
Editorial Introduction
Special Issue: Water for Food in Deltas

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# Deltas under pressure – addressing complex water and food challenges in deltas using a food systems approach

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**Abstract**
Worldwide, deltas are important food-producing areas with increasingly densely populated cities. These water-rich areas are also vulnerable to natural, development and climate change-induced disasters such as floods, droughts, cyclones, sea-level rise and water pollution. Sustaining livelihoods of the delta population now and in the future, is therefore increasingly stressed and with compounding challenges: population growth, urbanization, degradation of the environment, dietary change, and climate change. An integrated approach is necessary to navigate this complexity and to move towards a sustainable but uncertain delta future. We introduce three methodological building blocks to facilitate governance in the delta towards sustainability: A food system approach, co-creation of transition pathways, and scale sensitive governance. We underpin the approach, describing the building blocks while referring to the articles in this Special Issue and other recent research using similar approaches. In this way, the article brings together insights on food systems transitions in deltas from different professional backgrounds and provides insight into and contributes to improving governance in water and food-stressed delta regions.

**Keywords**: delta, food systems, transitions, adaptive delta management, water governance



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# 1. Introduction

**Deltas, water and food**

Worldwide, deltas are among the most productive areas for agriculture[1], but they are also extremely vulnerable to water and climate-related disasters, like floods, droughts, cyclones, and incrementing threats e.g. sea-level rise, salinity intrusion, and subsidence. This is in addition to water pollution and food production issues due to transition of fertile agricultural land into industrial or housing areas. (Bianchi, 2016; Reinhard and Folmer, 2009; Renaud *et al.*, 2016; Bucx *et al.*, 2014; Nicholls *et al.*, 2018; Higgins *et al.*, 2013; Hoanh *et al.*, 2010).

Climate change and socio-economic development are driving significant and rapid change in deltas. This means that the water and food system must transition towards higher sustainability and resilience to meet the increasing demands for food production (van de Guchte *et al.*, 2012; Nicholls *et al.*, 2018; Meyer, 2022). Not only is the number of people living in deltas increasing, but their diets are also changing, as are the risks (e.g. emergent diseases, supply chain risks) and constraints (e.g. use of agro-chemical) on production and environment (Reinhard and Verhagen, 2020; Nicholls *et al.*, 2018). The complex puzzle of improving production and creating livelihoods in rural areas while providing safe and affordable food for the urbanising population and coping with changes in diets and economic and environmental shocks due to growth and climate change is daunting.

The current challenges, as formulated in the Sustainable Development Goals, e.g. SDG2: Zero Hunger, will require a transition in food systems to address agricultural production, consumption patterns, food safety and nutrition, livelihoods and the environment. Water, soil and crop management are critical in shaping this transition (FAO, 2018) and the link to climate change, thus also linking to SDG6 and SDG13, which requires an integrated approach.

Addressing the longer-term changes in the deltas has recently been discussed via water-centered strategic plans for Bangladesh, Vietnam (the Mekong Delta) and the Netherlands (Zevenbergen *et al.*, 2018). The underlying view on development expressed in the Bangladesh Delta Plan 2100 emphasizes the need for an integrated, comprehensive and long-term delta vision and co-creating adaptive pathways (GoB, 2018). The integrated and comprehensive approach, in this case, focuses on water, and therefore, the outcomes are especially geared towards or formulated as water system-related solutions. However, to bring about change in the agriculture and food sectors, it is necessary to also include food systems systematically in the transition plans. How to approach this and include interaction with stakeholders? This article focuses on water, agriculture and food in transitions in deltas.

Arriving at transition pathways requires a dialogue that combines diverse perspectives to enhance mutual understanding and create new spaces for solutions and new insights. While interacting in a co-creation process with various stakeholders, this implies that agriculture and food people need to know about water, and water people need to know about agriculture and food. Exactly this is the journey to be undertaken, bringing knowledge together and gaining deeper insight, linking together, understanding each other's knowledge, and deepening that understanding on scale-sensitive solutions through the use of an integrated framework.

# 2. Food system approach and transition in deltas

A food systems approach (van Berkum *et al.*, 2018), Fig. 1 below, is used to work on the complex puzzle for deltas in a participatory way. The first step is to develop with stakeholders a long-term vision of the sustainable delta future, not limited to water, but also with a focus on agriculture and food. When focusing

[1] Agriculture is used in the wider sense of the word, including e.g livestock, aquaculture and fisheries

on the interlinkage between water and food, this could also be indicated as the water-food nexus[2].

The second step is to translate this vision into action. This is done by co-creating, again, with a range of stakeholders transition pathways that outline necessary developments, measures, and investments to achieve the future perspective.

In the third step, scale is important, and in this study, we particularly address **scale-sensitive governance,** identifying tensions and synergies[3]. A transition pathway prepared at the national level needs to be effective at the local level and vice versa. The planned intervention and investments will not always have an immediate impact across all scales; the impacts will differ over time per sector and geography. It is necessary to have stakeholder involvement in transition processes via top-down and bottom-up processes to guide and influence the process.

In summary, in this article, we describe three methodological building blocks to facilitate delta governance with the aim of a sustainable delta in the long run. We focus on water, agriculture and food in deltas and will illustrate this with examples from the articles in this Special Issue, to support our views. The building blocks presented in this article are:

(i) **Integrated approach**: using a "food system" approach for an integral analysis of the entire food system, or parts of it, in deltas, for a future vision (guided by the SDGs) to include all relevant elements and drivers of the food system

(ii) **Transition pathways and co-creation:** describing the steps to determine feasible routes towards the future and include relevant stakeholders in the process
routes towards the future and include relevant stakeholders in the process

(iii) **Scale-sensitive governance:** addressing governance of the process. Literature on integrated water resources management shows that governance can be a combination of top-down and bottom-up approaches, depending on the views and positions of the stakeholders and targets of the transition pathway (Homsy *et al.*, 2019; Kroontz and Newig, 2014; Smith, 2008).

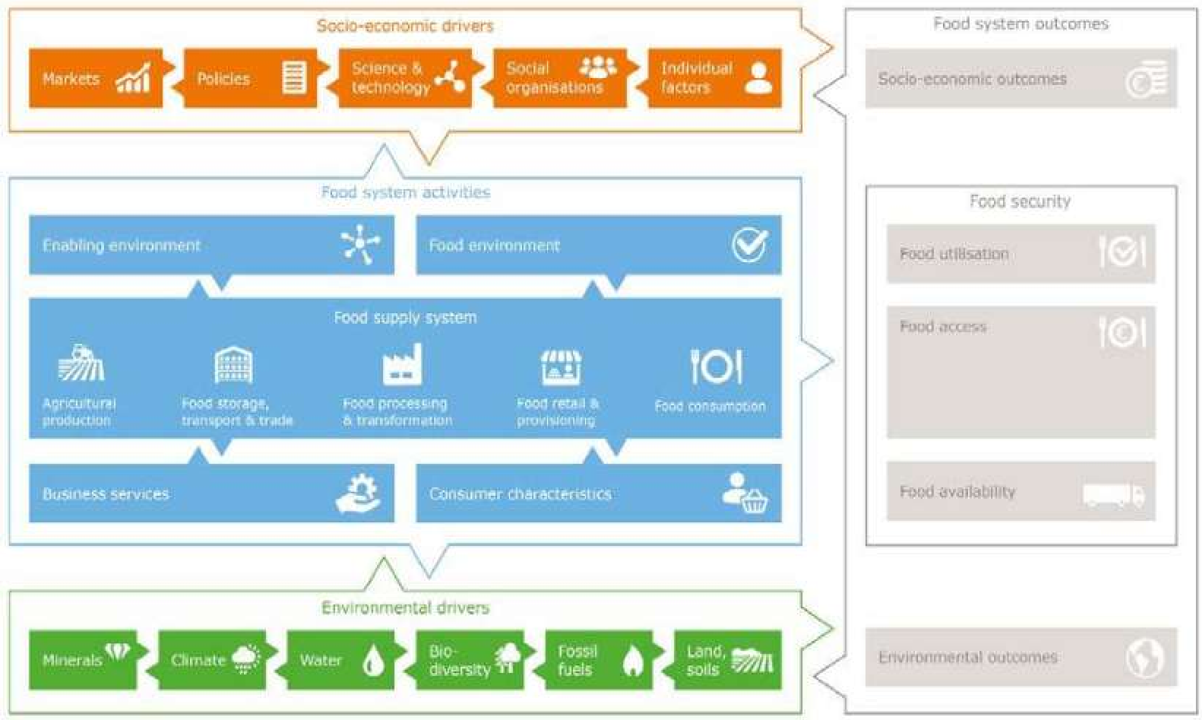
### 2.1 Building block (i): Integrated approach

A food system approach (FSA) as introduced by various authors (Van Berkum *et al.*, 2018, Bene, 2019; Arslan *et al.*, 2020; IFAD, 2020) can be used to study the overall setting in the delta and the transition dynamics towards food security. The FSA is a goal-oriented system's approach that takes all elements from production to consumption into account (Bene, 2019, Arslan *et al.*, 2020). The approach considers the various elements of the food system, such as agricultural production, processing, transport, and retail, all affected by socio-economic and environmental drivers. By defining the desired goals of the food system and understanding the relationships, processes, dynamics, and stakeholders in the food system (see figure 1), we can identify key barriers and related interventions and investments to overcome them. Acknowledging and identifying potential feedback loops is a critical part of defining scale-sensitive governance.

[2] Which could also be described in a wider context, as the water-food-energy-climate change-biodiversity nexus – FAO, 2014. We'll not elaborate here

[3] We would like to stress that we neither go into typical geographer's debates and concerns about scale here, nor into the larger academic discussion about scale (e.g. Sartas et al., 2020). For the purpose of this SI, we'll assume scales matter - a fairly pragmatic assumption given the very applied work the authors in this SI are undertaking

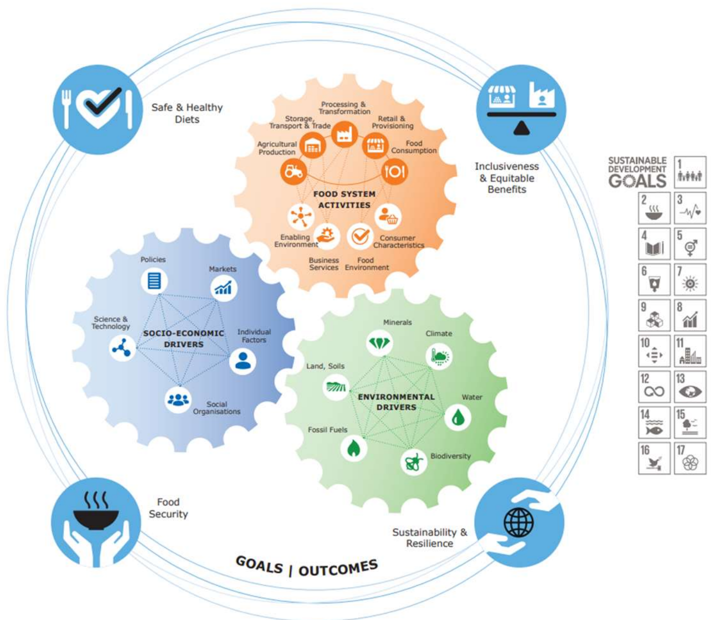
*Figure 1 – Schematic overview Food Systems Analysis*




*(source: van Berkum et al., 2018)*

Outcomes can be in terms of i) production, ii) safe, nutritious and healthy food, iii) addressing income (in)equalities, and resilience and climate change (van Berkum *et al.*, 2018) (see figure 2). The FSA sheds light on non-linear processes in the food system and possible trade-offs (nexus) between policy objectives.

*Figure 2 – Food System Approach indicating four goals*




*(source: WUR Communication, after van Berkum et al., 2018)*

The FSA provides three benefits. Firstly, it helps define the outcomes related to national or regional food and nutrition security and socio-economic and environmental targets. Secondly, it enables us to understand the national or local socio-economic and environmental drivers that define the context of the food system activities. Therefore, these feedbacks need to be included in the analyses. Thirdly and finally, it helps to map and include relevant parts of the food system required to achieve the set goals.

When doing detailed work on, for example, crops, animals, farms, value chains, and food safety, it is still essential to understand how the work is embedded in the food system. Linking knowledge and information from the detailed work via a FSA helps identify trade-offs and synergies between goals and the various components of the food system.

In this Special Issue, Veraart *et al.* present an analysis of Nature-Based Solutions (NBS) with a focus on food production and water resource management in Ghana and the Netherlands. The work uses a food system approach while addressing NBS for rainwater harvesting and wastewater reuse. The results highlight that there are several barriers to the full implementation of NBS, including biophysical and technical obstacles, as well as social and institutional, indicating and which water related NBS are more likely in different food production settings.

Deolu-Ajayi *et al.* (under preparation) also uses a food system approach providing an example of how fundamental research on abiotic stresses at the plot level for specific crops can be linked to farm management, the value chain, and the broader food systems change. This study argues that successful transitions require combining the interests and responsibilities of stakeholders across the food system.

Other recent research applying a food system approach in deltas provides insights into the ways in which environmental drivers (such as climate, land, and water) are linked to socio-economic drivers (such as policies and markets) and how they impact the value chain. For instance, Siegmund-Schultze *et al.* (2023) used the food system approach to study rice and shrimp farming in the Mekong Delta, focusing on how environmental drivers (such as climate change and salinity) and socio-economic drivers (such as the transition towards market-oriented production) affect farmers. Similarly, Terwisscha van Scheltinga *et al.* (2023) shows that in the southwestern delta of Bangladesh, environmental drivers (such as water and salinity) and socio-economic drivers (such as urbanisation and industrialisation) are impacting the food system via the value chains of livestock and mangrove-shrimp oriented food systems.

The food value chain, as one of the main elements in the FSA (see Fig. 1 earlier), is connected to water in different ways. In Egypt, local water resources are used to grow vegetable crops for export, thus exporting water, while water is imported in the form of wheat to satisfy the food demand in urban centres (Terwisscha van Scheltinga *et al.*, 2021). Linderhof *et al.*, (2021) highlight how the value chain also influences water quality and quality.

Water quality and quantity are essential to the food system, impacting production, transport, processing, wastewater, and packaging, with cross-sectoral consequences. For deltas, the challenges related to droughts, flooding and salinity which will exacerbate the current problems of water pollution, food safety and environmental quality. The presented examples highlight how water, both as a resource and its governance, affects the value chain, at the start of the value chain (production) as well as in the consumption part of the value chain.

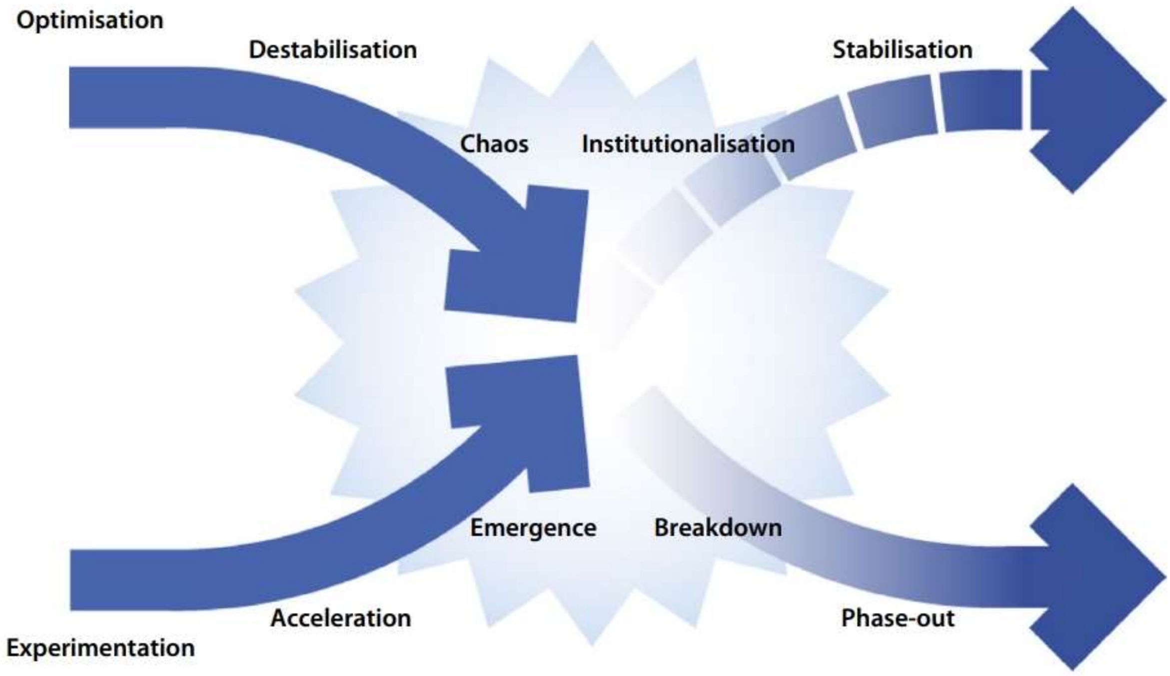
### 2.2 Building block (ii): transition pathways and co-creation

Deltas are dynamic environments in which change is a constant and disasters are always lying in waiting. Development and adaptation processes in deltas will have to find answers to how to deal with multiple issues. Governance of the food system in the delta is then essential. Transition pathways describe the interconnected slow and fast changes in biophysical and socio-economic drivers (Verhagen *et al.*, 2022). Uncertainty is a sure thing, and it's important to avoid lock-in situations e.g. by focusing the transition pathway on one crop or one factor, such as rice, water or technology. Transition pathways of food systems must be flexible and include mechanisms to learn and adapt. This is inherently a complex process and requires monitoring and learning.

The identification and development of transition pathways starts by consulting stakeholders to develop, or make explicit, one or more visions of a future sustainable food system for the area of interest in which the sustainability problems of the present system are addressed (integrated system analysis addressed in building block i).

Transitions can be described as the shift between the current and a future situation. A transition process is typically non-linear, evolves with and without interventions, involves trial and error in terms of intervention management, and involves many parties (actors) (Rotmans *et al.*, 2001, Loorbach, 2014)[4]. From an initially stable situation, change occurs towards a future, eventually stable, situation. Changes occur in the take-off phase and increase in the acceleration phase, before stabilization occurs. There are both new initiatives that come about through experimentation as well as initiatives that phase out. In the process, uncertainty, changing priorities and chaos can make it unclear which initiative is coming up or moving out (Loorbach, 2014, Hebinck *et al.*, 2022) (see figure 3 below).

*Figure 3 Transition curves, indicating the interaction of patterns of build-up and breakdown*




*(source: Hebinck et al., 2022)*

A transition pathway describes a change process from a current, undesired situation towards a more desired and uncertain situation, delineated by the integral system's analysis (building block i). Verhagen *et al.* distinguish three general steps in a transition pathway methodology for food systems in deltas (Verhagen *et al.*, 2022):

1. Vision building: develop one or more future visions (e.g. for the year 2035 or 2050) of a sustainable system for the domain of interest;

2. Back casting: Develop a set of plausible 'transition pathways', i.e. a set of innovation and change processes that lead from the future visions situation to the present;

3. Reflection: Reflect on the transition pathways by focusing on the role of specific stakeholders of

[4] Although the term "transformation" may be used in food systems literature, e.g. Arslan et al.(2020), we prefer to use the term transition. We understand transition as a process of change from one stage into another; while transformation indicates a more abrupt change (Hölscher et al., 2017). In some cases both terms could be used.

interest and what they can do under various circumstances to help realise more sustainable visions. Explore which incremental changes might lead the present system to develop into the future vision. Each of these incremental changes should be small enough to be conceivable or plausible. If each of the small changes is plausible, the transition pathway also becomes plausible, meaning that the vision for the future is also realistic to achieve.

Using the food system approach as the analytical framework, further work can be done clarifying the transition pathways by mapping and discussing change together with stakeholders. It may be noted that an innovation may not be perceived by all as an important and necessary step. There may be valid reasons to resist, and therefore stakeholders may not (wish to) be included in the change process. Co-creation does not ensure that there will not be conflicts of interest. And the co-creation process itself may be a reflection of the power relations.

In Verhagen *et al.*, (2022), the food system is used as an analytical framework to study transition processes in agriculture and food. They call it the TransPath model (Verhagen *et al.*, 2022). The strength of this model is that it identifies the critical elements of a food system, noting that food system analysis itself does not specify the processes by which such systems may change. To also analyze this change process, the TransPath approach builds on a "multi-level perspective" framework designed to explore socio-technical transitions to sustainability (Geels and Schot, 2007). Essential to developing transition pathways is the interaction with stakeholders at various levels and moments in time and the combination of top-down policies and bottom-up societal initiatives. Altogether summarized and visualised in Verhagen *et al.* (2022) as guidelines for co-creation with stakeholders (see figure 4 below).

*Figure 4 Guidelines for co-creation of transition pathways*


Guidelines for co-creation with stakeholders of food system transition pathways in deltas

1. Analyse together
2. Understand together
3. Prepare together
4. Design together
5. Partner together
6. Act together
7. Monitor, evaluate and learn together

(source: Verhagen *et al*., 2022)

One of the elements to formulate transition pathways is 'back-casting', applied to food systems in deltas. Back casting is a planning method used to outline the steps needed to achieve a predefined desired future, starting from that predefined future. Thus, the predefined future serves as the starting point from which to analyse the pathway back towards the present. By identifying which steps are needed and when these should be completed, a planning sequence is established. The method is particularly useful in planning processes for long term goals, such as the SDGs. In the water domain, examples are found in the delta plans and include creating a vision or road map towards the future (Haasnoot *et al.*, 2012; Haasnoot *et al.,* 2013; van Vliet and Kok, 2015). The construction of adaptation pathways in the form of a roadmap that indicates where different policy options (both current and future ones) run into trouble by reaching an adaptation tipping point, and which alternative adaptation policies can be adopted afterwards (Haasnoot *et al.* 2012, Ahmed *et al.* 2018).

This leads to the identification of opportunities, threats, timing and sequence of policy options, which policymakers can use to develop water management roadmaps into the future.

Different strategies for supporting improvements in food systems performance are possible. This requires the careful formulation and design of pathways that clearly outline the potential effects of interventions, innovations and incentives on food system interactions and outline possible trade-offs or synergies between food system outcomes. A comprehensive and integrated concept for adaptation in deltas is still missing (Schneider and van Asch, 2020), though work on linking adaptive water management processes to food system transition processes has been initiated (Terwisscha van Scheltinga and Timmerman, 2020).

Wilbers *et al.* (2025, this Special Issue) addressed the links between water quality and quality in relation to agriculture and livestock for the Vietnamese Mekong Delta. They further elaborate on how water management can contribute to the transition of these sectors, thus contributing to the analysing and understanding integrated transition pathways of water and food systems.

The paper by Nath *et al.* (2024, this Special Issue) shows that in transition processes in Bangladesh, farmers in water management organisations do not have the required capacity compared to water-related organisations at the national level. They argue that for a successful transition, capacity development is needed at the farmer's level.

In the contribution by Reinhard and Oliemans (this Special Issue) a first step in translating a vision has been undertaken, using an integrated step-wise approach, with similarities to the approach proposed in Verhagen *et al.*, 2022. In this case the vision is for adaptation pathways at polder level, though more focused on water management, and less on food and agriculture. It aims to contribute to local level implementation of the Bangladesh Delta Plan 2100, which was formulated with the national level as its main focus.

Besides in Bangladesh, also in the Netherlands and Vietnam, delta plans have been developed. In these plans, transition pathways and processes in these deltas are connected to ongoing developments and planning processes at the national and regional level, like e.g. the Five-Year Planning Cycles in Bangladesh and Vietnam (Mekong Delta Plan, 2013, GoB, 2018, Zevenbergen *et al.*, 2018). The delta plans focus on water management and include less on agriculture transition in the broader development context of environmental and socio-economic change. For agriculture, transition plans could include broad and specific goals for geographies and sectors like horticulture, fisheries and livestock.Supporting the development of such integrated pathways can for instance, be done in case studies, combining the a) institutional, b) organisational, c) economic, d) social, and e) technical changes needed in the food system to support a response to development and climate change-related challenges and linking to water-related changes as defined in the delta plans.

The paper by Joshi *et al.* (2025, this Special Issue) underscores that transition processes are highly contested processes, stressing the need not only to pay attention to co-creation but also to incorporate inclusiveness in transition processes. Co-creation of pathways for water and food systems, addressing transition while including stakeholders' perspectives and working together with them, is gaining momentum. Recent work on water-resilient food system transition (Matthews *et al.*, 2022) also stresses adaptiveness, vision building and co-creation and inclusiveness.

### 2.3 Building block (iii) Scale-sensitive governance

Key drivers of the food system are rooted in the socio-economic and environmental domains, operating and connecting at varying spatial and temporal scales. The scale of the problem and the scale on which it is governed are easily mismatched. It requires understanding and addressing cross-scale issues, e.g. vertical interplay between different levels of governance and the governance capability of rescaling.

In deltas, solutions at one scale may not be solutions at another scale. For instance, blocking the river in one place, if agreed locally, may provide income for local fisheries, but seen at the national level, if navigation of rivers is sought for, will not be considered a solution. Therefore, scale sensitive governance is important. Cash *et al.* (2006) made an important contribution to the scale debate by identifying specific governance scales, such as jurisdictional, institutional, management, knowledge, time and social network scales. Understanding and addressing cross-scale issues, e.g. vertical interplay between different levels of governance (Young 2002), is important to the governance capability for rescaling (Termeer & Dewulf 2014). This governance capability involves observing both cross-scale issues (scale mismatches) and cross-level issues (interplay), and strategies for organising connections across different levels and scales. Mismatches have been indicated by Cumming *et al.* (2006).

In agriculture, markets and consumers are important, and effective planning entails the collaboration of not only governmental bodies and their institutions but also the engaged participation of companies and farmers. The food system approach reflects the goal-oriented process and complexity, including the key actors.

Important cross-scale issues are likely to come up when the national plans have to integrate the results of the regional programmes. The identification of pathways can be done at different spatial scale levels (e.g. different sectors or regions and national). The interdependencies between levels will need to be addressed by the method. Different maps of adaptation pathways for different regions may conflict with each other, making it very difficult to add up the different maps into a national plan, for example. Adaptive delta-management has to deal with this temporal scale mismatch by identifying the implications of long-term developments and associated uncertainties for short and medium-term policy making.

In both countries, the top-down policy processes aim for transitions towards sustainable, market-oriented climate-proof agriculture. Although details may differ, the core of the case studies include primary production, markets, and value chains from a farmer's perspective. In the case studies, besides the overarching food systems approach, various tools and methods are used, including methods to engage with stakeholders, facilitate process analysis, and support developing, designing, and defining strategies for sustainable change. Documentation of these tools and methods can be found in the case study reports.

Joshi *et al.'*s article (2025, this Special Issue), stresses the importance of including local level stakeholders in order to make national level policies effective. It further clearly brings forward how water governance in polders in south west Bangladesh shapes food system transition. Another study in the same area, shows new developments in this regard: local excavation of drainage canals initiated by an NGO is undertaken by farmers to support their agricultural value chain activities (Mornout *et al.*, 2022). This case, however, also brings clearly forward the interlinkage between governance at the local and national level as the link of the local initiative to effective polder and national scale water governance seems essential for longer term sustainability.

In Wilbers *et al.* (2025, this Special Issue), suggestions for local level adaptation pathways for salinity are provided in support to the national level delta plans. It is recommended to pilot test at field level, before scaling up.

To address the gap between water management organisations at local scale as noted in the article by Nath *et al.* (2024, this Special Issue) and planning for longer term improvements at national scale as in a delta plan, it will be important to not only work at national scale on implementation of a delta plan, but also understand local scale ambitions for transition pathways, engage with local level stakeholders, and address water and food systems in an integrated manner, connecting local and national level governance.

It may be noted that Bene (2022) states that food system transformation may not be happening, as 'various self-reinforcing dynamics are contributing to lock food systems in their current unsustainable trajectories'. Bene indicates in the same paper that 'what is needed is not just a transformation of the food systems themselves, but a transformation of the governance of those food systems as well', indicating the need for public policy to pro-actively drive the process of change and innovations. This remark needs to be addressed in further research on deltas, preferably linking water and food systems and including a scale-sensitive governance angle.

## 3. Conclusion

This introductory article introduces a Special Issue that brings together policy-relevant research to influence and improve governance in water and food-stressed delta regions. The added value of this Special Issue is that researchers with very diverse backgrounds, contribute together to multidisciplinary insights in the papers and the papers together to insights that go beyond the individual papers. In this introduction, we provided a structure in 3 building blocks, to guide this overall insight on the interaction between changes in water and food systems in deltas. Food system analysis, together with transition thinking and co-creation with stakeholders, and combined with scale-sensitive water governance aspects bring an integrated perspective, which may assist to identify solutions in complex situations in deltas, addressing climate change as well as development challenges (population, dietary change, pollution).

Summarizing each block:

A. Integrated approach (food system analysis)

The diverse examples from Bangladesh, Vietnam, Ghana, the Netherlands and Egypt show a variety of recent studies on agriculture and food developments (from field level to national level agriculture, from aquaculture to livestock to plant), highlighting current changes and the dynamics within the food system. The papers extend on technical issues (e.g. abiotic stress) bringing them within a wider food systems framework and linking them to the relevant water governance aspects, thus elaborating the food systems approach. This more integrated approach, brings a broader perspective to the problem and sheds light on a novel array of options for sustainable water and food systems in future.

B. Transition pathways and co-creation

Different stages in transition processes can be distinguished, and these require different kinds of stakeholder involvement and knowledge. Insights of multiple disciplines need to be integrated within the adaptation pathway, to stimulate the realization of plans and a sustainable future. Various stakeholders with different goals and interests play a role in the transition process of a water and food system in deltas and this influences the transition.

C. Scale-sensitive governance

Multiple articles stress the issue of scale-sensitive governance. It was shown that stakeholders at lower levels need more training to effectuate their role in the transition process, and that barriers for adaption exist at different levels. Stakeholders contribute at different levels to transition of the water and food system to make it successful.

Further research using this three step approach of identifying forward looking solutions for complex problems using water and food systems analysis, co-creating transition pathways and addressing governance in a scale-sensitive manner, can focus on each of the building blocks as well as on their interaction. The approach identified in this Special Issue, can be linked to study current processes in deltas, and possibly support such processes with insights. Interaction with stakeholders (including researchers) from various backgrounds at different scales will be an important part, and in itself a valuable object of study both at local as well as national level. This introduction article has provided an overview of the concept of food systems and its application in deltas as we understand it so far. Together with the articles in this Special Issue, we hope it will help advance the knowledge on water and food systems transitions and its governance in an integrated manner.

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## Contributor Statement

CTvS has initiated the article, CTvS, SR, NDK and JV have conducted the work for this intro article and have written the article together.

## Conflict of Interest

There is no conflict of interest.

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