Bridging the gap between technology and policy

An assessment on how to report progress in efficient water use in agriculture by means of remote sensing data

Additional Thesis

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Delft University of Technology
Faculty of Civil Engineering and Geosciences

Author: I.I.O. Tantawy
Student number: 1523015

Supervisor 1: Dr. E. Mostert
Supervisor 2: A.M. Onencan

Ministry of Foreign Affairs of the Netherlands

TU Delft Delft University of Technology

Abstract

Water use has increased with double the rate of population growth in the twentieth century. Combined with changing diets due to increased global economic wealth, almost 50 per cent more food needs to be produced to meet demand, implying that fresh water availability will face even greater stress. At the same time, climate change is predicted to have a massive impact on water availability by drastically altering hydrological regimes across the globe.

The development of a tool to monitor water productivity is part of the first objective of the Dutch government to increase water use efficiency in agriculture with 25% in the Dutch partner countries. Water Productivity is an indicator that links agricultural yield with the amount of water that had been consumed for its production (kg/m^3). The FAO WaPOR (Water Productivity Open-access Portal) project, implemented by the Food and Agricultural Organization of the United Nations (FAO), has been funded by Dutch Ministry of Foreign affairs and uses remote sensing data to monitor agricultural land- and water productivity throughout Africa and the Middle East.

The Ministry of Foreign Affairs aims to have the FAO WaPOR data portal used as a tool to assist and provide policymakers with information needed to make policy decisions in a way that benefits and contributes to SDG 6. Furthermore, the data is supposed to be used for yearly reports in which progress of the projects that are funded with the Dutch developing aid budget are presented to the Dutch parliament. However, implementation of the FAO WaPOR data for monitoring has been a challenge due, among others, to the fact that both the use of satellite technology as well as the concept of water productivity are relatively new and still need time to embed in the current policymaking sector. In addition, it is not yet clear what information policymakers, such as the Dutch government and parliament, actually need to make good policy decisions with respect to SDG 6 and 2.

In this additional thesis, the definition of Crop Water Productivity will be limited to the crop yield per unit of water evaporated that was used for its production in (kg/m^3). The evaporated water is subsequently defined and limited to the amount of water that was brought in for irrigation purposes, the so-called blue water evaporation. A draft methodological note is proposed that includes guidelines on how to use and present the available information on FAO WaPOR data portal for results reporting and are complementary to the international frameworks and standards of SDG 6.4. A distinction was proposed between a so-called active and passive results. Passive results involve the investments made to enable policy and decision-makers with supporting tools (such as data provision) and capacity (building) to improve water use efficiency in agriculture. Active results directly contribute to improved water use in agriculture on the field level and can be quantified in terms of an increased percentage in water productivity. A final recommendation is given to invest in the partner countries that suffer from physical water scarcity, considering that the incentive to improve water productivity in those countries are much higher. Countries with physical water scarcity and are so-called partner countries of the Netherlands include, Egypt, Jordan, the Palestinian Territories, Yemen and Sudan.

List of Abbreviations

CWP	Crop Water Productivity
SDG	Sustainable Development Goals
FAO	Food and Agricultural Organization
WaPOR	Water Productivity Open-access Portal
IGG	Inclusive Green Growth

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1. Introduction

Water use has increased with double the rate of population growth in the twentieth century. Combined with changing diets due to increased global economic wealth, almost 50 per cent more food needs to be produced to meet demand, implying that fresh water availability will face even greater stress. At the same time, climate change is predicted to have a massive impact on water availability by drastically altering hydrological regimes across the globe.

The development of a tool to monitor water productivity is part of the first objective of the Dutch government to increase water use efficiency in agriculture with 25% in partner countries. Water Productivity is an indicator that links agricultural yield with the amount of water that had been consumed for its production (kg/m^3). The FAO WaPOR (Water Productivity Open-access Portal) project, implemented by the Food and Agricultural Organization of the United Nations (FAO), has been funded by Dutch Ministry of Foreign affairs and uses remote sensing data to monitor agricultural land- and water productivity throughout Africa and the Middle East. The ability to monitor in near real time is meant to assist relevant stakeholders in identifying water productivity gaps, proposing solutions to reduce these gaps and so contributes to a sustainable increase of agricultural production and thus food security, while at the same time considering ecosystems and the equitable use of water resources. The purpose of the database is to contribute to a more sustainable, productive and climate change resilient way of practicing agriculture, with a reduced impact on the environment in general and on fresh water resources.

The Inclusive Green Growth (IGG) department of the Ministry of Foreign Affairs of the Netherlands is committed to the Dutch international development policy on water, climate, food, energy, raw materials and the polar regions. The combination of social development and economic growth is at the core of the Netherlands' development policy. Within this policy, the focus is on themes in which the Netherlands is strong and can make a difference. The Netherlands has a special development relationship with 15 partner countries. In addition, specific regional programmes have been established for the Great Lakes region and the Horn of Africa. The themes have shared goals, such as sustainable development and reducing the negative impacts of climate change. Within the water theme, there are three objectives:

- Increase water use efficiency in agriculture by means of 25% water productivity increase;
- Improve river basin management and safe delta's
- Improve access to clean drinking water and sanitary facilities (WASH)

As defined by the Dutch Ministry of Foreign affairs, water Productivity is an indicator that links agriculture yield with the amount of water that had been consumed for its production (kg/m^3). Assessing land and water productivity gaps are complex tasks that include the monitoring of current level of productivity in various crop production systems, the comparison of such levels to potential ones, the analysis of underlying causes of the productivity gaps and the evaluation of options and workable solutions to reduce productivity gaps in different contexts. The WaPOR project, implemented by the Food and Agricultural Organization of the United Nations (FAO) and funded by Dutch Ministry of Foreign affairs uses satellite and remote sensing data to monitor agricultural land- and water productivity throughout Africa and the Middle East. The ability to monitor in near real time aims to assist relevant stakeholders in identifying water productivity gaps, proposing solutions to reduce these gaps to contribute to a sustainable increase of agricultural production and thus food security. In addition, the database will contribute to a more sustainable, productive and climate change resilient way of practicing agriculture, with a reduced impact on the environment in general and on fresh water resources.

The FAO WaPOR Project

The output of the WaPOR project is an action framework and consists of 4 segments to generate workable solutions:

1. An operational database, covering Africa and the Near East, with mainly satellite data, to monitor agricultural water and land productivity. Three different datasets (called 'levels') will be produced, comprising of several data components. Each of these levels provide data for a different region of interest and at a different spatial resolution. Table 1 shows the resolution and areas covered by the different levels. Actual Evapotranspiration, Net Primary Productivity, Land cover classification and Above Ground Biomass production will be produced at all three levels. The crop calendar and harvest index will be delivered for Level II and III. The crop calendar gives information about the phonological (periodic life cycle) stage of a crop. The harvest index will only be calculated for specific crops. For Level II these crops are wheat, maize and rice. Level III also includes wheat, maize and rice, as well as any other crop classified in the Level III region of interest.
2. A spatial and temporal assessment of agricultural land and water productivity, productivity gaps, and capacity development to close these gaps.
3. An assessment of the consequences and sustainability of possible increases in water productivity
4. Capacity development for stakeholders to increase water productivity sustainably

Level I	250m	Africa and the Near East (bounding box 30W 40N, 65E 40S)
Level II	100m	*Countries:* Benin, Burundi, Egypt, Ethiopia, Ghana, Kenya, Mali, Morocco, Mozambique, Rwanda, South Sudan, Jordan, Tunisia, Uganda, West Bank and Gaza Strip and Yemen *River basins:* Niger, Nile, Awash and Litani
Level III	30m	Irrigation schemes in Egypt, Ethiopia, Mali and Lebanon

Table 1: Resolution and Regions of Interest of the different levels

According to the project terms of reference, the following beneficiaries are expected:

- Local communities benefit by obtaining information and decision support systems to target interventions utilizing water for agricultural production more efficiently (e.g. find for a local hero and apply his best practices by knowledge sharing;
- National governments and irrigation authorities will improve their ability to monitor and evaluate land and water productivity. This subsequently will lead to an improvement of their water resource management and agricultural practices.

Irrigation authorities will have access to information to modernize their irrigation schemes and government agencies will be able to use the data on efficient use and impact for their decision-making in evident-based policies.

- The Dutch water sector can make use of this outcome for multiple purposes. Beneficiaries in the Dutch water Sector will be donors, NGO's, educational institution, policy makers and the private sector, since the database will provide access to improved evidence-based decision support instruments for planning, programming, and implementing water resource management practices
- The Government of The Netherlands can provide with aid to monitor, evaluate and seek solutions aiming at improving the water productivity sustainably in their partner countries and supported programs.
- Besides the traditional water sector and governments, relevant stakeholders can develop specialized Information and Communication Technologies (ICT's) solutions that enable locally relevant use of the data from the database.

UN-agencies, governments and international NGO's are expected to take advantage of this by means of monitoring and evaluating their goals, because the data is independent and universal and can thus be compared over time and space. In addition, the Dutch government will use the data for the dutch development results.

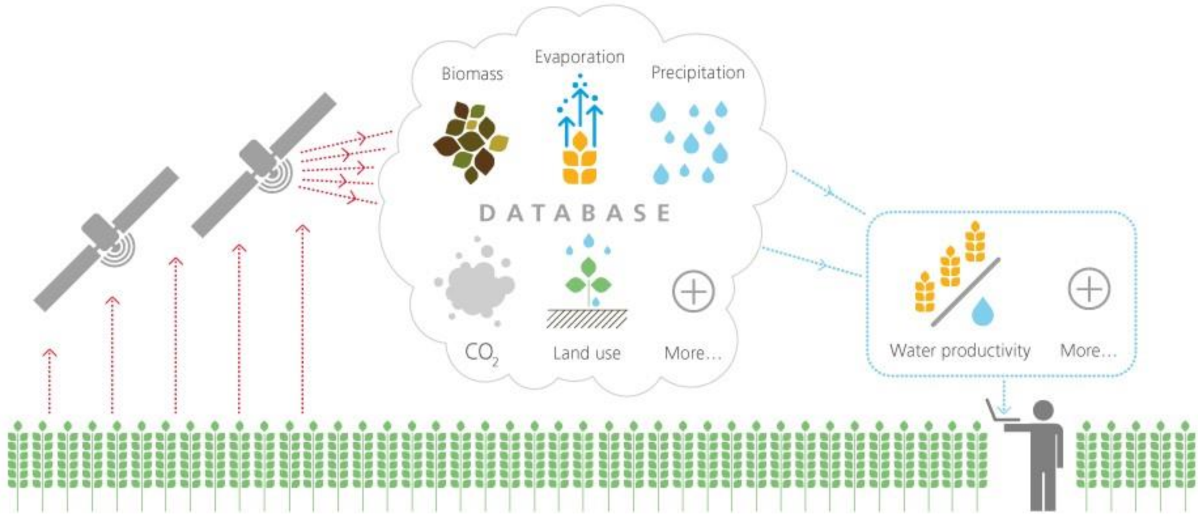

Figure 1: Impression of FAO WaPOR

Objective and research questions

The Ministry of Foreign Affairs aims to have the FAO WaPOR data portal used as a tool to assist and provide policymakers with information needed to make policy decisions in a way that benefits and contributes to SDG 6 and 2. Furthermore, the data will be used for yearly reports in which progress of the projects that are funded with the Dutch developing aid budget are presented to the Dutch government.

However, implementation of the FAO WaPOR data for monitoring has been a challenge due, among others, to the fact that both the use of satellite technology as well as the concept of water productivity are relatively new and still need time to embed in the current policymaking sector. In addition, it is not yet clear what information policymakers, such as the Dutch government and parliament, actually need to make good policy decisions with respect to SDG 6 and 2.

This additional thesis was set up complementary to the author's internship at the Ministry of Foreign Affairs of the Netherlands and her Master thesis on the application of the FAO WaPOR data portal to monitor efficient water use in agriculture. While the internship focused on the policy and decision-making regarding the FAO WaPOR project and the goal to improve water use efficiency, the Master thesis researched the technical boundaries and opportunities of WaPOR data. This additional thesis aims to bridge the gap between policy and technology and provides insight on how to improve evidence-based policymaking with big data.

In this additional thesis, the following research question will be answered:

> *What is the added value of FAO WaPOR data in monitoring and progress reporting, with special attention to the Dutch policy themes that aim to tackle water scarcity and help improve water use efficiency in agriculture in their partner countries?*

In order to answer this question, the following sub questions will be answered:

- What information is needed to assess efficient water use in agriculture?
- What are the boundary conditions and limitations of the information?
- In what form and context should this information be presented?
- What information is needed to help determine the contribution of Dutch development cooperation to improvement in water use efficiency in agriculture?

Methodology

The following methodology and information sources were consulted:

- Interviews with members of the water department of the ministry of foreign affairs (DGIS) and participant observation at the department, which was performed during an internship in 2017 and supplemented with interviews in the period between September and November 2018. The following members were interviewed:
    - Job Kleijn (Senior Advisor Water, currently retired):
      Job Kleijn has been committed to put water use efficiency in agriculture on the political agenda of the Netherlands' foreign policy. Furthermore, he is the initiator of the FAO WaPOR project and the author's supervisor during the internship. Job Kleijn has been consulted two times, on October 3rd and November 14th of 2018;
    - Job van Thiel (Advisor Water, Coordinator of the delta team Egypt):
      Job is the successor of Job Kleijn and is responsible for the implementation of the water use efficiency agenda for focus countries that are suffering from physical water scarcity, such as Egypt, Jordan and Yemen. Job van Thiel was consulted three times, on October 3rd, November 7th and November 14th of 2018;
    - Aart van der Horst (Senior Advisor Water, FAO WaPOR coordinator):
      Aart is currently running the FAO WaPOR project on behalf of the Ministry of Foreign Affairs. In addition, he is responsible for the proper implementation of the data from FAO WaPOR for the yearly development results report. Aart van der Horst was consulted on November 14th, 2018;
    - Laura van der Pol (Current intern Water Productivity):
      Laura is the current intern at the ministry that is assigned to work on the FAO

WaPOR project and the overall policy to increase water productivity. Laura was consulted on November 14th and December 12th of 2018;
    - Karin Roelofs (head of the water department):
      As the head of the water department, Karin is the final decisionmaker with regards to project budgets. Karin was consulted on November 14th, 2018.
- Interviews with FAO executives, responsible for the WaPOR project;
    - Jippe Hoogeveen (Senior advisor agriculture & water):
      Jippe is the project leader of the FAO WaPOR project within FAO and was consulted on November 14th, 2018;
    - Livia Peiser FAO (Water Accounting Analyst):
      Livia is involved in the technical aspect of the FAO WaPOR project within FAO and was consulted on October 17th, 2018 through Skype.
- Interview with Bart Hilhorst, a Dutch consultant that works on the Nile Basin Initative with big interest in the use of FAO WaPOR data and water use efficiency in agriculture. Bart was consulted on October 12th, 2018 through Skype.
- Policy documentation regarding the the FAO WaPOR project;
- Policy documentation regarding the methodology of the the Dutch development results;
- Policy documentation regarding Sustainable Development Goal 6.4.1: “By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity”;
- Scientific literature regarding the definition of water productivity and the water efficiency paradox, notably the Master Thesis of Merks, J. (2018). *The Water Efficiency Paradox*. Delft University of Technology.

A recommendation will be given to the Water division of the Inclusive Green Growth department of the Ministry, on how to use the data for their objective to improve efficient water use in agriculture with 25% in the Dutch partner countries. This recommendation will be given in the form of a so-called methodological note on water productivity, complimentary to Sustainable Development Goal 6.4. The findings include an overview of SDG target 6.4, its indicators and the link with the Dutch policy on sustainable water resource management. Finally, this report is presented to the Water department of the Ministry of Foreign Affairs.

In Chapter 2, crop water productivity is researched and defined by means of a scientific literature review and analysis. Chapter 3 elaborates on the role of geospatial data to contribute in achieving the sustainable development goals regarding water and links this to the FAO WaPOR project. In Chapter 4, the current Dutch policy on foreign trade and development is discussed and evaluated. Furthermore, the methodological note is presented regarding the goal to increase water productivity with 25%. Finally. chapter 5 provides a discussion on the results and presents a brief answer to the research question.

2. Defining Water Productivity

Given the scarcity of resources, the key strategy to increase food security should be to increase production per unit of resource (Bastiaanssen & Steduto, 2017). Throughout the last decades, the conventional resource to evaluate and improve efficient production has been land productivity, expressed in kg/ha. However, considering the fact that water resources are increasingly becoming one of the major constraints to achieving more food production, the evaluation of food production in terms of water becomes increasingly valuable as well.

In order to save water in agriculture, investments are done to improve irrigation efficiencies and reduce 'losses' from the system. However, the terminology of efficiency should carefully be considered, as it can be based on different considerations. The essence of this lies in the so-called water efficiency paradox (Merks, 2018). It is natural to expect that an increase in efficiency will decrease the demand and consumption of a resource, however, this is not necessarily the case. The engineering concept of efficiency is valid when designing irrigation systems, but misleading when water competition and scarcity beyond the boundaries of a project are put in perspective. It does not consider water that returns, unconsumed, back into the system and may (or may not) be used elsewhere. Furthermore, increasing irrigation efficiency means that with less withdrawal the same quantity of crops can be produced. From an economical perspective, a logical next step is to increase production and consequentially the use of the resource.

In the context of water resources, efficiency of water use was originally used from the viewpoint of engineering and irrigation. The Food and Agriculture Organization of the United Nations (FAO) has therefore proposed to use 'efficiency' for engineering applications and 'water productivity' for agricultural ratios such as yield per unit evapotranspiration or yield per unit water supply (Sadras, Grassini, & Steduto, n.d.). By distinguishing clearly between hydrology and production aspects of water systems, clarity is given when describing impacts of proposed interventions. Water productivity, in its broader sense, defines the ratio of the net benefits from crop to the amount of water consumed to produce those benefits. We can distinguish a physical water productivity, defined as the ratio of mass of product to the amount of water consumed ('more crop per drop'), and economic water productivity, defined as the 'value' derived per unit of water used. In this case the 'value' can refer to economic return or to nutrition, or more broadly to any other economic and social benefit (e.g. jobs, welfare, environment, etc.). Crop Water Productivity specifically, is defined by the United Nations as the crop yield per unit of water evaporated, expressed in kg/m^3 (Bastiaanssen & Steduto, 2017). Currently, the United Nations embraced Crop Water Productivity, expressed in kg/m^3, as part of the Sustainable Development Goals (SDG 6.4) indicators in their General Assembly (Zwart & Bastiaanssen, 2004; Zwart, Bastiaanssen, de Fraiture, & Molden, 2010).

According to FAO, water productivity is defined as the ratio of agricultural yield [kg] to the amount of water that has been used (or consumed) for its agricultural yield production [m^3] (FAO, n.d.). To make water productivity a useful performance indicator within the context of this research, it is important to define the term 'water consumption correctly'. Irrigation for agricultural purposes is considered the largest water-consuming sector in the world and has great potential to become more water-efficient. Rain-fed agriculture, however, does not influence the water balance within a catchment and can thus not improve its water efficiency. It is therefore only profitable to look at water productivity for irrigated agriculture.

Separating irrigated agriculture from rain-fed agriculture can be done by splitting the total evaporation in so-called green and blue water evaporation. Evaporation from green water is the part of the actual evaporation that is derived from rainfall that infiltrated into the soil, while evaporation from blue water is due to the use of human-made infrastructure such as pumps, with the purpose of irrigation. Blue water is withdrawn from rivers, reservoirs, lakes, and aquifers and is important to quantify as it directly influences the water availability of an area. Together, the sum of blue and green water consumption equals the total actual evaporation of a catchment. With blue water evaporation, the total water consumption [m^3] that was used for irrigation can subsequently be calculated. This can be used to then calculate the water productivity, but also provides insight into the current water management practices of a country (Tantawy, 2019). In the author's master thesis, the principle of the Budyko Curve was applied to partition precipitation into evaporation and runoff (Budyko, 1974). This basic schematization is a standard ingredient taken from the Water Accounting Plus procedure that was developed at IHE Delft by Wim Bastiaanssen et al. (Bastiaanssen, W.G.M., Coerver, 2017).

In this additional thesis, the definition of Crop Water Productivity will be limited to the crop yield per unit of water evaporated that was used for its production in (kg/m^3). The evaporated water is subsequently defined and limited to the amount of water that was brought in for irrigation purposes, the so-called blue water evaporation.

3. WaPOR for Sustainable Development Goal 6.4

Geospatial data and the SDGs

In September 2015, the majority of the states in the world adopted the 2030 Agenda for Sustainable Development, consisting of 17 Sustainable Development Goals (Hereafter: SDGs) with 169 targets. The 2030 Agenda includes a goal on water and sanitation, SDG 6, that sets out to “ensure availability and sustainable management of water and sanitation for all” (UNGA, 2015).

Data are the basis for evidence-based decision-making. Specifically, geospatial data can provide tools to monitor and visualise processes with a high spatial variability, subsequently leading to informed decision-making. The role of geospatial data is recognized by the United Nations in supporting the achievement of the SDGs. According to a report published by the UN Office for Outer Space Affairs (UN, 2017), it is shown that European Union space technologies support the fulfilment of the SDGs and states that all SDGs are positively impacted by the benefits stemming from the use of Earth Observation (hereafter: EO) data. Out of the 169 indicators associated with the SDGs, 65 are directly benefited by either monitoring the status of the achievement of a given SDG, or by actively contributing to its fulfilment (UN, 2017).

However, extensive methodologies and infrastructure are needed to facilitate proper implementation of EO to support and/or monitor the SDGs. It is crucial that local political organizations are informed and encouraged to implement geospatial efforts in their respective countries. Without their involvement, much of the derived data and information will remain in the field of science and research (United Nations, n.d.). To reach end users, the actors, the playing field and the tangible contribution of EO in relation to the SDGs need to be identified. This can be done by translating EO data into concrete products and services that are accessible by non-technical experts, combined with capacity building.

Geospatial data and SDG 6.4

SDG target 6.4 addresses water-use efficiency and water stress, aiming by 2030, to “substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity” (UN FAO, 2018). Two indicators were developed to track progress for this target:

- 6.4.1 Change in water-use efficiency over time
- 6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources

According to a study that was conducted by Deltares, eLEAF and CBS, EO data can be a valuable additional source for monitoring indicators 6.4.1 and 6.4.2. The number of EO satellites has been growing steadily over the past decades, that are able to derive actual evaporation. Evaporation is the sum of evaporation, interception and plant transpiration from the Earth's surface to the atmosphere. It is an important component of the hydrological cycle and therefore an important factor to calculate the overall water balance. In addition, it is also a good indicator for the volume of water used by the agricultural sector. The study's main conclusions were that the use of EO data is a powerful and cost-effective technique to assess agricultural production. This is especially the case for areas that are hard to reach, and data collection therefore becomes difficult. The main disadvantages are the facts that its main focus is mostly agriculture. Furthermore, it is difficult to precisely quantify actual irrigation water withdrawals and there is high variation in estimates of environmental water requirements (CBS, 2017).

WaPOR for SDG 6.4

In the authors Master thesis, an overall evaluation was done regarding the data of FAO WaPOR and its usability for improved water resource management and efficient water use in agriculture. The dissertation has successfully shown that WaPOR data can be processed into actionable information for various stakeholders and policymakers by monitoring trends and anomalies regarding indicators 6.4.1 and 6.4.2.

With FAO WaPOR data, Crop water productivity (hereafter: CWP) can be obtained. CWP is the ratio of agricultural yield of a certain crop to the amount of water that has been used for its consumption (kg/m^3) and can be used as a key performance indicator for efficient water use in agriculture on national level, complying with indicator 6.4.1. However, performing a qualitative assessment that is based purely on WaPOR data is not recommended without using additional ground data for validation. With ground data, reliable crop information can be used for a more accurate assessment of CWP. In conclusion, small scale assessments and monitoring of CWP can give good indications on best practices and indicate low-hanging fruit.

Calculating fresh water withdrawals for irrigation purposes (related to indicator 6.4.2) was successfully conducted with the available data on the FAO WaPOR portal. The qualitative analysis shows promising results when compared to the literature. This is especially the case for flat areas with sparse rainfall. Due to the generic approach error margins are uniform, thus, anomalies can be easily spotted.

However, much data processing and analysis is necessary, leading to the conclusion that a third party should always be involved to translate the data into actionable information. Table 2 gives an overview of the Boundary conditions, opportunities and limitations of the FAO WaPOR data portal.

Table 2: Boundary conditions, opportunities and limitations of the FAO WaPOR data portal

Opportunities	**Limitations and Boundary conditions**
Powerful and cost-effective way to assess water balance on big spatial and temporal scale	Less reliable in areas with eradicate rainfall
Reaches areas that are remote/hard to reach	Not (yet) validated by ground data; exact quantification cannot be assured until validation has been done with external resources.
Available data is capable to be translated into indicators to monitor SDG 6.4.1 and 6.4.2	Data can only be used for water use monitoring in the agricultural sector
More opportunities become available when combined with other data sources, such as governmental statistics	Due to limited validation, comparisons can only be done on small scales to assure the error margin is the same.
	Third party is necessary to translate the available data from WaPOR into actionable information for policymakers

4. Dutch policy on Foreign Trade and Development Cooperation

The Netherlands is considered to be an important trading nation and one of the world's most innovative and competitive economies. the Netherlands' policy on Foreign Trade and Development Cooperation (BHOS) aims to respond to international challenges and opportunities in the interests of the Netherlands.

According to the policy document on Foreign Trade and Development Cooperation (Dutch Ministry of Foreign Affairs, 2018a), the SDGs are set as the international guiding principles for BHOS policy. Therefore, in accordance with the policy changes, the result areas and indicators of the BHOS policy will be aligned with the SDG framework where possible.

By 2030, around 40% of the world's population may be affected by a shortage of clean drinking water. The Netherlands is renowned for its water resource management expertise. Therefore, water management is one of the priority themes of Dutch development cooperation policy. Within the water theme, there are three objectives:

- Improve river basin management and safe delta's
- Improve access to clean drinking water and sanitary facilities (WASH)
- Increase water use efficiency in agriculture by means of 25% water productivity increase;

In addition, the Netherlands is also focusing on transboundary water management in seven international river basins in Africa, Asia and the Middle East, aiming to improve cooperation between upstream and downstream countries. The international plans and goals of the Netherlands are reflected in the International Water Ambition (IWA). The aim is to increase water security and safety, with emphasis on developing countries, through an action-oriented approach that is coordinated by several subsidized programs, such as Partners Voor Water (PvW) and the Sustainable Water Fund (FDW). Moreover, the Netherlands invests largely in WASH initiatives to provide access to drinking water and sanitation in developing countries.

Water security requires cooperation, coordination and compromises between sectors and actors: the public sector, the private sector and society. In addition, innovation is needed to make water use more efficient. Eventually, both aspects can contribute to fairer water distribution.

According to the Theory of Change (Dutch Ministry of Foreign Affairs, 2018b), the Dutch deployment regarding the target to increase water productivity involves:

- The increase of water productivity with 25%, based on more efficient water use and improved water management for both rainfed and irrigated agriculture. The objective is meant for current Dutch-funded programs in the partner countries in Africa and the Middle East;
- The establishment of an open-access data portal (e.g. FAO WaPOR) to monitor and assess water productivity, enabling policy makers with insight in their current water management practices;
- Investing in behavioral change to stimulate innovation and entrepreneurship at the interface between water and agriculture through partnerships;

- Investing in farmers to improve their soil and water resources management as well as their agricultural practices.

Water productivity depends on the physical availability and quality of water, but also on the land, soil and water management of an individual farmer. Access to water for agriculture improves with the level of organization of water users and access to technology and knowledge. In addition, water pricing and land and water rights play a role. A better understanding of the water productivity provides a better insight into water use and can lead to improved water distribution.

In order to increase water productivity, stimulating water-smart entrepreneurship through the provision of information and the establishment of well-functioning institutions is important. Legal regulations enforce minimum requirements and innovations can lead to improved systems. Satellite data provides insight into the current water management practices in agriculture. On that basis, agricultural policy can subsequently be adjusted.

Development Results monitoring

As a direct consequence of resources invested by the Dutch government, a yearly report is made by the Ministry of Foreign Affairs, that covers results that were achieved in light of the BHOS policy. Based on information from partners, the ministry and embassies determine the progress and results of programmes on an annual basis. Insight on progress is important in order to make adjustments as well as the provision of accountability: to the Parliament, to Dutch citizens and to the people whose position the Dutch government aims to improve.

At the Ministry, progress is measured and determined based on indicators. This makes it possible to equally measure and compare results. However, considering the dynamic and varied context of development efforts, this is not always possible.

Therefore, in the Legislative Consultation of November 7th, 2016 (Dutch Ministry of Foreign Affairs, 2017) the government promised to substantiate 15 indicators, so-called methodological notes, that are used to track progress and define results of the Foreign Trade and Development cooperation budget. They ensure clarity on the following:

- It is clear what exactly is measured and how this relates to the policy targets;
- The selected indicators are measurable;
- The selected indicators are clearly understood, applied and measured (definitions are clear, no multiple interpretation possible);
- The collected data is of good quality;
- Every indicator can be aggregated unambiguously;
- What has been measured is verifiable (including conversion to the source).

The choice and support of the indicators is connected to international frameworks and standards as much as possible, including the monitoring framework of the Sustainable Development Goals.

Current deployment on the target to increase water productivity with 25%

Funding the FAO WaPOR portal was the first monetary investment to improve water productivity. However, since then, the water division has not been able to set out a clear strategy on how to achieve and report on the progress of the target (personal experience during internship of the author). As a consequence, a methodological note on the target failed to be substantiated.

Throughout several conversations with members of the water division, as well as with experience gained during the internship, it is made clear that the following matters have to be addressed, by means of a methodological note, to ensure an effective strategy to reach the target:

- Clarify *who* the actual beneficiaries/end-users of the Dutch funds are;
- Clarify *what* needs to be measured and how this relates to the target;
- Water Productivity as an indicator needs to be clearly and thoroughly defined for better understanding.

Developing a methodological note on improved water productivity in agriculture

With the goal to achieve a 25% increase in water productivity, the Netherlands facilitated open access of pre-processed satellite data to enable policymakers to monitor efficient water use in agriculture. Naturally, this data can also be used to monitor progress and develop results for the yearly report that is presented to the Dutch parliament. Therefore, the methodological note to define results for water use efficiency in agriculture should include guidelines on how to use the FAO WaPOR data portal for results reporting. Preferably, these guidelines should be complementary to the international frameworks and standards of SDG 6.4. (personal communication, Job Kleijn).

In table 3, a draft methodological note is proposed to track progress and results regarding the target to increase water productivity in agriculture with 25%. The methodological note is based on personal communication with members of the water division, as well as the author's personal experience during her internship and her dissertation regarding the application of the FAO WaPOR to measure efficient water use in agriculture.

Guiding principles are that Earth observation is the enabler of fact-based policymaking, concrete applications are developed to tackle the challenges regarding water use efficiency in agriculture, and that the policymaker is in the driver's seat.

To achieve this, close cooperation with national statistical institutions, ministries, agencies, knowledge institutions and the private sector is needed for capacity building and proper implementation. In that framework, the following actions are needed:

- Facilitation of (further) development, testing and operationalization of promising Earth observation applications, integrated into solutions;
- Capacity building at appropriate levels for all actors involved;
- Easily accessible, reproducible, scalable and workable products and services;
- Advocacy of successful solutions (at national and international level).

Regarding the result reporting to the Dutch parliament, the decision was made to make a distinction between active and passive results. Passive results involve the investments made to enable policy and decision-makers with supporting tools (such as data provision) and capacity (building) to improve water use efficiency in agriculture. Active results directly contribute to improved water use in agriculture on the field level and can be quantified in terms of an increased percentage in water productivity.

Finally, the following should be considered regarding the water productivity indicator:

- The indicator suggests that agricultural land is either irrigated or rain fed; however, in many regions and countries that is not the case, as it is often combined on the same land or parcel, contributing or adding to each other. Therefore, it is important that preparatory to assessing water productivity, insight should be retrieved regarding the water withdrawals for irrigation purposes of this particular agricultural land;
- Water productivity becomes more valuable when it is put in perspective with the agricultural yield and water consumption data. In doing so, the reason for low or high water productivity values can be better understood. Depending on the objective, a higher yield, or less water consumption, action can be taken accordingly.

Table 3: Concept methodological note for efficient water use in agriculture

<table>
<tr><th>Item</th><th>Instruction</th></tr>
<tr><td>Title of the indicator</td><td>Increased water use efficiency in agriculture by means of an improvement in water productivity with 25%.</td></tr>
<tr><td>Underlying target to be achieved</td><td>Ensure water and food security</td></tr>
<tr><td>Related performance question</td><td>To what extent has NL-supported intervention contributed in facilitating the improvement of water productivity?</td></tr>
<tr><td>Technical definition</td><td>Water Productivity links agricultural yield with the amount of water that had been consumed for its production (kg/m^3)</td></tr>
<tr><td>Rationale</td><td>Improving water productivity with 25% is one of the three main objectives of the Dutch water policy within the Foreign Trade and Development cooperation.

This objective contributes directly to Sustainable Development Goal 6.4, i.e.:
By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity
The Dutch objective to improve water productivity with 25% focuses on improving water use efficiency in the agricultural sector specifically. Results on the contribution to this target are expressed in the amount of yield harvested per volume of blue water evaporation (kg/m^3). However, the objective can be achieved actively as well as passively:

Actively, results are measured by the change of water productivity over time throughout NL-supported interventions that operate on the ground and actively focus on the increase of water productivity.

Passively, results are measured by the reach of enabling policy- and decisionmakers with supporting tools and capacity to improve water productivity. Guiding principles are that Earth observation acts as an enabler, concrete applications are developed and that the stakeholders (i.e. policy- and decisionmakers) are in the stakeholder’s seat. The passive achievement in results complies with so-called indicator SDG 6.a: “The amount of water- and sanitation-related official development assistance that is part of a government-coordinated spending plan.” A contribution can be done in two ways:</td></tr>
</table>

	- Direct provision of technology and tools, i.e. providing an open-access data; - Capacity building to enable beneficiaries to work with provided tools and technology.
Type of indicator	Quantitative trend indicator (relative change per year).
Timelines	Yearly situation as compared to situation before NL-intervention started.
Coverage	This indicator refers to SDG 6.4.1's aim to increase water use efficiency in agriculture and DGIS's policy target of improving water productivity with 25%
Baseline	The results measurement per activity starts at the moment the Dutch financing begins. Each program is expected to set a baseline within the local context.
Data calculation and guidance	For active results, data should be gathered within the boundaries of a Dutch funded program that aims to increase water use efficiency. The following data should be gathered on a yearly basis, starting with a base measurement (i.e. the initial situation), subsequently followed up by a yearly progress analysis of: - The water productivity (kg/m^3); - Blue water evaporation (m^3); - Total yield that was harvested (kg); By tracking these indicators, a complete insight is given on the efficiency of the water and agricultural management practices within a project. For passive results, the reach is referred to as: - Reach of beneficiaries (i.e. policy and decisionmakers) that were enabled to work with tools and technology (i.e. earth observation data) to improve and monitor water use efficiency in agriculture. - Reach of provision of technology and tools, provided by Dutch-funded projects (i.e. FAO WaPOR); - Reach of capacity building on using technology to monitor and improve Water Productivity, executed with Dutch-funded projects.
Data source(s) and validation	Active: Data mentioned in the data calculation and guidance section will be obtained through: • Involved parties that obtain ground data within Dutch-funded project • FAO WaPOR data (also for validation purposes), potentially pre-processed by a third party/consultant • FAO AQUASTAT data (also for validation purposes)

	Passive: Data will primarily be obtained from the progress reports of the organizations responsible for the implementation of practices, processes and technologies (capacity building) for policy and decisionmakers, that support progress the improvement of water productivity.
Reporting roles	The implementing organizations and/or consultants will provide progress data in the annual report. DGIS will collect progress data of the various contributing activities and calculate aggregate values for measuring progress towards the overall policy objective.
Data disaggregation	Disaggregate by • Crops • Administrative regions • Agro-Ecological zones[1]
Data issues	Regional differences in climate and water availability must be considered. Therefore, defining an initial baseline and threshold for improvement within a project is crucial.

[1] Agro-ecological zoning defines zones on the basis of combinations of soil, landform, and climatic characteristics. The particular parameters used in the definition focus on the climatic and edaphic requirements of crops and on the management systems under which the crops are grown ((FAO Land and Water Division, 1996). Since each zone has a similar combination of constraints and potentials for land use, it can thus be effectively targeted with specific recommendations to improve water productivity. By assessing the variability of water productivity within an agro-ecological zone, the physical variability is masked, limiting the reason for variability in agricultural management.

5. Discussion

To achieve the goals that are set by the Ministry of Foreign Affairs regarding water use efficiency in agriculture, proper monitoring and reporting tools are needed to track progress. This will help decision makers identify and prioritize what, when and where interventions are needed to improve implementation. Information on progress is also essential to ensure accountability and generate political, public and private sector support for investment.

Throughout this additional thesis, opportunities and limitations of FAO WaPOR and overall Earth Observation data has been explored to investigate the added value of FAO WaPOR data in monitoring and progress reporting, with special attention to the Dutch policy themes that aim to tackle water scarcity and help improve water use efficiency in agriculture in their partner countries. The following sub questions were answered accordingly:

What information is needed to assess efficient water use in agriculture?
Crop Water productivity is defined as the ratio of agricultural yield [kg] to the amount of water that has been used (or consumed) for its agricultural yield production [m^3]. To make water productivity a useful performance indicator, the term 'water consumption' has to be defined correctly. Irrigation for agricultural purposes is considered the largest water-consuming sector in the world and has great potential to become more water-efficient. Rain-fed agriculture, however, does not influence the water balance within a catchment and can thus not improve its water efficiency. It is therefore only profitable to look at water productivity for irrigated agriculture. Besides yield information, so-called blue evaporation data should be derived from FAO WaPOR in order to assess water productivity within context of Ministry's ambition to address water scarcity within the agricultural sector.

What are the boundary conditions and limitations of the information?
With FAO WaPOR data, Crop water productivity (hereafter: CWP) can be obtained. However, performing a qualitative assessment that is based purely on WaPOR data is not recommended without using additional ground data for validation. With ground data, reliable crop information can be used for a more accurate assessment of CWP. In conclusion, small scale assessments and monitoring of CWP can give good indications on best practices and indicate low-hanging fruit. Calculating fresh water withdrawals for irrigation purposes (related to indicator 6.4.2) was successfully conducted with the available data on the FAO WaPOR portal. However, much data processing and analysis is necessary, leading to the conclusion that a third party should always be involved to translate the data into actionable information. In chapter 3, Table 2 provides an extensive overview of the Boundary conditions, opportunities and limitations of the FAO WaPOR data portal.

In what form and context should this information be presented?
As a direct consequence of resources invested by the Dutch government, a yearly report is made by the Ministry of Foreign Affairs, that covers results that were achieved in light of the BHOS policy. At the Ministry, progress is measured and determined based on indicators. Therefore, the government promised to substantiate 15 indicators, so-called methodological notes, that are used to track progress and define results of the Foreign Trade and Development cooperation budget. The choice and support of the indicators is connected to international frameworks and standards as much as possible, including the monitoring

framework of the Sustainable Development Goals. Therefore, the methodological note to define results for water use efficiency in agriculture should include guidelines on how to use the FAO WaPOR data portal for results reporting. Preferably, these guidelines should be complementary to the international frameworks and standards of SDG 6.4. (personal communication, Job Kleijn).

What information is needed to help determine the contribution of Dutch development cooperation to improvement in water use efficiency in agriculture?

In table 3, an extensive draft methodological note is proposed to track progress and results regarding the target to increase water productivity in agriculture with 25%. It includes guidelines on how to use and present the available information on FAO WaPOR data portal for results reporting and are complementary to the international frameworks and standards of SDG 6.4. Guiding principles are that Earth observation is the enabler of fact-based policymaking, concrete applications are developed to tackle the challenges regarding water use efficiency in agriculture and that the policymakers are in the driver's seat. A distinction was proposed between a so-called active and passive results. Passive results involve the investments made to enable policy and decision-makers with supporting tools (such as data provision) and capacity (building) to improve water use efficiency in agriculture. Active results directly contribute to improved water use in agriculture on the field level and can be quantified in terms of an increased percentage in water productivity.

6. Conclusion

It has become evident that the use of Earth Observation data is a powerful and cost-effective technique to assess agricultural production and is therefore internationally acknowledged to support SDG 6.4. With the launch of the FAO WaPOR data portal, the possibility to obtain more insight into the African continent regarding the hydrological processes and biomass production was expanded. Subsequently, the data can be processed into actionable information for various stakeholders and policymakers regarding water productivity. However, much data processing and analysis is necessary, leading to the conclusion that a third party should always be involved to translate the data into actionable information.

Funding the FAO WaPOR portal was the first monetary investment to improve water productivity. By developing a methodological note for the Dutch target to increase water productivity with 25%, an effective strategy to reach the target is believed to be ensured.

When it comes to water governance, a government has a responsibility related to effective water management, ensuring water security nationwide. While society may have the incentive to increase water productivity, agricultural producers may not. The adoption of measures to improve water productivity, either operational, technological or infrastructural, will therefore require an enabling policy and an institutional environment that aligns the incentives of producers, resource managers and society. Therefore, ensuring the implementation of SDG 6.4 and an improvement of water productivity in agriculture should come from policy and decision-makers rather than farmers.

A final recommendation is given to invest in the partner countries that suffer from physical water scarcity, considering that the incentive to improve water productivity in those countries are much higher. Countries with physical water scarcity and are so-called partner countries of the Netherlands include, Egypt, Jordan, the Palestinian Territories, Yemen and Sudan. Furthermore, it is important to ensure the feasibility of improving water use efficiency with 25%. A baseline should be set preparatory to understand what the boundary conditions are regarding the project site.

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