Nature-based Solutions for Climate Resilient and Circular Food Systems: a narrative

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Setting the scene

Food systems encompassing food production, transportation, processing and consumption, are currently not delivering what is expected or needed to ensure their desired outcomes in terms of food security, an affordable, safe and healthy diet for all people, ecological sustainability and resilience (Figure 1). Climate change will add further stresses on food systems at multiple scales that need to respond to future trends of increasing population, changes in diet and urbanisation (Shukla et al., 2019). FAO (Food and Agricultural Organisation of the United Nations) estimates that at least 26% of the costs of damage and loss from climate related disasters, are absorbed by agricultural sectors (FAO, 2015).

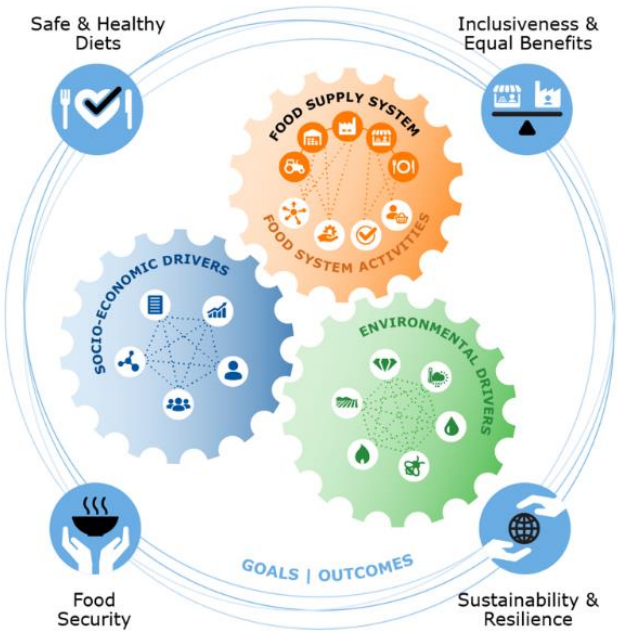


***Figure 1**: Graphical representation of the food system, its drivers and desired outcomes (van Berkum et al., 2018): Figure: van Berkum et al., 2019.*

***Picture** Terraces build up by vegetative strips over several decades in humid-tropical Ethiopia - example of intrinsic NBS at landscape scale. This NBS increases climate resilience of the food systems due to an increase in water holding capacity and reduction of runoff (S. Keesstra)*

Additional stressors on food systems are coming from some of the mitigation strategies meant to slow climate changes before irreversible impacts occur such as displacing fossil fuel energy with biomass and biofuel crops.

New pathways must be found to ensure that all people have access to affordable, sufficient and nutritious food all year round, and to ensure sustainable use of natural resources.

The unsustainable character of current food systems has triggered the call for circular food systems (De Boer et al., 2020. Circular food systems better optimize the use of scarce resources and reduce food losses. Circularity in food systems focusses on efficient use of land and closing the water, nutrient and carbon cycles to minimize resource loss and environmental degradation. Moving towards a circular food system implies searching for practices and technology that minimise the input of finite resources, encourage the use of regenerative ones, prevent the leakage of natural resources (e.g. carbon (C), nitrogen (N), phosphorus (P), water) from the food system, and stimulate the reuse and recycling of inevitable resource losses in a way that adds the highest possible value to the food system (Jurgilevich et al., 2016). To accomplish this, integrated systems are needed that make smart connections between terrestrial production cycles (plant and animal based) and marine production cycles. These integrated systems should aim at closing and strengthening production cycles and networks to replace linear chains. Circularity in food systems also implies changes in consumer behaviour and governance structures.

At the same time, there is increasing awareness that nature can be a source of inspiration in providing viable contributions to reduce the impact of anticipated negative effects of climate change (Sonneveld et al., 2018). These so-called nature-based solutions (NBS) or interventions use and deploy the properties of natural ecosystems and the services that they provide in a smart and in some cases an 'engineered' way. The term NBS is relatively new in relation to solutions to sustainability issues in the agricultural sector. Its features, however, first entered the mainstream scientific literature on agriculture in the early 2000s, for example in the form of integrated pest management and use of wetlands for wastewater treatment (Potschin et al., 2016).

What are nature-based solutions?

Different definitions for NBS are in use. We start from the definition from the EU Research and Innovation policy agenda:

"...measures that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions"

In NBS there are gradations in the use of natural processes, and the level and type of engineering applied to ecosystems, along with the number of ecosystem services delivered and the stakeholder groups involved (Cohen-Shacham et al. (2016), Somarakis et al., (2019).

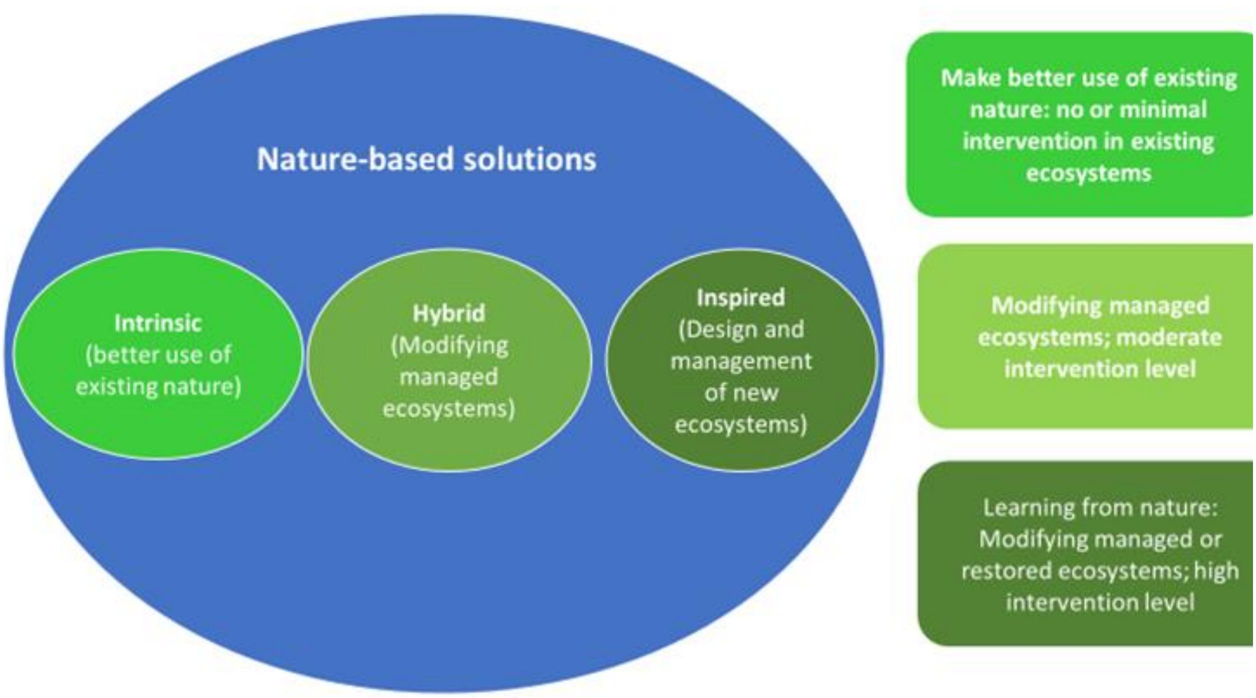


Figure 2, *Typology nature-based solutions: intrinsic, hybrid and inspired solutions.*

Intrinsic NBS make better use of existing natural or protected ecosystems. There is no or minimal intervention in ecosystems involved. Intrinsic NBS maintain or boost the effects of certain ecosystem services in already existing natural or weakly managed ecosystems. This type of NBS promotes better use of natural/protected ecosystems for the delivery of multiple ecosystem services (e.g. Measures to increase fish stocks in an intact wetland to enhance food security). Intrinsic NBS have a direct positive impact on biodiversity at local, but often at wider scale.

Hybrid NBS are based on modifying managed or restored ecosystems (e.g. re-establishing traditional agro-forestry systems based on commercial tree species to support poverty alleviation). Their impact on biodiversity may be direct or indirect at local or large scale.

Inspired NBS involve the creation of new ecosystems and/or the use of new technologies copying ecosystems to sustainably increase service provision. Their impact on biodiversity are often indirect and at local scale. Examples include the controlled use of modified micro-organisms in fermentation processes to synthesize food ingredients as flavours or exploiting genetic diversity of plants in natural pest control or the use of helophyte filters for treating wastewater. Their impact on biodiversity may be direct or indirect at local or large scale.

Adding inspired and hybrid nature-based solutions to the current discourse increases opportunities to sustainably achieve climate resilient and circular food systems

In the discourse on NBS the intrinsic type of NBS tend to prevail. The experiences developed in the project show, however, that for food systems challenged by climate change impacts, scarcity in resources (water, land, biomass) and dietary changes adding inspired and hybrid NBS to the current discourse increases opportunities to sustainably achieve climate resilient and circular food systems. NBS can be implemented at different and/or multiple scales (e.g. farm, watershed, landscape, region, food system) and require multi-level governance support. Available knowledge on potentials and limitations of NBS is fragmented or lacking.

Key questions:
- *What are potential and limitations of different types of NBS?*
- *What are potentials and limitations of scaling NBS ?*

Primary agricultural production / farm level: In practice, at the farm level examples of NBS include mixed cultivation, intercropping, novel robust cultivars, cultivar mixtures, habitat management techniques to support biodiversity, biological pest control, improvement of soil quality, anti-erosion, biological nitrogen fixation, water management and on-farm recycling of nutrients, energy and waste while avoiding contaminants as baseline for food safety.

Food supply chain system: At food supply chain level NBS may address the redirection of water and nutrient flows from the food processing industry to the rural and coastal areas and be (re-) used as input to improve soil quality and as a measure to reduce the surface water demand for food production. Wetland can be used to purify (industrial) waste water for agricultural purposed addressing drought risks cation can be using e.g. wetlands and water (re-)use in processing and the effect on water quality could be

addressed as well. Consumers can be seen as provider of raw material for food production (e.g. urban waste).

Inspired and hybrid NBS for Climate Resilient Water supply

Under average climatic conditions, freshwater supply for Dutch agriculture is excellent. 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 competition for land is high in the Netherlands. As a result it becomes more difficult to realize more intrinsic NBS solutions for the food processing industry that make use of (constructed) wetlands. A combined approach in which both constructed wetlands and other microbial systems (e.g. desalination using micro-algae) as well as NBS that are inspired by nature in their working principles such as the use of solar heat and wind energy for electrical driven treatment options can make food production less dependent on conventional water resources. Beverage companies and horticultural sector show interest in experimenting with such combination of NBS to explore potentials to make both delta nature and food production more climate resilient.

Landscape, Delta and catchment scale: Especially intrinsic NBS are often spatial in nature and benefit from a landscape (restoration) approach. Soil related solutions promote a better soil health, from which climate change resilience and mitigation is generated, which in turn ensures better food security and soil related ecosystem services. The landscape solutions are based on the concept of connectivity, in which the interventions are promoting dis-connectivity of the water and sediment fluxes in the landscape. These solutions can be small scaled (using mulch in cropping systems), medium (like grass strips, soil bunds or riparian vegetation), or large-scale like the use of wetlands to trap sediment before entering a reservoir.

For examining potential and limitations of different types of NBS at landscape and supply chain levels, we make use of QUICKScan, a participatory GIS based planning and design tool, to identify stakeholder preferences and biophysical, socio-economic potentials and limitations of NBS under different climate change scenarios (Figure 3)

Picture: rainwater harvesting at catchment scale - example of hybrid NBS at landscape scale in Ghana. This NBS increases the resilience against agricultural droughts.

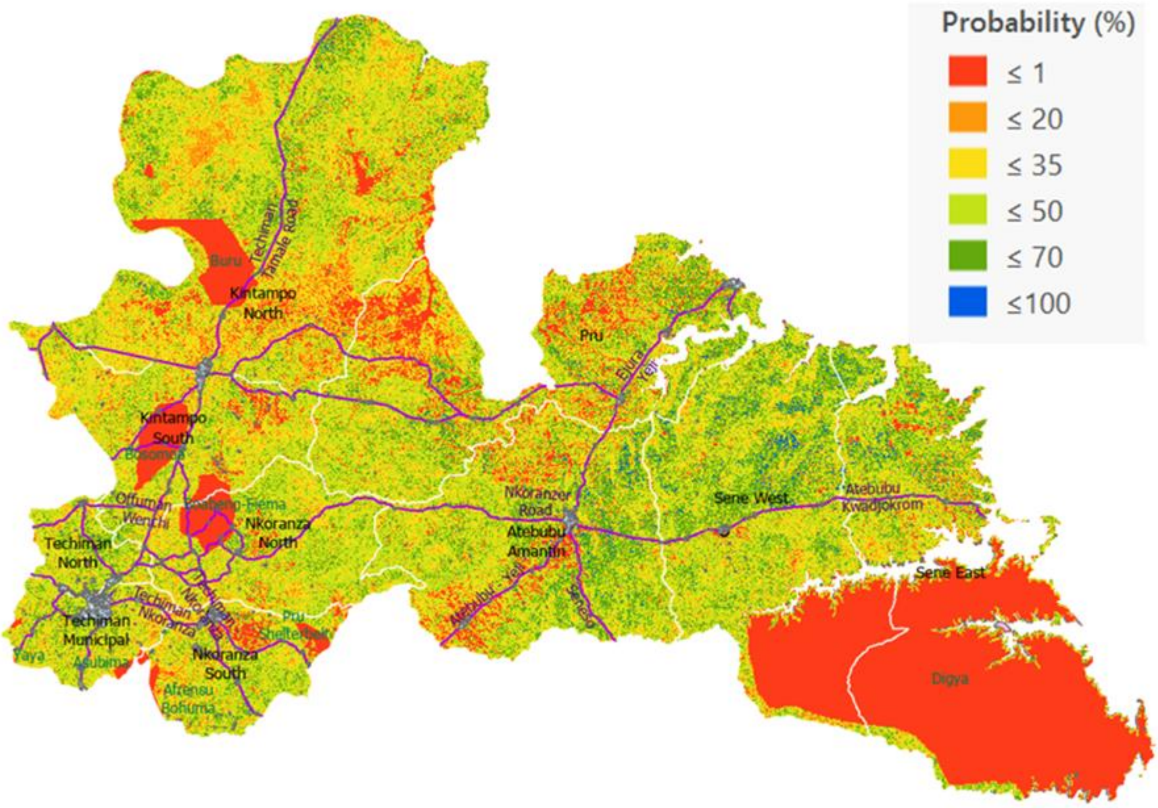


***Figure 3** shows the feasibility map which reflects the probability that an area is suitable for rain water harvesting interventions in Bono East, Ghana, which is the output of the Bayesian network modelling in QUICKScan.*

Understanding diversity as working mechanism

Currently, there is only limited understanding about the underlying mechanisms of NBS, which hinders the design and implementation of these interventions. We look at different forms of diversity: crop diversity, genetic diversity, social diversity and financial diversity supporting the implementation and contribution of NBS to address climate change impacts (droughts, floods, diseases) and circularity.

Nature-based solutions as transition pathway towards climate resilient and circular food systems

How can NBSs help to foster the transition process towards a climate resilient and circular food system?

Understanding actors and factors supporting and hindering the implementation and scaling of NBS is important to support the transition towards climate resilient and circular food systems. Consequently insights into lock ins and leverage are helpful to bring about fundamental change. For strip cropping lock ins include social-economic factors (e.g. labour availability and costs), institutional (e.g. subsidies) and technical (e.g. availability of appropriate harvesting technologies)

Picture: *Strip cropping in the Netherlands (Wijnand Sukkel) - example of hybrid NBS at farm scale. The NBS increases efficiency with light, water and nutrients, reduces pest and disease pressure, increases biodiversity and carbon sequestration and improves soil quality and reduces erosion.*

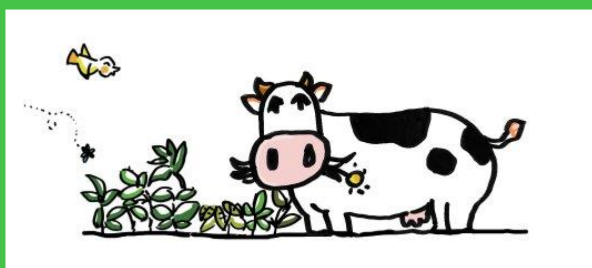
There are no business models readily available for nature-based solutions targeted at the impacts on food systems.

Enhancing biodiversity through spatial crop diversity
(literature research)

- We found contradictory results on whether crop diversity enhances biodiversity;
- Clustering of the literature on different cultivation methods that promote crop diversity at the field level provides meaningful results.

Herb-rich grassland for dairy health
(literature research)

- 46 herb species in the Netherlands with a positive contribution to dairy health have been identified;
- The majority of health herbs belong to the *Asteraceae* family. These herbs are common or very common in the Netherlands pastures.
- The active substances (bitter components, essential oils, inulin, mucilage, alkanoids, silicic acids) together with secondary metabolites (flavonoids, saponins, tannins) are compounds directly involved in improving cows' health;
- Active substances are species-specific such as the taraxine in *Taraxum officinale;*
- In rare case some herbs such as *Ranuculus* can be toxic if consumed in high doses.



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