context of specific geopolitical and ecological conditions that shape conflicts. The Dutch armed forces' need for military innovation is intimately tied to their three core tasks: defending national and allied territories, enforcing the national and international rule of law, and providing disaster and crisis assistance. As indicated by multiple press releases and policy documents, the Dutch government acknowledges that climate change and energy transition have direct implications for the security landscape, thereby influencing operations associated with these core tasks.

Specifically related to sustainability in the armed forces, the MoD states that climate change and energy transition directly impact the security situation and therefore influence operations related to these three core tasks of the Dutch armed forces. To address sustainability within the armed forces, the Dutch MoD has outlined three mission statements that encompass a range of objectives. First, the MoD is concerned with the anticipation of climate change effects in the design of military operations and examines which "adaptations" are required. Examples here include the potential to reuse water in military camps and to make properties more sustainable. Second, the MoD wants to reduce its dependency on fossil fuels, adhering to the Dutch government-wide goal of reducing CO_2 emissions by 55% by 2030. The MoD states it will invest heavily in high-performance equipment in the coming years. Since they expect fuel consumption to increase, they highlight that military equipment will have an increasing impact on total CO_2 emissions. About 60% of the MoD's CO_2 emissions come from operational equipment, which includes military, encampments, and the equipment of individual soldiers. Kerosene has by far the largest share of operational equipment emissions (more than half), followed by marine diesel and the diesel consumed by vehicles. Third, the MoD strives to develop the circular use of material, goods, services, and infrastructure. Concerned with diminishing raw materials, the MoD expresses a desire to reduce their use of these resources and work towards climate-neutral business operations (van der Maat, 2023). The MoD believes that the achievement of these mission statements relies on the development of innovative military concepts and the adaptation of existing ones.

The Dutch Army employs "concept development and experimentation" (CD&E), which aligns with the NATO doctrine in facilitating the creation and refinement of the necessary novel military concepts. This process involves a comprehensive analysis of operational requirements, followed by the identification and testing of potential solutions within an experimental framework before their implementation across military services. The CD&E process not only validates technological solutions but also facilitates the development of associated military concepts, which define the operational procedures and implications of introducing novel technologies into military organisations and operations (Kõrts, 2022). This process further concentrates on the use of available solutions in existing markets, as opposed to more lengthy technological development programs that follow a linear Research and Design structure. This means that the MoD is specifically interested in civilian concepts with a high level of maturity or readiness, and not so much in developing new technologies, purely designed, and tested for the military setting. The Army's Innovation Branch focuses on these dual-use themes, of which energy transition is a priority, and establishes connections and partnerships between civilian societal challenges, technological opportunities, political needs, and military realities.

The CD&E process encompasses several distinct phases, ensuring a systematic approach to testing and implementing novel technologies. The four main phases of this process, as operationalised by the Army, are outlined below. The first phase, scouting of CD&E opportunities, involves active surveillance of technological advancements and external collaborations to identify relevant solutions in civilian settings that align with operational needs. The second phase, the articulation of operational needs, involves a comprehensive analysis of the requirements, considering factors such as logistics, maintenance, compatibility with current military practice, and the impact on existing doctrine (such as the use of energy sources). The objective is to create a clear understanding of the implications of implementing the novel technology in military operations. A third phase focuses on conducting experiments and developing and refining the associated military concept. It involves testing the identified solution in experimental settings to assess its feasibility, functionality, and effectiveness. Such experiments are first conducted in smaller experimental settings (such as the FieldLab SmartBase discussed in the next section), before being sent out to active military exercises or even operations, if possible. The experimentation phase may include collaborations with civilian or industrial partners, allowing for smaller-scale testing and evaluation before progressing to large-scale procurement and implementation within the military. The final phase involves documenting the developed concept and releasing it to the appropriate organisational locus for implementation and adaptation. This phase ensures that the concept is effectively communicated, and necessary adjustments are made to facilitate successful integration into military practice. The goal of the CD&E process, therefore, is not the implementation of developed concepts, but the delivery of implementable concepts, fit for military practice.

The CD&E process, within a partially open innovation environment, not only aids the military in addressing the environmental impact of military operations but also provides valuable contributions beyond military contexts. Collaborations with civilian and industrial partners offer a twofold benefit. Firstly, such collaborations assist the military in mitigating the environmental consequences of its operations. Secondly, the unique nature of military capability development and the niche provided by military organisations can aid in bridging the gap between conceptualisation and solution development for civilian use of technology, potentially overcoming challenges commonly referred to as the “valley of death” in innovation. Experimental grounds, such as those in Ede, serve as examples of environments where successful collaborations and experimentation have taken place.

The CD&E process plays a vital role in incorporating novel technologies into military operations. By systematically analysing operational needs, testing potential solutions, and developing associated military concepts, the military can ensure the successful implementation and deployment of innovative technologies. The process facilitates collaborations with civilian and industrial partners, allowing for knowledge exchange and the potential transfer of technological advancements to civilian applications. The Army's phased approach to concept development and experimentation serves as a valuable framework for future innovation initiatives within the military sector, leading to enhanced operational capabilities and reduced environmental impact.

The energy transition program in the Army highlights a significant shift in the relationship between the military institution and the private and corporate sectors. In realising this transition, the private and corporate sector has become a more prominent and important actor in military capability development. This change is driven by several factors, including the recognition that the military does not possess all the necessary answers and solutions within its sphere. Instead, there is a desire to leverage existing solutions from the civil market, particularly in the context of dual-use technologies with high readiness and concept maturity levels. In the energy transition, the complexity of managing the entire supply chain and achieving goals such as reducing fuel dependency requires close cooperation with civilian partners. This represents a departure from the established norms and practices within the military context. Collaboration with civilian partners brings a different perspective and expertise, enabling the military to explore innovative and open ways of addressing societal challenges. It also aligns with the government's role of avoiding market disruption and adopting an ecosystem perspective in which the military increasingly plays a role in servicing civilian economic settings as well.

Breaking the traditional chain of procurement is another crucial aspect of this changing relationship. In developing energy transition concepts, the military actively invites external and civil partners to participate in the process. Rather than having a predefined understanding of the desired outcomes, the military is now engaging in pre-procurement collaboration to explore potential solutions. This shift is in line with the more open approach adopted by organisations such as NATO, where problem statements are published to encourage external input and collaboration.

13.3.2 The military base of the future?

In 2016, the Army's Innovation Branch initiated the "FieldLab Smart Base", which serves as a physical environment and business program dedicated to exploring and developing the concept of the "military base of the future". The Fieldlab Smartbase is a great example of an experimentation environment in which a multitude of public and private players can not only test their specific technology but also act as a platform for innovation where combinations of technologies can lead to new concepts. Located near the town of Ede, this facility enables military personnel to experiment with sustainable solutions and materials. Examples of ongoing investigations include the utilisation of solar panels, advanced energy storage systems, and geothermal energy. A fitting example of how existing solutions can contribute to the development of military concepts is the "Battery Wagon" or BaWa (Wolting, 2023). By using existing energy storage technologies (batteries) and placing these in a shipping container, similar to how diesel generators would be built, a technique called "peak shaving" becomes possible in remote locations and on military encampments. Peak shaving is about managing unexpected spikes in energy demand. The BaWa can thus function as an additional energy source when needed.

In the MoD online magazine, a commanding officer writes that since we currently know that diesel is bad for our planet, numerous alternatives are being considered to reduce the use of fossil fuels in various operations. In addition, the units currently used provide much more power than is required. By adding the BaWa, fewer generators need to be deployed in less time, because the BaWa can take over a very large part of the energy supply. This reduces diesel consumption and overall costs of energy. At the same time, the maintenance burden is automatically reduced because the generator has fewer running hours. The noise and heat signature of the unit is also reduced. According to the program manager for Energy Transition, Gerben Seevinck, the BaWa came out of an experiment with a civilian trailer and a large accumulator. Although they found that it worked on a concrete slab, something more robust was required for the battery to operate in the field. "Because that's always what we're all about," Seevinck adds, "finding as many advantages as possible for the men and women doing the operation. Well, step two was quick. Not a civilian trailer but a military trailer that could easily be put behind a four-ton truck – it could go straight into the field" (Wolting, 2023).

A high degree of energy security and an increase in readiness offers the Dutch Army an operational advantage. An additional advantage is that this battery wagon is highly mobile, and currently experiments in mobile settings are also being conducted. Trend-wise, the energy consumption of (weapon) systems (heavier, bigger, and faster), in real estate in the Netherlands and encampments in mission areas is increasing. Simultaneously, the cost of fuel is fluctuating, and reducing fossil fuel consumption is becoming increasingly important for the effectiveness of both readiness and actual operational deployment of units. While there are currently no intentions to purchase BaWa en masse, researchers have collected enough data to further develop the wagon, install solar panels, and continue to promote its usefulness in various conditions.

The BaWa is one example of reducing the carbon footprint of operational encampments (as it would in a civilian setting) and brings military advantages such as silent generation of power, a decreased need for generator backup, and less logistical pressure on the delivery of diesel. The Smart Base also facilitates collaborations between the military and civil and commercial partners, ensuring the development and provision of necessary applications. By enhancing their operational capacity, and adaptability, and reducing their ecological footprint and dependence on fossil fuels, the Dutch military aims to address the challenge of reducing the environmental impact of military operations (van der Maat, 2023).

A second example here concerns the Kitepower Project, which is a system that generates electricity by flying a kite tethered to a generator. Together with the Delft University of Technology, the system was specifically developed to be lightweight, mobile, and easy to maintain, repair, or replace (da Costa et al., 2023). Specifically, the Kitepower Falcon 100kW Airborne Wind Energy System (AWES) is being deployed within the Dutch Defence's training area near wind farm "Vader Piet" on the island of Aruba. The primary objective of this endeavour is to test the operational viability of the system as part of the military exercise Caribbean Engineer 2021. According to the developers of Kitepower, these tests mark a significant milestone for both Kitepower and the broader Airborne Wind Energy industry. It signifies the first-ever deployment of a Kitepower operation beyond the confines of the European continent and represents the inaugural utilisation of an Airborne Wind Energy system within the Caribbean region. According to the company's press release, the logistical operation provided an excellent opportunity to evaluate the system's transportation and installation advantages, reaffirming its considerable potential. Unlike the challenges encountered when transporting conventional wind turbines, such as issues related to excessive weight and dimensions, the transportation of the Kitepower Falcon 100kW AWES demonstrated its strategic capability to reach rural and remote areas using ordinary and even narrow roads. The successful completion of the entire journey with the involvement of two standard trucks, one for the Kitepower system and another for the Greener battery, further underscored the system's logistical prowess (Kitepower, 2021).

The utilisation of these systems within the framework of EU defense holds the potential to bolster the availability of renewable energy sources. This can be achieved through their integration into military microgrids, thereby contributing to the mitigation of fuel consumption, particularly concerning diesel generators, and reducing reliance on fossil fuels. Consequently, this innovative approach not only yields cost savings but also aligns with the articulated aspirations of EU MoDs in terms of greenhouse gas emissions reduction, bolstering resilience and energy security, and facilitating the alignment of the defense sector with EU objectives about energy and climate neutrality by the year 2050. Moreover, defense-related initiatives of this nature possess the ancillary advantage of expediting the advancement of novel technologies that have the potential for broader civilian applications and can facilitate the ongoing energy transition.

The collaboration between civilian industries and the military presents potential risks, such as the weaponisation of technology and the malevolent use of initially peaceful technologies. In response, the MoD states that they have implemented policy instruments, including export controls, institutional oversight, and labeling of Dual Use Research of Concern by the World Health Organisation (WHO, 2020). Moreover, the clear distinction between military operational challenges and societal challenges is becoming less feasible, with safety and security emerging as prominent societal concerns in Western society (Montgomery, 2020).

13.4 Conclusion

Recent scholarship seems increasingly concerned with how warfare impacts the environment, or how the environment is weaponised in times of violent conflict. Historians show "that weapons and armies become ever capable of creating environmental disturbances that continue to increase in magnitude, type and, perhaps, frequency" (Hupy, 2008, p. 417). Yet others – including advocacy groups – are quick to point out that preparing for war and maintaining military capacity cause environmental harm long before the actual and more visible use of the weapons of war. Indeed, building and sustaining military forces consumes vast quantities of resources and this is only likely to increase in the foreseeable future. In this chapter, we have attuned this scholarly attention to the role of the military as a climate actor. Militaries across the world increasingly recognise the important linkages between climate change, their ecological footprint, and their capacity to prevent, intervene, or otherwise respond to geopolitical tensions and conflict. We have examined how the Dutch Army aims to adhere to national goals to reduce greenhouse gas emissions by transitioning to new energy sources and solutions.

Moving beyond oil in any meaningful way remains a challenge to many industries and state institutions, and the military is no exception. Decarbonisation, however, as many also identify, is in the self-interest of state-armed actors. The tightening of international and legal regulations regarding greenhouse gas emissions, together with the increasing costs and dependency on fossil fuels as an operational vulnerability, has made it possible to imagine the reality of low-carbon warfare (Depledge, 2023). As of now, major militaries across the world, including the US, India, and China, appear to improve their energy efficiency and examine the use of new systems based on, for example, solar power. The energy transition in the Dutch Army illustrates a fundamental transformation in the relationship between the military institution and the private and corporate sectors. The increasing importance of the private and corporate sectors as a partner in realising this transition reflects a recognition that the military cannot achieve its goals alone. The shift towards collaboration, open innovation, and ecosystem thinking enables the military to tap into existing solutions, address societal challenges, and navigate the complexities of the energy transition more effectively and sustainably.

The energy transition in the Dutch Army poses several challenges that need to be addressed. These challenges can be categorised into technological, logistical, and operational aspects. Technological challenges arise from the need to adopt and integrate renewable energy technologies within the existing infrastructure of the Dutch Army. This includes transitioning from fossil fuel-based energy sources to alternative energy sources such as solar, wind, and geothermal energy. Logistical challenges stem from the requirement to establish robust and reliable energy supply chains to support military operations. The deployment of renewable energy systems, such as solar panels and wind turbines, necessitates effective planning and coordination to ensure an uninterrupted energy supply, even in remote or challenging environments. This involves addressing issues related to energy storage, transmission, and distribution to meet the power demands of military bases, vehicles, and equipment. Operational challenges emerge from the need to adapt military strategies, tactics, and procedures to account for the energy transition. The use of renewable energy sources may impact the mobility, range, and endurance of military assets. It may require new operational concepts, such as energy-efficient practices, optimised mission planning, and changes in training and doctrine. Additionally, the integration of renewable energy technologies may introduce new vulnerabilities and risks that need to be identified and mitigated to ensure the resilience and security of military operations. Financial considerations also pose a significant challenge. The transition to renewable energy technologies and the associated infrastructure investments requires substantial funding. Securing the necessary financial resources and managing the cost-effectiveness of energy transition initiatives while balancing other defense priorities can be complex.

It is also important to remain cautious here and to recognise the potential to “greenwash” military operations by foregrounding its intentions and marginal programs that aim to account for its significant environmental impact. Indeed, much of what we have discussed here is still in the early stages and has yet to be implemented on a larger scale. The question that we ultimately might see come to the fore relates to how efforts to decarbonise the military eventually impact the reality and practice of warfare altogether. Would the development and use of sustainable energy sources and weapons broaden the scope of how adversaries fight each other? Will the potential of low-carbon warfare and thus the realisation of cleaner conflicts perhaps increase the likelihood of the use of violence and aggressive strategies? These are fundamental issues, in line with a conflict studies school of thought that critically assesses whether the pursuit of decarbonisation is "simply another way of perpetuating the use of war by extending the utility of military force into a net-zero future?" (Depledge, 2023, p. 684)

Although small in terms of impact and application, the innovations and strategies discussed in this chapter demonstrate that developments in the Dutch Army are promising. It is clear how the Army could make use of new partnerships and alternative energy sources to reduce its environmental impact. As a nationally significant and politically powerful institution and polluter, the Dutch Army can be a prominent driver of a broader shift towards more sustainable energy sources. Ideally, as Middendorp (2022) points out, these efforts can eventually be scaled up to the development of more advanced materials and international collaborations and strategies. This also involves raising awareness among military personnel and politicians about the importance of sustainable energy practices and fostering a culture of energy conservation and efficiency. At the same time, training programs and educational initiatives should be implemented to ensure that soldiers and personnel are adequately equipped with the knowledge and skills to operate within the constraints and opportunities of renewable energy systems.

For now, by explicitly recognising their impact on the environment and stating the desire to reduce their carbon footprint, militaries shift away from more conventional strategies regarding ecological damage: to stay silent. The Dutch Army obviously cannot address the sizeable impact militaries across the world have on the environment on their own. Yet, the Netherlands can potentially accelerate this trend by endorsing significant changes on a European, and possibly global scale. As a NATO member state, the Netherlands can contribute to regional cooperation that aims to recognise and reduce the environmental impacts of defense expenditures and industries.

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CHAPTER 14

Alternative Fuels, Propulsion and Power Systems for the Future Navy – A Route Towards Reduced Emissions and Signatures, and Fossil Fuel Independence

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Abstract

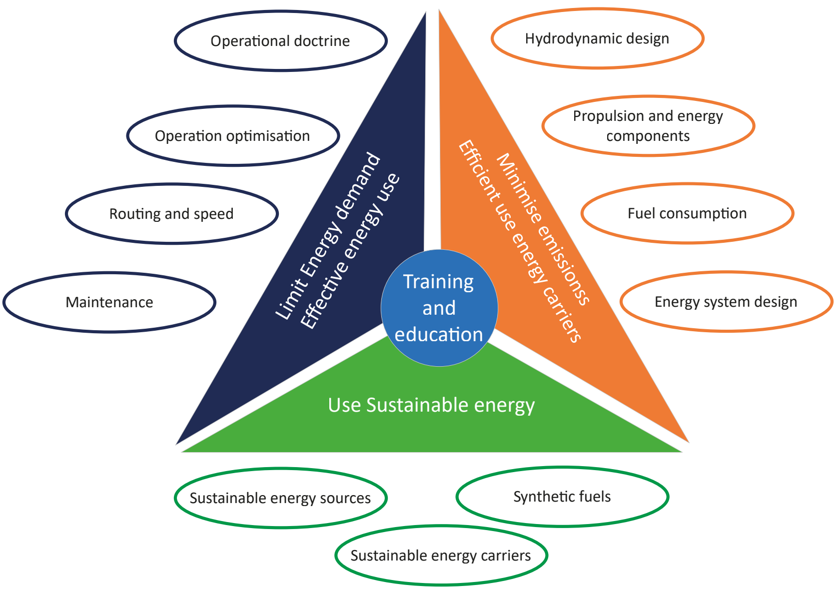
The sustainability policy requires the Netherlands Ministry of Defense (MoD) to become largely independent of fossil fuels in the coming decades, while at the same time the geopolitical situation requires the Armed Forces to operate globally. Therefore, the Royal Netherlands Navy needs to reconsider its fuel strategy, to gradually change to energy carriers from renewable sources, and to redesign its power and propulsion system, both to improve efficiency and to reduce its emissions and signatures. The aim of this chapter is to provide a critical review of the challenges and opportunities of the transition to alternative energy carriers and energy systems and to provide a direction for the required research and development towards the future Navy fleet that can operate independently of fossil fuels and with minimal signature. First, the chapter reviews production, expected availability and projected development of cost of the various alternative fuels, with a specific focus on hydrogen, methanol, and renewable drop-in alternatives for naval distillate fuels, according to NATO F-76 specifications. Subsequently, the chapter will discuss the impact of these three fuels on three differently sized navy vessels, that are currently considered for replacement: diving vessels, seagoing support vessels, and future surface combatants. For these three use cases, the chapter also discusses the potential power and propulsion system configurations and the opportunities to reduce signatures by alternative power supplies, such as fuel cells and batteries. Based on this analysis, the chapter will propose a fuel selection strategy for future navy vessels and will discuss the required research and development that is required to achieve the identified opportunities. The chapter closes with conclusions and recommendations on the route towards a future fleet that can operate globally independent of fossil fuels.

Keywords: military, ships, energy, power systems, fuel, emissions

14.1 Introduction

The fourth International Maritime Organisation (IMO) Greenhouse gas (GHG) Study 2020 (Faber, et al., 2021) concludes that shipping greenhouse gas emissions have grown from 2012 to 2018 due to a growth in shipping activity and that the IMO's GHG reduction ambition of 50% by 2050 (International Maritime Organisation, 2018) can only be achieved using low-carbon fuels. At the same time, the Netherlands Ministry of Defense (NL MoD) also strategically wants to reduce its dependency on fossil fuel, according to its energy and environment strategy (Bijleveld-Schouten, & Visser, 2019) and the subsequent sustainability policy (Maat, van der, 2023). Concurrently, it aims to minimise signatures, such as noise and infrared, for operational reasons. Because of this strategy, the Royal Netherlands Navy must become progressively independent of fossil fuels, while maintaining its operational autonomy and reducing its signature. The 'Roadmap Energietransitie Operationeel Materieel' (Gales, 2022) describes how the Netherlands MoD aims to reduce its dependency on fossil fuels by three courses of action, the so-called '*trias energetica*' illustrated in Figure 14.1: limiting the energy demand by effective use of energy, minimising emissions by efficient use of energy carriers and use of sustainable energy sources.

Figure 14.1. 'Trias Energetica' of the MoD – three lines of reducing the MOD's dependency on fossil fuels supported by training and education, adapted from (Gales, 2022).



The first course of action to reduce the dependency on fossil fuel is to reduce the energy demand of naval vessels. Optimal operations planning (Laan, Barros, Boucherie, Monsuur, & Noordkamp, 2020), ship weather routing (Zis, Psaraftis, & Ding, 2020), improved maintenance (Valchev, et al., 2018; Kartatug, Arslanoglu, & Guedes Soares, 2023) and hull optimisation and Energy Saving Devices (Schuilinga, & Terwisga, 2017) can contribute to significant reductions of the required propulsion power. Therefore, during fleet planning, operational doctrines and tactics need to be developed, during ship design, the hull form needs to be optimised and during the lifetime of naval vessels, maintenance strategies and energy saving devices should be considered, such as the hull vane for the Holland class OPV's (Bouckaert, Uithof, Moerke, & Oossanen, 2016). Unfortunately, the reductions resulting from these measures are insufficient to reach the goals of the IMO GHG strategy and Defence Operational Energy Strategy (Faber, et al., 2021). Therefore, this work focuses on minimising the emissions and using energy carriers efficiently through the power plant design with hybrid propulsion and power generation (Geertsma, Negenborn, Visser, & Hopman, 2017) and the possibilities and limitations of using sustainable energy carriers (Pothaar, Geertsma, & Reurings, 2022).

14.1.1 Literature review

Figure 14.2 shows the possible pathways from energy source to use in the energy system of the ship (Pothaar, Geertsma, & Reurings, 2022). Every conversion step from energy source to energy carrier costs energy, as will be covered in Section 14.2. It is practically possible to convert sustainable energy sources to drop-in fuels as energy carriers like e-diesel, which also is the aim for aviation with Sustainable Aviation Fuels (SAF) (Juan, Hoang, & Cheng, 2023). The Well-To-Tank (WTT) efficiency of these so-called *electro fuels* is significantly higher when using short chain energy carriers such as hydrogen or methanol (Brynolf, Taljegard, Grahn, & Hansson, 2018) (Table 14.3). On the other hand, large surface combatants, one of the types of naval ship considered in this article, have a very challenging typical autonomy requirement of 30 days of independent operation at sea and a range of 5000 NM at 18 kts. With a typical fuel capacity of 600 m3 or 530 tons for a Large Surface Combatant, replacing diesel oil with lower density hydrogen or methanol fuels directly adds 1200 or 600 tons displacement, respectively (Pothaar, Geertsma, & Reurings, 2022), as shown in Figure 14.3 (Van Kranenburg et al., 2020). Moreover, operations take place worldwide in international NATO fleets and refuelling from any NATO partner is a requirement when operating in a NATO context. Therefore, when establishing the future fuel strategy, the trade-off between production cost and the impact on the ship design and its global operation needs to be considered.

Figure 14.2. Possible fuel production pathways from energy source to biofuel and e-fuel (Pothaar, Geertsma, & Reurings, 2022).

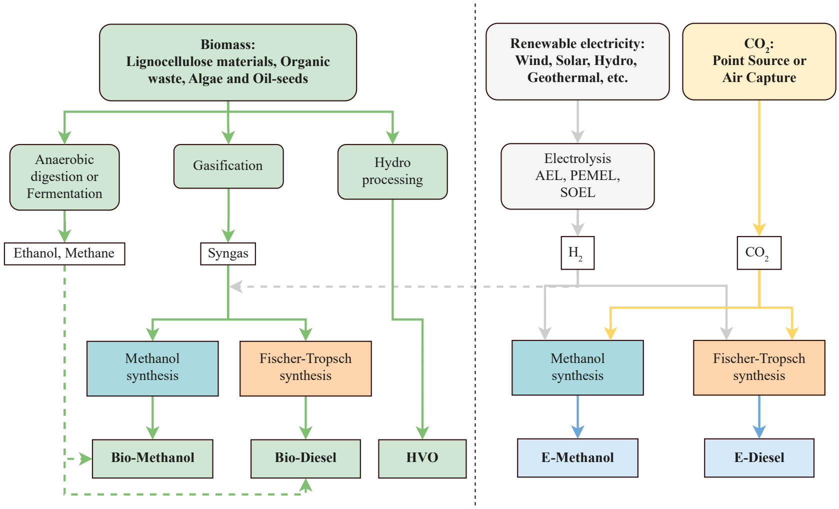
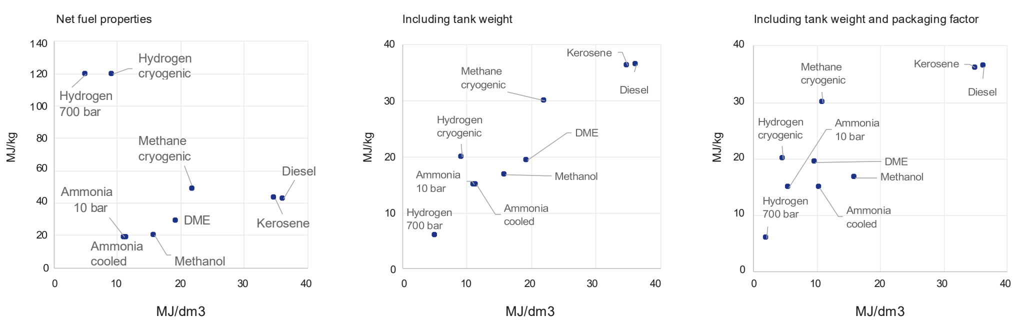


Figure 14.3. Energy density and specific energy of fuels with and without the tank weight and volume (Kranenburg, et al., 2020).



The choice of fuels considered for maritime application is extensive and ranges from hydrogen, alcohol fuels, such as methanol, ethanol and butanol, other carbon-based fuels, such as dimethyl ether, methane, liquefied natural gas (LNG) and liquefied petroleum gas (LPG) to ammonia, which contains no carbon, like hydrogen. Methanol is a liquid fuel that is representative of other alcohol fuels and dimethyl ether, which are more energy intensive to produce (Brynolf, Taljegard, Grahn, & Hansson, 2018). Gaseous fuels, such as methane LNG and LPG, are fossil fuels, are more difficult to store, and cannot be produced more efficiently from sustainable feedstock then methanol. Therefore, this study considers hydrogen as a fuel which can be applied for small assets as the starting point for all green fuels, methanol as the most easily produced green fuel that is liquid in ambient conditions and biodiesel and e-diesel, as a sustainably produced drop-in-fuel for distillate fuel oil. The biggest impact of alternative fuels on the ship design is determined by the energy density of the fuel as shown in Figure 14.3 (Kranenburg, et al., 2020). The fuel choice also drives other design aspects, such as safety measures as cofferdams and separated fuel treatment or pump rooms, the choice of propulsion and power system architecture and the choice of power sources.

14.1.2 Aim and contribution

This chapter aims to discuss the impact of fuel choice and propulsion and power system architecture on the design of several typical naval vessels, to provide a strategy for research and development towards sustainable power systems with minimal emissions and sufficient autonomy for the future Navy. First, the chapter reviews the production, expected availability and projected development of cost of the various alternative fuels, with a specific focus on hydrogen, methanol, and renewable drop-in alternatives for naval distillate fuels, according to NATO F-76 specifications, based on an extensive literature review. Subsequently, the chapter discusses the impact of these three fuels on three differently sized navy vessels, that are currently considered for replacement: diving vessels, seagoing support vessels and future surface combatants. For these three use cases, the chapter also discusses the potential power and propulsion system configurations and the opportunities to reduce signatures by alternative power supplies, such as fuel cells and batteries, and assesses these configurations qualitatively. Based on this analysis, the chapter will propose a strategy for fuel selection for future naval vessels and will discuss the required research and development to achieve the identified opportunities. The chapter closes with conclusions and recommendations on the route towards a future fleet that can operate globally independent of fossil fuels.

14.2. Production, Availability and Cost of Sustainable Fuels

The fuel choice has a major impact on the ship design, the power system design and operation of the ship. Table 14.1 (van de Ketterij, 2018; Verhelst, Turner, Sileghem, & Vancoille, 2019; Moirangthem & Baxter, 2016; Ryste, Wold, & Sverud, 2019; Ellis & Tanneberger, 2015) reveals the most important fuel characteristics of the different fuels discussed in this chapter. Energy density, usually described by the Lower Heating Value (LHV) of the fuel, together with gravimetric density and boiling point, determine required mass and volume for storage of the energy required for the operation. Toxicity, flash point and explosion limits directly follow from the chemical composition of the fuel and determine required safety precautions and safe zones around the fuel system.

Fuels with a boiling point well below atmospheric conditions are stored on board of a ship mostly as a liquid at low temperatures. For hydrogen, this would require a storage temperature of around 20 Kelvin, which is hard to obtain, so storage at a pressure of 700 bar is also considered. This leads to considerable weight and volume costs for storage. Storage of 1 ton of hydrogen typically requires 10 to 15 tons of storage system, and 30 to 40 m³ of volume. Table 14.2 lists the resulting volumetric requirements for the storage of different fuels, compared to diesel.

Table 14.1. Properties of the fuels considered in this study.

		Diesel*	Hydrogen	Methane	Gasoline***	Methanol	Ethanol	Dimethyl ether	Ammonia
Chemical composition		$C_{14}H_{30}$	H_2	CH_4	C_8H_{18}	CH_3OH	C_2H_5OH	CH_3OCH_3	NH_3
liquid density	kg/m³	847	708,5	426	750	792	789	660	683
density (gas)	kg/Nm³		0,083**	0,66				1,62	0,77
LHV	MJ/kg	42,6	119,9	50	44,5	20,3	22	28,4	18
energy density	MJ/NL	37,2	1,45	0,076	43,6	14,3	17,5	18,7	0,024
flash point	°C	70,5	-253	-188	-42,8	11,1	13	-41	NA
boiling point	°C	180 – 280	-253	-162	150	65	78,1	-24	-33,2
cetane number	-	38-53	-	-	18	5	12	60	-
octane number	RON	15-25	135	120	90-98	108,7	110	15	130
auto ignition temp	°C	255	560	595	460	464	363	350	650,9
flame speed	m/s	0,8	3,25	0,4	0,41 – 0,58	0,56	0,58	0,45	0,18
Flammability limits (vol)	%	1,85-8,2	4-75	5-15	1,4-7,6	6,7-36	3,3-19	2-50	15-28
heat of vaporisation	kJ/kg**	250	224,5	512	375	1089	841	467	1371

** ranges from* C_9H_{20} *to* $C_{25}H_{52}$

*** at a pressure of 1 bar, excluding construction weight; at 700 bars, density is 42 kg/m³*

**** content is a mixture ranging from* C_6H_6 *to* $C_{10}H_{22}$

Table 14.2. Volumetric and mass requirements (only energy carrier, excluding constructional weight) for energy storage of different fuels compared to diesel.

		Diesel	Hydrogen**	Methane	Gasoline	Methanol	Ethanol	Dimethyl ether	Ammonia
Storage capacity	m^3	200	1460	677	216	449	416	423	680
Volume compared to diesel	(-)	1	7,2	3,4	1,1	2,2	2,1	2,1	3,4*
Storage capacity	ton	169	62	288	162	356	328	279	464
Mass compared to diesel	(-)	1	0,36	0,9	1	2,1	1,9	1,5	2,4
Weight of fuel and storage	ton	330	1200***	382	316	693	640	496	781
Total mass compared to diesel		1	3,3	1,2	0,96	2,1	1,94	1,5	2,4

** when stored as a liquid*
*** when stored at a pressure of 700 bar, excluding construction volume*
**** reference: (Hoecke van, et al., 2021)*

14.2.1 Production process and production efficiency

The production efficiency of a bio-, or e-fuel is an important parameter when assessing the overall impact of the fuel chosen on potential independence of fossil fuels. The efficiency represents the ratio between the energy requirement of the production process and the resulting energy in terms of Lower Heating Value (LHV) stored in the fuel resulting from the production process. Table 14.3 shows the production efficiency typical for the different fuels. Hydrogen appears to be the most promising fuel from a production perspective, with ammonia the second best. Production efficiency of e-diesel is slightly lower than of e-methanol. This is the result of additional production steps required to produce the longer molecule chain of diesel. E-hydrogen can be produced at quite high efficiency. The process is rather simple and can easily be scaled-up. Ammonia requires nitrogen to combine with hydrogen. Nitrogen is abundantly available in the atmosphere, whereas carbon dioxide – required to produce e-methanol and e-diesel – is less abundant in the atmosphere. This explains the higher efficiency of e-ammonia compared to e-methanol or e-diesel.

Production efficiency of biofuels is generally higher than that of e-fuels, and shows a large variation. The higher efficiency is caused by the fact that energy for the feedstock production is not accounted for, as nature delivers this energy. The large variation is caused by the production process. Bio-methanol and biodiesel can be produced through various production processes. The process depends on the desired fuel and the used feedstock. Organic waste from food processing or crops is typically used for anaerobic processes such as fermentation or digestion, resulting in ethanol and biogas (consisting mainly of CH_4 and CO_2), respectively. Lignocellulose feedstocks are considered suitable for gasification. This is a process that converts biomass by endothermic reaction without combustion to synthesis gas, consisting of H_2, CO, CO_2, H_2O and CH_4. If desirable, the resulting products, hydrogen, and synthesis gas, can be further synthesised into other fuels. Vegetable oils are commonly used to produce FAME biodiesel and HVO biodiesel through transesterification and catalytic hydro processing, respectively. To increase the production yields of biomass, H_2 can be added to the excess CO and CO_2 generated in the biomass-to-fuel conversion process. This will generate additional fuel without the need for energy intensive carbon capture. Huang & Zhang (2011) estimated the biomass-to-fuel efficiency for bio-methanol around 54% and around 51% for biodiesel, by dividing the energy in the resulting fuel and the energy content in the biomass, without significant inputs or outputs of other energy.

Table 14.3. Overall production efficiency of methanol and diesel for two different production options (table extracted from Pothaar, 2023; Jepma, Kok, Renz, Schot, & Wouters, 2018; Fasihidi & Breyer, 2018; IRENA & Methanol Institute, 2021; van de Ketterij, 2018; Prussi, yugo, & Prada, 2020).

Fuel Type	**Overall production efficiency %**
Bio-methanol	54 – 75 %
Biodiesel	51 – 83 %
E-methanol	41 – 62 %
E-diesel	37 – 60 %
E-hydrogen	73 %
E-ammonia	66 %

14.2.2 Future availability

Methanol is a readily available product worldwide, with a production of around 100Mt per annum. Most of the produced methanol originates from fossil sources, natural gas and coal (Methanol Institute, 2021), leading to more GHG emission than diesel in a life-cycle analysis under equal circumstances (Balcombe, et al., 2019). The availability of sustainable methanol is limited: currently the production capacity is below 1% of the yearly produced methanol volume. For future availability of sustainably produced methanol, the Methanol Institute (International Energy Agency, 2021) in 2021 and DNV in 2023 analysed the market development of sustainable methanol production facilities. DNV expects that 11 million tons of oil equivalent (Mtoe) will be produced worldwide, and that this worldwide production can grow gradually to between 500 and 1200 Mtoe in 2050 (Sekkesaeter, Ovrum, Horschig, Henriksen, & Heggen, 2023). However, this production capacity needs to be shared between all sectors.

The Methanol Institute (Methanol institute, 2023) gives an overview of the bio-methanol and e-methanol production increase based on 80 renewable methanol projects and expects renewable bio-methanol production to increase sharply from 0,16 MT year to over 8 MT / year in 2027. This increase is much steeper than the expected growth of all biofuels of 7% per year for the period up to 2027 (Univdatos, 2023). The increase is fed by both an increase in energy needs and increasing government regulations for cleaner and more sustainable fuels.

Due to the limited availability of feedstock for bio-methanol production, in the energy mix e-methanol would also be required. The disadvantage for e-methanol is that it requires large amounts of renewable energy. If e-fuels will be fully deployed in shipping, it might double or even triple the maritime sector's energy consumption on a well-to-wake basis, due to the inherent thermodynamic conversion inefficiency that occurs when producing e-fuels (Lindstad, Lageman, Rialland, Gamlem, & Valland, 2021). Therefore, the feedstock for future production of sustainable fuels for shipping should consist of a combination of sustainably obtained biomass supplemented with sustainably produced hydrogen and CO_2.

For the future availability of e-diesel for maritime use, there are no concrete plans yet for large scale production facilities. Aviation is dependent on sustainable aviation fuels (SAFs) for making aviation more sustainable (Holladay, Abdullah, & Heyne, 2020). SAFs are longer chain sustainable fuels, such as e-kerosene and bio-kerosine. The production process of SAFs has many similarities with the production process of sustainable diesel and its upscaling could therefore play a crucial role in the pathway to sustainable diesel for maritime use. However, the energy consumption for the production significantly increases with increasing molecule chain sizes, as more conversion steps are required and each step reduces well-to-tank efficiency, as shown in Table 14.3.

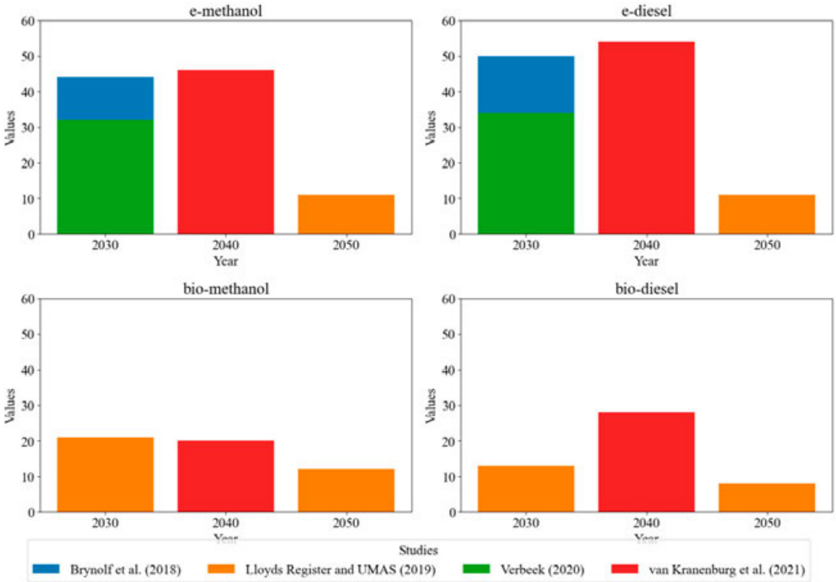
14.2.3 Fuel production cost estimates and assumptions

Decarbonisation of the shipping industry is strongly driven by cost evolution of sustainable fuels. Figure 14.4 and Table 14.4 provide an overview of cost estimates from various studies that have been performed over the past years (Brynolf, Taljegard, Grahn, & Hansson, 2018; Lloyds Register and UMAS, 2019; Verbeek, 2020; Kranenburg, et al., 2021). At first glance, it seems to indicate a huge uncertainty and disagreement in cost estimates, which is caused by different assumptions and is a confirmation of the volatility of the fuel market. This is confirmed by the study of (Brynolf, Taljegard, Grahn, & Hansson, 2018), shown in Figure 14.4. This study indicates a large uncertainty range.

Table 14.4. E-fuel cost estimates (€/GJ) (Brynolf, Taljegard, Grahn, & Hansson, 2018; Lloyds Register and UMAS, 2019; Verbeek, 2020; Kranenburg, et al., 2021).

Fuel	Source	2030	2040	2050
e-methanol	Brynolf et al. (2018)	44	-	-
	Lloyds Register and UMAS (2019)	23	18	11
	Verbeek (2020)	32	-	-
	Kranenburg et al. (2021)	-	46	-
e-Diesel	Brynolf et al. (2018)	50	-	-
	Lloyds Register and UMAS (2019)	25	17	11
	Verbeek (2020)	34	-	-
	Kranenburg, et al. (2021)	-	54	-
Bio-Methanol	Brynolf et al. (2018)	-	-	-
	Lloyds Register and UMAS (2019)	21	16	12
	Verbeek (2020)	-	-	-
	Kranenburg et al. (2021)	-	20	-
Bio-Diesel	Brynolf et al. (2018)	-	-	-
	Lloyds Register and UMAS (2019)	13	10	8
	Verbeek (2020)	-	-	-
	Kranenburg et al. (2021)	-	28	-

Figure 14.4. E-fuel cost estimates (€/GJ) (Brynolf, Taljegard, Grahn, & Hansson, 2018; Lloyds Register and UMAS, 2019; Verbeek, 2020; Kranenburg, et al., 2021).



In the study of Brynolf, Taljegard, Grahn & Hansson(2108), the authors reviewed literature to analyse the factors affecting production costs of the e-fuels and collected production costs and efficiencies associated with e-fuel synthesis. Then, they established the total production cost of the e-fuels in a consistent manner. Most other studies do seem to fit in the uncertainty range provided by Brynolf, Taljegard, Grahn, & Hansson, (2018), except the study from Lloyd's Register and UMAS (Lloyds Register and UMAS, 2019), which appears to have used more positive assumptions. This last study does provide a useful trend for the development of the cost of various fuels and solidly justifies this but does not address uncertainty. All studies agree that the difference between biodiesel and bio-methanol and between e-diesel and e-methanol is only a limited percentage of the estimated cost of the fuels, in the range of 5% to 30% depending on the assumptions of the cost of sustainable electricity and feedstock, due to the lower efficiency of the production process of bio- or e-diesel. Concluding, the studies agree on a 5% to 30% increase in price from bio- or e-methanol to bio- or e-diesel and a reducing trend in the cost of sustainable fuels as production capacity and technological readiness increases.

14.3 Introduction of Three Example Naval Vessels

The impact of hydrogen, e-methanol and e-diesel is analysed on three differently sized and different types of naval vessels, that are currently considered for replacement. The vessels have different tasks, from full scale warfare to peacetime operations, different operational autonomy, from months at sea to operations of typically one single working day, different operating environments, from open ocean and coastal operations to inland shipping and ports, and very different displacements from 6000 tons to 200 tons. These typical vessels are: the Air defence and Command Frigates (ACF) of the *'Zeven Provinciën'* class, for which the replacement is currently in the study phase (Netherlands Ministry of Defence, 2022); the hydrographic survey vessels, which will be replaced in the period from 2026 to 2030 (Maat, van der, 2022); and the inland diving vessels of the *'Cerberus'* class, which will also be replaced in the period from 2026 to 2030 (Maat, van der, 2022). The evaluation of the different fuels for these various types of vessels against its diverse operations, results in development of a strategy for evaluating and selecting fuels and the associated power system for future naval vessels and a strategy to progress from current fossil fuels to biofuels and e-fuels progressively over time, while maintaining effectiveness and improving military performance.

The vessels of the *'Cerberus'* class are diving vessels that divers use as a platform for their diving operations in coastal waters, inland waters and seaports. These divers perform several tasks, such as clearing explosives, executing underwater maintenance on naval vessels and recovering wrecks from under water. As these tasks are performed in the Dutch inland and coastal waters, they typically need to perform operations that can last up to 5 days. The typical operation of these vessels consists of a transit to an operating area within the Netherlands inland or coastal waters, a diving operation while berthed or at anchor and subsequently a transit either to a next diving operation location or return to a port or the home port. The main particulars of Hydra and Nautilus, which have been enlarged in length to provide space for additional accommodation, are listed below in Table 14.5 and diving vessel *Nautilus* is illustrated in Figure 14.5.

– Displacement: 332 tons
– Length: 38 m
– Beam: 8.8 m
– Draught: 1.5 m
– Propulsion power: 560 kW (diesel mechanical – 2 propellers)
– Installed generator power: 100 kW
– Maximum speed: 10.5 knots
– Crew: 8 base crew and 22 additional crew

Table 14.5. Typical operating profile for inland diving vessels during a training week of 6 days.

<table>
<tr><th colspan="2">Operation</th><th>Relative power in % of nominal</th><th>Average speed in kts</th><th>Operating time in %</th></tr>
<tr><td colspan="2">Diving operations at anchor or berth</td><td>96</td><td>0</td><td>30</td></tr>
<tr><td colspan="2">Hotel facilities (day) for maximum crew at anchor or berth</td><td>28</td><td>0</td><td>32</td></tr>
<tr><td colspan="2">Hotel facilities (night) for maximum crew at anchor or berth</td><td>18</td><td>0</td><td>32</td></tr>
<tr><td colspan="2">Economic cruising</td><td>210</td><td>7</td><td>3</td></tr>
<tr><td colspan="2">Fast cruising</td><td>398</td><td>8.5</td><td>1</td></tr>
<tr><td colspan="2">Manoeuvring</td><td>134</td><td>5</td><td>1</td></tr>
<tr><td colspan="2">Slow speed sailing</td><td>98</td><td>3</td><td>1</td></tr>
<tr><td>Total operation</td><td>12MWh effective energy</td><td>56</td><td></td><td></td></tr>
</table>

Figure 14.5. Diving vessels MV Nautilus, left, and MV Argus, right, (Picture NL MoD).

The hydrographic survey vessels Zr.Ms. Snellius (2003) (Figure 14.6) and Zr.Ms. Luymes (2004) perform hydrographic surveys for civil and military tasks. To perform their tasks, they have been designed to operate at sea for 210 days per year with resupply in port every two to three weeks, with an extra fuel storage capacity for refueling the vessels at sea. As the ships have a relatively low operating speed of 8 kts, their energy requirement is limited for the three-week operating schedule (Guns, 2004). Zr.Ms. Snellius is shown in Figure 14.33 and the main particulars of this hydrographic survey vessel are:

- Displacement: 1865 tons
- Length: 81.4 m
- Beam: 13.1 m
- Draught: 4.0 m
- Propulsion: 1150 kW (diesel electric – 1 propeller)
- Total installed power 1860 kW (3 generators)
- Maximum speed: 12 knots
- Crew: 23 Persons

Figure 14.6. Zr.Ms. Snellius (Picture NL MoD.)

The Air defence and Command frigates (ACF) of the *'Zeven Provinciën'* class can defend a fleet of vessels with Smart-L radar, the APAR multifunction and fire control radar, an Mk-41 vertical launch for Evolved Sea Sparrow Missile and Standard Missile 2 and goalkeeper and Oto Breda gun systems. Air defence frigates, such as the ACF, have typical autonomy requirements to operate independently at sea for 30 days or longer and a typical range of 5000 NM at 18 knots, sailing on direct geared drive diesel engines. For these types of vessels, the autonomy and the signatures, such as underwater noise and infrared, which are mainly determined by the propulsion and power system, are very important characteristics. Air defence and

Command Frigate *'Zr.Ms. Evertsen'* is shown in Figure 14.7 and its main particulars are:

– Displacement: 6050 ton
– Length: 144 m
– Beam: 17 m
– Draught: 7 m
– Propulsion:
  - 2 x 5000 kW (diesel mechanical geared) or
  - 2 x 19000 kW (gas turbine mechanical geared)
– Maximum speed: 30 knots (on gas turbines)
– Crew: 174 Persons (plus 28 staff members)

Figure 14.7. Zr.Ms. Evertsen at sea (picture NL MoD).

14.4 Impact of Fuel Choice on Ship Design

The choice of fuel significantly affects the design of a ship, particularly concerning the vessel's tank volume and deadweight as shown in Table 14.2 and covered in (Biert, van, 2020). Fuel choice influences the options for power sources (Nguyen, et al., 2021); the static and dynamic behaviour of these power sources (Geertsma, Negenborn, Visser, Loonstijn, & Hopman, 2017), the subsequent choice of propulsion and electric power system architecture (Geertsma, Negenborn, Visser, & Hopman, 2017) and the required safety measures to deal with fire and explosion risk and toxicity (Inal, Zincir, & Deniz, 2022; Verhelst, Turner, Sileghem, & Vancoille, 2019). Safety can require additional systems to mitigate fire, explosion, and toxicity risks, and can influence the best positioning of the fuel storage and power sources. While the fuel choice mainly influences energy density, the power source strongly determines power density, which is of particular interest for high-speed vessels, such as frigates. The static and dynamic behaviour limit the possibilities of applying certain power sources, such as Solid Oxide Fuel Cells, for propulsion and power systems with highly dynamic load, such as electric propulsion (Biert, van, 2020). This can be resolved with selecting a hybrid power system architecture or adding energy storage, such as batteries (Geertsma, Negenborn, Visser, & Hopman, 2017).

The choice of fuel has its most significant effect on the design of a ship due to the resulting tank volume and deadweight. Diesel is the most favourable option. Based on the required mass of the fuel only, hydrogen seems a good choice, but storage of hydrogen requires significant additional construction weight and volume compared to the fuels stored as liquid under atmospheric conditions. When including the construction weight and volume of the storage system, the weight and volume increases by a factor 2.1 and 2.2 for methanol, 2.4 and 3.4 for ammonia and 3.3 and 5.3 for hydrogen, all compared to diesel. For ammonia and hydrogen additional volume might be lost as these fuels are mostly stored under pressure in cylinders, which lead to a volume loss compared to storage in a rectangular tank. The required energy carried with the ship and the required power delivered by the ships' systems, is directly linked to the required autonomy and propulsion-, mission-, and auxiliary power. This determines the suitability of a fuel for certain types of naval vessels.

14.4.1 Impact of fuel choice on inland diving vessels

The evaluation of the feasibility of alternative energy carriers considers electric propulsion with full battery electric, hydrogen fuel cell or methanol combustion engine power generation. These alternatives could be feasible as the ship often sails at low power or is anchored, and the propulsion power for transit mode is no more than 3 times the auxiliary power. In the study, the diving vessel Nautilus (Figure 14.5) was used as a baseline vessel. First, the impact of the fuel on the weight and volume of the energy storage was established based on the energy requirement of the typical operating profile of these vessels with the Ship Power and Energy Concept tool (SPEC) as introduced in Astley, Grasman, & Stroeve (2020) and used in Streng, Kana, Verbaan, Barendregt, & Hopman (2022) and Streng J. (2021). Subsequently, a high-level cost analysis was performed to compare the cost of the three options. Then, a basic design for the vessel with a hydrogen fuel cell power generation was established. The basic design was then evaluated to establish the main risks of hydrogen. In a Hazard Identification Process with stakeholders these risks were identified, and the applicable regulations and design intent that could be used to mitigate these main risks were evaluated. This Section discusses the main risks, possible mitigation, the future work to address these risks, the cost evaluation and the conclusions established from this analysis, with all quantitative aspects based on public sources.

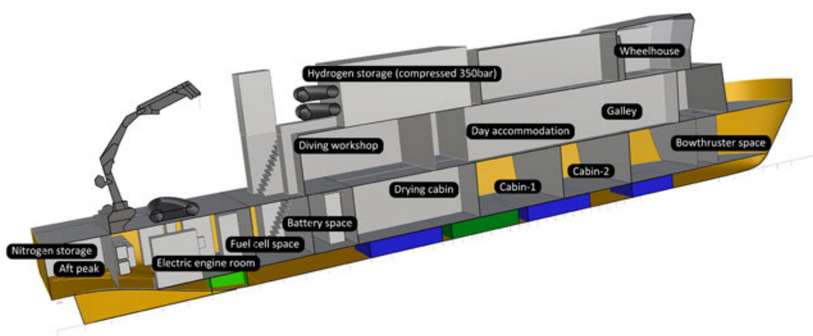
Table 14.6 shows the results of the weight, volume and cost of the stored energy and the power system power sources for the various means of energy storage. The required battery capacity for full battery electric propulsion considers a maximum depth of discharge of 80% and 20% loss of capacity over the lifetime of the battery (Tang, Roman, Dickie, Robu, & Flynn, 2020). The consequential weight and cost estimates are based on Romanovsky, Nikiforov, & Avramenko (2021). The ship weight increased by some 150 tonnes, which is half the weight of the original ship and thus considered not feasible. When using methanol, the required storage capacity easily fits in the current volume of the tanks. Therefore, methanol is considered feasible. The impact of methanol on naval vessels is discussed in the section on the impact for the seagoing support vessels. The required capacity of hydrogen can be stored in two 20 ft containers. Thus, from the high-level impact analysis, hydrogen appears potentially feasible. Therefore, a potential design for the existing inland vessels with hydrogen fuel cell power generation system was evaluated to establish whether and how a safe design could be achieved.

Table 14.6. Power system main component weights, volumes and cost for battery electric, hydrogen fuel cell electric and methanol combustion engine electric power system, based on parametric design evaluation with open-source parameters from (MARIN, 2023).

Operation		**Battery electric**	**Hydrogen Fuel cell electric**		**Methanol combustion engine electric**	
			Hydrogen	Battery	Engine	Battery
Effective energy per trip	MWh	12	12	0,45	12	0,255
Stored energy	MWh	18	32	0,7	36	0,4
Stored energy volume	m³	244	64	9	10	5
Stored energy weight	t	149	35	6	9	3
Energy weight fraction		0.31	0.09	0.02	0.03	0.01
Stored energy CAPEX	M€	11.56	0.7	0.4	0.01	0.2
Power of components	kW/t	600	600	600	600	600
Power intensity	kW/t	1.8	1.8	1.8	1.8	1.8

Operation		Battery electric	Hydrogen Fuel cell electric		Methanol combustion engine electric	
			Hydrogen	Battery	Engine	Battery
Power system volume	m³	7	31	7	13	7
Power system weight	t	5	25	5	15	5
Power system CAPEX	M€	0.8	2.0	0.8	1.1	0.8
Total system volume	m³	251	95	16	22	12
Total system weight	t	154	60	10	24	8
Total system CAPEX	M€	12.3	2.7	1.2	1.2	1.0

Figure 14.8. Side view of the Zr.Ms. Nautilus.



On the baseline concept design in Figure 14.8, a Hazard Identification process (HAZID) was performed. The key risks were primarily related to the flammability and explosivity hazards of hydrogen and secondarily to the asphyxiation hazard due to the use of nitrogen as an inerting gas and the exhaust gas of the fuel cell. In the hydrogen design of the converted diving vessel, the design intent was to limit the risks for personnel by positioning the hydrogen storage in exchangeable containers on the upper deck, like previous projects in the Netherlands such as MV Antonie and the inland containerships of Future Proof Shipping. This led to a safety zone within the container, within the double walled hydrogen piping and within the fuel cell, which are designed to contain potential leakage within its cabinet.

All risks of leakage outside these areas should be mitigated by hydrogen sensors, fast cut-off valves, ATEX certified equipment to prevent explosion initiation and sufficient ventilation to prevent explosion levels in the fuel cell space and the trunks leading to the fuel cell space. The fast cut-off valves limit the quantity of hydrogen in the fuel cell space as the storage is on the upper deck. The risk of hydrogen leakage can be retained to a minimum by applying double-walled piping and an intrinsically safe fuel cell. In case of leakage, the ship can return to port on battery power. The exhaust in the chimneys is used both for the fuel cell exhaust, which is dangerously depleted of oxygen, and for the emergency venting of the hydrogen, for example in the case of fire. This leads to a safety zone 1 with a 6 m radius around the venting mast according to the IGF-code and safety zone 2 that extends 4 m beyond zone 1. With this design and associated safety measures a safe design can be achieved, while exact sizing of safety zones and ventilation requirements for the machinery spaces should be further investigated to subsequently improve design guidelines from the used regulations such as ESTRIN 2021 (CESNI, 2021/1), ABS guidance notes on risk assessment (ABS, 2020), the IMO IGF-code (International Maritime Organisation, 2015) and DNV rules, part 6 Additional class notations (DNV, Edition July 2020).

14.4.2 Impact of fuel choice on seagoing support vessel

The feasibility study into methanol as an alternative energy source than diesel considered electric propulsion with methanol combustion engine power generation. In the study, the hydrographic survey vessel Zr.Ms. Snellius (Figure 14.6) was used as a baseline vessel. First, a basic design for the vessel with electrical propulsion and methanol combustion engine power generation was established. The basic design was then evaluated to establish the main risks of methanol as a fuel. In a Hazard Identification Process with stakeholders these risks were identified, and the applicable regulations and design intent that could be used to mitigate these main risks were evaluated. Subsequently, a high-level cost analysis was performed to compare the cost of the three options. This Section discusses the main risks, the possible mitigation, the future work to address these risks, the cost evaluation and the conclusion established from this analysis, with all quantitative aspects based on public sources.

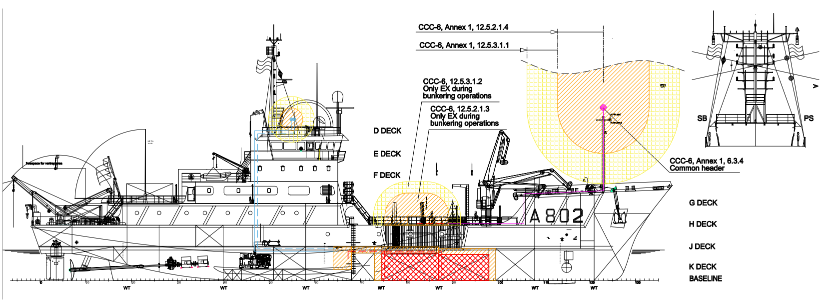
Within the Green Maritime Methanol (GMM2.0) project the Defence Materiel Organisation (DMO – now COMMIT) studied the impact that use of methanol would have on the existing ship (Alkemade & Astley, 2020). The study identifies three hazardous zone types (Hulsbosch-Dam & Deul, 2022).

- Zone 1: “area in which an explosive gas atmosphere is likely to occur occasionally in normal operation”.
- Zone 2: “area in which an explosive gas atmosphere is not likely (less than 10 hours per year) to occur in normal operation, but, if it does occur, will exist for a short period only”.
- Zone 3: “area in which an explosive gas atmosphere will not occur in normal operation”.

Methanol tanks are considered zone 1, and the area immediately outside a methanol tank is considered zone 2. To avoid identification of accommodation spaces or engine rooms as zone 2, a cofferdam is required between methanol tanks and engine rooms or accommodation spaces. Small tanks could be double walled with the same purpose. This is different from conventional diesel tanks, which usually do not have cofferdams when adjacent to engine rooms or accommodation spaces. Instead, sufficient insulation to contain a fire for more than 60 minutes is considered sufficient. For the same reason – limitation of zone 2 areas – double walled piping is applied for transportation of methanol within the ship. This has some consequences for required space, but this is limited.

Figure 14.9 shows the side view of the general arrangement plan of the Snellius, adapted for methanol. The energy capacity of the fuel tanks was reduced by 60% compared to diesel tanks, which was acceptable as the refueling capability of the ship was skipped. Thus, the energy weight fraction of the original vessel of 0.05 was reduced to 0.04 instead of increased to 0.11, for a vessel with a power intensity of 1 kW/t. Moreover, a safety area around venting pipes of 3 metres is to be kept free around venting pipes, and around bunkering stations during bunkering. Around this area a zone of 2 metres is reserved, where dangerous concentrations of methanol are not likely, but possible during short periods.

Figure 14.9. Side view of the Zr.Ms. Snellius – with methanol tanks. CCC-6 referring to legislation of the IMO subcommittee on carriage of cargoes and containers, adopted on its 6th session in September 2019.



On a relatively large vessel like the Snellius these extra space requirements are inconvenient, but do not require very large adaptations to the vessel. For small vessels these additional space requirements have a significant impact on ship design, and adaptation of existing vessels is severely hampered. Future work should thus be focused on limiting the technical impact of the safety measures, by considering alternative solutions for fire ingress and leakage to cofferdams, and investigating alternative venting solutions, such as venting under the waterline.

14.4.3 Impact of fuel choice on future frigates

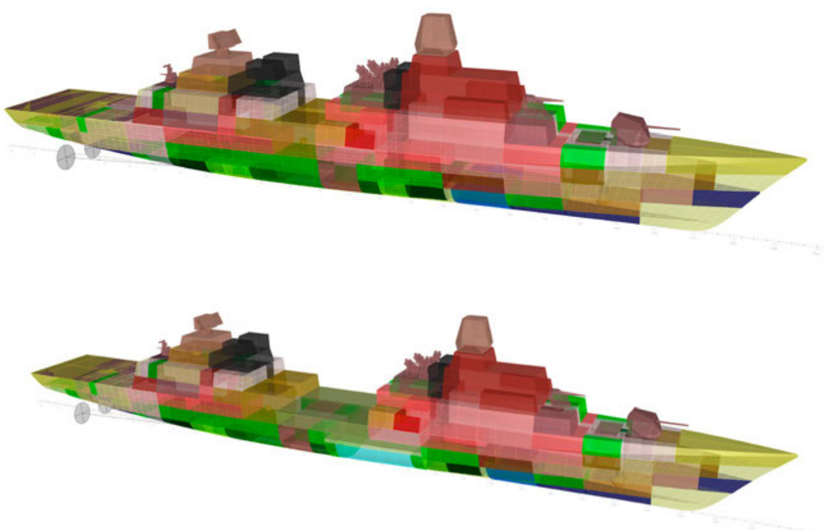
The impact of fuel choice on future frigates has recently been studied with three different approaches, using a parametric design (Streng, Kana, Verbaan, Barendregt, & Hopman, 2022), using a fixed hull design with varying draft (Pawling, Bucknall, & Greig, 2022) and using a fixed design that is lengthened (Pothaar, Geertsma, & Reurings, 2022). Streng et al. (2022) use a parametric design approach with the Ship Power and Energy Concept tool (SPEC) as introduced in Astley, Grasman, & Stroeve (2020). This assumes the ship is resized maintaining its hull form with increasing displacement, thus leading to increasing ship resistance. Pawling et al. (2022) use an approach that includes a high-level zonal layout design. Within certain displacement limits the hull form does not change and additional space for energy storage leads to an increased draft. Finally, Pothaar et al. (2022) use an approach that maintains the hull form but lengthens the hull when additional volume for energy storage is required. The advantage of this approach is that the resistance does not increase considerably, but the lengthening does have a limitation for damage stability and manoeuvrability. These three different approaches lead to different impacts of methanol as a fuel compared to diesel, as the impact additional displacement has on ship resistance is different, as shown in Table 14.7.

Table 14.7. Impact of methanol as a fuel compared to diesel for frigate design with parametric design approach (Streng, Kana, Verbaan, Barendregt, & Hopman, 2022) for frigate with combined diesel or gas turbine propulsion plant (CODOG), fixed hull design with varying draft approach (Pawling, Bucknall, & Greig, 2022) for frigate with combined diesel electric and diesel propulsion plant (CODLAD) and fixed hull shape with varying ship length approach (Pothaar, Geertsma, & Reurings, 2022) for frigate with combined diesel electric or gas turbine (CODLOG) and combined diesel and diesel (CODAD) propulsion plants.

Design approach	**Displacement baseline**	**Fuel weight fraction baseline**	**Propulsion layout and power**	**Displacement methanol**	**Relative increase**	**Fuel weight fraction methanol**
Parametric design	6050 t	0.100	CODOG 6.2 kW/t	9600 t	0.58	0.23
Fixed hull design with varying draft	3862 t	0.104	CODLAD 8.5 kW/t	4817 t	0.247	0.248
Fixed hull shape with varying ship length	6050 t	0.092	CODLOG 6.0 kW/t	6936 t	0.146	0.147
Fixed hull shape with varying ship length	6420 t	0.085	CODAD 6.0 kW/t	7267 t	0.135	0.135

Figure 14.10 shows a 3-D plot of a study into a notional Future Air Defence and Command Frigate (FUADEF) performed by Pothaar (2023). The upper plot shows the original configuration of the FUADEF, whilst the lower plot gives an impression of the required overall dimensions of the vessel to accommodate for the additional fuel volume when using methanol, in light blue, as its only energy carrier, by lengthening the design. Based on this study, the conclusion was that, although technically possible, use of methanol as an energy carrier would lead to either halving the range, or an extension of the tank volume to around 900 m^3 (Pothaar, Geertsma, & Reurings, Energy transition for the replacement Air Defense and Command Frigate, 2022). This volume increase would in turn also lead to an increase of 20 metres in ship length and 900 tonne displacement, marginal damage stability and a single point of failure with one tank location, while splitting would require additional cofferdams and thus ship length. Also, at this moment, there are no gas turbines available running on methanol. As a compromise, the Navy could consider a dual fuel option. In peace time, the Navy could run on methanol with limited autonomy and use (bio-)diesel in war time, which would significantly reduce the impact of methanol and enable alternative engine combustion strategies, such as RCCI, which could lead to reduced noise, emission, and signatures.

Figure 14.10. 3-D render plot of the baseline concept design (top) for a study into Future Air Defence and Command Frigate and the impact of methanol as a fuel (bottom). (Pothaar, Assessing the impact of sustainable fuels for large surface combatants, 2023).



The differences between the impact of methanol as a fuel with the three different design approaches demonstrate that the impact is very much determined by specific choices in the ship design approach and that more detailed design studies are required to establish the true impact. All studies confirm that the impact of the choice for methanol as a fuel has huge implications on the ship size or range. Three different approaches should therefore be considered as well. First, we could consider fuels that are a trade-off between ease of sustainable production and energy density, such as butanol, as evaluated in Streng, Kana, Verbaan, Barendregt, & Hopman (2022). Secondly, the ship could be designed with a fuel flexible approach, which allows operation on fuels that can be more efficiently produced in peacetime, such as methanol, and a switch to operation on energy dense fuels such as e-diesel in wartime. This fuel flexible approach could also be used to increase engine efficiency and reduce emissions and signature by using advanced combustion strategies and a combination of low and high reactivity fuels. Finally, when fuel cell technology becomes mature and its cost reduces due to increased scale of production, hybrid power system architectures utilising a combination of fuel cells and combustion engines can be used, which can also contribute to reduced emissions and signatures (Sapra, et al., 2021). Continued investigations are required to follow developments and establish the moment when the benefits of alternative fuels and power sources on efficiency, emissions and signatures outweigh the increased risk and cost for future frigates.

14.4.4 Future fuels strategy

This work reviewed the impact of energy storage and alternative fuels such as hydrogen, methanol, and bio- or e-diesel based on three case studies. The maritime industry's transition towards sustainable and clean energy solutions has been gaining significant momentum. A strategic shift from conventional fossil fuels to biofuels and ultimately to e-fuels is gradually occurring. This progression is driven by the impact of alternative fuels on vessel autonomy, environmental implications, as well as economic and logistical considerations. The autonomy of a vessel, especially those operating over extended distances or periods, is greatly influenced by the energy density of the chosen fuel. Long-chain fossil fuels like F-76 diesel offer high energy density, providing extended autonomy but also releasing significant carbon emissions. A feasible strategy for reducing emissions while maintaining vessel autonomy is the progressive introduction of biofuels. These fuels can replace a growing portion of fossil fuels over time without requiring major alterations to existing infrastructure (Doss, Ramos, & Atkins, 2009). It is crucial to establish a strategic alliance at an international level to support the transition to cleaner fuels. Organisations such as NATO can play a key role in fostering the development of production facilities for alternative fuels, improving logistics for distribution, and promoting the end-use of these fuels in naval operations.

The main limitations of batteries are the limited energy density and high initial purchase cost for its energy storage capacity. The analysis and results have shown that batteries can provide a zero-emission propulsion and power generation, but only for a very limited time. Typical examples are operations up to a few hours, such as entering a port or loitering, and operations up to one day for low power applications, such as diving vessels. Extending the operational range of battery-powered vessels will be a key focus for research and development. This will involve improving the energy density and efficiency of batteries, but also managing heat development and mitigating the risk of thermal runaway of lithium-ion batteries and its propagation from cell-to-cell, or the development of more energy dense battery chemistries that are inherently safe for thermal runaway. As the capability of methanol engines to deal with dynamic loads might be low due to knock and misfire limits, batteries can also be used for load levelling. In high-end warfare vessels, such as future air defence frigates, battery energy storage could be used to provide a very silent and zero-emission operating mode for a short period of time, provide fault ride through during failures of generators while reconfiguring the electrical distribution and for load levelling. Therefore, the main opportunity for battery application in naval vessels is in hybrid power supply, for which further development of advanced control concepts is required to realise these opportunities.

The two main limitations of hydrogen are its limited energy density and the high risk due to its explosivity and flammability. To mitigate the risk of harm to personnel in manned vessels, hydrogen is best stored high in the superstructure of a vessel, at a location where no personnel is regularly performing work. Alternatively, it can be stored in a well-protected space inside the vessel, with sufficient ventilation to prevent explosive mixtures and with ventilation exits at the highest point in the space due to the low density of hydrogen. This would enable safe and feasible application of hydrogen on support vessels with sufficient space in the superstructure, such as the diving vessels. However, for most naval vessels the superstructure is the most valuable space for mission systems, either for sensor, weapon, and communication equipment on high end warfare vessels, such as frigates, or for cranes, boats, easily accessible storage, for example with containers, and deck handling equipment on seagoing support vessels. Also, for naval vessels the ventilation requirements to prevent explosive hydrogen mixtures when stored low in the vessels, would require significant additional volume, on top of the already poor energy density of hydrogen compared to methanol. Moreover, both the cost of the fuel cells, its storage and distribution system and the cost and limited availability of green hydrogen currently means that other alternative fuels, such as sustainably produced methanol and diesel, can provide a larger impact on reducing fossil fuel dependency and well-to-wake greenhouse gas emissions at lower cost. Therefore, hydrogen in the short term is mainly applicable to small unmanned assets that have sufficient space for its fuel, such as unmanned drones and possibly unmanned surface vehicles or submarines. When used in combination with fuel cells, hydrogen has the added benefit of no emissions and reduced noise and infrared signatures.

Sustainably produced methanol is fluid at ambient conditions, which enables easier handling. Methanol can be produced from various non-food biomass and can lead to an 83% to 89% greenhouse gas emissions saving when produced from biomass feedback (European Parliament, 2018) and 100% when produced from sustainable electricity and captured CO_2. The use of methanol directly leads to a reduction of the autonomy of 62% for the same tank volume. For ships with a limited autonomy or sufficient volume in the vessels, such as support vessels and the hydrographic survey vessels, this impact is limited. On small ships, the required additional space for cofferdams may be problematic for ship design. Therefore, further research is required in establishing an alternative safety barrier between tanks and machinery or accommodation spaces against leakage and heat ingress during fires, that requires less space than cofferdams.

The extra safety requirements due to the toxicity and flammability of methanol lead to extra safety considerations of hazardous areas in the ship and therefore extra safety systems with consequential additional cost. Methanol storage has more restrictions than diesel. In between a methanol storage tank and an engine room or crew accommodation spaces, cofferdams are required. For naval vessels with a high autonomy requirement, the use of methanol as a fuel leads to a significant increase in the size and thus cost of the vessel. Depending on the design approach this leads to displacement increases from 20% to 25%. An approach in which the ship sails on methanol in peacetime and during training and uses sustainably produced diesel in warfare operations deserves further research. This might also allow the possibility to improve noise and infrared signatures with advanced combustion strategies such as Reactivity Controlled Compression Ignition (RCCI). The impact on the design, when considering survivability, the impact of the additionally required cofferdams and safety systems and the limitations in using the same tanks for methanol and diesel, due to poor miscibility, require further research to establish the feasibility of this fuel flexible approach for high end naval vessels.

Ammonia seems a feasible option at first sight. The energy density is slightly higher than methanol and synthetic production of ammonia will have a slightly higher efficiency than that of methanol. Ammonia is highly toxic and is a gas under atmospheric conditions. Storage should be done under pressure or at low temperatures. Due to its toxicity, it cannot be stored in tanks directly at the outer hull of a ship. Therefore, for naval purposes, ammonia is not considered a feasible option at this moment.

For high end warfare vessels with a conventional crew size, the autonomy requirement and the need for refuelling from all NATO partners' tankers drives the need for a drop-in replacement for Marine Diesel Oil (MDO) according to F-76 or similar specifications. In the short term, this can be achieved by mixing biofuel with fossil F-76. DNV expects that 11 million tonnes of oil equivalent (Mtoe) will be produced worldwide, and that this worldwide production can grow gradually to between 500 and 1200 Mtoe in 2050 (Sekkesaeter, Ovrum, Horschig, Henriksen, & Heggen, 2023). To prevent damage to equipment or loss of power, it is important to evaluate the suitability of biofuels as a drop-in for fossil diesel, as this strongly depends on the feedstock and production process and experience from long-lasting trials is still lacking. As naval vessels often refuel from various sources, such as NATO replenishment vessels, it is necessary to perform this evaluation in the international NATO context. The most promising current biofuel in this regard is Hydrotreated Vegetable Oil (HVO) due to its high oxidation and storage stability. This fuel has a limited feedstock and production growth. In the longer term, production through gasification and Fisher Tropsch synthesis can lead to higher quantities of biodiesel (Sekkesaeter, Ovrum, Horschig, Henriksen, & Heggen, 2023). Biofuel production is expected to be insufficient to meet the full demand of the maritime sector due to competition for biofuel with other transportation sectors. Therefore, in the long run, synthetic production of fuel is required. Sustainable synthetic fuel is produced based on sustainably produced hydrogen and captured CO_2. To achieve this reduction of dependence on fossil fuels, collaboration is required in NATO to develop a NATO-wide strategy for the development of production facilities, logistics and end-use of fuel.

14.5 Conclusions and Recommendations

The selection of fuel type for naval ships is dictated by a confluence of factors including operational requirements, autonomy, safety, logistical support, and environmental impact. Biofuels and e-fuels, such as biodiesel, e-diesel, methanol and hydrogen, have emerged as viable alternatives to traditional fossil fuels.

While hydrogen is feasible for vessels such as diving vessels, the cost of the power system and sustainable produced hydrogen currently prevents its introduction on large vessels. For smaller assets and potential future autonomous vessels, hydrogen is a compelling choice. Hydrogen fuel cells can produce electricity efficiently and emit only water, making them a clean energy source with no noise and signatures, supporting undetected operations. The storage and handling of hydrogen present unique challenges due to its low energy density per unit volume and flammability. These challenges could potentially be mitigated with the development of onboard hydrogen production systems, utilising water electrolysis powered by a mother-ships power system. Such systems could offer enhanced autonomy for unmanned assets operating from mother vessels.

Methanol presents a promising option for naval vessels with a limited operating autonomy and lower threat operating environment. Given its relatively high energy density and ease of handling, methanol can support naval operations with limited power demands for weeks at sea. Furthermore, the production of methanol could be made carbon-neutral if generated from renewable energy sources, making it an environmentally sound choice for support vessels, such as the investigated survey vessels and diving vessels.

For future high-end warfare naval vessels, the range limitations of methanol and the international logistics prevent the use of alternative fuels such as methanol in the short to medium term. With the evolving landscape of maritime propulsion and a shift towards sustainable fuel sources, it becomes vital for international organisations like NATO to develop a comprehensive strategy for the adoption of sustainable drop-in alternatives for F-76 Marine Diesel Oil. As for infrastructure and Logistics, NATO could foster the establishment and expansion of production facilities for biofuels and e-fuels, streamline distribution logistics, and encourage their use in naval operations. NATO could also play a vital role in promoting collaboration among its member countries to share best practices and invest in innovative solutions for efficient and safe use of alternative fuels in naval operations.

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CHAPTER 15

Helicopter Formation Flight for Improved Mission Effectiveness

Mark Voskuijl and Wessel Groote Schaarsberg

Abstract

Formation flight is a technique used for tactical reasons in military aviation. Recent numerical and experimental research has demonstrated that formation flight conducted with helicopters also yields aerodynamic benefits and has the potential to reduce fuel consumption. A new physics-based mathematical model has been developed which can be used to quantify the effect of formation flight on fuel burn, range and endurance (flight time) for typical military missions conducted with multiple helicopters. Simulations with the new mathematical model show that a total fuel saving of about 10% can be achieved at the expense of 7% extra flight time for a long-range cruise flight with two UH-60A Black Hawk helicopters. The results underline that significant fuel savings can be achieved by the Royal Netherlands Air Force and its NATO allies if formation flight is applied to large scale transport missions with multiple helicopters.

Keywords: formation flight, helicopter performance, military operations, fuel efficiency

15.1 Introduction

Formation flight is a well-known technique in military aviation used for various tactical reasons such as the maximisation of firepower and mutual protection (Department of the Navy, 2017). Formation flight is defined by the European organisation for the safety of air navigation (Eurocontrol) as a flight consisting of more than one aircraft which, by prior arrangement between the pilots, operates as a single aircraft with regard to navigation and position reporting, as well as clearances issued by air traffic control (Eurocontrol, 2019: 22). In a standard military formation each aircraft/element of this formation shall remain within one nautical mile horizontally and 100 ft. vertically from the formation leader (Eurocontrol, 2019: 12). The US Navy Air Training Command defines the general objective of formation flying as follows. To employ and control multiple aircraft flying in close proximity to accomplish an assigned mission in a manner that will minimise the effectiveness of enemy opposition (Department of the Navy, 2017: vi).

More specifically, the main advantages of formation flight in military aviation are the following. By flying in close proximity, it becomes more difficult for enemy radar systems to detect and identify separate aircraft. Vice-versa, formation flight is beneficial for the search and detection of enemy targets. From the early days of aerial combat, the visual search and detection of targets has been of high importance and the techniques for visual search in air combat are therefore taught in military aviation schools (Schallhorn, 1990). The human eye can only focus at large distances in a narrow 2 degree fixation. It therefore takes a significant amount of time to visually search the sky for enemy aircraft. The likelihood of visual detection can be improved greatly by application of formation flight because members of the formation only have to systematically search a specific sector in the sky (Stillion, 2015). Even with the technological advances in sensors, visual search remains important. Furthermore, different aircraft in a formation may have different sensors. In addition to detection related benefits, multiple aircraft in formation can also have more firepower than a single aircraft. Another advantage of formation flight in military aviation is the reduced need for radio communication (Department of the Navy, 2017). Only the lead aircraft has to communicate with for example airborne early warning and control (AWACS) or the Joint Terminal Attack Controller (JTAC) and the other aircraft follow the actions of the lead. Other military examples where formation flight is employed are aerial refuelling and air assault missions. In air assault missions, ground combat forces are transported by helicopters with the aim to seize or hold terrain (Department of the Army and Marine Corps Combat Development Command, 2004).

Over the past 20 years, various experimental research studies conducted by the United States Air Force and NASA have demonstrated that formation flight can also be used effectively to reduce fuel consumption. This reduction in fuel consumption can be achieved by making use of the basic physical principle that all aircraft generate wake vortices as a result of a pressure difference on the wing. These wake vortices, which contain a significant amount of energy, remain present at large distances behind an aircraft. In a specific region of a wake vortex, the air has an upward motion (upwash). A second aircraft can achieve an aerodynamic benefit if it is positioned in this upwash region of a wake vortex. Effectively, the second aircraft can perform a descending flight relative to the air which has an upward motion. A descending flight requires less power than a flight at constant altitude. Relative to the earth, the second aircraft remains at the same altitude.

The most important fixed-wing flight test programs of the last 25 years, focused on the quantification of achievable fuel reduction by means of formation flight are summarised in Table 15.1. Note that some of the results in this table represent savings for a single flight condition whereas other results are for a complete mission.

Table 15.1. Overview of key experimental flight test programs in the United States since 1998.

Year	Program	Aircraft type(s)	Fuel savings	Reference
1998	NASA Autonomous formation flight	F/A-18	18%	Vachon et al. 2002
2001	USAF TALON GAGGLE	T-38	~11%	Wagner et al. 2002
2003	NASA SURF	F/A-18, DC-8	~29%	NASA 2003
2004	USAF F-16 DOLLAR	F-16	~13%	Morgan 2005
2010	NASA/USAF/Boeing C-17 CAPFIRE	C-17	~7%	Pahle et al. 2012
2012	DARPA AFRL $AVE	C-17	> 10 %	Bieniawski et al. 2014
2016	NASA Cooperative trajectories	C-20 – GIII	8%	Hanson (2015)

A more complete and extensive overview is provided by Nangia and Brown (2020) for the interested reader. Altogether it can be concluded that fuel reductions in the order of 7–10% can be achieved for military transport aircraft and fighter aircraft in a typical mission, when the trailing aircraft of the formation consistently flies in the upwash of the wing vortex of the lead aircraft of the formation. In recent years many research studies have been conducted to investigate the potential of formation flight for commercial aviation. For sake of brevity, these studies are omitted from the current chapter.

All research in the field of formation flight has been focused so far on fixed-wing aircraft. It was hypothesised by Voskuijl (2018) that fuel reductions may also be achieved when helicopters fly in formation. Helicopters leave a wake similar to a fixed-wing aircraft. Close behind a helicopter the wake is very complex and unstructured with tip vortices emanating from individual rotor blades. The wake is however fully developed in a system comparable to that of fixed-wing aircraft at about a length of 10 to 20 rotor diameters behind a helicopter. Due to the asymmetric nature of helicopters, the wake is however also asymmetric. The upwash region is stronger on the advancing blade side (Caprace et al., 2017). Experimental research and numerical simulations conducted at the Netherlands Defence Academy in collaboration with Delft University of Technology have recently confirmed the hypothesis (Duivenvoorden et al., 2022). In fact, even larger fuel reductions can be achieved at a single flight condition compared to fixed-wing aircraft due to the asymmetric nature of the wake of a helicopter rotor. So far, the research has focused on a proof of concept. The numerical simulation models used so far are quite complex and computationally expensive. These models are suitable to assess the formation flight performance in a single flight condition defined by the weight of the helicopters, the airspeed and flight altitude. The models are however not suitable for flight mission analysis in which optimal trajectories are computed for a variety of operational conditions.

The aim of the current research is twofold. The first objective is to develop a generic physics based model that can be used to quantify the effect of formation flight on flight mission performance parameters such as fuel burn, optimal flight speed and flight time. This model should be accurate and computationally efficient. The second objective is to use the new model to quantitatively analyse the effect of formation flight for typical military missions conducted by the Royal Netherlands Air Force and its NATO allies.

The article is structured as follows. In Section 2, an overview is given of previous research in rotorcraft formation flight with the aim to improve efficiency. This section also includes a description of the type of helicopter selected for this research and the rationale for choosing this specific helicopter. Next, a new equation is proposed in Section 3 which can be used to model formation flight for flight performance and mission analysis. Section 3 also includes the verification and validation of the mathematical models. The new equation is used in Section 4 to analyse the potential effect of formation flight on fuel burn, range and flight time for military missions. Finally, conclusions and recommendations are made.

15.2 Background

A detailed numerical simulation model of two UH-60A Black Hawk helicopters in formation flight was developed by Duivenvoorden et al. (2022). This specific helicopter was chosen as a use-case primarily because a vast amount of flight-test data of this helicopter has been published in the public domain as a result of the UH-60A Airloads Program (Kufeld et al., 1994). Furthermore, the UH-60A is representative of a typical military utility helicopter with a conventional main rotor and tail rotor. The numerical simulation model of the follower aircraft in the formation is based on a rigid multi-body dynamics model (Pastorelli, 2008). The inflow of the main rotor is modelled with a Peters-He model (Peters and He, 1995). These models are known to be accurate for performance, stability and control applications (Manimala et al., 2007). The numerical simulation model of the follower helicopter is validated against the FLIGHTLAB Generic Rotorcraft model, a validated commercial off-the-shelf rotorcraft simulation model. The presence of the lead helicopter in the formation is modelled with a flat wake model (Wilson, 1991). The follower helicopter is positioned by an automatic flight control system within the simulated wake of the lead helicopter. A complete description of the numerical simulation model is provided by Duivenvoorden et al. (2022).

The key result obtained with the numerical simulation model is presented in Figure 15.1. It shows the reduction of the required main rotor power of the follower helicopter as a function of the lateral and vertical position with respect to the lead helicopter. The lateral position (*y*) and vertical position (*z*) are nondimensionalised with respect to the rotor radius (*R*). The weight of both helicopters is identical and the airspeed is 57 m/s for the simulations presented in Figure 15.1. A maximum reduction in main rotor power of 22% is achieved at the optimum location. This reduction occurs when there is a small lateral overlap of the helicopter rotors. It should be noted that the flat wake model does not include the effect of self-induced displacement. In reality, the optimal vertical position of the follower helicopter will be somewhat below the lead helicopter unlike the predicted vertical position in Figure 15.1. The follower helicopter should be located about 15 rotor diameters (*D*) behind the lead helicopter such that the wake is fully developed (Caprace, 2007). An impression of the resulting formation is displayed in Figure 15.2. It is essentially a combination of an echelon formation and a trailing formation.

Figure 15.1. Main rotor power reduction as a fraction of solo flight for UH-60 Black Hawk helicopters in formation flight (Image source: Duivenvoorden et al., 2022).

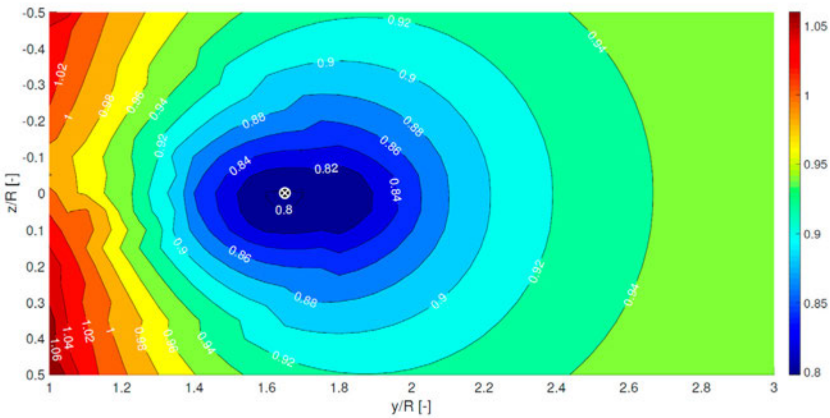
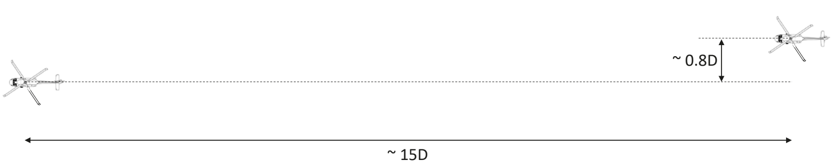


Figure 15.2. Typical geometry of the formation to achieve the maximum aerodynamic benefit.



The effect of airspeed on the maximum achievable main rotor power reduction was investigated in Duivenvoorden (2019). In terms of a percentage, the main rotor power reduction decreases with airspeed. It should however be noted that in absolute terms, the required power in solo flight increases with airspeed.

Table 15.2. Optimal main rotor power reduction as a function of forward airspeed for two UH-60A Black Hawk helicopters in formation flight.

Airspeed [m/s]	**Main rotor power required of follower helicopter [% of solo flight]**
41	66
46	71
51	76
57	78
62	83

Parallel to the numerical simulations, two wind tunnel campaigns were conducted at the Netherlands Defence Academy (Morée, 2019 and van der Veen, 2020). These experiments confirmed that a main rotor power reduction can be achieved and showed reductions in the same order of magnitude as the numerical simulations.

15.3 Modelling Formation Flight for Helicopter Mission Analysis

The theory of helicopter performance modelling for mission analysis can be found in various text books (e.g. Johnson, 2013 or Prouty, 2001). In its simplest form, it is typically based on the blade element method and actuator disc theory (van Holten and Melkert, 2002). The total power required by the main rotor in forward flight consists of several terms.

$$P_{MR} = P_i + P_p + P_d + P_{par} + P_c$$

Where P_i is the induced power. It is calculated with the following equations.

$$P_i = kW\overline{v}_i\sqrt{\frac{W}{2\rho\pi R^2}}$$

$$\overline{v}_i = \frac{1}{\sqrt{(V\sin\alpha + v_i)^2 + (V\cos\alpha)^2}}$$

The factor k in the equation accounts for non-uniform inflow and rotational velocities in the wake. The relation for the nondimensional induced velocity ($\overline{v}_i$)

is derived based on the theory developed by Glauert (1926). The angle of attack is calculated based on force equilibrium in forward flight, assuming the helicopter is a point mass and neglecting H-forces (van Holten and Melkert, 2002). H-forces are forces acting in the tip-path-plane of the rotor disc which are the result of a periodic change in the lift induced drag and the zero lift drag of the rotor blade over a revolution. In the equation, the nondimensional velocities ($\overline{V}$ and $\overline{v_i}$) are defined as the airspeed and the induced velocity, respectively, divided by the induced velocity at hover. The profile drag power in forward flight ($P_p + P_d$) can be estimated as an analytical function of advance ratio (μ) using blade element theory (van Holten and Melkert, 2002).

$$P_p + P_d = \frac{\sigma \overline{C_{D_p}}}{8} \rho (\Omega R)^3 \pi R^2 (1 + n\mu^2)$$

The parasite power (P_{par}) is the power required to overcome the drag of the fuselage and empennage of the helicopter. It is expressed as an equivalent flat plate area multiplied by the dynamic pressure and the airspeed.

$$P_{par} = \sum (C_D S) \frac{1}{2} \rho V^3$$

The equivalent flat plate drag area (m^2) for the UH-60A helicopter is a function of the angle of attack of the fuselage (Yeo, Bousman & Johnson, 2004). The angle of attack in this equation is defined in radians.

$$\sum (C_D S) = 3.265 + 13.45 \alpha^2$$

The climb power (P_c) is equal to the weight of the helicopter (W) multiplied by the climb rate (C), which is in fact the time rate of change of the potential energy.

$$P_c = WC$$

The tail rotor also requires power. The horizontal component of the tail rotor thrust multiplied by the distance of the tail rotor to the main rotor (l_{tr}) must equal the main rotor torque to achieve a moment equilibrium if the contribution of the vertical tail is neglected. With the tail rotor thrust known for a given flight condition, the power required for the tail rotor (P_{TR}) is calculated analogous to the main rotor power. Finally, the total engine power is computed by summing the main rotor power and tail rotor power and by accounting for gearbox and transmission losses.

$$P_{total} = (P_{MR} + P_{TR}) k_{gb}$$

The numerical values of the performance model are summarised in Table 15.3.

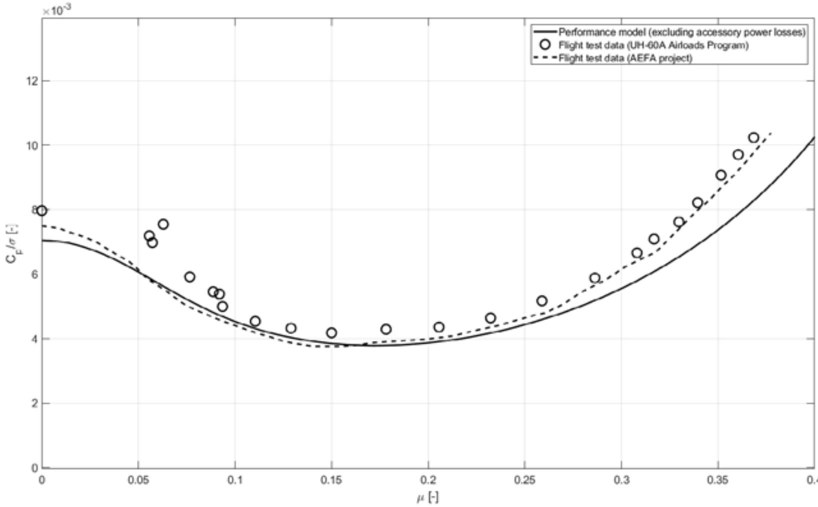
Table 15.3. Helicopter and performance model parameters.

Description	**Variable**	**Value**	**Reference**
Mean profile drag coefficient	$\overline{C_{D_p}}$	0.009 [-]	Johnson 2010
Distance tail rotor	l_{tr}	10.67 [m]	Department of the Army 1996
Factor to relate advance ratio to profile drag power	n	4.65 [-]	Johnson 2013: 177
Main rotor radius	R	8.18 [m]	Shinoda, Yeo & Norman 2002
Tail rotor radius	R_{tr}	1.68 [m]	Johnson 2010
Main rotor solidity	σ	0.0862 [-]	Shinoda, Yeo & Norman 2002
Tail rotor solidity	σ_{tr}	0.1875 [-]	
Main rotor rotational velocity	Ω	258 [rpm]	Shinoda, Yeo & Norman 2002
Tail rotor rotational velocity	Ω_{tr}	1159 [rpm]	Johnson 2010
Power specific fuel consumption	SFC	0.288 [kg/kWh]	Johnson 2010
Gearbox and transmission losses	k_{gb}	1.04 [-]	Johnson 2015

With these values, a baseline performance model of the UH-60A Black Hawk was constructed. For a gross mass of 8732 kg, the nondimensional power coefficient (C_p) computed with the performance model is compared to the power coefficient measured in flight for two separate flight test campaigns. Results of the comparison are presented in Figure 15.3.

In general, the performance model is in good agreement with the flight test data sets. Accessory power losses are not included in the performance model whereas the engine power measured in the flight tests includes accessory power. Hence, it is expected that the performance model predicts a somewhat lower power coefficient. Especially at higher advance ratios, the model shows somewhat larger discrepancies with the flight test data. It should be noted that both flight test campaigns also show differences. The aim of the current research is however not to develop a highly accurate flight performance model. A representative model is required which can be used to evaluate the relative effect of formation flight. Based on the comparison in Figure 15.3, the performance model is deemed representative and suitable for the current research.

Figure 15.3. Comparison of the baseline performance model of the UH-60A helicopter with flight test data (Bousman and Kufeld, 2005).



The power reduction of the follower aircraft in the formation is directly related to the strength of the wake vortices of the lead helicopter. The strength of these wake vortices in turn are directly related to the induced velocity of the lead helicopter. It is therefore proposed to model the power reduction in formation flight with the following equation.

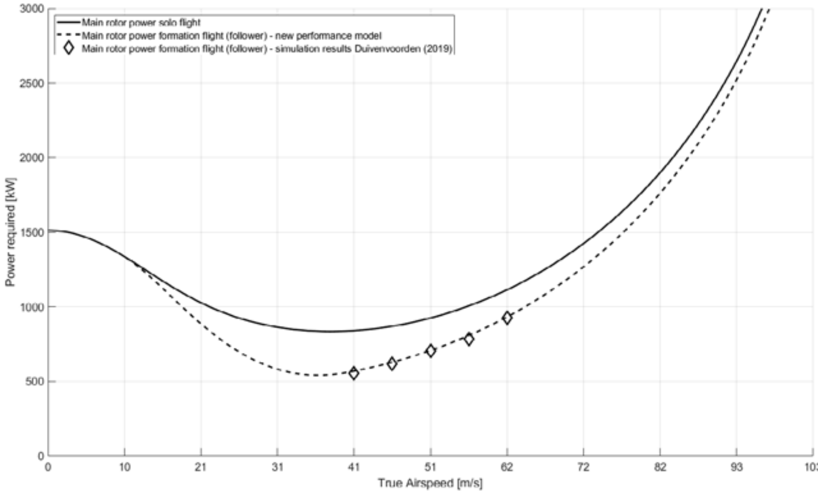
$$P_{follower,formation} = kW\left(v_{i_{follower,solo}} - k_f B\, v_{i_{lead}}\right)$$

The factor k_f accounts for several physical phenomena which are not directly captured by the equation. The velocity field of the wake is not uniformly distributed and it may be that only part of the rotor disc is located in the wake. Furthermore, the magnitude of the velocity of the upwash in the wake can be different from the induced velocity of the lead helicopter. Altogether the factor k_f can be interpreted as an efficiency and it is expected to be less than 1. This new equation is implemented in the performance model, and at airspeeds below the speed for minimum power it is gradually phased in with a one minus cosine function (B) according to the following equation.

$$B = \frac{1}{2} - \frac{1}{2}\cos\left(\left(\frac{V - V_1}{V_2 - V_1}\right)\pi\right)$$

The factor B gradually varies from 0 to 1 in between the speeds V_1 and V_2. In this study, the formation flight effect is phased in the speed range of 10–40 m/s.

Figure 15.4. Performance diagram for the baseline model and the extended model for formation flight (standard atmospheric conditions at sea, mass of both helicopters 8732 kg).

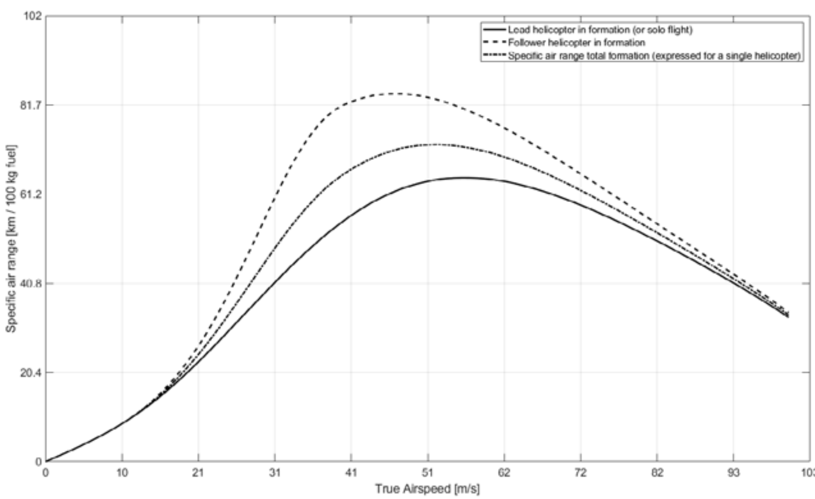


The results of the extended performance model are displayed in Figure 15.4. The baseline performance model shows the required power of the lead helicopter as a function of airspeed. The performance benefits as predicted by Duivenvoorden (2019) in Table 15.2 are applied to this power curve and displayed in the figure as well. Next, the factor k_f was tuned such that the formation flight performance model matches well with the predicted performance benefits. For this case, a factor k_f of 0.7 was selected. It can be observed that the extended model captures the performance benefits very accurately for airspeeds ranging from 41 to 62 m/s. If formation flights at airspeeds outside this range are of interest, then additional simulations with the detailed simulation model of Duivenvoorden et al. (2022) should be conducted in order to tune the factor k_f correctly. However, one should note that the most relevant range of airspeeds lies in between the airspeeds for maximum endurance (~39 m/s) and maximum specific air range in solo flight (57 m/s). In the next section, the formation flight performance model is used to analyse the effect of formation flight on mission performance in terms of range, endurance and optimal airspeeds.

15.4 Results and Discussion

The specific air range, defined as the distance a helicopter can fly per unit of fuel is a key parameter for mission analysis. The airspeed at which the specific range is maximal, is considered to be the optimal airspeed to achieve maximum range (for a given flight range it results in minimum fuel consumption). This optimal airspeed gradually changes during flight when the weight of the helicopter reduces and atmospheric conditions change. In case of a formation flight with the aim to reduce fuel consumption, the specific air range of the follower aircraft is different from a solo flight. The fuel consumption is reduced and the optimum airspeed for maximum efficiency is also changed. The specific air range for both solo flight and formation flight is displayed in Figure 15.5.

Figure 15.5. Specific air range in formation flight (aircraft mass 8732 kg, standard sea level atmospheric conditions).



The optimal airspeed in solo flight for the conditions specified in Figure 15.5 is about 110 knots whereas for the follower helicopter in the formation, the optimal airspeed is about 92 knots. The specific air range of the follower helicopter when flying at this optimal airspeed is almost 30% higher. In formation flight, both helicopters must however fly the same airspeed. The optimal airspeed for the formation as a whole is approximately 103 knots and the corresponding specific air range of the complete formation compared to two solo flights is 12% higher. With the ability to assess the effect of formation flight on fuel use and flight time for a specific flight condition (point performance) it becomes possible to analyse a complete flight during which the helicopter weight gradually changes by means of numerical integration (path performance). The results of a complete cruise flight analysis, for different starting masses of the helicopters and flight ranges, are summarised in Table 15.4.

Table 15.4. Fuel required [%] and flight time [%] of a formation flight compared to two solo flights (constant altitude flight at 304.8 m in standard atmospheric conditions).

		Range [km]		
		200	*400*	*600*
Mass at start of cruise [kg]	*6350*	-8.0% / +5.8%	-7.7% / +5.8%	-7.6% / +5.6%
	7258	-9.1% / +6.3%	-8.9% / +6.3%	-8.6% / +6.3%
	8165	-10.0% / +6.9%	-9.7% / +6.8%	-9.6% / +6.7%
	9072	-10.7% / +7.8%	-10.6% / +7.4%	-10.4% / +7.2%

Hence, the total fuel saving is in the order of 8–10% for a cruise flight at the cost of a 6–7% increase in flight time. For the long range cruise flight over a distance of 600 km at the maximum starting mass of the helicopters (9072 kg), the total fuel saving is 182 kg at the expense of 13 minutes extra flight time. It can be observed that the relative fuel savings increase with the weight of the helicopters. This can be explained by the fact that the required power for a helicopter increases with weight. The velocities induced in the rotor wake by the lead helicopter therefore increase as well and this effect is key for the aerodynamic benefit of the trailing helicopter. The results show that the effect of flight range on the relative savings is small. This is expected as the maximum total mass of the fuel stored in the internal fuel tanks (1110 kg) is relatively low compared to the maximum take-off mass of the helicopter (9185 kg). Hence the weight variation throughout a cruise flight is relatively small.

15.5 Conclusions and Recommendations

Experimental research and numerical simulations conducted at the Netherlands Defence Academy in collaboration with Delft University of Technology have recently confirmed the hypothesis that significant fuel savings can be achieved if two helicopters fly in formation.

A generic physics based model was developed that can be used to quantify the effect of formation flight on flight mission performance parameters such as fuel burn, optimal flight speed and flight time. This new model was applied to simulate the UH-60A Black Hawk helicopter in formation flight. It was demonstrated that the aerodynamic benefit as a result of formation flight can be accurately captured by the model. The baseline model, without aerodynamic benefits due to formation flight, was compared to flight test data of the UH-60 Airloads Program. The comparison showed that flight test data and simulation results are in good agreement and it was concluded that the performance model is representative for the current research

The new model was subsequently used to quantitatively analyse the effect of formation flight for typical military missions conducted with multiple helicopters. The effects of flight distance (range) and the weight of the helicopter at the start of the flight on fuel use and flight time was analysed. For cruise flights conducted at 304.8 m altitude in standard atmospheric conditions, fuel savings of 8–10% are achieved at the cost of a 6–7% increase in flight time. For a long range cruise flight over a distance of 600 km at the maximum starting mass of the helicopters (9072 kg), the total fuel saving is 182 kg at the expense of 13 minutes extra flight time.

Two recommendations are made for future research. First, it is recommended to investigate the potential aerodynamic benefit of formation flight on manned-unmanned teaming operations. The generic physics based model suggests that very large fuel savings can be achieved if a small unmanned system flies consistently in the upwash of the rotor wake of a large helicopter. A second recommendation is to perform a flight test with full-scale manned helicopters to prove the concept of formation flight in real-life conditions.

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CHAPTER 16

Solar Geoengineering as a Threat to Climate Security, Cooperation and State Sovereignty

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Abstract

Solar geoengineering, also known as solar radiation management, is a set of techniques seeking to artificially lower the global temperature. This chapter explores the various risks that these techniques pose to the security of populations and to states' sovereignty, i.e. their ability to ensure security on their own territory. A deregulation of the global atmosphere by the technical action of one or more states would have consequences for the economic, political, and security stability of all states. In the absence of any international legal framework, national security can be compromised by these techniques. Unravelling such risks is key in order to be prepared and monitor developing projects. Geoengineering will constitute a challenge in new and intangible ways, thus creating breaches in international law and openings for hybrid conflicts.

Keywords: climate, security, geoengineering, state sovereignty, international legal framework

16.1 Introduction

Solar geoengineering, also known as solar radiation management (SRM), involves deliberately increasing the amount of solar radiation reflected by the Earth to offset the warming caused by the soaring greenhouse gas concentration. Originally proposed by Soviet scientist Mikhail Budyko in the 1970s, solar geoengineering was brought into the public debate by Nobel laureate in chemistry Paul Crutzen in 2006. It was observed that atmospheric pollution increased the amount of solar radiation reflection. Paul Crutzen thus suggested replacing harmful atmospheric pollution with a deliberate injection of a smaller quantity of aerosols into the stratosphere to preserve this cooling effect. So far, stratospheric aerosol injection has been the most extensively studied solar geoengineering technique. However, solar radiation management (SRM) encompasses other techniques of varying invasiveness, ranging from increasing surface reflectivity (such as painting buildings white) to enhancing cloud reflectivity through cloud seeding.

SRM projects have recently been gaining increasing interest in developed, thus emittive, countries, particularly the United States, where Harvard University is developing the main research program on solar geoengineering: the Stratospheric Controlled Perturbation Experiment (SCoPEx). According to openly accessible data, the United States has indeed become the global leader in solar geoengineering research, thanks in large part to funding from philanthropists and private benefactors towards academic research projects (Stephens et al., 2021). Faced with the inefficiency of international climate governance, proponents of solar geoengineering, such as Gernot Wagner and David Keith, argue that it is imperative to master such techniques in order for them to be quickly implemented in the increasingly likely scenario where mitigation policies prove insufficient (Wagner, 2021; Keith, 2013). In this context, a research program on solar geoengineering options was deemed necessary by the National Academies of Science, Engineering, and Medicine (NASEM) in a report published in March 2021 (NASEM, 2021); and in March 2022, the White House Office of Science and Technology Policy launched a five-year research plan to explore these options.

Therefore, we can observe a form of normalisation of solar geoengineering projects within American research communities, which consider them legitimate research initiatives (Biermann et al., 2022). This normalisation aligns with a broader technoscientific approach to addressing climate change, at the expense of systemic solutions, and has led to tangible developments in this field. The aim of this chapter is to explore various risks that this approach poses to the security of populations and to states' sovereignty, i.e. their ability to ensure security on their own territory. In order to do so we take three consecutive steps. Firstly, we will examine the physical and moral risks solar geoengineering poses to climate security. Secondly, we will delve into its specific impacts on the territorial sovereignty of states. Lastly, we will assess to what extent solar geoengineering could seriously jeopardise international cooperation on climate policies.

16.2 A Threat to Climate Security

To date, physical risks associated with solar geoengineering techniques are poorly understood and still subject to exploratory studies in atmospheric sciences. The techniques involving particle injection into the stratosphere raise significant environmental and health uncertainties, especially due to the proposed active substances such as sulfuric acid, which is destructive to the ozone layer and highly toxic (Lawrence et al., 2018). Moreover, sulfur, a component of sulfuric acid, could later precipitate as acid rain, causing health problems and damage to local ecosystems (Chalecki & Ferrari, 2018). There are also uncertainties regarding the effects of solar geoengineering on weather patterns (Baughman et al., 2010) and agricultural production. In this regard, risks posed by solar geoengineering on food security are starting to be explored, but studies on the subject remain limited. Some studies highlight risks of reduced crop yields in regions heavily influenced by summer monsoon systems, particularly in East Asia (Robock et al., 2008; Tilmes et al., 2013). Another study suggests that by reducing available solar radiation on Earth, stratospheric aerosol injection could negatively impact crop photosynthesis (Proctor et al., 2018). A reduction in solar radiation would also affect solar energy production based on photovoltaics (IPCC, 2022, 1491). However, given the global scope of solar geoengineering techniques, the variability of both impacts across regions and intervention methods hampers a comprehensive understanding of the risks they entail. The effects of such techniques depend on numerous variables that determine their deployment, such as their place within broader strategies for addressing climate change, the materials used, the season, etc. (IPCC, 2022, 1489). Furthermore, studies on these techniques largely rely on difficult-to-verify numerical models. Therefore, it is possible that the risks associated with the proposed techniques may not be fully understood prior to their deployment (Oomen & Meiske, 2021).

Another significant risk in the context of solar geoengineering deployment is the risk of sociotechnical lock-in, meaning the adoption of an irreversible pathway of the developed techniques in this field (Cairns, 2014). In this scenario, technological developments could lock in sociotechnical entanglements closely tied to financial investments and political positioning, making it unlikely for the techniques to be abandoned, even in light of negative impacts evidence. This irreversibility, commonly observed in Western technological developments, is exacerbated in the context of solar geoengineering due to the "termination shock" (Parker & Irvine, 2018). If solar geoengineering were to be deployed and managed to temporarily neutralise global warming, stopping the deployment would lead to a sudden temperature increase. Since the lifespan of stratospheric aerosols is one to three years, the injection of stratospheric aerosols would need to be repeated annually (Niemeier et al., 2011). As for marine cloud brightening operations, continuous spraying of sea salts into the clouds would be required, as their lifespan is only about ten days (MacDougall et al., 2020). Thus, two risks emerge from the necessary continuation of interventions: heavy dependence on resource-intensive technological developments (financial, energy, and mineral resources) and the potential for rapid and devastating global warming if events like natural disasters or supply disruptions were to halt the deployment.

In addition to physical risks associated with solar geoengineering techniques, there is a "moral hazard" (Preston, 2013) that could arise from the deterrent effect of these techniques, specifically their existence in the collective imagination regarding mitigation and adaptation efforts. Since the early 2000s, this risk has been increasing due to the "technoscientific promises" made by their advocates and the speculative hopes they raise about the possibility of a technical solution to climate change. Indeed, these techniques' development relies on the promise that a disruptive technology will replace or supplement mitigation policies and system-level transformational change. This promise undermines commitments to mitigation (Asayama et al., 2019) and is echoed by certain industrial sectors, particularly the energy industry, in their search for technical alternatives to climate policies (Low & Boettcher, 2020). By suggesting that a technique could temporarily suspend global warming while carbon emission reduction policies take effect, it leaves open the possibility of postponing those policies. In this context, the moral hazard is even more significant when the effectiveness of the techniques is uncertain. A 2020 atmospheric science study precisely questions this effectiveness in the absence of carbon emission reductions, highlighting a structural climate element not addressed by solar radiation interventions: the impact of greenhouse gases on cloud cover, which deteriorates as these gases accumulate (Schneider et al., 2020). Increasing greenhouse gas emissions lead to cloud thinning – and, in extreme cases, cloud – reducing their ability to reflect solar radiation. Despite the implementation of solar geoengineering techniques, significant global warming can still occur if CO2 continues to accumulate in the atmosphere.

In this sense, solar geoengineering cannot compensate for a delayed political response to climate change. Moreover, the risks associated with these techniques are multifaceted and not yet fully understood. They encompass environmental, health, agricultural, and societal dimensions. The environmental and health uncertainties arise from the injection of particles into the stratosphere, with potential repercussions on the ozone layer, ecosystem health, and regional climate systems. The agricultural risks involve potential reductions in crop yields, particularly in monsoon-dependent regions, and the adverse effects on photosynthesis and solar energy production. The societal risks include the possibility of irreversible technological lock-in and the moral hazard that diverts attention and resources from necessary mitigation efforts. Furthermore, the complex and global nature of solar geoengineering introduces challenges in comprehensively assessing its risks across different regions and intervention strategies.

16.3 A Threat to State Sovereignty

Given the current state of knowledge and the uncertainties surrounding solar geoengineering, it is crucial to approach its development and deployment with caution. Continued scientific research, rigorous risk assessment, transparent governance frameworks, and inclusive international dialogue are essential to navigate the complex and potentially far-reaching implications of solar geoengineering as a potential climate change mitigation strategy. We will nonetheless demonstrate that these conditions are not gathered, neither at the international nor at more local levels.

Experiments and observational studies, which are essential for understanding the risks involved, face challenges in materialising due to prevailing public opposition. The scientific uncertainties surrounding the effects of solar geoengineering and the issue of public acceptance are mutually reinforcing: the lack of adequate knowledge about potential impacts makes any field experimentation controversial, while controversies surrounding small-scale experiments hinder the acquisition of field knowledge. Indeed, the need for field knowledge is a key factor shaping current and future geopolitical tensions surrounding these techniques. These tensions are manifested through strong reactions from local actors who oppose any experimentation on their own territory. Populations' reaction to experimentation is the first level of political opposition and questions the validation scale (should a project be validated at the international, national or local level?). Opposition to geoengineering, which aims to modify the atmosphere, a global common good, becomes a divisive element on the international stage due to the absence of a global legislative framework. Several attempts at small-scale experimentation, such as SPICE and SCOPEX, have been halted. In the case of SCOPEX, the Sami people strongly opposed a balloon launch test planned to take place in Sweden in 2021. Private actors also engage in this field, and develop parallel projects, releasing minuscule amounts of particles in the atmosphere without permission and facing unanimous condemnation from the scientific community. One example is the American company Make Sunsets, which sold "cooling credits" corresponding to the release of a certain quantity of aerosols. The company conducted several launches on Mexican territory but relocated its operations to Nevada following condemnation by the Mexican government. The Mexican government has expressed its intention to ban all geoengineering experiments on its territory and is expected to become the first state in the world to develop geoengineering legislation. Another instance is Andrew Lockley, who conducted an experiment on British territory in collaboration with the company European Astrotech in September 2022. As part of this experiment, a balloon released several hundred grams of sulfur dioxide into the atmosphere. While the controversy surrounding Andrew Lockley's experiment highlights the highly sensitive nature of intervening in a global common, controversies surrounding the SCOPEX project and the Make Sunsets company emphasise the even greater sensitivity when such interventions occur from the territory of another state.

Solar geoengineering operations can thus be perceived as symbolically violating territorial sovereignty through the chemical modification of the stratosphere, which falls below the threshold that demarcates a state's airspace. The latter constitutes one of the challenges of international governance and state sovereignty enforcement: indeed, it is still under discussion whether this threshold is located at 80 or 100 km above sea level. The aforementioned experiments could have been taking place above this threshold and still affect the agriculture or the environment of neighbouring states underneath. Therefore, it is important to develop legal frameworks around such deployments and define limits with the current blurred lines calling for actions which could infringe state sovereignty, all the more when the state has not been informed of these activities.

Pushing further the study of sovereignty-related risks and global insecurity, the potential array of reactions of affected states are to be highlighted. Non-informed affected states could indeed react through intergovernmental organisations, mobilising the United Nations Security Council or calling up the ENMOD convention. This convention regulates the uses of environmental modifications for military or "hostile" purposes. Its ambiguity could nonetheless be used by geoengineering-supportive states, underlining their "peaceful" intentions (Raczek, 2022). As underlined before, transparent governance frameworks and inclusive international dialogue are essential to navigate the potential repercussions of geoengineering deployment. It is however necessary to acknowledge the difficulty, if not the impossibility, to find such agreements in the current geopolitical context.

Touching upon international security, based on limited available options for a country to halt the deployment of geoengineering technologies in the vicinity of its territory, one can imagine a military based reaction, a "focused strike" as suggested by Versen et al. (2021) aiming at the deployed geoengineering technology. The reduced concrete diplomatic action panel materialises military action as a considerable risk, which should not be misconsidered. In addition, the activity of the private sector in that matter being central, one could underline the need for every state to get national legal frameworks enabling state control over geoengineering projects. State sovereignty will indeed be assessed by its capacity to regulate activities conducted by companies acting or headquartered on its territory. Along the same lines, the question of the positioning of states regarding geoengineering proves to be a fundamental element in the equation: whether states approve or disapprove of geoengineering activities will condition their legal frameworks, their ability to intervene following the call of a third party or another country and their cooperation capabilities.

The topic is still being swept under the rug at the international level, and it is difficult to map out the positioning of countries with regards to this nevertheless critical issue: around 50 countries started working on geoengineering technologies, according to the World Meteorological Organisation (Raczek, 2022), developed countries the vast majority. The challenge of understanding who works on what, and to anticipate debates in intergovernmental arenas, needs to be overcome in order to prepare for a context in which unilateral action, often difficult to attribute, could lead to escalation, and in which state sovereignty will be threatened in an unprecedented manner.

Whether it be the social skepticism against local level experiments, blurred lines, and loopholes in the global governance of such technologies, crystallised geopolitical context, or the array of reactions to potential state sovereignty infringements, conditions of a safe and secure deployment of solar geoengineering technologies have not been gathered. As a result, each and every full-scale experiment conducted by the private sector or academia could lead to escalation and represent a security risk at the international level.

16.4 A Threat to Climate Cooperation

Considering the interest in using such technologies alongside the variety and difficulty of assessing associated risks, no international consensus has been reached, leaving these techniques under a legal loophole. Their implementation could nonetheless give rise to tensions and conflicts, given the lack of a global arena to democratically agree on their use. Their likely unilateral deployment could not only undermine international climate cooperation but also give rise to counter-geo-engineering operations, to reverse effects of the first deployment. These conflict risks are intrinsically linked to the global scope of solar geoengineering operations. A deregulation of the global atmosphere by the technical action of one or more states would indeed have consequences for the economic, political, and security stability of all states. In the absence of any international legal framework, state sovereignty is compromised by these techniques.

Solar geoengineering projects remain limited in number and unevenly distributed globally, primarily due to the substantial financial investment and technological advancements required. The United States is the largest funding source, with support from both the government (such as the NOAA project) and philanthropic organisations like Silverlining. Research projects are also being carried out in the European Union, China, and India. The dominance of Western countries in solar geoengineering perpetuates global climate inequality on multiple levels: Western countries bear significant responsibility for past carbon emissions, they possess greater financial and technological capacities to adapt to climate shocks, and they hold decision-making power and influence in global climate change governance. This development of solar geoengineering projects by the West reinforces control over present and future atmospheric conditions, leaving countries in the Global South less responsible for global warming with little control. These states lack the resources to conduct field research and are particularly vulnerable to potential climate disruptions resulting from atmospheric intervention. This is how

Biermann and Möller problematise the development of geoengineering as a process of "marginalization of the global South" and call for total political control by all states in the international community (Biermann & Möller, 2019). In their efforts to reduce or offset this marginalisation, developed countries also tend to establish or deepen dependencies on financial, scientific, and technological levels. For instance, the British NGO *DEGREES Initiative* is funded up to $2 million to develop expertise on solar geoengineering in the Global South. This demonstrates the continuation of a power imbalance for knowledge and atmospheric control. Such imbalance tends to be compensated by technology transfer and capacity building, nonetheless keeping the global order as it is.

This is challenged by the resistance of some Southern countries rejecting the technocentric vision of Western climate strategies. For example, African civil society organisations signed a letter last year urging the African Union to reject geoengineering in Africa. Such resistance is part of a broader resentment amongst Southern countries towards the historical responsibility of the West and its failure to reduce dependence on fossil fuels. Taken to the extreme, the resistance of certain states can transform into geostrategic competition, with the aim of achieving dominance in solar geoengineering technology, which would redefine climate influence. This competition would no longer solely rely on a state's capacity to lead climate mitigation policies but on its ability to offer a solution. China's increasing prominence in solar geoengineering reflects its ambition to play a decisive role in future climate negotiations, involving the multilateral deployment of solar geoengineering programs. This role would allow China to counterbalance Western influence while advancing its national interests and those of developing countries.

In a context that is highly conducive to tension, conflict and competition, solar geoengineering techniques require global governance under the control of multilateral institutions and effective monitoring and enforcement over the deployment of these technologies (Holahan & Kashwan, 2019). However, international law remains extremely vague on this point, and currently, no institution has the legal capacity to regulate international decisions regarding geoengineering. It is precisely in the absence of such governance mechanisms that the startup Make Sunsets was able to freely carry out several small-scale stratospheric aerosol injections (sulfuric acid) in Mexico, highlighting two types of risk: firstly, the physical risks discussed in part I, which would result from a unilateral and large-scale deployment of solar geoengineering techniques by a public or private actor; secondly, the risks of conflicts between the driving state of this deployment and states that have not given their prior consent described in part II. However, the establishment of governance tools is compromised by the desire of a number of states to deploy them without legal constraints. In 2019, Switzerland and nine other countries submitted a resolution proposal to the United Nations Environment Programme, which aimed to undertake an assessment of geoengineering options and their risks, citing the "precautionary principle." However, it was blocked by the United States, Brazil, and Saudi Arabia (Chemnick, 2019). With no consensus reached on this issue, it is inconceivable for the international community to agree on the deployment of a specific solar geoengineering process and technical details such as the mode of substance diffusion, quantity, and duration of deployment. Therefore, solar geoengineering projects pose serious challenges to global governance and, according to some authors, appear incompatible with democratic decision-making (Stephens et al., 2021).

In the context of a climate emergency, intergovernmental disagreement over the deployment of a solar geoengineering technique would not lead to its abandonment but rather to its implementation by a coalition of states or even unilateral implementation. Such a possibility, facilitated by the low cost of deployment, has been problematised by Wagner & Weitzman, who originated the concept of the "free driver effect" (Wagner & Weitzman, 2012). Specifically, these authors highlight the highly positive economic ratio between the costs of geoengineering deployment and potential benefits, particularly the cancellation of global warming coupled with the avoidance of mitigation policies. Furthermore, this effect benefits from a favourable context characterised by the "free rider effect": climate change is a collective problem, but in the short term, responding to it through mitigation measures does not serve the individual interest of anyone. It is within the framework of the widespread inaction that currently characterises the international community and in the absence of an effective governance framework technological developments in solar geoengineering proliferate.

Moreover, as the field is seemingly dominated by the United States, it is possible that they may take the lead in future unilateral deployment of geoengineering, with the risk that the technological management of climate change primarily serves US national interests (Stephens & al., 2020). The United States' interest in this research field is, in fact, linked to strategic perspectives related to preserving its economic and military hegemony. The successful deployment of a geoengineering technique would open the way for the expansion of fossil fuels, which support its hegemony while also providing a response to climate change, considered a national security threat by the US military. This explains the involvement of US defence, intelligence, and foreign policy institutions in the development of solar geoengineering within the framework of "militarization logics" (Stephens et al., 2020). Given the strategic nature of such technologies for the United States, it is also likely that competing powers such as China or Russia will develop similar technologies with the aim of rebalancing forces.

Such a race for solar geoengineering would inherently entail a significant risk of technical escalation if one technology were deployed. If a "free driver" were to initiate unilateral deployment, other states could deploy "counter-geoengineering" programs to respond to the initial deployment. Two forms of "counter-geoengineering" have been theorised: a "neutralization" form that would involve dispersing new substances to accelerate the atmospheric deposition of already dispersed substances, and a "compensation" form seeking to reverse the effects of the dispersed substances by injecting warming agents (particles or greenhouse gases) (Heyen et al., 2019). Thus, the atmosphere could become the theatre of singular confrontations involving interventions and counter-interventions for planetary cooling. Such confrontations could occur against the backdrop of ideological divisions concerning the solution to climate change, particularly based on the contestation of US technoscientific hegemony. In this sense, the potential deployment of solar geoengineering technology not only poses the risk of technical disruption of atmospheric phenomena but also an additional disruption within the framework of technological escalation, stifling any possibility of international climate governance in a highly conflict-prone context. Nevertheless, in the absence of any legal framework for regulating these technological developments and considering the reflections exposed on the free rider effect, it is highly likely that unilateral deployments, like the Make Sunsets initiative, will multiply, ultimately leading to a technological lock-in of solar geoengineering and a weakening of mitigation policies.

16.5 Conclusion

Geoengineering could thus lead to simultaneous environmental, social, and economic (through agriculture and tourism) issues, hampering human security with challenges never faced before. It is of paramount importance to assess both these risks and the governance problematics associated. The lack of an international framework is at the core of difficulties in terms of monitoring and control, opening opportunities for states and non-state actors to act unilaterally at the expense of neighbouring communities and countries. In this chapter, we have tried to underline the aforementionned risks, to highlight the lock-in trends which would be inevitably associated with the deployment of such technologies and the moral plea arising from a technological solution to offset our CO2-intensive economy. Furthermore, this chapter introduced various escalation risks to be considered as critically probable, from technical counter measures, injecting more chemicals into the atmosphere, when countries are equipped with such possibilities, to military-like "focus strike" responding to geoengineering by traditional weapons (missiles, rockets, drones) to damage, destroy and neutralise deployment infrastructures. We argue that geoengineering deployment in the absence of any intergovernmental framework represents one of the most threatening disruptions in the geopolitics of nature and a new risk for state sovereignty.

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Timothy Clack is the Chingiz Gutseriev Fellow at the University of Oxford and an associate fellow of the Centre for Historical Analysis and Conflict Research (CHACR). Tim's anthropological work has focused primarily on issues of conflict, identity, and heritage in various parts of the world, including the Horn of Africa, Central Asia, and the South Atlantic. Tim is the Director of the Climate Change & (In)Security Project, a collaboration between Oxford and CHACR. He is the General Editor of the Routledge Advances in Defence Studies (RAiDS) book series and co/editor of numerous books including: *Climate Change, Conflict and (In)Security* (2023); *Cultural Heritage and Armed Conflict* (2022); *The World Information War* (2021); *Before Military Intervention* (2018); and *At the End of Military Intervention* (2015).

Dr. **Andrea Coraddu** was born in Pietrasanta in 1979. He was awarded a Laurea degree in Naval Architecture and Marine Engineering from the University of Genoa in 2006, followed by a Ph.D. from the University of Genoa's School of Fluid and Solid Mechanics, where he focused on Modelling and Control of Naval Electric Propulsion Plants. He currently serves as an associate professor in the Maritime and Transport Technology Department at Delft University of Technology. Throughout his career, he has held various academic and research positions, including roles as associate professor at the University of Strathclyde, research assistant at Newcastle University's School of Marine Science and Technology, senior research engineer at DAMEN Research and Development Department in Singapore, and Post Doc research fellow at the University of Genoa. Dr Coraddu has successfully secured grants from research councils, industry partners, and international governmental agencies. His research primarily focuses on designing, integrating, and controlling complex marine energy and power management systems. His work contributes to the development of advanced, multi-functional vessels, addressing environmental concerns related to human activities in the marine environment.

Dr. ir. **Edwin Dado** is associate professor of Civil Engineering at the Faculty of Military Sciences of the Netherlands Defence Academy. His research interests include water management, design principles, process management, systems engineering, and Construction IT applied in a military context. After an initial career at an engineering firm, he obtained a PhD at TU Delft.

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Prof. dr. **Paul C. van Fenema** is professor of defense logistics at the NLDA. He received his PhD from RSM Erasmus University and worked for this university as well as Florida International University and Tilburg University. His research focuses on interorganisational cooperation in logistics, combinatory analytics, service networks and digital innovation. He has published in Organization Science, MIS Quarterly, Joint Forces Quarterly and International Journal of Management Reviews.

Prof. dr. ir. **Georg Frerks** held the chair of Conflict Prevention and Conflict Management at Utrecht University and the chair of International Security Studies at the Netherlands Defence Academy till his retirement in 2021. Till mid 2014 he also held the chair of Disaster Studies at Wageningen University, the Netherlands. Frerks served for nearly twenty years in the Dutch Foreign Service both at the headquarters and abroad. He also was head of the Conflict Research Unit of the Netherlands Institute of International Relations 'Clingendael' in the Hague. Frerks focuses on conflict and conflict management as well as on international and national conflict-related policies and interventions, and the international security architecture. During his period at Wageningen University he worked on natural and man-made disasters and humanitarian emergencies. Recently, he has worked on rebel governance especially by the Liberation Tigers of Tamil Eelam (LTTE) in Sri Lanka. Frerks has (co-)authored or (co-)edited 25 academic books, over 120 journal articles and book chapters, and 90 policy reports and monographs in his field of expertise. Frerks has directed or participated in various policy-related studies and evaluations in the field of conflict and peacebuilding and participated on the boards of several national and international conflict and peace related NGOs.

Commander (E) dr. ir. **Rinze Geertsma** (CEng, FIMarEST) was born in Kollum, the Netherlands in 1975. He received his MSc. degree in Marine Engineering at University College London, UK, in 1999, and obtained his PhD degree from Delft University of Technology, the Netherlands, in 2019 with his thesis on 'Autonomous Control for Adaptive Ships with Hybrid Propulsion and Power Generation'. He is currently assistant professor in Military Energy Systems for Ships with the department of Military Technology at the Netherlands Defence Academy, Breda, and guest researcher at Delft University of Technology, the Netherlands, with a research interest in military energy systems for naval vessels. He previously has been marine engineering officer of HNLMS de Ruyter and HNLMS Tromp. Earlier experience includes system and project engineering and innovation roles.

Alex Grasman was born in Sneek, the Netherlands, in 1990 where he soon became inspired by boats and yachts and found out that he wanted to become a yacht designer. After high school, he moved to the UK and obtained his Bachelor degree in Yacht and Powercraft Design at Southampton Solent University in 2011. Soon after that he started a job as a naval architect at Van Oossanen in Wageningen, where he performed conceptual and basic design of large motor yachts. Whilst working on a different project for a hybrid ferry for Lake Geneva, he became inspired by Power Systems and Energy Carrier developments. Feeling the need for a change and the importance of the maritime energy transition in 2019, he started his current position at MARIN (Maritime Research Institute Netherlands) as a Specialist in Marine Power & Energy Systems. His work focuses on how future Power & Energy Systems can be assessed, compared, and integrated in ship designs. He works on tools to compare technologies and give ship owners, yards and design offices insight into the pros and cons associated with these technologies.

Wessel Groote Schaarsberg is an officer at the Royal Netherlands Air Force. He recently graduated from the Netherlands Defence Academy with a bachelor's degree in Military Systems and Technology.

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Lieutenant Colonel **Sieds Haitsma**, MSc, BA is an assistant professor of defense logistics at the NLDA. He started his military career in the Royal Netherlands Air Force in 2001. He had several positions at Leeuwarden Air Base and worked for the F-35 Procurement Program. Before his current position he worked at the Staff of Netherlands Ministry of Defense. Since 2022, he has been working for the NLDA and tutoring military logistics.

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Saskia Hollander is a senior research fellow at the EU & Global Affairs Unit at Clingendael. Her research revolves mainly around EU governance & politics, (labour)migration- and climate policy. On behalf of Clingendael, Saskia was part of the scientific staff of the State Commission on 'Demographic Developments 2050', that was appointed by the Dutch government to advise government and parliament on the social and economic impact of demographic developments, in particular ageing and migration. Prior to joining Clingendael, Saskia was the director of The Broker, a Dutch-based knowledge brokering organisation in the field of international development. In 2006 and 2007 she worked at the Netherlands Scientific Council for Government Policy on projects related to European integration and development policy. In 2012 and in 2022 she worked at the Dutch Advisory Council on International Affairs as deputy secretary of the European Integration Committee. Saskia holds a PhD in political science from Radboud University Nijmegen. Her dissertation dealt with the politics of referendum use in the EU.

Bart Hollants MSc. works as Innovation Broker at the NATO Innovation Hub, part of the headquarters of Allied Command Transformation, based in Norfolk, Virginia. The NATO Innovation Hub has been facilitating open military innovation throughout the Alliance for over a decade, stimulating and facilitating member states in pursuing open innovation and coordinating NATO innovation efforts between the two strategic headquarters in Mons (BE) and Norfolk (USA). The NATO Innovation Hub brings together Allies, academia, knowledge centres, and industry. Bart previously worked as an innovation scholar and lecturer at the Copernicus Institute for Sustainable Development at Utrecht University and remains a freelance scholar.

Ir. **Danny Janssen** is a PhD student at Delft University of Technology and the Netherlands Defence Academy. In his research, he investigates the multifunctional application of military equipment during high-water crises, with a specific focus on the BresDefender. Danny Janssen is expected to defend his thesis in 2024.

Dr. ir. **René Janssen** is associate professor of mathematics and operations research at the Faculty of Military Sciences of the Netherlands Defence Academy. His research interest focuses on network theory and stochastics related to military operations research.

Dr. **Thijs Jeursen** is an assistant professor in Conflict Studies at Utrecht University. His current work explores connections between climate change and violent conflict, focusing on the role of militaries as ecological actors. In another research project, "mapping environmental damage", he works on monitoring environmental harm during conflict, analysing the applications of satellite imagery.

Dr. **Relinde Jurrius** works as assistant professor of Mathematics & Operations Research at the Netherlands Defence Academy. Her research and teaching focuses on the application of new techniques in mathematics and computer science to relevant military problems, as well as the theory behind it.

Dr. **Jori Kalkman** is an associate professor at the Faculty of Military Sciences of the Netherlands Defence Academy and was a visiting scholar at the Swedish Defence University. His research focuses primarily on crisis management and disaster response. He is particularly interested in the implementation of these activities by specialised crisis organisations. Recently, he published a book called 'Frontline Crisis Response' with Cambridge University Press, in which he discusses eleven dilemmas that crisis professionals encounter time and again in their work.

Prof. dr. ir. **Robert van de Ketterij** was born in Velsen in 1968. He studied Naval Architecture at Delft University of Technology and received a PhD at the faculty of Applied Earth Sciences, also in Delft. After his study, he held several positions as naval architect at major shipyards in the Netherlands. In 2005, he returned to science in a role as assistant professor at the Netherlands Defence Academy in Den Helder. Between 2007 and 2017, he held various positions in the field of design and development of complex systems in the field of dredging and (deep sea) mining with an increasing focus on improved energy systems and emissions reduction. Since 2017, he has been full professor of Systems Engineering and chair of the section Military Technological Sciences at the Netherlands Defence Academy. His research focuses on complex energy systems of naval ships, emissions and signatures related to the operation of these systems.

Dr. B.M.J. (Berma) **Klein Goldewijk** is the director of cooperation on research methodology for the Faculty of Military Sciences & Higher Defence Education at the Netherlands Defence Academy, Ministry of Defence. She is a senior research affiliate at the Dep. of International and Political History, Faculty of Humanities, Utrecht University, and a research fellow at the Faculty of Military Sciences. Her research interests include armed conflict and war studies, diplomacy and negotiation, international relations, critical theory, and intelligence studies.

Selected publications: War diplomacy in Ukraine: Causes and endings of Russia's military invasions. In M. Rothman et al. (Eds.) *Reflections on the Russian-Ukrainian War*. Leiden University Press; (2021) Why still critical? Critical intelligence studies positioned in scholarship on security, war, and international relations. *Intelligence and National Security 36*(4): 476–494; (2018) (with Joseph Soeters) Peace operations and 'no peace to keep'. In D. J. Galbreath & J. R. Deni *Routledge Handbook of Defence Studies*, 260–271. London: Routledge; (2018), Border security, boat migration and

Mediterranean operations in the frames of securitisation and law enforcement: Causal explanation and process tracing, in: H. Monsuur et al. (Eds.), *Coastal Border Control: From Data and Tasks to Deployment and Law Enforcement*, 63–88. The Hague: T.M.C. Asser Press.

Prof. dr. **Jeroen Klomp** is a full professor on arms export control at the Faculty of Military Sciences of the Netherlands Defence Academy and associate professor of economics at the Wageningen University & Research. His research is mainly concerned with the political economy aspects of arms trade and the strategic competition among states.

Ing. **Dennis Krabbenborg** is a lecturer at the Faculty of Military Sciences (FMW) of the Netherlands Defence Academy. After graduation Dennis worked at a construction company in the Civil Engineering industry on large infrastructural projects. In 2005 he joined the section Military Engineering at the FMW as a lecturer, supporting and facilitating research projects. For these purposes he is also managing the Military Engineering laboratory in Breda.

Major **Sebastiaan Leertouwer**, MA, works as a lecturer at the Faculty of Military Systems and Technologies at the Netherlands Defence Academy. Within the faculty he works in the section of Military Engineering, providing classes for the cadets and midshipmen mixing the operational environment and problems with academic education. In the next few years, he will be conducting research in the field of Military Engineering.

Sarah Lokenberg is a junior research fellow at the Planetary Security Initiative and the EU & Global Affairs Unit at the Clingendael Institute. Her work revolves around conducting research and analysis on climate security and energy security. Core interests underpinning her work are the geopolitics of the energy transition and the security implications of climate change. In addition to her focus on climate- and energy security, Sarah also has an interest in non-state armed groups, rebel governance and legitimacy. She holds a BSc in Psychology with a major in Social Psychology and a minor in Conflict Studies from Utrecht University. She attained an MA in International Relations (cum laude) from Leiden University where she researched under what conditions resource-rich rebels govern civilians.

Dr. **Hans Melissen** is assistant professor of mathematics, operations research and statistics at the Faculty of Military Sciences of the Netherlands Defence Academy. His research interests include the application of optimisation in military and geometric problems.

General (Ret) **Tom Middendorp** is a former Chief of Defense of The Netherlands. He was involved in over twenty different military missions and experienced how climate change is already acting as a risk multiplier. He triggered a public debate in the Netherlands with his speech in the Peace Palace in 2016 on the nexus between climate and security that gave him the nickname climate general. When he retired he founded – and was appointed as the Chairman of – the International Military Council on Climate and Security (IMCCS): a global network of security experts and research institutes from over 40 countries. In 2022 he published his book 'Climate General' in Dutch which he dedicated to his children. In 2023 the English and French versions of this book were published and in 2024 it will be filmed in a three-part documentary. Tom joined The Clingendael Institute as a Senior Visiting Fellow and is attached to The Hague Center for Strategic Studies as a Strategic Security Expert. Tom is also the Dutch Special Envoy on European Defense cooperation.

Prof. dr. **Herman Monsuur** is professor of Military Operations Research at the Faculty of Military Sciences of the Netherlands Defence Academy. His current research interests include network theory, search and detection, game theory, the optimal deployment of UAVs, and critical infrastructure security and resilience.

Lieutenant General (Retd) **Richard Nugee** CB CVO CBE has earned international recognition for bringing the implications of Climate Change and Sustainability to the Defence and National Security sectors. After a full operational career in the British Army, as his final role he wrote a Review of Defence's approach to Climate Change and Sustainability. He was the Non-Executive Director for Climate Change and Net Zero for the Ministry of Defence. He has expanded this policy interest into delivery, as the Chair, Director, and Advisor of several renewable energy and environmental sustainability start-ups. He is CEO of a medical research charity, The Scar Free Foundation, Chair of the Royal NAAFI Board, Director of his own Strategic Advisory Company, a strategic advisor to several consultancies and organisations, including the Hague Centre for Strategic Studies, Oxford University's Climate Change (In)Security Project and a climate-focused venture capitalist group.

Ir. **Alexander van Oers** is assistant professor of mathematics and operations research at the Faculty of Military Sciences of the Netherlands Defence Academy. His current research interests include numerical analysis, machine learning and partial differential equations.

Irina Patrahau is a strategic analyst at HCSS, part of the HCSS Energy and Raw Materials Initiative and Climate and Security Programme. Her areas of expertise are the geopolitics and geo-economics of energy and raw materials and climate security. Irina's work is focused on the energy transition and its implications for inter- and intra-state relations, with a particular focus on (critical) raw minerals. In addition to her work on the implications of climate change mitigation, Irina is also part of broader HCSS work on the climate-security nexus. She is part of the Water, Peace and Security Partnership, a consortium that seeks to address water-related security challenges through innovative tools and services. Irina holds a BSc degree (cum laude) in Political Science with a specialisation in International Relations from Leiden University and a minor in Geo-Resources for the Future at the TU Delft. She attained her MSc degree (cum laude) in Political Economy from University of Amsterdam, where she studied the energy relations between China and Eastern Europe in the context of the energy transition. Prior to joining HCSS, she was an intern at Karama Europe, an NGO supporting women's rights activist groups in the Middle East and North Africa.

Ir. **Maarten Pothaar**, born in Sneek in 1996, is employed as a marine engineer at the Maritime Systems Department within the Materiel and IT Command (COMMIT). With a profound interest in sustainable and energy systems for naval ships, he earned his Master's degree in Marine Technology in 2022 at Delft University of Technology. Maarten's commitment to advancing naval technology is evident through his graduation research at the Defence Materiel Organisation (COMMIT was formerly named DMO). Focusing on the energy transition for the replacement Air Defense and Command Frigate, his work resulted in a published paper presented at the International Naval Engineering Conference and Exhibition (INEC) in 2022. Prior to his master's pursuits, Maarten obtained a Bachelor's degree to become a maritime officer in 2019 at the Maritime Institute Willem Barentsz Terschelling. His academic journey showcases a dedication to the maritime industry, coupled with a keen interest in innovative solutions for the sustainable future of naval engineering.

Commander (Ret) Drs. **Jan Pieter de Rooij** is an assistant professor of defense logistics at the NLDA. After 38 years in the Royal Netherlands Navy as a supply officer and several international postings in the Netherlands Antilles, USA and Italy, JP de Rooij retired in January 2018. He initially started as a freelancer, and subsequently accepted a job at the Netherlands Defense Academy, Faculty of Military Sciences as an Assistant Professor in Navy Logistics, with specialty in procurement and material disposal.

Louise van Schaik is Head of Unit EU & Global Affairs. She also coordinates Clingendael research in the field of climate change and sustainable development. In her research she has extensively analysed the EU's performance in multilateral bodies, including in the fields of climate change, health and food standards. She has also published on related research areas such as EU foreign policy, EU climate change and energy policy, EU research policy, scarcity of natural resources and green growth. Louise has published various policy reports, books, academic articles and commentaries. She regularly gives presentations and lectures to various groups of professionals. She was responsible for the acquisition and implementation of several research projects for governments, (international) foundations, the private sector, and others. She has a Master's degree in Public Administration from Leiden University (2003) and a PhD in Political Science from the KU Leuven (2010). Prior to joining Clingendael in 2006, she was a Research Fellow at CEPS, the Brussels-based think tank, for four years.

Colonel (Ret) ir. **Gert Schijvenaars** is an assistant professor in military logistics and information management at the Netherlands Defence Academy and is a retired army colonel. He got his master's degree in mechanical engineering and studied maintenance management at Delft University. He has been working within the NLMOD sustainment organisation on a large variety of assignments and at all different levels. His current research interests focus on IT-asset management.

Ir. **Alexander J.M. Schmets** is assistant professor of Military Engineering at the Faculty of Military Sciences of the Netherlands Defence Academy. He is a physicist with a background in neutron scattering, battery materials, complex fluids, etc. He has co-initiated the international research area of self-healing materials. Currently, his research involves transient seismic effects, explosion protection and emergency response.

Louise Selisny is Research Affiliate with the University of Oxford, where she is a co-founder of the Climate Change & (In) Security Project. She is also an Expert Participant of the International Military Council on Climate Security (IMCCS). With experience across UK MOD, the United Nations, and Amnesty International, Louise currently supports policy development and analysis within a number of defence and security forums, including the All-Party Parliamentary Group for Climate & Security, where she is the Secretariat Coordinator. In addition to being the co-editor of the Routledge Advances in Defence Studies (RAiDS) volume, *Hot War*: *Climate Change, Conflict and (In)Security* (2023), Louise contributed a chapter focused on Climate Intelligence.

Matti Suomenaro is a freelance Middle East conflict and security researcher with a focus on armed non-state actors, intrastate conflict, and third-party military interventions. His current work includes documenting and analysing conflict and political violence trends in Iraq and climate adaptation in the Arabian Peninsula. He previously worked as a Research Analyst at the DC-based Institute for the Study of War (ISW) advising US policy on Syria and has published research on American, Russian, and Iranian interventions in the Middle East. He holds a Master's degree in Crisis and Security Management from Leiden University and has contributed to research at different Dutch think tanks, including HCSS.

Dr. **Tim Sweijs** is director of research at The Hague Centre for Strategic Studies and a senior research fellow at the Netherlands' War Studies Research Centre. His work is multidisciplinary in nature and straddles political science, strategic studies and war studies. He is a board member at the European Initiative for Security Studies where he chairs the War, Coercion and Statecraft Working Group. He is also a research affiliate at the Center for International Strategy, Technology and Policy in the Sam Nunn School of International Affairs at the Georgia Institute for Technology. Tim has advised international organisations, governments and defence departments across the globe. He has provided expert testimony to the United Nations Security Council, the European Parliament, the Dutch Parliament, as well as to NATO's Parliamentary Assembly. He teaches an advanced graduate and executive staff command course on the future of war. Tim holds degrees in War Studies (PhD, MA), International Relations (Msc) and Philosophy (BA) from King's College, London and the University of Amsterdam. His most recent book is on state threat behaviour and interstate crisis escalation over the past century titled *The Use and Utility of Ultimata in Coercive Diplomacy* (Palgrave Macmillan, 2023). Visit the book's website at www.coercivediplomacy.com. His forthcoming volume titled *Beyond Ukraine: Debating the Future of War* will be published by Hurst in March 2024.

Julia Tasse is a senior research fellow at IRIS, where she heads the Climate, Energy and Security Program. Her research focuses on the interlinkages between climate and security. She is the co-director (with François Gemenne) of the Defense and Climate Observatory [hyperlink: https://defenseclimat.fr/], financed by the French ministry of Armed Forces. She adds to this research topic a specialisation in maritime affairs and ocean from a geopolitical perspective. She has a specific approach linked to her background in climate sciences (Master in Environmental Sciences) and her experience in the maritime field for various organisations, among which are the World Ocean Council, the Food and Agriculture Organisation of the UN and the French development agency (Agence française de développement).

Recent publications:

- Tasse, J. (2024) Fish stocks, IUU fishing and violence at sea, *Démeter* (to be published).
- Tasse, J. & de Guglielmo Weber, M., (2023) Changements climatiques et basculement sécuritaire: vers la fin de la paix?. *Revue Internationale et stratégique*, 131(3).
- Tasse, J. (2023) How to articulate scientific incertainties, political action and climate tipping points: the case of maritime spaces. *Revue internationale et stratégique n°131*, September 2023
- Abis, S. & Tasse, J. (2022) *Géopolitique de la Mer*. Eyrolles.

Job Timmermans is an associate professor of Business Ethics at the Faculty of Military Sciences of the Netherlands Defence Academy. His interests cover the philosophical and sociological issues arising from the intersections of ethics, integrity, and compliance within organisations. He has worked on several projects on Responsible Research Innovation (RRI) at Wageningen University, De Montfort University (UK), and Delft University of Technology.

Prof. dr. ir. **Mark Voskuijl** is professor of Weapon- and Aviation Systems at the Faculty of Military Sciences at the Netherlands Defence Academy. His research is focused on the performance and flying qualities of fighter aircraft, helicopters and unmanned aerial vehicles.

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