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Urbanizing river deltas are highly susceptible to sea level rise and extreme weather events such as floods and droughts. Water-related disasters are already happening more often due to climate change, rapid urbanization, unsustainable land use and aging infrastructure threatening a large fraction of human and natural environments in these low lying and sinking areas around the globe. As stress levels of climate change are accelerating, societal and physical transformations are essential for adapting our deltas to climate change. In the Netherlands, imagination and evidence by design in the form of a long-term spatial vision, played a pivotal role in the past century to set, share and accomplish a new direction to overcome flood disasters by altering the coastlines and riverbeds of the Rhine–Meuse–Scheldt delta. The unprecedented rainfall in July 2021 and the storm in December 2021 which hit Western Europe revealed the effectiveness of this new direction. We therefore plea for a prominent role of design in climate science and delta management to imagine, analyse and communicate future perspectives for climate adaptation in urbanizing deltas.

Large river deltas are among the world's economic engines and at the same time they are hit harder and earlier by the effects of progressive climate change than anywhere else because they are sinking and shrinking due to climate impacts and anthropogenic activity. As they are low-lying, at the downstream end of river catchments, they are exposed to sea level rise[1,2], reducing sediment depositions and changing streamflow regimes[3]. Deltas cover only 5% of the global land area, but have a population density up to 10 times higher than average—a number, that is increasing rapidly, especially for deltas in Asia and Africa[4].

Urban migration is the main contributor to the explosive and uncontrolled population growth of most cities in these deltas of which on average one-third are living below the poverty line[5]. In addition, the deltas of the Low and Middle-Income Countries (LMICs) host the world's largest absolute number of climate migrants[6]. The rising global sea level, subsidence and the increasing frequency of natural hazards, such as flooding, will have a progressively detrimental impact on these urbanizing deltas, especially affecting the living environments of the urban poor[7].

The more urbanised and tamed river deltas of the High-Income Countries (HICs) suffer from a developmental and technological 'lock-in', whereby upgrading or replacing existing flood protection systems is becoming prohibitively expensive and complex[8]. The associated investment decisions involve long lead times, requiring the establishment of performance criteria and risk margins to account for various risks, such as economic risks and uncertainties, that extend over decades, thereby introducing significant levels of uncertainty[9]. At the same time, as climate impacts become more visible, conventional modelling approaches (including climate models) supporting climate science and delta management are increasingly being compromised. These models assume the complex delta system to fluctuate within a confined, unchanging envelope of variability[10]. But due to increasing uncertainties they are likely to provide poor estimates of future (notably cascading) impacts of climate change and human activities on the delta system[11]. While it is crucial to acknowledge the limitations and uncertainties inherent in such models, they remain essential tools for enhancing our understanding of these future impacts.

These climate adaptation challenges require a larger adaptation potential and high-end climate change scenarios reveal limits to adaptation. In addition, the rate of 'green transformation' towards sustainability of the HICs is relatively slow when compared with some deltas of the LMICs, and is arguably not fast enough to cope with a rapidly changing world[12]. However, in the deltas of the HICs there is an opportunity for a 'reset' as the sell-by date of many current infrastructure systems is near[13].

Although we see some glimpses of positive change in climate adaptation, there is too much emphasis on short-term solutions and incremental adaptation, assuming that climate change is a smooth and gradual process[14]. Consequently, disruptive weather events have at best provided 'the negative tipping points' to transformative change in delta management. This omission has thus far prevented to focus on opportunities for realizing desirable and plausible futures and to explore options to benefit from 'the positive tipping points' in both economic and social realms[15]. Positive tipping points are those that accelerate transition and help unlock the lock-in or 'paralysis by complexity'. They are a result of a deliberate, creative process where potential moments of synergies and opportunities for radical redirection are

identified and exploited to trigger self-reinforcing feedbacks that drive the transformative process[16]. Here are some examples of reaching a tipping point where targeted actions become self-propelling: the transformation of cities through water-sensitive principles and practices of the Water Sensitive City initiative in Australia[17] and the rapid shift to battery electric vehicles (BEVs) in the EU and China[18].

There is growing support for the notion that a lack of imagination is hindering our ability to find effective solutions to the pressing planetary crisis[19]. Additionally, imagination is recognized as an essential component of collective agency driving fundamental advances "in all arenas of humanity, from technological innovation to literature and arts"[20]. From Dutch history, we learn that imagination by design has the ability to shape vision, communicate direction, and engage people powerfully in creating these positive tipping points to survive climate change. As such, the practice of Dutch Delta Design is a concretisation of general methods to imagine transformative futures[21,22].

Delta management in the Netherlands and beyond

A significant portion of the Netherlands is situated in a delta. Much of the land is prone to flooding and about one-quarter is below sea level, resulting in significant challenges with both the sea and the inland rivers that discharge into it. For centuries, thousands of smaller infrastructural works such as dikes, dams and polders were built to provide (amongst others) flood protection. From the 1920s onward, initiated after the devastating Zuiderzee flood of 1916 and the North Sea flood of 1953, this strategy of predominantly locally led, small-scale interventions was replaced by a national program encompassing large-scale delta works to shorten the coastline. The implementation of the Delta Works began promptly after the flood of 1953, with the first project launched in 1954. It took nearly three decades to complete all 13 projects comprising dams, sluices, locks, dikes, and storm surge barriers. The swift start was possible because the design and underlying research had already begun two decades earlier[23]. Initially, the design and plans for the Delta Works were not conceived as a final solution but rather as a spatial vision for a long-term transformation process allowing the large sea arms to silt up naturally aimed at creating a more natural delta[24].

After the wake-up calls of the near-miss Rhine and Meuse floods in 1993 and 1995, the flood protection strategy of the large Dutch rivers shifted from using hard infrastructure to creating more space for rivers through the so-called Room for the River and Meuse Works programs. This approach included strategies such as depoldering, dredging new and deeper channels, and lowering the floodplain. This transition was facilitated by a professional and societal shift in the Netherlands towards "nature-based" water management that started in that same period[25]. The new approach emphasized working with natural processes to enhance flood protection, restore ecosystems, and improve the overall resilience of the river landscape. The designs that shaped the Room for the River Program were developed and scientifically supported by modelling and prototyping studies, which started already in the 80 s, making them ready for implementation after the near disasters of 1993 and 1995.

The recent unprecedented storms and heavy rain that impacted Western Europe in 2021 and 2023 have demonstrated the effectiveness of these programs in preventing severe coastal and river flooding in the Netherlands. For example, despite the extremely high water levels in the Meuse River near the towns of Itteren and Borgharen in 2021, which corresponded to a return period of approximately 200 years, no flooding occurred. These towns had previously experienced significant flooding in 1993 and 1995, with return periods of approximately 160 and 80 years, respectively, prior to the implementation of the Room for the River program. Notably, the peak discharge in 2021 was higher, further underscoring the program's effectiveness[26].

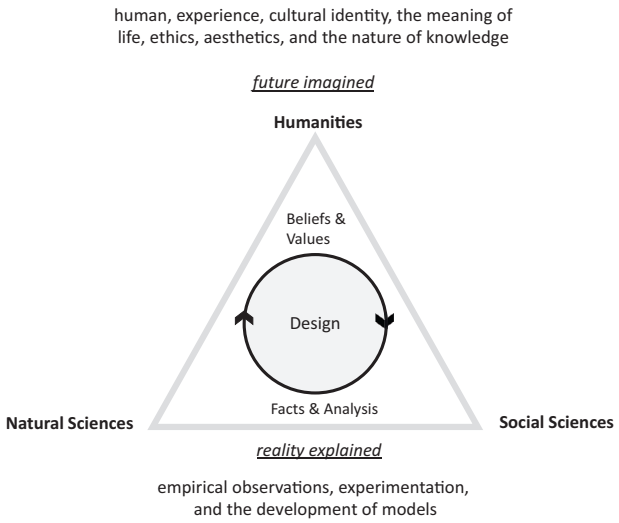

Fig. 1 | Uniting Sciences and Humanities by design: Sciences, both natural and social, value objectivity and rationality to explain reality by focusing on the study of the physical and natural world and on the behavior and patterns in the human world, respectively. They emphasize empirical observation, experimentation, and the development of models. Humanities aim to explore questions about the human experience, cultural identity, the meaning of life, ethics, aesthetics, and the nature of knowledge. The humanities value subjectivity, including imagination. Design brings them together though informed imagination, evidence-based plans and scenarios, and long-term visions. As such design overcomes different viewpoints, while design future-proofs human society and culture while advancing scientific theories and models.

As concerns regarding the implications of climate change for The Netherlands grew, a new national program known as the Dutch Delta Program was launched in 2010. The program coordinates the water-related challenges of climate-proofing the Netherlands. At the core of the program are three over-arching thematic policy frameworks and coherent sets of measures, known as Delta plans for flood protection, fresh-water availability, and spatial adaptation. The program is evaluated and re-calibrated every six years. This reassessment examines both content and methodology.

The Dutch Delta Program started its operation under the implicit assumption that climate change primarily involved gradual trends that were straightforward to monitor and anticipate following an adaptive delta management approach. The impacts of climate change requiring more radical system interventions were assumed to occur in a later phase, likely after 2050. However, since the launch of this program, extreme rainfall, droughts, and heatwaves are showing that climate change manifests itself in unpredictable weather events with increasing intensity and frequency[27]. Moreover, the timeframe within which multiple long-term transformative strategies are still realistic options is rapidly narrowing. These observations are now urging an acceleration of the pace of implementation and a change of direction from incremental (adaptive) to transformative delta management of the program[28].

The need to shift from incremental (adaptive) to transformative delta management has sparked a renewed focus of the Delta Program on imagination and design to address climate change. Building upon previous

Fig. 2 | Envisioning the Dutch delta in 2022. Spatial design of a section of the Dutch delta (Fig. 2**a**) developed to protect the Port City area of Rotterdam. This will be achieved by rerouting the current flood defense (dike ring 14) and creating a sponge city. The port will continue to be elevated incrementally while simultaneously transitioning to a green economy (see visual representation Fig. 2**b**). Design was created by Lola, Urbanisten and Royal Haskoning DHV in 2022 as part of the Redesigning Deltas Design Study[22]. Written permission for its use has been granted.

experiences both imagination and evidence through spatial visualizations by design are currently used for the scientific exploration of new perspectives on the future of the Dutch delta. The ambition is to create appealing long-term visions on what these futures might look like including the pathways to achieve them. Research institutes, national, regional and local governments, specialised consultancy and engineering bureaus, building and dredging companies, are working together to further develop these long-term solution directions. These outcomes will be used in the upcoming reassessment in 2027 of the Delta Program to review the existing policy frameworks and Delta plans[27].

Similar design-driven trajectories have also been followed in recent efforts to future-proofing the Mississippi delta in the post-Hurricane Katrina 'Dutch Dialogues' (2008–2014) and the Hudson-Delaware delta in the New York Post-Sandy adaptation plan 'Rebuild by Design' supported by The Rockefeller Foundation (2013-ongoing) and the 'Water as Leverage' initiative for urban climate resilience of Asian cities. The resulting innovative and creative ways of disaster recovery ('build back better'), brought hope and inspiration to the local communities and decisionmakers[29]. In such examples, design complemented the traditional largely science-based approaches with imaginative appeals by conceptualizing and visualizing futures. This involves navigating spatial translations and their consequences, all while reconciling societal beliefs and desires with the innovative spatial concepts being introduced[30].

Design is a complex and multi-dimensional field that has numerous meanings. It refers to a process as well as to a product. We define design for urbanized deltas in two ways. First, design is a plan, scheme, or model that highlights new challenges for political and societal debate, creates narratives linking various subproblems, scales, and interests, and guides future directions that give insight in what decisions can be made[31]. Through imaginative visual communication, it has the power to transcend current limitations or blocked visions of the future, enabling free reasoning about alternative futures. Second, design is the activity, process, or action functioning as a knowledge brokerage instrument, bringing stakeholders together to conceive and create integrative plans for human interventions that shape complex environments through interactions with human and natural processes over time[32].

Role of Design for transformative change. What can we learn from these experiences? Five crucial conditions for transformative change appear to be evident in subsequent instances within these national and international programs. These conditions are grounded in the model 'Five Dimensions of Futures Consciousness' by Ahvenharju, et al.[33]. The first condition relates to the strong beliefs of agency. Disasters or the threat of natural hazards, along with opportunities and appealing perspectives, can act as powerful catalysts and tipping points for change. The second condition relates to the time perspective: the existence of a long-term spatial vision that spans decades into the future, appeals to our imagination and is informed by the past and the present, directs and enforces the development of an alternative strategy. The third condition relates to the openness to alternatives. Imagination by design thrived in the pre-disaster era as there was sufficient time for creativity, exploration and investigation, which mutually reinforced each other in a design process. These allowed authorities and experts to leverage a more diverse range of perspectives, opening up the design-driven solution space. As a result, the formulation and implementation of these programs could commence almost immediately after the (almost) disaster occurred. The fourth condition concerns systems perception, focussing on the dominant role of natural processes in design, the holistic integration of nature-based solutions, the acknowledgment of humans as integral components of the natural ecosystem, and the dynamic interplay of these elements within the delta. Lastly, this condition focuses on the ethical and social aspects of futures thinking. Climate change exemplifies the ethical and social dimensions of futures thinking as the effects of present-day activities will profoundly impact future generations. The urgency to make use of what moves people to provoke climate action has become manifest in the Netherlands and in many other deltas. Dutch history has shown that imagination and evidence by design have the power to take professionals, policy and the general public beyond present conditions of life, spatial relations, and contexts required to initiate and direct transformative change for climate proofing the Netherlands.

Elevating imagination. In the end, our ability to endure the challenges of the climate crisis hinges on our capacity to purposefully and consciously cultivate a profound desire for change before the next disaster strikes. We believe that only through the interaction of imagination and evidence creation we will be able to shape, analyze, and effectively communicate appealing futures that drive change. History showed us that design has the ability to inspire human society while advancing scientific theories and models and creating space for engaged professional and civic participation. We plea for a shift in attitude in climate science and delta management, one that elevates imagination by design to an equal level as modelling and analysis of natural and social subsystems of deltas. This requires interdisciplinary approaches uniting the realms of Natural Sciences, Social Sciences and the Humanities (see Fig. 1). Considering past delta system transformations in the Netherlands, we conclude that design may be the key to boundary spanning. Design should therefore be strengthened as a capacity in academics, professional practice, and society at large. In order to do so we need a Delta Program for all our sinking deltas. One that can enable positive tipping points. A program that serves as a catalyst for propositional, creative, iterative, and collaborative thinking to advance and share our understanding of the challenges of sea level rise and other climate-related issues. The Dutch Delta Program may serve as a pioneering example in this direction, having recently initiated concrete steps toward transformative delta management. By organizing hackathons and design workshops that involve a broad range of stakeholders and disciplines, the program aims to imagine, analyze, and communicate desirable and plausible long-term futures and pathways (see example in Fig. 2)[28].

Data availability

No datasets were generated or analysed during the current study.

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References

1. Giosan, L. et al. Climate change: Protect the world's deltas. *Nature* **516**, 31–33 (2014).
2. Edmonds, D. A. et al. Coastal flooding will disproportionately impact people on river deltas. *Nat. Commun.* **11**, 4741 (2020).
3. Loucks, D. P. Developed river deltas: are they sustainable? *Environ. Res. Lett.* **14**, 113004 (2019).
4. PBL (Netherlands Environmental Assessment Agency) The Geography of Future Water Challenges Bending the Trend, The Hague, PBL publication number: 4376 (2023). https://www.pbl.nl/sites/default/files/downloads/pbl-2023-geography-of-future-waterchallenges-bending-trend-4376_0.pdf

5. McLeman, R. International migration and climate adaptation in an era of hardening borders. *Nat. Clim. Chang.* **9**, 911–918 (2019).
6. United Nations Press Release Secretary-General, statements and Messages: Stressing Rising Seas Already Creating Instability, Conflict, Secretary-General Says Security Council Has Critical Role in Addressing Devastating Challenges (SG/SM/21688, 14 February 2023) (2023).
7. Bucx, T., Marchand, M., Makaske, B. & van de Guchte, C. Comparative Assessment of the Vulnerability and Resilience of 10 Deltas – Synthesis Report. Delta Alliance Rep. 1 (2010).
8. Santos, M. J. & Dekker, S. C. Locked-in and living delta pathways in the Anthropocene. *Sci. Rep.* **10**, 19598 (2020).
9. Bloemen, P. et al. Lessons learned from applying adaptation pathways in flood risk management and challenges for the further development of this approach. *Mitig. Adapt Strateg Glob. Change* **23**, 1083–1108 (2018).
10. Her, Y. et al. Uncertainty in hydrological analysis of climate change: multi-parameter vs. multi-GCM ensemble predictions. *Sci. Rep.* **9**, 4974 (2019).
11. Willcock, S. et al. Earlier collapse of Anthropocene ecosystems driven by multiple faster and noisier drivers. *Nat. Sustain* (2023).
12. Soergel, B. et al. A sustainable development pathway for climate action within the UN 2030 Agenda. *Nat. Clim. Chang.* **11**, 656–664 (2021).
13. World Bank People's Republic of Bangladesh Multisector Approaches to Delta Management Investment Plan for the Bangladesh Delta Plan 2100. 1: The Plan (Final Report No: ACS23966, 31 July 2017). Washington, DC: World Bank / International Bank for Reconstruction and Development (2017).
14. Tessler, Z. D. et al. Profiling risk and sustainability in coastal deltas of the world. *Science* **349**, 638–643 (2015). PMID: 26250684.
15. Finn, E. & Wylie, R. Collaborative imagination: A methodological approach. *Futures* **132**, 102788 (2021). ISSN 0016-3287.
16. Lenton, T. M. et al. The Global Tipping Points Report 2023. University of Exeter, Exeter, UK Cunningham (2023).
17. Wong, T. H., Rogers, B. C. & Brown, R. R. Transforming Cities through Water-Sensitive Principles and Practices. *One Earth* **3**, 436–447 (2020). ISSN 2590-3322.
18. Mercure, J. F., Lam, A., Buxton, J., Boulton, C., Lenton, T. M. Evidence of a cascading positive tipping point towards electric vehicles. https://doi.org/10.21203/rs.3.rs-3979270/v1 (2024).
19. Bendor, R. Imagination. In: Interactive Media for Sustainability. Palgrave Studies in Media and Environmental Communication. Palgrave Macmillan, Cham. (2018).
20. Ketonen-Oksi, S. & Vigren, M. Methods to Imagine Transformative Futures. An Integrative Literature Review. *Futures* **157**, 1–13 (2024). Article 103341.
21. Meyer, H. & Nijhuis, S. Urbanized Deltas in Transition, Amsterdam: Techne Press, ISBN:978-90-8594-054-8 (2014).
22. Hooimeijer F. L. & Kuzniecow Bacchin T. Redesigning Deltas design study and a manifesto for the 'new Dutch delta'. Delta Links. https://flowsplatform.nl/#/redesigning-deltas-design-study-and-a-manifesto-for-a--new-dutch-delta--1677063227312 (2023).
23. van Veen, J. Dredge, drain, reclaim, The art of a nation. 5th edition, Martinus Nijhoff, The Hague (1962).
24. van Veen, J. Afsluitingsplannen der Tussenwateren, Januari 1953. De Haag: Ministerie van Verkeer en Waterstaat, Rijkswaterstaat, Directie Benedenrivieren (RWS, BER) (1953).
25. van Staveren, M. F., Warner, J. F., van Tatenhove, J. & Wester, P. Let's Bring in the Floods: De-Poldering in the Netherlands as a Strategy for Long-Term Delta Survival? *Water Int.* **39**, 686–700 (2014).
26. Strijker, B., Asselman, N., de Jong, J. & Barneveld, H. The 2021 floods in the Netherlandsfrom a river engineering perspective. *J. Coast. Riverine Flood Risk.* **2**, 6 (2023).
27. Kreibich, H. et al. The challenge of unprecedented floods and droughts in risk management. *Nature* **608**, 80–86 (2022).
28. National Delta Programme. DP2024: Now for later. The Hague: Ministry of Infrastructure and Water Management / Ministry of Agriculture, Nature and Food Quality / Ministry of the Interior and Kingdom Relations, (2023).
29. Rockefeller Foundation. *Evaluation: Rebuild by Design Phase One*. (Washington, Urban Institute 2014).
30. Kempenaar, A., Laeni, N., van den Brink, M., Busscher, T. & Ovink, H. 'Water as Leverage': design-led planning for urban climate resilience. *Plan. Pract. Res.* **39**, 72–92 (2022).
31. Colombo, F., van Schaick, J. Witsen, P. P. & Ovink, H. *Shaping Holland: Regional Design and Planning in the Southern Randstad* (New York, NY: Routledge 2022).
32. Meyer, H. The State of the Delta. Engineering, Urban Development and Nation Building in the Netherlands, Nijmegen, VanTilt (2016).
33. Ahvenharju, S., Minkkinen, M. & Lalot, F. The five dimensions of futures consciousness. *Futures* **104**, 1–13 (2018).

Author contributions

C.Z., P.B., M.H., M.v.H. wrote the main manuscript. T.B. prepared the figures. All authors reviewed the manuscript.

Competing interests

The authors declare no competing interests.

Additional information

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