Increasing resource use efficiency by scanning the right nature-based solution for the right place

1. Introduction

Critical changes in current food production and consumption practices are required to achieve the SDG2 target of a world without hunger in a sustainable way. The current practices are fraught with several challenges. In different parts of the world, some of these challenges require more urgent action than others. For example, in sub-Saharan Africa, the most critical challenge is inability to feed a growing population whereas in Europe and North-America, the inability to maintain environmental sustainability is a major challenge. Nonetheless, climate change is likely to amplify the effects of current challenges irrespective of the geographical location. Climate change is already affecting the frequency and intensity of floods, droughts and water demand in general and creating critical mismatches between supply and demand of (waste) water, adversely affecting food system's activities. Climate change, however, can also have positive effects and provide new opportunities for supporting food security.

Nature-based solutions (inspired and intrinsic) can offer sustainable solutions to replace unsustainable food production and consumption practices, enhance climate resilience and increase circularity of resources. Given that different geographical regions face different food production and consumption practices as well as climate risks, identification of best-fit and best-bet nature-based solutions are a critical step. This requires insight into a broad range of factors, including biophysical, climatic and socioeconomic factors explaining how they support nature-based solutions in delivering ecosystem services. Furthermore, nature-based solutions are often randomly implemented in isolation, without taking into account their wider ecological, socio-economic and institutional context. This undermines the ability to maximise synergies between different solutions proposed in food systems, as well as to minimise their trade-offs. Identifying the potentially promising nature-based solutions within a landscape and integrating these through smart spatial planning would therefore be an effective pathway to enhance climate resilience, more efficient (waste) water use and stronger circularity of food systems.

Therefore, this study applies a landscape-based approach to examine and act upon nature-based solutions with the aim to address the mismatch between (waste) water demand and supply. The research activities take place in two different geographical areas (i.e. the Netherlands and Ghana) where food systems face different challenges and specific climate risks. In both areas we take into account (a) opportunities and constraints that stakeholders may perceive; (b) future technological development in both cropping and waste water treatment and (c) the benefits for nature. We chose these countries because each one is a typical representation of a larger region which face typical food production and consumption practices, specific climate risks and which have resource capacity (natural/space or human) to implement a category of nature-based solutions i.e. intrinsic or inspired. In both the Netherlands and Ghana (Bono region) use will be made of a GIS based decision support system that allows stakeholders to identify best-fit and best-bet nature-based solutions for enhancing climate resilience, food security and circularity within an integrated landscape-based approach.

2. Research questions

In general terms we aim to address the following research questions:

1. What are the underpinning mechanisms of (a set of) nature-based solutions that aim to address the mismatch between (waste) water demand and supply, and how do they function?
2. To what extent do/can nature-based solutions contribute to food security, circularity and climate resilience?
3. What are the fostering and hampering factors for implementing and scaling nature based solutions within specific spatial contexts?
4. What are essential processes, data, information and (visualization) tools for supporting multi-stakeholders in a food system to jointly explore promising nature-based solutions and appropriate locations at landscape level?

3. Study areas

a) Ghana's food basket in a changing climate

The Bono East region is Ghana's food basket. Climate change has made farming in this region more difficult and risky because farmers are no longer able to predict the onset of the rainy season, and experience prolonged dry spells and erratic rainfall, making agriculture an unreliable and unprofitable investment. In the adjacent northern region rainfall patterns have changed even more dramatically, putting pressure on extensive animal husbandry. Herders are therefore moving southward, putting more pressure on the increasingly scarce resources in the Bono region. Resulting heat stress, lack of water at crucial times, and pests and diseases are further aggravated by climate change. To cope with these climate–induced challenges people tend to increase their dependence on natural resources, not only through intensifying their agricultural and animal husbandry activities, but also by increasing their use of naturally occurring trees for charcoal production, massive illegal chainsaw operations in forest reserves, and encroachment into forest reserves. Increased pressure on land is increasingly leading to conflict between stakeholders, especially farmers, pastoralists and forest dependent communities. This has consequences not only for the Bono East Region, but for the entire country and West African sub-region, which is supported by the Bono East Region food system.

Table 1. Potential nature-based solutions to be considered in Ghana and their contribution to food security, climate resilience, circularity, and economic viability.

Potential nature-based solutions	Contribution to ...			
	Food security	Climate resilience	Circularity	(Potential) Economic viability
Rainwater harvesting for irrigation (RWHI) in Ghana	RWHI has many potential benefits: i) crop production in drylands; ii) crop yield gains in areas with high rainfall variability; iii) it facilitates the cultivation of crops at a commercial scale, which also impacts the food value chain in a broader perspective.	RWHI is important for improving agricultural conditions in dryland regions. It increases the soil water content in the root zone, leading to crop yield gains. Hence, RHWI can also play important role in climate risk mitigation as it can indirectly lead an increasing carbon absorption by the vegetation and soil.	RWHI have direct and indirect effect on circularity. Firstly, it is clear that the rainwater reuse plays a direct effect on circularity. Secondly, it enables increasing crop yield rates, which leads to soil fertility and nutrient cycling in a long run.	RWHI is designed for smallholders and included in national policies, providing subsidies for its implementation. It is economically viable, as it provides increasing crop yields, to payback the investments.

Ecosystem restoration (ER)	Land degradation reduces soil and water efficiencies and thus decreases food production. This raises prices through external inputs (e.g., fertilizers) and increases food insecurity. Restoring land can help improve productivity. It can be done in multiple ways including reforestation, rangeland improvement, soil enrichment and multifunctional land use such as agro-forestry.	ER enhances the buffering capacity of ecosystems to reduce risks and damage from heat stress, droughts, floods, landslides. It is both a mitigating and an adaptation measure as it enhances carbon stocks and increases climate resilience at the same time.	Restoring ecosystems enhances nitrogen fixation, combat soil loss, promote carbon sequestration and storage. These close the nutrient loops and stimulate circularity.	Initial investment costs of restoration taper off over the years as nature is able to start working for itself. Multiple financial models for ER are currently being developed and funded through blended finance.

b) Waste water connectors in the Netherlands

Food processing industries in the Netherlands are increasingly exploring how water use per unit of produced product can be reduced in farming systems and within the factory. Some are considering whether residual water streams can be re-used within the factory or by neighboring land owners (e.g. horticulture, livestock, onshore aquaculture, cattle). Also, substances dissolved in the water can be re-used. In turn, the food industry can also use residual flows from other sectors.

In Delta regions water availability for food production comes under increasing pressure due to climate change, especially in regions where the water supply is mainly dependent on rainwater. The risk of salt and drought damage within the food supply chain increases as a result. It is true that under average climatic conditions, freshwater supply for Dutch agriculture is excellent, in contrary to our twinning case study in Ghana. A large part of Dutch agricultural areas can be supplied with water from the rivers. However, in situations with a low river discharge and a high precipitation deficit, the freshwater supply cannot meet agricultural freshwater demand during the growing season. This is particularly true for the rain-fed agricultural areas in the southwestern part of the Netherlands that have no access to river water. The flipside of the coin is that the competition for space is high in the Netherlands, making it more difficult to realize intrinsic nature-based solutions for the food processing industry that make use of constructed wetlands. The context of the two sub-cases is different, but similar criterions are used in decision making.

The reuse of waste water (residential and food processing) reduce the dependence on groundwater and surface water and can be therefore qualified as a climate adaptation option. Current waste water treatment plants (WTTPs) are large installations in which all water is collected and treated to one certain quality fit for discharge and quality for reuse is not considered yet. With regard to circularity it is interesting to explore trade-offs between, for example, water reuse and energy requirements between food industry, nature and agriculture. Also barriers and constraints in legislation and public perception (food security), which may hamper adoption of these type of technologies need to be addressed.

The following potential nature-based solutions will be considered in the Netherlands:

- Alternative water resources from (food) industry for irrigation and other purposes by using nature- based waste water treatment options. By reusing the wastewater and components present in the wastewater (raw or partially treated) for crop production, nature and industry, destruction of nutrients and other valuable components in the conventional wastewater plant and discharge of water and nutrients to rivers will be prevented. Nature-based solutions for treatment that will be considered are both intrinsic solutions such as constructed wetlands and other microbial systems (i.g. desalination using micro-algae) as well as nature-based solution that are inspired by nature on their working principles such as using solar heat and wind energy for electrical driven treatment options;
- Realize water buffers: water conservation in the soil and ground water bodies by rainwater harvesting in winter (precipitation surplus) to meet water demand in summer in both nature and agricultural areas.
- Increase water supply by reuse of waste water combined with strategies to reduce water demand in food systems by a transition from arable farming towards (salt tolerant) aquaculture. This line of thinking has been done before. The innovation in this case study is thinking in the opposite way: What are spatial explicit scenarios for the *current and future* water demand and water quality for nature, crops and industrial activities in a specified region and how does this fit to the potentials of reusing wastewater treated by nature-based solutions?

Our hypothesis is that reuse of treated waste water combined with nature-based innovations make food production less dependent on conventional water resources and offer opportunities to make both delta nature and food production more climate resilient. Opportunities for such nature-based innovations are identified and assed with the use of a spatial explicit participatory scenario approach we want to assess in the coming years.

4. Proposed approach

In order to compare nature-based solutions to the full extent, we propose to use spatial analysis and scenario modeling as a way to support spatial decisions often related to NBS and trade-offs through an inter- and transdisciplinary approach implemented in two cases, one in the global South (Ghana) and one in the global North (Netherlands). In both areas, we will use scenario assessment of the potential nature-based solutions and their potential outcomes for food security, climate resilience and circularity. These assessments are embedded within larger knowledge co-production processes in which end users of the envisaged product participate iteratively over time to allow for a truly inter- and transdisciplinary approach. The methodology has a strong focus on transdisciplinary research. The project adopts a mix of methods including literature review, participatory and action-oriented approach using mixed methods for the collection of data that supports the identification of promising nature-based solutions and how they can be sustainably incorporated within agri-food systems. Partners from the case studies in Ghana and the Netherlands will collaborate with local stakeholders, using existing knowledge and experiences of farming systems, to identify key challenges and co-develop innovations to improve their systems. We leverage momentum from already-established stakeholder engagement as we build upon the outcomes of previous projects implemented by WUR and local partners. This will ensure a swift start and secure post-project uptake by end users, to ensure sustainability of the outcomes.

5. Value addition and innovation

The value addition from this KB project lies in embedding new scientific knowledge about biophysical and socio-ecological processes underpinning the functioning of a set of nature-based solutions at landscape level, stakeholders' knowledge and interests within a participatory spatial planning process. We introduce an approach that combines deterministic impact assessment with participatory scenario building. The challenge is to enrich assessment tools with practical and scientific knowledge about water (use & supply), land use, social structures and regional economics in order to make the nature-based solution spatially explicit.

At the KB project level, the value created lies in the opportunity to integrate information stemming from (a set of) different nature-based solutions proposed, and draw comparative insights between scenarios applied within a single area or landscape. At the case study level, our work will provide an opportunity to pair stakeholder visioning, narratives and dialogue with quantitative assessment of landscape trade-offs. The outcomes allow for participatory planning for future food systems to be more climate resilient and circular, in both Ghana and the Netherlands.

6. Deliverables

This project deliverables for 2020 include:

1) Report describing and analysing underpinning mechanisms of (a set of) nature-based solutions that aim to address the mismatch between (waste) water demand and supply, and water resources use efficiency and how do they function;
2) Feasibility maps of potential nature-based solutions for enhancing food security, climate resilience and circularity in both Ghana and the Netherlands
3) GIS based participatory decision support method for identifying best-fit and best-bet nature-based solutions within an integrated landscape context
4) Capacities of end-users developed to ensure uptake and use of the outcomes, to effectively address unsustainable food production and consumption practices and arrive at enhanced food system outcomes.
5) Report that describes the societal and technological opportunities, constraints, trade-offs for layered nature-based solutions innovations in future (based on workshop and literature survey);
6) Specified regions within the Netherlands and Ghana will identified where we want to develop (20102 e.v.):

    a. Spatial explicit participatory scenario's to explore in-depth the feasibility of nature - based approaches;
    b. Elaborative research on a nature based solution for waste water treatment in the Netherland (to be selected)