Programming Study Multi-Year Mission-Based Innovation Programs (MMIP)

Food & Nutrition Security

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1 Introduction

The Dutch Ministries of Agriculture, Nature and Food Quality (LNV), of Infrastructure and Water Management, Ministry of Health, Welfare and Sport, together with top sectors A&F, T&U, Water & Maritime, industry, knowledge institutions and regional governments have drawn up the Knowledge & Innovation Agenda (KIA) Agriculture, Water, Food 2020 - 2023.

The agenda is framed in six Multi-year Mission-based Innovation Programs (MMIP) related to societal challenges for the theme Agriculture, Water, Food. The idea is twofold. First by investing in knowledge development and innovation, a major contribution is made to solving societal issues. Second by combining efforts of science and the private sector chance of solutions being implemented are increased. Overall, the work will by smart solutions to current and future issues in agriculture, horticulture and the water sector contribute to the quality and visibility of the knowledge economy of the Netherlands.

The Management Board Strategy, Knowledge & Innovation (SK&I) has determined that the theme of food security will also be rolled out through a MMIP approach. The topic is included in Mission D. Valued, healthy and safe food and labelled: D5 Food Security.

This study was done in 2020 and discussed in a small group in the first half of 2021.

1.1 Assignment & Approach

The overall aim of the assignment is to provide guidance and formulate recommendations to the Ministry of LNV on impact areas and actionable research that will contribute to achieving food security objectives as formulated the letter of 2019 from the Minister for Foreign Trade and Development Cooperation and the Minister of Agriculture, Nature and Food Quality to the House of Representatives[1].

The assignment comprises 4 main steps

1. Check/quick scan policy analysis food security. overview of recently completed and ongoing research on the FS
   a. Donors, research parties, description of research, main findings of completed research
   b. Research instruments and programmes
   c. Identify topic/niches
2. Recommendations for a reorientation of topics e.g. linked to recent developments
3. Recommendations of specific foci for LNV, including geographical accents.
4. Identification of opportunities to cooperate with the top sectors and the Ministry of Foreign Affairs.

For LNV sustainable development Goal 2: Zero Hunger, remains the main focus. This is also echoed in the three goals of the existing food security policy as outlined in the 2019 letter to the parliament[1].

These goals are formulated as follows:

1. Eradicate current hunger and malnutrition (SDG 2.1 and 2.2), with the aim of a Dutch contribution to a sustainably better nutritional situation for 32 million young children over the period 2016-2030.
2. Promote inclusive and sustainable growth in the agricultural sector (SDG 2.3), with the aim of a Dutch contribution to a sustainable increase in productivity and income for 8 million smallholder farmers over the period 2016-2030.

[1] AVT19/BZ128916 'Towards a world without hunger in 2030: the Dutch contribution' 2019.

3. Realize ecologically sustainable food production systems (SDG 2.4 and 2.5), with the aim to contribute to an ecologically sustainable use of 8 million hectares of agricultural land over the period 2016-2030.

At the 2021 Food summit the focus is on actions to transform the way the world produces and consumes food. In short, a transition to more sustainable food systems. To achieve this major transition the energy from science, education, business, policy, health, practitioners, youth, and consumer are combined and channelled into five action tracks[2]:

1. ***Ensure access to safe and nutritious food for all***
   will work to end hunger and all forms of malnutrition and reduce the incidence of non-communicable disease, enabling all people to be nourished and healthy.
2. ***Shift to sustainable consumption patterns***
   work to build consumer demand for sustainably produced food, strengthen local value chains, improve nutrition, and promote the reuse and recycling of food resources, especially among the most vulnerable.
3. ***Boost nature-positive production***
   will work to optimize environmental resource use in food production, processing and distribution, thereby reducing biodiversity loss, pollution, water use, soil degradation and greenhouse gas emissions.
4. ***Advance equitable livelihoods***
   will work to contribute to the elimination of poverty by promoting full and productive employment and decent work for all actors along the food value chain, reducing risks for the world's poorest, enabling entrepreneurship and addressing the inequitable access to resources and distribution of value.
5. ***Build resilience to vulnerabilities, shocks and stress***
   will work to ensure the continued functionality of sustainable food systems in areas that are prone to conflict or natural disasters.

The following outcomes are foreseen clear actions contributing to the sustainable development goals, awareness and activate actors in the food systems, develop principles to guide government and food system stakeholder and define a system of follow-up and learning[3].

The Netherlands and notably LNV is involved in the 2021 food summit and the ministry is committed to a successful outcome and follow-up. The challenges for LNV are mainly linked to actions tracks 2, 3 and 5. The three food security goals formulated by LNV fit well in ambitions of the food track. Special foci for LNV are related to circular agriculture, the role of science and innovation in the transitions.

In order to make the transition to more sustainable and circular food systems, the MMIP will focus on the integral themes of nutrition, gender, employment, innovation, climate adaptation and food losses, as well as on two specific areas: starting materials and oceans/fishing.

For the goal-oriented transition process we use the food system as analytical and communication framework. Food systems are highly complex systems which encompass all the stages to feed the population: agricultural production, harvesting, packing, processing, transforming, marketing, consuming and disposing of food[4,5]. Figure 1 gives a schematic representation of the Food System.

[2] https://www.un.org/en/food-systems-summit/action-track
[3] https://www.un.org/en/food-systems-summit/about
[4] van Berkum, S., Dengerink, J., & Ruben, R. (2018). The food systems approach: sustainable solutions for a sufficient supply of healthy food. Retrieved from https://library.wur.nl/WebQuery/wurpubs/538076
[5] FAO (2018) Food systems for healthy diets. Rome, FAOhttp://www.fao.org/3/CA2797EN/CA2797EN.pdf

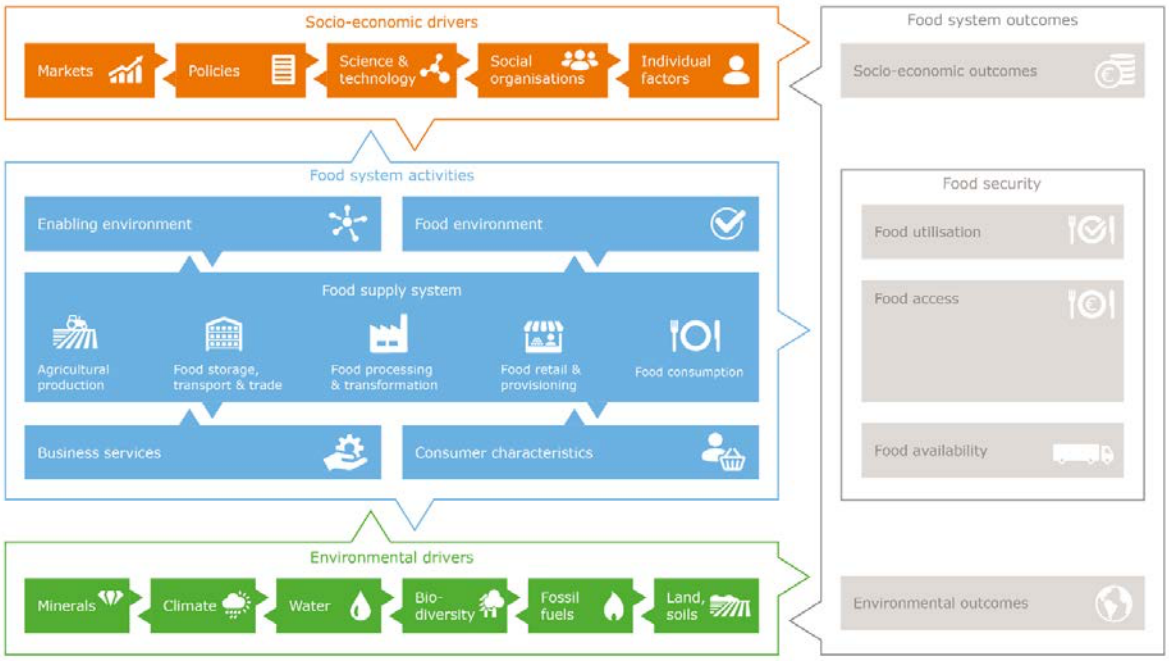

Figure 1 *The Food system*

The Food System allows the analyses of the relationships between the different parts of the system in relation to the desired or anticipated outcomes. In-line with the target-oriented SDGs a Food System Approach (FSA) starts with defining the outcomes and ambitions.

Working from these outcomes the framework offers several benefits. It provides a map for policymakers, companies, practitioners and researchers to pin the location or niche of their respective work or activities in the food system. It also provides a list of possible connected drivers and activities that are relevant to reach the outcomes, so helping to map critical intervention points.

The FSA is scalable which means that more detailed information on for example food system activities and drivers, but also specific outcomes can be defined at appropriate scales.

The FSA provides a framework showing where the main interactions and feedback between the subsystems occur[6,4]. A food system approach increases focus on outcomes and links policy domains (sustainability, health, food) to relevant socio-economic and environmental drivers, it helps in understanding relations and design transitions in how we produce, process and consume food.

In short a food system approach:
- maps out opportunities for a more efficient use of natural resources.
- highlights the important role of the food system's socio-economic context.
- shows the implications of the food system for health and malnutrition.
- helps to shed light on the trade-offs between different intervention strategies.
- sheds light on non-linear processes and feedback loops in the food system.

The food system is already used in science and policy-making at higher integration levels with a broad mandate and multiple outcomes, such as the SDGs. Furthermore, the approach provides insight through ex-post analysis by identifying critical success or fail factors. It has not yet been fully embraced by the private sector. Perhaps the clear niche or strong focus, such as for example financial services or a particular value chain or client group of private sector stakeholders with a less direct benefit of a higher-level analysis are debit to this.

[6] UNEP (2016) Food Systems and Natural Resources. A Report of the Working Group on Food Systems of the International Resource Panel. Westhoek, H, Ingram J., Van Berkum, S., Özay, L., and Hajer M.

And although the food system is scalable over spatial and system scales, via e.g. the soil, crop, landscape, farming system, value chain, processing and consumers, the approach is static. Transitions are basically two steady states, the process and development pathways i.e. the sequence of activities to shape the transitions requires more in depth work.

The MMIP process uses the concept of Technology Readiness Levels (TRLs) covering the entire innovation chain, from research (TRL 1) to implementation (TRL 12) (see Table 1). It is built on the idea that technologies rooted in research after several steps is mature enough to be implemented. Although the approach doesn't provide a concrete timeline of the path from fundamental research to implementation, it does imply that there it is a linear process, and the end station is implementation of a technology or method.

Table 1 *Technology Readiness Level (TRL)*

Research	Development	Demonstration	Implementation
TRL 1-3	TRL 4-6	TRL 7-9	TRL 10-12

The inventory and analysis were done via several on-line sessions with the Wageningen team and will be used as basis for discussion with other stakeholders, notably the ministry of Foreign affairs and the topsectoren: horticulture and starting material[7] and Agri-Food[8]. The outcome steps are presented in the following sections.

[7] https://topsectortu.nl/nl
[8] https://topsectoragrifood.nl/en/

2 Stock take, directions and emerging topics

2.1 Stock take

The landscape is mapped by first looking at the key groups that work on food systems or finance food system relevant work on the relevant TRLs. The focus of the assignment is on actionable science that connect (fundamental) research to more demonstration and implementation-oriented activities.

Table 2 *Key groups and institutes*

Technology Readiness Level (TRL)	Research phase TRL 1-3	Development phase TRL 4-6	Demonstration phase TRL 7-9	Implementation phase TRL 10-12
Examples of programs, instruments, methods	NWO, KNAW, EU, Knowledge base, strategic resources	applied research, policy support research (BO)	Experimental labs, living lab, field labs	Subsidies, investment, regulation, knowledge dissemination, networking, campaigns
Dutch (research) groups	Universities, TO2, KNMI	TO2, BPL, ISS, KNMI, Universities, ISRIC, IHE	TO2, applied universities, SNV	TO2, applied universities, SNV
International research/development	Universities	CGIAR, Agrinatura members (EU)	FAO, UNEP, UNDP	Companies, NGOs
Donors	EU	LNV, BuZa, EU, WB	RVO, companies, WB, regional banks	Companies, regional banks

Actionable science

Presenting an overview of recently finished and ongoing activities proved difficult, the information is scattered and, even the accessible datasets is not up to date. We tried to look at research from 5 years ago to ongoing research. Table 3 presents the outcome of this quickscan, linking to the three food security goals as presented in the 2019 letter to the parliament[1].

Table 3 *Quickscan*

	KB/WUR investment funds	BO	Dutch ministries/NWO/WOTRO/CGIAR	Topsectoren	EU
Eradicate current hunger and malnutrition	• Effects of transition to market orientated production on household diets. • Salt and drought in primary production.	• Water management in Northern Africa. • Dairy in East Africa.	• Applied Research Fund • Global Challenges Program • SDGP • FDOV • FDW • G4AW • A4NH • CCAFS (adaptation & mitigation) • SEEDNL, market access	• Smart technology for soybean production • Dairy in East Africa	• DeSIRA-LIFT (DEVCO), coordinated by WUR, focusing on monitoring and evaluation of DeSIRA food and climate projects, lessons learned for research, evidence for policy makers
Promote inclusive and sustainable growth in the agricultural sector	• Improving food systems in less-favoured rural areas of East Africa • Organisation of markets: producers & consumers. • Global impact and robustness of national food security plans			• Climate resilient agri sourcing in Africa	
Realize ecologically sustainable food production systems	• Waste management	• Circular systems: • aquaculture and vegetables • Manure and crops/circular	• Biodiversity International • WLE • GRA • SWFF, WE4F	• Circular agriculture	• DeSIRA-LIFT (see above)

Most of the work for BO and topsectoren targets national or regional work, complementing the other programs which also focus on the global agenda. There seems to be less attention for the social agenda in the inclusive and sustainable growth domain.

Over the last five years the main shift in systems work has been in applying the food system to work towards, or contribute to, solutions and for more fundamental and technical research working in placing innovations and technologies in the context of the food system, thereby increasing their applicability and effectiveness. In addition to the ongoing work there are several relevant programs that just started or will start soon.

The recently agreed next European R&I Framework Programme 2021-2027, Horizon Europe[9], will have a key impact on the direction of the national foci. Horizon Europe will be implemented in three pillars (Figure 2). Most relevant for this assignment is pillar 2 which includes clusters like Digital Industry and Space, Climate Energy and Mobility and Food, Bioeconomy, Natural Resources, Agriculture and Environment.

Besides theses clusters EU's five mission areas are an integral part of Horizon Europe. These missions are commitments to solve the biggest challenges facing our world, such as fighting i) cancer, ii) adapting to climate change, iii) healthy oceans, seas coastal and inland waters, iv) protecting our

[9] https://ec.europa.eu/info/horizon-europe_en

oceans, greening cities and v) ensuring soil health and food. Over 35% of Horizon Europe spending will contribute to climate objectives.

Strongly linked to Horizon Europe is the European Green Deal, one of the main initiatives of the European Commission, and a vital part of the EU's long-term plan to achieve climate neutrality by 2050. It targets all sectors including energy, biodiversity and food. The biodiversity strategy focusses on the protection of European Union's marine and terrestrial biodiversity, part of the strategy is to protect at least 30% of the land and 30% of the sea area. But also includes targets linked to the production oriented "Farm to Fork" strategy such as: reduce the use of pesticides by 50% by the year 2030, and increase the area under organic farming and increase biodiversity in agriculture.

The Farm to Fork strategy is designed to make the transition to a sustainable food system.

The targets of the "Farm to Fork" are quantified and will guide the implementation of the strategy. Targets for 2030 are a reduction of 50% in pesticide use and fertilizer use, a 50% reduction in nutrient losses, reduce the use of antimicrobials for farmed animals and in aquaculture by 50%, reduce food waste by 50%, and organic farming will need to grow to 25% of total farmland in 2030.

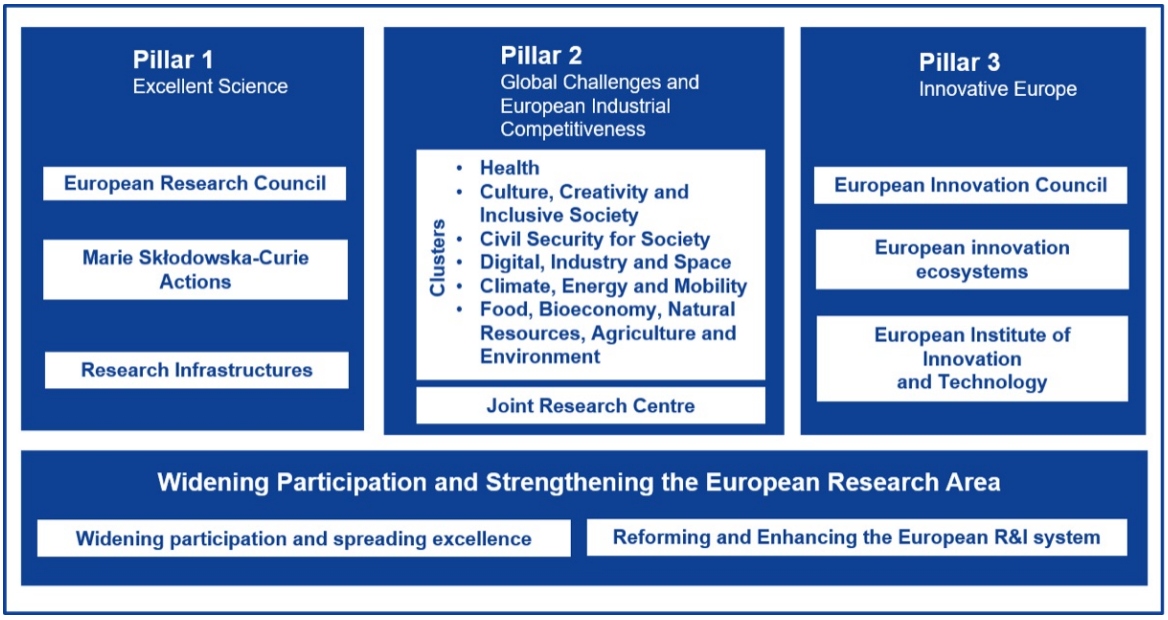

Figure 2 *Preliminary structure of Horizon Europe*

The topics are not perse new nor is the quantitative approach to the target-oriented strategies. Most of the EU targets and instruments relate to social and environmental outcomes with an obvious focus on the EU trade-zone. However, we know that agricultural commodities are traded internationally and that agriculture in many countries is also a political matter. The geopolitical impacts and the impacts on international trade are not clearly defined. If access to the EU market also means that producers need to comply not only with food safety rules but also with

The CGIAR[10], strongly linked to the ministry of Foreign Affairs, is the only worldwide research partnership addressing agricultural research for development. Since its start in 1971 the CGIAR worked via institutional lines or specialised centers and is now working on the transition to "one CGIAR". This transition is partly driven by the donor landscape but also by the reality that science for impact needs an interdisciplinary approach. The new CGIAR 2022-2030 will focus on five impact areas:

1. Nutrition, Health, and Food Security
2. Poverty Reduction, Livelihoods, and Jobs
3. Gender Equality, Youth, and Social Inclusion

[10] https://www.cgiar.org

4. Climate Adaptation and Mitigation
5. Environmental Health and Biodiversity

All impact areas will target the SDGs and focus on upscaling and accelerating progress by investing in technological and institutional innovations, partnerships, capacity development, and policy engagement.

2.2 Directions and emerging topics

In this section we will briefly touch on directions, trends and issues in society and science that will remain or become relevant for the near future and affect food security and have a bearing on the direction of future research.

2.2.1 COVID19

COVID19 had and will have a major impact on everything we do and how we do things. Existing vulnerabilities are exacerbated by the virus and new ones revealed. Elderly are disproportionally hit, people's health and livelihoods are lost. The economic and social disruption caused by the pandemic is devastating: tens of millions of people are at risk of falling into extreme poverty, while the number of undernourished people, currently estimated at nearly 690 million, could increase by up to 132 million by the end of the year[11].

The effects of COVID19 ripple through the entire food system. Trade restrictions and reduced access to markets, for both inputs and selling of produce, disrupted local and international supply chains, all affecting the entire food system. Border closures, trade restrictions and confinement measures prevent farmers from accessing markets to buy inputs and selling their products and with limited mobility agricultural, often migrant, works are left jobless and crops are not harvested reducing the availability and access to food.

The fact that almost all countries will dive into a recession, advanced countries with about 7% and developing economies with 2,5%, and per capita income will drop is perhaps the most important source of food insecurity in developing countries.

In a recent UN report[12] it is concluded that the international food markets have experienced fewer supply pressures than feared at the outset of the pandemic. The report indicates two major reasons for the weak effect of the pandemic on international food markets. First, production in the major producers of wheat, maize and soybeans, three of the four crops supplying more than 75 per cent of international food markets, are highly mechanized and an eventual negative effect of the pandemic on labour productivity is not an issue. Second, in developing countries in which agriculture is highly labour-intensive, the pandemic has been mostly prevalent in urban centres, leaving the farming sector less affected. This could change depending on the extent to which the virus spreads to rural areas.

The pandemic will extinguish at different speeds in different regions and countries, depending on how hard countries are hit by the virus and access to the vaccine. To work on food security, it seems imperative that livelihoods via restoration of jobs and income are prioritised. Some of these jobs could be related to the food systems and will require fair and equitable opportunities for all actors. But poverty alleviation will require a nation-wide economic uplift, not limited to the food system alone.

[11] https://www.who.int/news/item/13-10-2020-impact-of-covid-19-on-people%27s-livelihoods-their-health-and-our-food-systems

[12] UNCTAD,(2020) Impact of the COVID-19 pandemic on trade and development: transitioning to a new normal (UNCTAD/OSG/2020/1

2.2.2 Health

"Tell me what you eat and I will tell you what you are"[13], or, the more common, "you are what you eat" are proverbs connecting the food that we consume to our physical and mental health. Yet it has only been recent that the nutritional value of food is firm on the research agenda. Studies on food security have shifted from focussing on the availability of and access to food at different levels, often related to population increase, to include healthy diets. Low-quality diets pose health risks leading to malnutrition either by undernourishment or overnutrition. The latter often linked to obesity.

Malnutrition key facts[14]: 1.9 billion adults are overweight or obese, while 462 million are underweight. 47 million children under 5 years of age are wasted, 14.3 million are severely wasted and 144 million are stunted, while 38.3 million are overweight or obese. Around 45% of deaths among children under 5 years of age are linked to undernutrition. These mostly occur in low- and middle-income countries. At the same time, in these same countries, rates of childhood overweight and obesity are rising.

To acknowledge the importance of nutrition the definition of food security was changed in 2012[15] and now refers to "Food and nutrition security" and reads as follows: "Food and nutrition security is achieved when. adequate food (quantity, quality, safety, socio-cultural acceptability) is available and accessible for. and satisfactorily used and utilized by all individuals at all times to live a healthy and active life."

The move away from caloric intake and the increasing demand by a growing population and towards nutritious diets and the needs of the individual and groups, in an ageing and urbanising world, was instrumental to refocus research and work on nutritious diets for consumers. It also called attention, via the food system, to the impacts of dietary choices to impact on the planet. COVID19 also made people to rethink the health and food relation and the how food is sourced and gave urban farming an impulse.

2.2.3 Climate change

We are now 5 years after the Paris agreement[16], an international treaty on climate change with the key goals of holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change; and increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production.

Energy and food are central to the agreement. Fossil fuel is the key source of CO_2 emissions, a key greenhouse gas and drivers of global warming. Agriculture and the food system not only emit greenhouse gases, notably N_2O and CH_4 but also are impacted by climate. Both require actions in the food system. Reducing greenhouse gas emissions and adapting to climate change and building resilience to climate shocks are the key challenges related to climate change.

The climate convention has focussed on keeping atmospheric greenhouse gas concentrations within acceptable boundaries from the onset in 1992. Efforts on mitigation strategies in energy and land use, including agriculture, were always part of the solution. Over the last decades, sustainability has become part of business strategies. It is now used to improve processes, create value and in competition between products and companies. Greenhouse gas emissions emerged and to become a key indicator in defining sustainability. This is also echoed by the notion that consumer behavioural and dietary choices can help in contributing to greenhouse gas emissions.

[13] Brillat-Savarin (1825) La Physiologie du goût ("Dis-moi ce que tu manges, je te dirai ce que tu es".)
[14] https://www.who.int/news-room/fact-sheets/detail/malnutrition
[15] COMMITTEE ON WORLD FOOD SECURITY (2012) Thirty-ninth Session Rome, Italy, 15-20 October 2012. http://www.fao.org/3/MD776E/MD776E.pdf
[16] https://unfccc.int/sites/default/files/english_paris_agreement.pdf

Food production is responsible for about 25% of the total greenhouse gas emissions. Of this 31% percent is linked to livestock and fisheries (about 30% to livestock), 27% to cropland, 24% to land use change, and about 18% is related to the supply chain (processing, transport and retail)[17].

It is mainly primary production that drives the greenhouse gas emissions from agriculture via fertilisation (N_20) and livestock (CH_4). Agriculture is also an important driver in land use change and responsible for about 24% of food system related CO_2 emissions[17].

Reducing emissions or mitigation is strongly linked to efficient use of natural resources (soil and land) and inputs (agro-chemicals) for the primary production process in animal husbandry and crop land management. The Global Research Alliance on Agricultural Greenhouse Gases[18] has been working for almost a decade to find ways to grow more food without growing greenhouse gas emissions. And although progress is made in research, e.g. via increased efficiency of inputs and circularity. However, it remains a key challenge in agriculture to reduce greenhouse gas emissions in practice.

Besides being a driver of climate change the food system, notably primary production, is also a victim of climate change. Because agriculture is a climate sensitive sector which is important for the livelihoods of a many rural poor and is key to the stability of countries and economies, food production is specifically mentioned in the Paris agreement. Countries are requested to report, via the Nationally Determined Contributions, on progress on the key objectives: to increase the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development. Whereas at the global level the emissions reduction goals are linked to the 2-degree target, for adaptation there is no equivalent target. The absence of clear adaptation targets has hampered large scale coordinated actions. Targets need to be specified for the individual countries, regions, systems, sectors or communities. This is also why the national adaptation plan (NAP) process includes links to initiatives and start from the diversity and exchange of ideas and solutions to move forward.

For the food systems adaptation connects to responding to direct and indirect climate impacts such as increased temperature, variability in water supply, storms, sea level rise, hail and other events including changes in pest and diseases, on primary production, transport, and processing. Climate change in this context is a development issue with the potential to directly affect the efficiencies in investments in the food system.

In many countries the first focus is on maintaining production systems and less on possible transitions needed to be able to support production functions in the medium and long term.

Although the reality of climate change is not under dispute and directions of change and order of magnitude are becoming clearer the actual changes are hard to foresee response strategies will have to deal with variability, uncertainty and surprises.

Understanding resilience in food systems can help in designing for resilience to environmental shocks and create safe fail or fail safe (sub)systems. More specifically for the food system to deliver the desired outcomes functions and relations need to be designed in such a way that economic, environmental and social shocks can be absorbed or cause limited damage. It is therefore more prudent to describe the resilience of food systems as "the capacity of [the food system] to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks" [19].

2.2.4 Biodiversity and natural resources

Our economies and societies, from subsistence to industrialised, depend on the natural, terrestrial and marine, resource base, which we share with other species. This fact has however not yet resulted in a

[17] https://ourworldindata.org/food-ghg-emissions
[18] https://globalresearchalliance.org/
[19] Voorn, G. Van, Hengeveld, G., & Verhagen, J. (2020). An agent based model representation to assess resilience and efficiency of food supply chains, 1–27. https://doi.org/10.1371/journal.pone.0242323

shift of our relationship with the planet. Agriculture is man's most intimate relationship with the earth, and it is also clear that agriculture is and is projected to be the largest contributor of biodiversity loss[20].

Habitat destruction and fragmentation have been the largest impacts on biodiversity, but also the impacts of agricultural activities resulting in physical, chemical and biological degradation contributed to the decline of biodiversity and undermining the natural resource base. And although agriculture also contributes to biodiversity via crops and animal species, the trend in agriculture has been to replace traditional crop varieties with high-yielding varieties. Which in turn has taken part of the pressure away from land conversion from agriculture.

The debate of land sparing or land sharing has been ongoing for decades it started with a discussion on coexistence and land claims between agriculture and biodiversity. So far, the hypothesis that increased yield levels result in lower claims by agriculture on land are not supported by evidence also given the latest reports[20,21].

The discussion is moving to environmental services and planetary boundaries linking to sustainable consumption and production[22]. The concept of planetary boundaries connects to systems thinking as used in the food system, it also shows how production and consumption are responsible for changes in environmental quality and allows for target-oriented actions and monitoring as shown in the European environment state and outlook 2020[23].

2.2.5 Science

Progress in production-oriented agriculture is strongly rooted in science and supported by policy, which has led to an increase in yields and efficiency in production methods[24]. Over the decades, concerns and priorities have changed and environmental and social problems in particular have moved up the agenda. The link between policy and science remained important; in industrialised economies, the importance of the private sector in the food system increased. This is most striking in the way we conceptualise the food system. The shift from producers to consumers is an important and logical step. It also determines the way in which the food system is used in low and middle-income countries, where a guiding and co-decisive role of the consumer in decisions is often less clear. The role of society and, more specifically, the role of citizens in discussions and actions focused on the shape and direction in which food systems evolve is beginning to take shape more recently. Where the consumer has an inactive receiving role in the food system, the citizen is an active agent who can bring about change.

Understanding personal changes and "nudging" people to do the "right thing" is part of the solution for the health and climate change challenges we face. This part of science is unfortunately not well developed in agricultural or food system research.

Calls for radical change or transition in the food system to address the societal challenges such as health, climate change, biodiversity loss, requires changes in for example governance, ways we do research and how we behave. The main quest is to achieve the complex transitions to a sustainable, affordable, trustworthy and high-quality food system that will fulfil the needs of a diverse and growing world population. We simply depend on food and the environment in which we live and grow food. And

[20] IPBES (2019): Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. S. Díaz, J. Settele, E. S. Brondízio E.S., H. T. Ngo, M. Guèze, J. Agard, A. Arneth, P. Balvanera, K. A. Brauman, S. H. M. Butchart, K. M. A. Chan, L. A. Garibaldi, K. Ichii, J. Liu, S. M. Subramanian, G. F. Midgley, P. Miloslavich, Z. Molnár, D. Obura, A. Pfaff, S. Polasky, A. Purvis, J. Razzaque, B. Reyers, R. Roy Chowdhury, Y. J. Shin, I. J. Visseren-Hamakers, K. J. Willis, and C. N. Zayas (eds.). IPBES secretariat, Bonn, Germany. 56 pages. https://doi.org/10.5281/zenodo.3553579

[21] Williams, D. R., Clark, M., Buchanan, G. M., Ficetola, G. F., Rondinini, C., & Tilman, D. (2020). Proactive conservation to prevent habitat losses to agricultural expansion. Nature Sustainability, 1–9. https://doi.org/10.1038/s41893-020-00656-5

[22] Campbell, B. M., D. J. Beare, E. M. Bennett, J. M. Hall-Spencer, J. S. I. Ingram, F. Jaramillo, R. Ortiz, N. Ramankutty, J. A. Sayer, and D. Shindell. 2017. Agriculture production as a major driver of the Earth system exceeding planetary boundaries. Ecology and Society 22(4):8.

[23] The European environment state and outlook 2020. Knowledge for transition to a sustainable Europe

[24] Ewert, F., Rounsevell, M., Reginster, I., & Metzger, M. (2005). Future scenarios of European agricultural land use I. Estimating changes in crop productivity. Agriculture, Ecosystems and Environment, 107. Retrieved from http://linkinghub.elsevier.com/retrieve/pii/S0167880904003627

although there are gaps in our knowledge most people agree that interventions and actions should be evidence based, and this evidence should be collected via transparent and reliable, controlled, rigorous, systematic, valid and verifiable, empirical and critical research.

Acknowledging the above-mentioned key societal challenges and confirming the complexity of the food system and the need for a multi-disciplinary approach in order to achieve workable solutions Wageningen in 2017[25], provided an overview of eight developments in modern science that are particularly relevant to the transition agenda:

- Smart animal and plant breeding (optimising genetic pools; innovations in breeding techniques; enhancing photosynthetic efficiency)
- Next-level agriculture (use of certain key enabling technologies in primary food production, respecting and making better use of biodiversity and natural resources (e.g. soil) for improved growth and resilience)
- Blue growth (making better use of freshwater and marine resources)
- Protein transitions (a more sustainable production of animal proteins or their replacement with proteins from plants and other sources)
- Innovations in post-harvest food production and processing (un-refining food ingredients, return to basic molecules, full utilisation of harvested biomass for feed and food)
- Digital societies (utilising the information available in the Internet-of-Things era)
- Food practice (consumer empowerment, dissemination of information, choices about, and interaction with, food, social innovation)
- Public and global one health and wellbeing (food safety and personalised nutrition and health, including attention for zoonotic diseases, food safety and mycotoxins)

These research fields are also connected through an interdisciplinary systems approach.

2.2.6 Geopolitics

Food and energy are commodities which are essential in the stability and functioning of societies. The energy transition has a clear target and is moving away, be it slow, from the use of fossil fuel towards environmentally friendly produced energy. Progress in defining a common direction and transition in agriculture has been slow and less coordinated. Many see opportunities to reshape the food system and advocate a major transition towards sustainable ways of food production and consumption. The complexity of the food system, with its many actors and different interests are not helping in setting clear common targets.

In high income countries the importance of the agricultural sector in economic and social terms is relatively low, in political terms it however remains relevant, as for example is seen in the importance of the common agricultural policy in the EU. In low- and middle-income countries large parts of the population still depend on the food system for their livelihood[26], making investments in agriculture also part of poverty reductions efforts. With a diverse set of starting points and targets perhaps the focus of research should be on understanding the different development pathways and consequences on countries and international relations rather than finding global targets.

International trade in agricultural commodities connects different political systems, ranging from state-controlled to market-based. The relations are formalised in international treaties via the WTO, and via bi-lateral trade agreements between governments or blocs. In recent years the idea to use trade policies to achieve compliance with environmental goals is gaining momentum[27], for example by linking the Paris Agreement to the negotiated European Union (EU)-Mercosur Trade Agreement. None trade related concerns of food safety; environmental and social standards are already in place for imported products to the EU.

[25] Kampers, F. W. H., & Fresco, L. O. (2017). Food transitions 2030: How to achieve the transitions to a sustainable, affordable, trustworthy and high-quality food system in the next decade or two that will fulfil the needs of a diverse and growing world population. Wageningen University & Research. https://edepot.wur.nl/423601

[26] Swinnen, J. F. M. (2010). The political economy of agricultural and food policies: Recent contributions, new insights, and areas for further research. Applied Economic Perspectives and Policy, 32(1), 33–58. https://doi.org/10.1093/aepp/ppp012

[27] Pascal Lamy et al., "Time to Green Eu Trade Policy: But How?," (Paris: Jacques Delors Institut, 2019).

Greening trade policies also will impact the geopolitical setting. Integrated assessments and scenario studies linking production, consumption and trade flows to economic and environmental impacts are useful tools to evaluate strategies and policies, most of these relate to technical issues of production increase or political aspects related to subsidies but have yet to include links to the geopolitical context.

The 1992 UN Rio conference on environment and development, or Earth Summit, saw two key conventions the United Nations Framework Convention on Climate Change (UNFCCC), and the Convention on Biological Diversity (UNCBD). The Intergovernmental Panel on Climate Change (IPCC), founded in 1988, provides the scientific input to the UNFCCC process. This science-policy combination has proven successful in defining and shaping climate policies and actions. In 2010, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) was established, which is formally linked to the UNCBD but has a boarder mandate than the IPCC[28]. Both science platforms provide information, via assessments, to larger stakeholder groups. Science has been instrumental in decision making in relation to climate change, both governments and private sector are on board and formulate and take actions to combat and respond to climate change. For biodiversity the process is ongoing but also here the scientific underpinning of a complex topic helps in communicating science to policy makers and other stakeholders, an essential basis for action.

Both IPCC and IPBES have their own niche but are also strongly linked; one of the apparent links is agriculture or the food system. Initiatives related to the Food Summit of 2021 are working on an intergovernmental panel for agriculture and food to provide assessments on the science-related to food systems. Coordination with both IPCC and IPBES is needed. However, the importance of agriculture in defining the future of the planet and its inhabitants justifies a scientific assessment on agriculture and food aiming at global and local decision-makers.

[28] Brooks, T. M., Lamoreux, J. F., & Soberón, J. (2014). IPBES ≠ IPCC. Trends in Ecology and Evolution, 29(10), 543–545. https://doi.org/10.1016/j.tree.2014.08.004

3 Recommended Impact areas

We start with Sustainable Development Goals and notably SDG 2 Zero Hunger, the stocktake and combined this with the three original goals:

1. Eradicate current hunger and malnutrition
2. Promote inclusive and sustainable growth in the agricultural sector
3. Realize ecologically sustainable food production systems

From the stock take three topics stood out that will be on the agenda for the coming years and therefore should be visible at the impact level: i) climate change, ii) biodiversity and iii) resilience. Based on this the group defined impacts areas and action tracks. Impact areas are high-level domains related to policy goals and societal challenges or concerns.

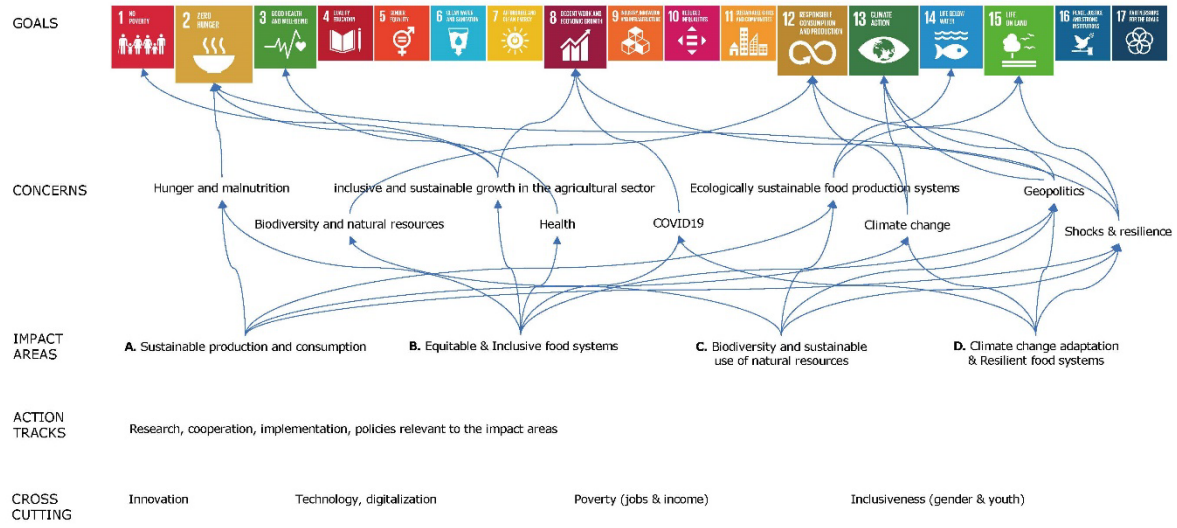

Figure 3 *Overview of the relations between the elements in the study. Size of the goals is an indication of importance of the SDG to the proposed impact areas*

Besides the impact areas there are issues that are cross-cutting and should be addressed by all Action Tracks and activities, when appropriate. The cross-cutting issues can also be used to define or evaluate projects. Following the impact areas, the action tracks are the sub-programs in which individual projects or activities can be defined and where impact is created, this can be done for example via research, trade agreements, public private cooperation

The proposed impact areas and action tracks are presented in Table 4.

Table 4 *Proposed Impact Areas and Actions Tracks*

IMPACT AREAS	A.	Sustainable production and consumption	B.	Equitable & Inclusive food systems	C.	Biodiversity and sustainable use of natural resources	D.	Climate change adaptation & Resilient food systems
Action Tracks	A.1	Sustainably increase food production.	B.1	Enhancing incentives for actors in the food system.	C.1	Respecting planetary boundaries (soil, water, biodiversity).	D.1	Adaptation of the food system to slow onset change related to actual or expected climatic change, including climate variability.
	A.2	Reducing and preventing food losses & waste	B.2	Identify services needs for different target group: ranging from subsistence to commercial farmers, youth, consumers, traders, governments.	C.2	Promote nature inclusive agriculture and agroecology	D.2	Designing for resilience in society combining social, economic and environmental systems
	A.3	Increasing availability of healthy and safe food	B.3	Design new value chains for affordable supply of nutritious food.	C.3	Soil Health/Quality	D.3	Strengthen resilience of the food system to fast onset shocks (economic, climate, weather extremes, diseases / pests, conflict and political crises)

The link of climate change to impact area A relates to the mitigation component i.e. reducing greenhouse gas emissions or emission intensity, whereas in impact area D this relation is defined by climate change adaptation (see Figure 3). Adaptation and resilience are combined in impact area D with the key focus of resilience is on fast onset shocks and to design or deal with these, while climate change adaptation has a stronger focus on slow onset change, such as sea level rise, or gradual changes in precipitation patterns and variability. Clearly some climate shocks are fast and can be addressed under resilience, but resilience is not limited to climate related shocks but also include economic, market and social crises. Action track Soil Health/Quality (C3) is introduced because of the importance of soil as natural resource base, as is also acknowledge in Horizon Europe.

In the section below, the action tracks for each impact area are presented, this overview was worked out by the project team via online sessions. Please note that both the impact areas and the action tracks are still open for discussion. In order to keep the overview manageable and comprehensible, a maximum of three action tracks per impact area was set. By using the Impact Areas and Action Tracks we should be able capture all TRLs and address key areas.

3.1 Impact Area A: Sustainable production & consumption

This impact area is perhaps the most conventional and focusses on the increasing demand for food with a growing, urbanising and ageing societies and the environmental impacts. Sustainable production within planetary boundaries remains a crucial goal. Note that climate change mitigation is part of the sustainably increase food production action track. Waste management, including avoiding and reuse of waste remains important for circularity in food systems. With a growing and urbanising population and demand for nutritional, high quality and safe food will only increase in importance in the diet, in this impact area the role of food in public health will also be considered.

	Action tracks	Research phase TRL 1-3	Development phase TRL 4-6	Demonstration phase TRL 7-9	Implementation phase
A.1	Sustainably increase food production.	• Breeding for production increase: improve photosynthesis (e.g. C3 –>C4). • Pest and disease control via breeding & agroecology. • mitigation efforts in primary production.	• Develop methods and tools to guide transition pathways aiming at both environmental and production goals. • Contribute to climate. change mitigation: fossil free.	• Demonstration of e.g. new seeds, tillage methods, fertilizer application and education.	
A.2	Reducing and preventing food losses & waste	• Breeding for shelf live. • Improve protein handling and protein storage (room temperature stable protein)	• Reduce post-harvest losses • Reuse of waste in the food system • Improved storage methods • Identify effective entry points for policies and actions to reduce food losses.		
A.3	Increasing availability of healthy and safe food	• Understanding human behaviours & choices	• Increase availability of healthy & safe fruit & vegetables • Linking consumers to producers • Development of strategies to increase consumption of (more) healthy foods.	• demonstrate safe production, processing methods • Hygiene/ food preparation demonstration	

3.2 Impact Area B: Equitable & Inclusive food systems

A food system is equitable and inclusive when also the most vulnerable can participate and benefit from the activities in the food system. This includes all active in starting from producers and ending with consumers. This impacts area mainly connects to the organisation, service provision and the roles of consumers, governments and private sector in organising and sharing responsibilities and benefits.

	Action tracks	Research phase TRL 1-3	Development phase TRL 4-6	Demonstration phase TRL 7-9	Implementation phase
B.1	Enhancing incentives for actors in the food system.	• Assessment of methods, mechanisms, tools and policies aiming at knowledge and innovation system development • Barriers and drivers for development of innovations (technical, social) and for making these innovations available	• Design strategies and transition processes to lift institutional and legal barriers to implement, technical, and social innovations. • Design strategies to overcome trade-offs between fair price for producers and affordability for consumers. • Improve local / regional processing, packaging, transportation. • Redesign international trade and business models (given circular agri in EU/ NL)		
B.2	Identify services needs for different target group: ranging from subsistence to commercial farmers, youth, consumers, traders, governments.		• Identify services needs for different target groups (framers, consumers, governments) • Identify barriers in availability and accessibility of services		
B.3	Design new value chains for affordable supply of nutritious food.		• Designing new value chains, • linking urban and rural areas,		

3.3 Impact Area C: Biodiversity & sustainable use of natural resources

Agriculture adds to biodiversity, but this role is overshadowed by the impact of agriculture in the decline of biodiversity via habitat destruction, defragmentation and degradation of the natural source base via the misuse of agro-chemicals. Changes in society, consumption preferences and patterns are reflected in agricultural land use and practices. The aims and priorities of what the food system needs to deliver will vary per country, economy and culture. Some might focus on the volume and price of food while others focus on food quality the environmental impacts. In all cases, the impact of the food system on biodiversity and natural resources must be positive or neutral. This impact area is aimed at finding solutions to achieve this.

	Action tracks	Research phase TRL 1-3	Development phase TRL 4-6	Demonstration phase TRL 7-9	Implementation phase
C.1	Respecting planetary boundaries (soil, water, biodiversity).	• Development of improved life cycle analyses methods to add value for farm management decisions and policy−making. • Map the impact of global and national trade policies on natural capital (soil, water, biodiversity) and food security • Linking food demands to production and planetary boundaries.	• Apply circularity at farm and value chains to reduce GHG emissions, nitrogen loads and biodiversity impacts. • Design trade policies to promote global and national material flows to become circular.		
C.2	Promote nature inclusive agriculture and agroecology	• Nature based solutions • Develop methods and tools for the assessment and evaluation of nature inclusive agricultural practices and technologies	• Evaluation of effectiveness of nature inclusive agricultural on biodiversity and production.		
C.3	Soil Health/Quality	• Understanding the role of soil in service provision (nutrient, biodiversity, crop production,..)	• Soil policies to target UNCCD, UNCBD and UNFCCC goals		

3.4 Impact Area D: Climate change adaptation & Resilient food systems

Coined as the greatest threat to the planet climate change is high on the societal, political and business agendas. Most attention is towards the 1,5 – 2 degrees goal as formulated in the Paris agreement and the energy transition needed to move away from fossil fuel and improved land use (see also Impact Area A).

The evidence so far is not encouraging as mitigation efforts are failing, heat records are broken, and the Paris commitments are insufficient to stay below the agreed 2 degrees. We are heading for a > 3-degree world. Adapting to climate change is already necessary in a < 2-degree world, but we are entering unknown territory with a > 3-degree world. Unfortunately, temperature are changes are faster than previously anticipated and is already impacting human and natural systems. The food systems and particular primary production are climate sensitive making climate change is a development issue and short- and medium-term adaptation are a key priority.

Designing resilient systems is a specific way of adapting. The starting point is that surprises and shocks will not go away, and specific designs can absorb these shocks or lead to less damage. Examples of shocks that may impact the functioning of the food systems are economic or price shocks, environmental including climate shocks and social shocks or conflicts.

	Action tracks	Research phase TRL 1-3	Development phase TRL 4-6	Demonstration phase TRL 7-9	Implementation phase
D.1	Adaptation of the food system to slow onset change related to actual or expected climatic change, including climate variability.	• Understanding and breeding for salt and drought stress	• Coping with salt water and drought via crop and water management	• Field and on farm trials	
D.2	Designing for resilience in society combining social, economic and environmental systems	• Design for resilience in natural and human systems. • Understand FS interactions and trade offs for short-term long term resilience/ rural-urban demands/ diversifying and specialising functions/ self-sufficiency and import dependency/ intensified versus sustainable and regenerative use of natural resources • Leverage point to increase Food System resilience.	• Coping with climate, weather extremes, diseases / pests, and economic shocks		
D.3	Strengthen resilience of the food system to fast onset shocks (economic, climate, weather extremes, diseases / pests, conflict and political crises)	• Understanding resilience in natural and human systems. • International governance and powers, Understanding options for interventions.	• How to build in disaster preparedness in food systems for urban areas (link with WFP) • Strengthen resilience of the food system to economic, conflict and political crises.		

4 Recommendations for LNV

The main focus of the work is the policy support for LNV and more specifically, the work of the agricultural councillors. By working with impact areas and action tracks, we chose to remain in line with the goal-oriented approaches used in policy making.

In this assignment, the entry was provided by the policy goals and key challenges. The food system is not yet used as an overarching tool to formulate policy goals, guide questions and target resources to work on food and nutrition security. Also connecting to the MMIP process and TRLs is not worked out yet. The food system is mainly used in science, it is not yet mature enough to guide policy making or connect to decision-makers in the private sector. It is only recently introduced in the ministry of LNV, and it will take more effort to work out the practical use and added value of the food system approach in non-scientific communities. This is a line of work that needs to continue and should connect to the private sector.

The design of the MMIPS is linear flowing from low to high TRLs and seems to lack a line flowing back from the work at higher TRLs back to research, without this feedback loop it will be difficult to learn from activities in the field.

All four Impact Areas are relevant for LNV. In Table 5, the most appropriate action tracks for policy support are shaded grey. The main action tracks are those where the socio-economic component is less central, or the integration level is appropriate for national policy-makers and for agricultural councillors.

Table 5 *Relevant actions tracks for LNV (grey tone indicates importance)*

IMPACT AREAS	A.	Sustainable production and consumption	B.	Equitable & Inclusive food systems	C.	Biodiversity and sustainable use of natural resources	D.	Climate change adaptation & Resilient food systems
Action Tracks	A.1	Sustainably increase food production.	B.1	Enhancing incentives for actors in the food system.	C.1	Respecting planetary boundaries (soil, water, biodiversity). With special attention to circular agriculture	D.1	Adaptation of the food system to slow onset change related to actual or expected climatic change, including climate variability.
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When international negotiations linked to treaties (e.g. UNCBD, UNFCCC), trade agreements or possible follow-up of the Food summit in 2021 are included in the portfolio the action tracks A.1, B.1, C.1, C.1 and all tracks in D are perhaps more relevant (see Table 6).

Table 6 *Relevant actions tracks for international negotiations related to UNCBD, UNFCCC. (grey tone indicates importance)*

IMPACT AREAS	A.	Sustainable production and consumption	B.	Equitable & Inclusive food systems	C.	Biodiversity and sustainable use of natural resources	D.	Climate change adaptation & Resilient food systems
Action Tracks	A.1	Sustainably increase food production.	B.1	Enhancing incentives for actors in the food system.	C.1	Respecting planetary boundaries (soil, water, biodiversity). With special attention to circular agriculture	D.1	Adaptation of the food system to slow onset change related to actual or expected climatic change, including climate variability.
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	A.3	Increasing availability of healthy and safe food	B.3	Design new value chains for affordable supply of nutritious food.	C.3	Soil Health/Quality	D.3	Strengthen resilience of the food system to fast onset shocks (economic, climate, weather extremes, diseases / pests, conflict and political crises)

With the limited resources, it is important to work out topics in actions tracks that allow for a broader, perhaps national, approach linking not only other ministries but also the private sector. Opportunities in technology and precision agriculture, adaptation to saline conditions, or financial resilience are examples of options that allow for combining countries and working on topics that the Netherlands is strong at. Another strategy could be to connect to other donors and countries to explore areas in which the Netherlands wants to learn, for example on nature inclusive agriculture.

In the following sections we will go into more detail in three examples, two related to action tracks and one related to a cross cutting issue.

4.1 Promote nature inclusive agriculture and agroecology

The upcoming United Nations Food Systems Summit 2021 will address this threat. The action track 'Boost Nature Positive Production at sufficient scale' calls the global community of policy makers to transform the current "net-nature-negative" into "nature positive" situations at the global scale, by developing and applying effective and efficient incentives. Nature positive food production keeps soils healthy, water flowing, helps store carbon and provides homes for a range of biodiversity, both above and below the ground. Food can be produced in way that works with nature, not against it. The impact of a nature-positive food system on biodiversity and natural resources must be positive or at least neutral.

4.1.1 Knowledge and innovation challenges

The concept of using natural processes to design more biodiversity friendly food systems is gaining momentum. The underlying assumption is that nature-inclusive agriculture brings more diverse, nature, natural features and processes and at the same time is able to deliver food and other products to provide a fair income to the farmer. However underlying science on what works why and where is not yet fully understood. The focus of this item is related to the incentives needed to make this work in low- and middle-income countries.

Relevant research questions are:

- What are appropriate incentives to change the mind set of farmers', consultants, scientists and other actors in the Food system towards a nature-positive food systems considering the time delay between the implementation of nature positive practices and the resulting benefits (actors in the food system are used to fast acting techniques such as fertilizers and pesticides)
- What are factors enabling and hindering nature positive food production at farm level
- What are factor (technical, institutional, financial, social) are enabling and hindering nature positive food systems at multiple scales (farmer's field, landscape, national).
- What are enabling factors and lock ins impeding the transformation towards a nature - positive knowledge and information system for food systems (education, advisory services, research)
- What are profitable business models for nature positive food production
- What are trade-offs of nature positive food systems (between food systems outcomes
- What are appropriate criteria for designing nature positive farm types
- What are appropriate indicators to assess the (short and long term) effects of nature positive food systems at multiple scales (what indicators to be used)
- What are cost effective measures / interventions that support the transformation towards nature positive food systems (e.g. via supporting biological pest control, carbon sequestration, collaboration between farm (types), financial incentives)
- How to scale these cost-effective measures / interventions that support the transformation towards nature positive food systems (what are effective scaling mechanisms)

4.1.2 Potential partners

The 'Transforming Agricultural Innovation for People, Nature and Climate' campaign is part of the UK's *Nature* campaign for COP26—is co-led by the UK Foreign, Commonwealth & Development Office of the UK Government (FCDO) and the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

4.2 Climate change adaptation

Adaptation to climate change is a must for agriculture. Agriculture is a climate-sensitive sector that will be one of the first to be hit and possibly also the hardest hit. Most countries are already working on adaptation strategies or adaptation planning of the most important or vulnerable sectors. Since the Paris agreement (2015), national adaptation planning, in which climate concerns are mainstreamed in sectoral policies, took off. This approach safeguards and allows for flexibility and aligning short term action and long-term planning.

For low and middle incomes countries, agriculture is still a key economic sector and essential for the livelihoods of large parts of the population. Early action to prepare for the impacts of climate change or exploit opportunities related to changing climate conditions require insight and foresight.

Also, when linking to the interest of the sector and farmers adaptation is the key entry point, more so than mitigation. The plans and commitments of countries are presented via nationally determined contribution[29] and the national communications submitted to the UNFCCC, but also in the national adaptations plans or strategies. The movement from planning to evidence-based action to shape the

[29] http://www.fao.org/3/i6400e/i6400e.pdf

transition to a climate resilient agricultural food system requires cooperation between the sector, farmers, science and society.

This cooperation is needed for long term planning and visioning future farm types or agriculture This vision but will have to rooted in facts related to current biophysical conditions and possible environmental and desired socio-economic changes. In the Netherlands the dialogue on what agriculture could like is part of the social debate. The food systems approach can help in connecting the dots and defining the transitions needed.

The impacts of climate change are already visible, so adaptation is already needed, and ongoing in many places. Even when meeting the 1.5-degree target set in the Paris agreement, the effects such as droughts and floods will continue requiring further efforts to deal with the impacts of climate change.

This will be notably true for sea levels rise, which will continue during this century. For low lying coastal areas, this will inevitably lead to increased saltwater intrusions impacting local agriculture.

These issues are also affecting agriculture in the Netherlands. How do we develop systems in which further salinification is countered, opportunities for brackish/saline water are explored and utilized, and freshwater users always have sufficient freshwater of sufficient quality? Increasing salinization demands innovations in crop breeding for salt tolerance and innovations in field and water management, including desalinization.

Two lines emerge: i) planning for long-term transitional change and ii) responding to direct needs and cope with the impacts of salination in agriculture.

4.2.1 Scope

i: planning for long-term transitional change
Given climate change and socio-economic changes, agriculture will need to change over the coming years. Dutch expertise in green education and the private sector can contribute to shaping this change. By linking to priorities as defined in national adaptation plans and national communications, options to contribute to sectors, e.g. livestock, (greenhouse) horticulture, and other elements of the food systems, such as food safety, distribution, finance, services, can be mapped and prioritised. Relevant research questions are:

- what are key priorities listed in national determined contributions and national communications in the for NL relevant countries.
- critical scoping of the documents to check the scientific basis (facts and assumptions) of the national plans.
- identify possible key contributions that NL can provide to these selected countries to adapt to climate change and plan for change
- identify needs and barriers to possible cooperation on the selected topics.

ii: responding to direct needs and cope with the impacts of salination in agriculture
Making use of the existing genetic variation in crops and developing stress-tolerant varieties (drought and salt tolerance) offers part of the solution. However, these solutions need to be embedded in crop and soil management in the field and connect to local practices. The search for workable solutions needs to be done in cooperation with the sector and companies. Research on integrated strategies (crop choice, rotation, soil, water, crop protection) should preferably be formulated and tested within a farm and region-specific context. Relevant research questions are:

- What are alternative crops that are more resistant to the new climate?
- To what extent is it possible to breed stress-tolerant crops/varieties? (aimed at salt and drought stress)
- What are possible interactions with pest and disease pressures?
- What are effective soil and water management options?
- What is the potential to development and up-scaling sensor technology, early warning and control systems?

4.2.2 Potential partners

Potential partners in research range from crop breeding to crop cultivation, farm management and water management and technology. The same range would apply to private sector partners: breeding companies, farm extension and equipment manufacturers (including water purification).

For the national planning in most countries the ministry of planning or internal affairs in combination with finance are in charge. For sectoral issues the line ministries agriculture and water are relevant.

4.3 Monitoring

Monitoring transition processes to track progress and trigger interventions that can accelerate the transition process or get it back on track to align to the goals is essential. Monitoring is at the same time also a learning process. Currently index-based systems are mainly used. Indices to monitor, understand progress, learn and prompt decision making in food system transition are emerging but so far experience using these indices is limited. This is not because there is a lack of indices, but food systems are complex and have multiple aims so interventions in one domain are likely to impact other domains and associated goals. So, adjustments targeting one goal may complicate achieving other goals. Monitoring and timely information on potential effects off interventions are crucial in guiding decision making.

4.3.1 Scope

Monitoring the food system is part of the process of improving the system. With the diversity of food systems and a long list of aims, we need to focus our energy. Two examples with a limited set of aims to monitoring the food system, using indicators, are worked out. Besides food and nutrition security, the aims will connect to international treaties on biodiversity and climate change.

The first case will address which indicators are needed to assess the impact and progress of international vegetable trade on food and nutrition security and, for example, GHG emissions. By applying the food systems approach, possible trade-offs between socio-economic and environmental oriented interventions are mapped, and policy and non-policy options to reduce these trade-offs discussed for a selected number of countries.

The second case will address a circular system in which reuse of agri-residues and increased efficiency in the value chain are central. An indicator-based system[30] is used to assess the impact and progress of the multiple aims (food security and environment) for a selected number of circular systems (for example: oil palm, coffee, soy). The food system approach is used to identify leverage points to adjust and reach the set socio-economic and environmental goals.

Both approaches will connect to already existing indices (e.g. SDGs and national or local systems) that can be monitored to assess check and guide corrective interventions. the results serve as examples in the use of the food system approach combined with index-based monitoring.

Relevant research questions need to be worked out in more detail but:
- select system and identify socio-economic and environmental aims
- define indicators and link with existing monitoring systems (e.g. SDGs)

4.3.2 Potential partners

Cooperation with FAO and CGIAR and for circularity the private sector. Options to include ICT companies that already invest in agriculture and food industry.

[30] Wolter Elbersen, Anton Schultze-Jena, Siemen van Berkum, Just Dengerink, Maria Naranjo-Barrantes, Elisabeth Obeng. 2021. Identifying and implementing circular applications of agri-residues. A practical tool for assessing circularity of different agri-residue applications.

Corresponding address for this report:
P.O. Box 16
6700 AA Wageningen
The Netherlands
T +31 (0)317 48 07 00
www.wur.eu/plant-research

Report WPR-1094

To explore the potential of nature to improve the quality of life

Corresponding address for this report:
P.O. Box 16
6700 AA Wageningen
The Netherlands
T +31 (0)317 48 07 00
www.wur.eu/plant-research

Report WPR-1094

The mission of Wageningen University & Research is "To explore the potential of nature to improve the quality of life". Under the banner Wageningen University & Research, Wageningen University and the specialised research institutes of the Wageningen Research Foundation have joined forces in contributing to finding solutions to important questions in the domain of healthy food and living environment. With its roughly 30 branches, 6,800 employees (6,000 fte) and 12,900 students, Wageningen University & Research is one of the leading organisations in its domain. The unique Wageningen approach lies in its integrated approach to issues and the collaboration between different disciplines.