8 game changers for

sustainable production of safe and healthy food

Healthy nutrition from a healthy planet

8 game changers for

sustainable production of safe and healthy food

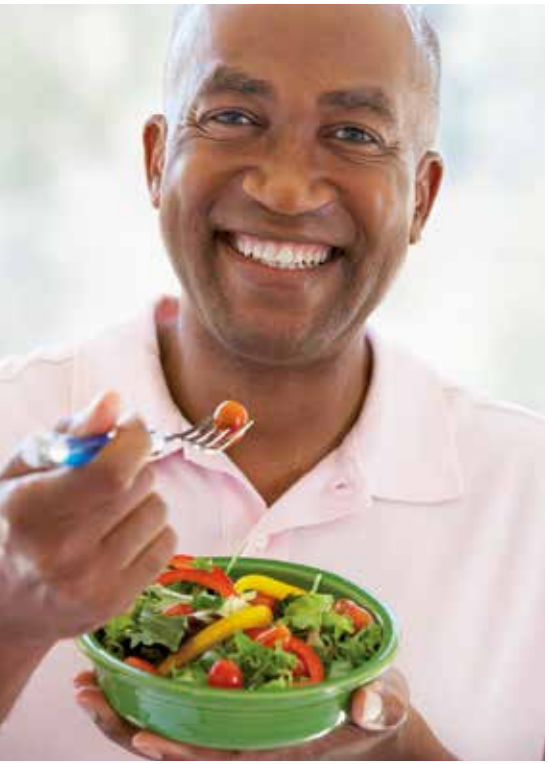
The innovative Dutch National Science Agenda (NWA [1]) lists 140 fundamental scientific questions, identified during a bottom-up consultation process involving members of the public and many organisations. The agenda is an invitation – to scientists, the business community, government and the general public – to map out new routes collectively. One of these routes is 'Sustainable production of safe and healthy food', which is being led by three of nine 'Top Sectors'[2] for enterprise and innovation in the Netherlands: Agri & Food, Horticulture & Starting Materials, and High-Tech Systems & Materials. During the past two years these sectors have mobilised stakeholders who have agreed to work together to create one global game changer in the field of food – a game changer with economic and scientific impact for the Netherlands.

The problem

By 2050, over 9 billion people need to be fed on this planet, while food production will take place under increasingly difficult conditions. Water, nutrients and energy are all becoming scarcer. Agricultural lands are becoming exhausted and are being lost due to erosion. Harvests are failing as a result of climate change. We have to produce sustainably if we want to guarantee

1 www.wetenschapsagenda.nl

2 Progress through renewal. 2016 Enterprise policy report.



healthy and safe food for everyone in the future. The Netherlands produces high-quality, affordable and safe food. However, increasing scale and intensification are causing the exhaustion of farmland, a high level of pesticide use, habitat and biodiversity loss, and the impoverishment of rural areas. Moreover, large amounts of food are lost during all stages of production, processing, marketing and consumption. Despite our high ranking in the Global Food Index, consumer trust in the food sector is relatively low. Contributing factors include: lack of transparency, the distance between consumers and producers, and the oversupply of cheap, high-calorie food which contributes to diet-related diseases.

Transformation is needed

The Netherlands is ideally equipped to take up the challenges of producing food sustainably and functioning as a living laboratory. Many improvements can be made to the ways in which national and global food production are organised. The matter is urgent, however, and will require radical changes to the system: new basic principles in which consumers play a prominent role. To achieve these transformations, the 'Sustainable production of safe and healthy food' route must work together with other routes on the NWA. These could include Personalised health, Big data, Smart industry, Smart liveable cities, Circular economy, Environmental quality, and Logistics & transport. In this way integrated food systems can be achieved in which there are no losses, natural resources are saved, and soil ecology and biodiversity are strengthened. Only through a robust system we can provide future generations with sufficient high-quality food and will well-informed consumers be able to make responsible dietary choices that are adjusted to their lifestyle and stage of life.

Figuur 1: Relations between the different game changers

The game changers

Game changers enable the required organisational, social and technological transformations. Game changers focus on new basic principles for future solutions and mobilise the Dutch expertise that is available for strengthening and accelerating scientific developments. They will enable the Netherlands to make the food sector sustainable in a fundamental and integrated way, strengthening its position as global leader in the production of healthy and safe food. For this route, eight game changers have been devised, which together make up one global game changer. The game changers emerged from workshops held with representatives from science, knowledge institutes, businesses, civil society organisations and the public sector. During the first workshop – attended by 110 people – new connections between scientific fields were identified. In the second workshop – attended by about 170 people – these new connections were further developed into game changers. During a third workshop, research plans were made for implementing these game changers. The game changers interact in many ways, as the figure above shows.

Ready for the start

The game changers will require an extra investment of 1 billion euros. Of this, 250 million euros are expected to come from industry and 250 million euros from European subsidy programmes. The remaining 500 million euros will be made available through the knowledge investment agenda arising from the National Science Agenda.

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game changer

The competent consumer

There is enormous confusion about healthy, safe and sustainable food. The information available is complex and often ambiguous. What might be healthy and safe for one person is not necessarily healthy and safe for someone else. Factors upon which this depends include age, health/illness and level of physical activity. A large proportion of the population now suffers from health problems caused by a poor diet and overeating. Many consumers find it difficult to make healthy food choices by themselves. Moreover, we choose our food not only on the basis of rational arguments; taste, convenience and price play just as big a role.

Consumers need to be prompted urgently to make responsible food choices, to improve individual well-being and public health, and to curb healthcare costs. An equally important source of motivation is the prevention of food waste. **The game changer is behavioural change, using new tools with which consumers can monitor and improve their own behaviour, physiology and health, simply and quickly.** The tools help to create motivated and better informed consumers, and will increase our understanding of the choices consumers make and their risk perception.

Research is needed on technologies that enable consumers to grasp the consequences of their actions the moment they make a purchase. Apps, sensors and wearables that record what people eat and where, as well as the nutritional composition and safety of the food, are a way for users and researchers to gain hard data on food intake. And this data can be linked to other behavioural and biological measurements, thus contributing to the development of tools that can stimulate real changes in behaviour. Understanding the effect and effectiveness of the tools, and accountability concerning ethics and privacy, are crucial. By refining underlying algorithms it may be possible to advise on product development or provide individual dietary and health advice, enabling consumers to become actively involved and shape innovations.

The proposed research requires new links to be built between researchers and developers in the fields of life sciences, measuring and information technology, social sciences and the humanities, and with Dutch food sector organisations (FNLI, CBL), businesses and NGOs (Voedingscentrum). Furthermore, consumers must be actively and interactively involved from the start.

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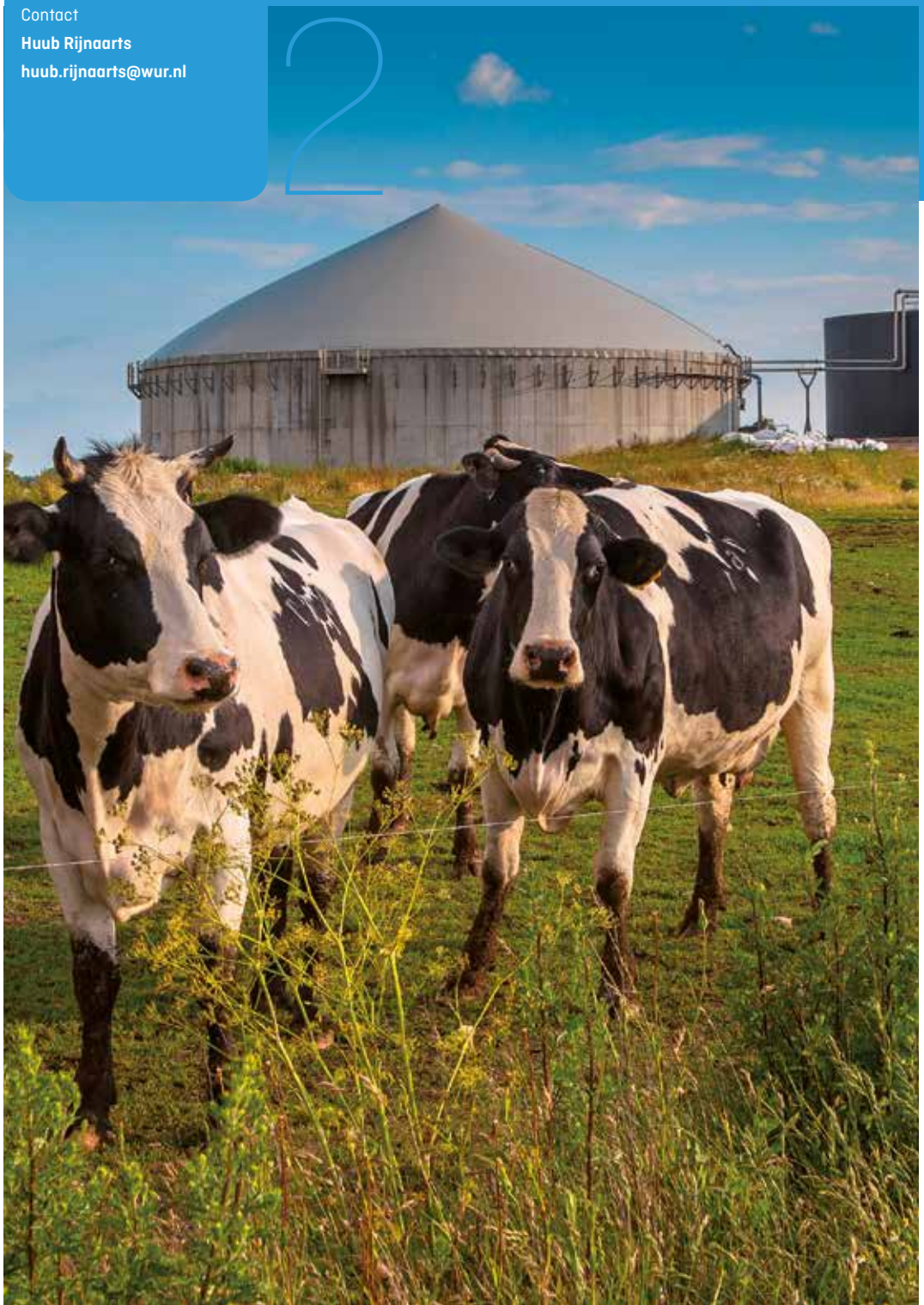

game changer

Closing cycles

Agriculture and horticulture use 70 per cent of the earth's fresh water and are responsible for 30 per cent of the world's energy consumption. Moreover, food production is exhausting and wasting raw materials, and causing farmland depletion and biodiversity loss. Calls for clean water, sustainable energy and healthy food will become louder in the coming decades. We can only change this by adopting an integrated approach and creating synergy between the water, energy and agricultural production sectors.

The game changer is the transition from the current linear to circular agricultural production. Among other things, this means that water, energy and nutrient cycles need to be as closed as possible, at local, regional and intercontinental levels. Closed-cycle food production requires new, integrated concepts, developed in close cooperation with all stakeholders. The aim is for the first practical implementations to be in place in several regions, in the Netherlands and abroad, by 2020-2030. The successful examples can then be rolled out from 2030-2050. Dutch knowledge institutes and businesses can play a leading role here.

The research is conducted in strategically chosen living labs, where closed-cycle agricultural production methods are developed and the most promising ones are tested. The concepts are then rolled out on a bigger scale in the Netherlands and abroad. Closed-cycle agriculture products must be of good quality; for example they need to be effective and must not contain any pathogens or other micro-contaminants.
A living lab can focus on material flows, or on a sector or area. Examples:
Material-flow focused:
- phosphate recovery from the agricultural production chain and from domestic waste water for conversion into phosphate fertilisers.
- purification, desalination and storage of water.
- recovery of trace elements (including zinc and selenium) and restoration of these in depleted areas, especially in Africa and South America.

Sector focused:
- developing concepts for animal feed-manure-food cycles.

Area focused:
- closing regional water and mineral cycles, for example in the Randstad metropolitan area of the Netherlands, or in a water-authority area.

This type of research requires a broad range of scientific knowledge and expertise on agricultural production methods, biological and chemical process engineering, complex systems and business management. Experience with transdisciplinary approaches and transition management is also needed. Input comes not only from universities and research institutes, but also from the food industry, energy suppliers and chemicals manufacturers, supermarket chains, innovative SMEs, agricultural and horticultural organisations, the public sector, water authorities and environmental and consumer organisations.

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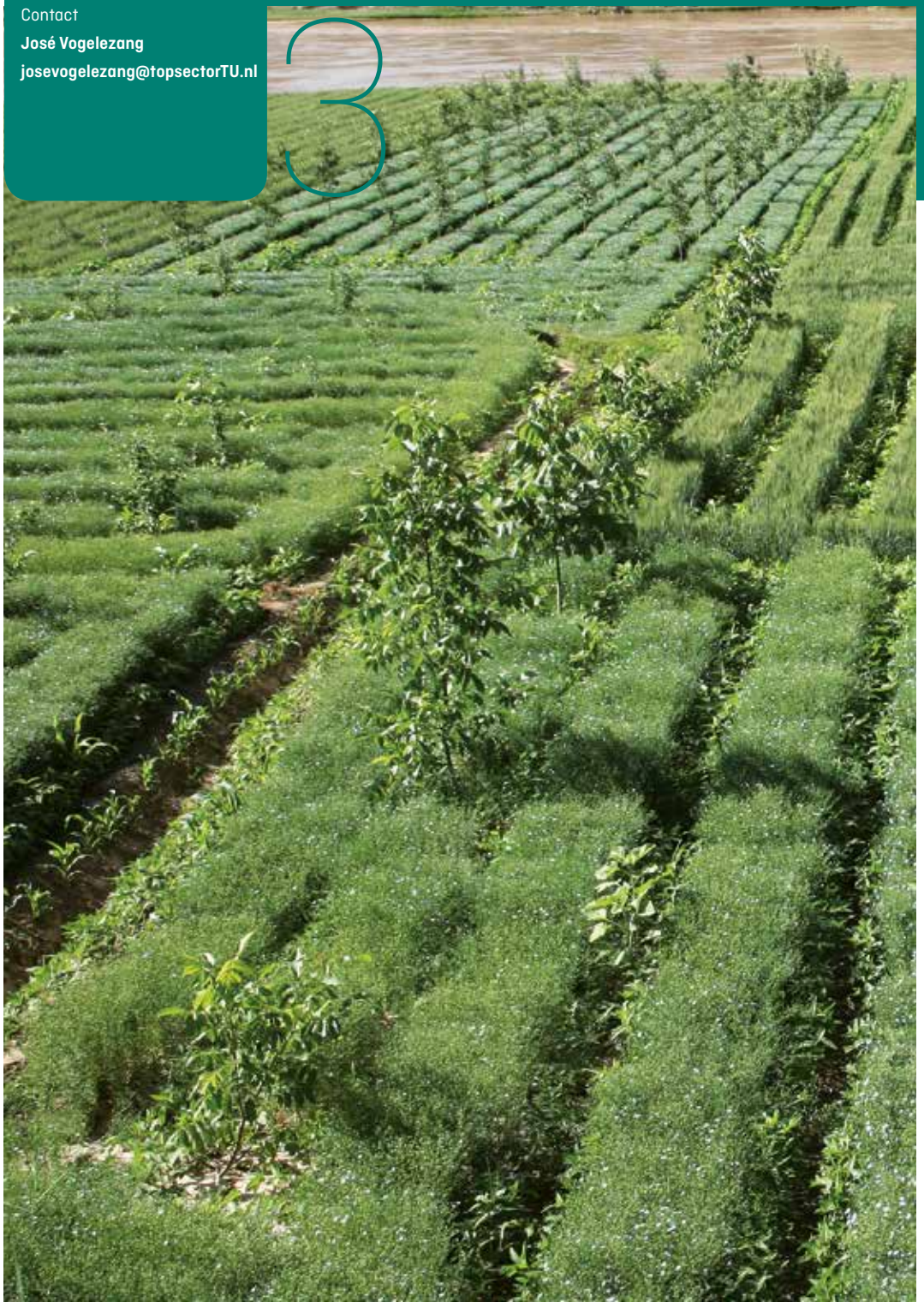

game changer

Green biodiversity

Agricultural production systems have become vulnerable and unstable as a result of their increasing scale and intensification. Calamities and interventions have increased due to decreased (bio)diversity (monocultures) and greater numbers of animals being kept in livestock concentration areas. Outbreaks of animal diseases and widespread use of antibiotics for livestock are causing human health risks, such as Q fever and untreatable bacterial infections. The current production systems are also reducing biodiversity. The dramatic decrease in numbers of meadow birds, insects, and pollinators is raising societal questions about the sustainability of the present production systems.

The game changer for agriculture and horticulture is the transition to robust production-ecosystems. These are based on diversity, biodiversity and resilience and are thus better able to deal with external threats. In plant cultivation systems, for example, new forms of intercropping will be developed, as crop diversity results in fewer diseases and pests, more efficient use of nutrients, increased production and improved soil quality. In animal production systems, for example, more resilient animals are important in order to reduce the risk of infectious diseases.

New knowledge on biodiversity and resistance can be opened up by aggregating diverse datasets (e.g. multiomics) using new analysis techniques such as bio-informatics and big-data analysis. This creates possibilities for avoiding conventional crop model studies, and starting directly with complex life systems studies in which the effects of greater biodiversity, tolerances and resistance at the level of genes, soil, plant/animal and production systems can be evaluated for their contribution to resilience at farm level. Fundamental research will still be needed too, for example to determine the suitability of varieties and species for intercropping, and soil management that makes use of interactions between microbiome and rhizosphere. Lab-on-a-chip based technologies can also make a big contribution to building knowledge and understanding of complex production systems.

The proposed research requires a transdisciplinary approach, combining life sciences and social sciences, and collaboration with centres for biodiversity and genetic material, agricultural organisations (BioNext, LTO, Plantum, Nefyto, Artemis), private companies and NGOs. The participation of omics companies and biodiversity-informatics institutes is crucial. As intercropping systems require a completely new form of mechanisation, it will be necessary to collaborate with the High-tech and IT game changer.

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game changer

Blue biodiversity

Food from the sea – fish, shellfish and crustaceans and seaweed – is highly nutritious and protein rich. Fish is already the most important source of protein in the densely populated coastal areas of various developing countries. However, marine ecosystems are subject to increasing pressure (overfishing, habitat destruction, pollution and estuaries are becoming inaccessible). Like the green revolution, we now need a blue revolution that respects the biodiversity and resilience of marine ecosystems so that we can feed the growing world population in a sustainable way.

The new blue revolution must result in an integrated approach comprising ecosystem services, natural processes and maritime technology. The aim is to develop smart combinations of food production, wind energy, raw material extraction, goods transport, water recreation and land reclamation. **The sustainable blue revolution will lead to new, integrated and ecologically based methods for producing seafood and bio-based marine materials that can be used in the Netherlands and other coastal areas.**

The research focuses on new concepts for catching and producing fish, shellfish and crustaceans, and algae and seaweed in the shallow continental waters of the world's seas and oceans (mariculture). These concepts will strengthen ecosystem services and the marine ecosystem, for example by combining sustainable food production with energy production (wind farms) and natural coastal defence systems (building with nature). All new forms of mariculture will have to be evaluated before they are introduced, which will require a spatial analysis that includes assessment of the potential effects of habitat disturbance and the carrying capacity of the system. The approach will also contribute to innovations in and increasing the sustainability of the Dutch fishing industry (more selective fishing, prevention of by-catch and habitat destruction, new fishing technologies and methods), shellfish fishing (new space for open sea cultivation) and seaweed cultivation on a commercial scale.

The execution of this research programme requires scientific expertise on aquaculture, fisheries, marine biology and ecology, climatology, ecosystem services, marine and civil engineering, marine spatial planning, bioprocess technology, food technology and business economics. The living lab is the way to organise, together with all stakeholders, pilot projects that involve smart combinations of maritime technology or mariculture, offshore wind farms, habitat development and food production. This requires intensive collaboration between universities, research institutes and stakeholders (ministries, fisheries sector, aquaculture businesses, maritime industry, energy sector, food industry and NGOs).

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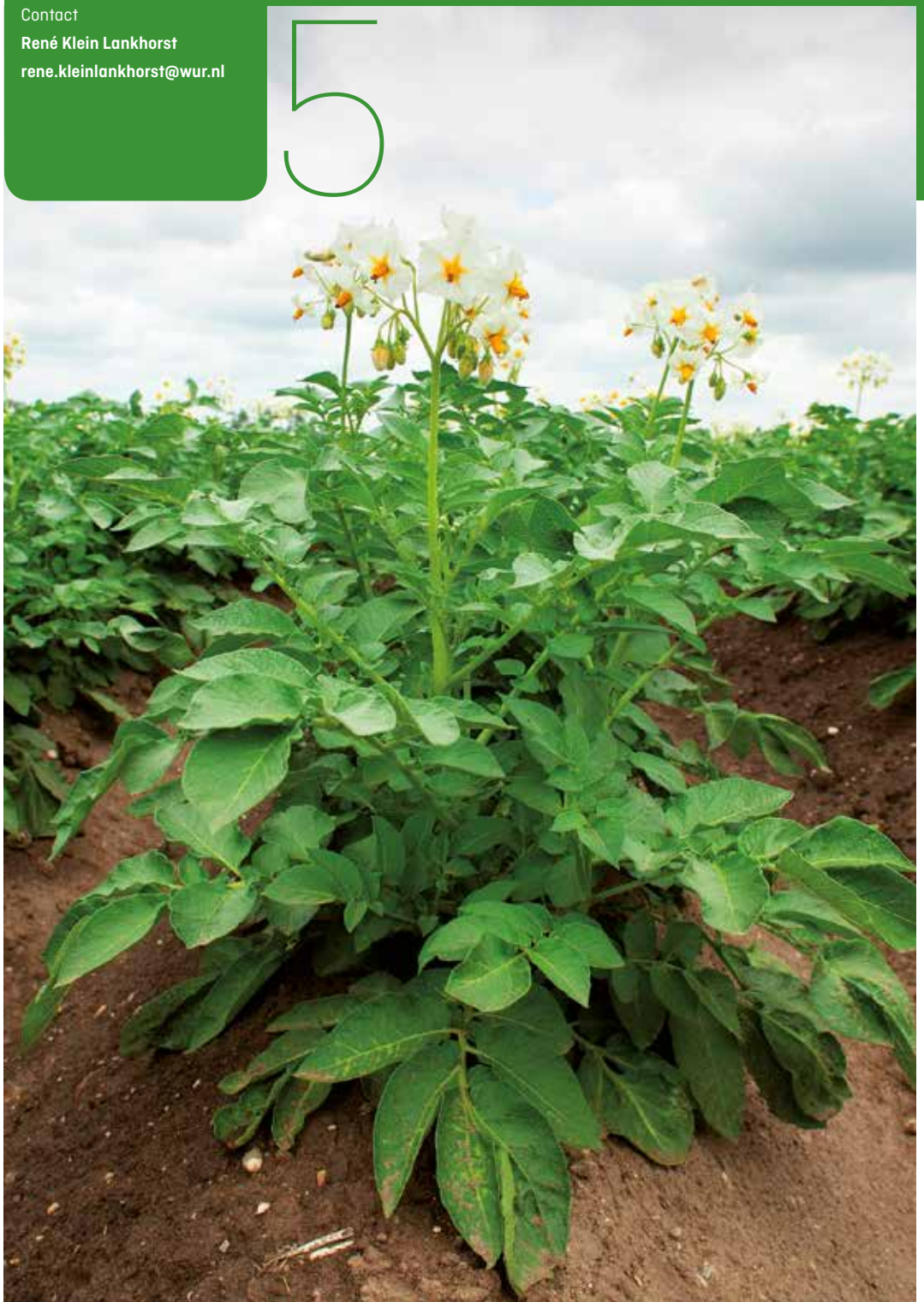

game changer

Turbosynthesis

To be able to feed the world's population in 2050 we will need to increase food production by 70%. Climate change is an additional challenge: extremes such as drought, heat and mineral stress are placing increasing pressure on food production. While much attention is focused on improving cultivation systems, photosynthesis also offers great potential. On average, crop plants convert only 0.5% of incident sunlight into biomass. **More robust and efficient photosynthesis – turbosynthesis – will bring climate-proof, high-yielding food crops within reach.**

Some wild plants convert sunlight up to eight times more efficiently than our food crops. We need to study how this mechanism works so that we can develop crops that will produce higher yields even under extreme conditions. The aim is that by 2020 the first technology will be available for plant-breeding companies to develop crops capable of turbosynthesis. By 2030, a complete toolbox of methods (breeding by design (non-GMO) or synthetic biology) will be ready for breeding crops that yield at least twice as much as they do currently. Turbosynthesis will improve food production in areas that face hunger and nutritional problems, and could also contribute to the transition from a fossil economy to a sustainable bio-based economy. Dutch plant breeders are world market leaders, making the Netherlands an ideal living laboratory.

Turbosynthesis requires an entirely new, fundamental redesign of photosynthesis. This multi-disciplinary research will involve all relevant academic institutes in the Netherlands and translational research with industry. The most important research topics are the genetic basis of photosynthesis, exploration of current biodiversity, crop physiology, physics of light reactions, source-sink interactions, climate adaptation, modelling and simulation, phenotyping, urban agriculture, and social impact and acceptance.

To redesign photosynthesis we will need to forge new connections between scientific disciplines. Genetics is the binding factor between these disciplines and this linkage constitutes a unique new approach. The end product is genetic information that plant breeders can use to develop new crops. Furthermore, the new crops will have to be adapted to sustainable cultivation systems, which requires linkages with disciplines like agronomy, soil ecology and agri-systems research.

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game changer

Protein efficiency

Sustainable protein production is one of the biggest food challenges the world faces in the coming decades. Due to population growth and rising prosperity levels, demand for animal protein is increasing and scarcity is a threat. To ensure that people have enough protein we need to extend our potential sources of protein, ensure that proteins are used optimally in feed and food, and shape more sustainable patterns of protein consumption. All this requires systemic changes throughout the food chain.

The 'Efficient protein production' game changer meshes well with current initiatives: sustainable protein consumption, alternative protein sources such as seaweed and insects, and optimal use of plant and animal by-products, and waste materials for food and feed.
The Netherlands is already a global leader when it comes to innovations in protein production. Its innovations in the fields of sustainable, nutritious, safe and affordable protein, and protein-rich products that are acceptable to consumers will enhance the country's knowledge-export position.

This game changer combines three lines of action:

1: New knowledge and models to guide the global protein-producing platform (local to global level). The scenarios help to determine sustainable balances of production, processing and consumption, and anticipate climate change. Important indicators are: circularity of raw material flows, animal welfare, consumer health and safety, affordability, economic profitability, environmental effects and social/regional impact.

2: Focus on innovations that contribute to safe and sustainable protein production. These include cultivation innovations, biomass valorisation, conversion of biomass into products, and process optimisation. Technology can bring about a step change.

3: Promotion of sustainable protein consumption together with the 'The competent consumer' game changer. The development of objective information (links to action 1) and of applications and products that foster competent behaviour (links to action 2) will support changes in consumption patterns.

The consortium builds on existing sustainable protein initiatives and responds to questions concerning current and future protein production. Contributing stakeholders will include universities, research institutes, NGOs, non-profit organisations, alliances, protein transition centres, and the food, feed and technology sectors. These are stakeholders capable of developing demand-driven knowledge, making it available and using it for fundamental systemic changes. Available knowledge from existing alliances and consortia will be used for this.

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game changer

Global food security

Producing affordable and healthy food for everyone in a sustainable way is a global challenge. Economic growth, urbanisation and inequality are additional challenges. Besides hunger and malnutrition, overweight and obesity are also symptoms of poverty. To produce food, we must use scarce resources (soil, water, energy, minerals) efficiently and develop robust cultivation systems and distribution chains that can withstand natural disasters and market risks.

Partial solutions have insufficient impact because they do not address the interrelatedness of the technical, socio-economic and cultural factors involved. Game changer tasks include addressing the overconsumption of unhealthy food products, improving nutrition by running campaigns within nutrition programmes, and providing targeted income support. Large-scale losses and waste in the food chain can be prevented by introducing improved methods of food processing and storage, and stimulating agricultural producers and consumers. 'True pricing', in which the environmental effects and social costs are included in food prices, will help make sustainable and healthy food more attractive and will encourage healthy eating patterns and robust food systems.

By focusing on healthy and sustainable food and steering the food system, this game changer contributes to strategies that make the food chain and food consumption more efficient, more effective, more robust and fairer.

A healthy diet is particularly important for vulnerable groups (pregnant women, infants, young children, adolescents, elderly people) in which malnutrition can lead to irreparable damage. To achieve food security, the focus is on ways in which people can organise and regulate affairs themselves.

This game changer requires (a) an analysis of patterns of relationships and interactions between food, consumers, producers, traders, the food industry, institutions and policymakers; (b) development of micro-models of technical and organisational innovations which can contribute to increased demand for better food and to an understanding of the role of behavioural change in actors in the food chain; (c) a public debate on the relationship between local/regional food systems and other global developments.

Bold interdisciplinarity is required: economic, social, administrative, business, agricultural, nutritional, health, logistical, meteorological and communication expertise is combined with systems engineering, transition science, political sciences, history, jurisprudence, behavioural sciences, anthropology, educational sciences, linguistics and ethics. A transdisciplinary and multi-stakeholder approach mobilises public, private and civil society partners to seek and find scalable solutions at local to global level.

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game changer

High-tech and IT

The previous game changers have set their sights on the next green revolution, which will result in a more circular and robust production system for safe and healthy food. Or: 'better and more with less'. To achieve these ambitions, science and industry will have to combine their knowledge and expertise on agricultural and horticultural production, ecosystems and nutrition with high-tech and IT. Attention must also be paid to acceptance of these technological innovations by the general public.

High-tech and IT applications can help to bring about more sustainable production in many ways. Small robots can be used for efficient and soil-friendly cultivation and harvesting of an optimal mix of plant species (multi-cropping systems). Producers can receive tailor-made advice based on precise monitoring of agricultural land, soil processes and plant growth, and on the right plant models and data-analysis methods. In greenhouse horticulture, robots allow optimal climate conditions for plant growth. Smart technologies make the production of meat, milk and eggs more efficient, healthier and more animal friendly. Smart logistics increase transparency and efficiency in the food system and reduce waste in the production chain.

This game changer is closely interwoven with the other game changers, involving an integrated, multi-disciplinary systems approach with input from diverse disciplines. Multi-cropping requires new, more efficient soil-cultivation and harvesting methods. Farmers and machine builders will have to be persuaded of the future-proofness and efficiency of this form of agriculture. IT technologies such as vision processing, big data, and artificial intelligence will have to be optimised so they can be used in the agro-food world. These developments are costly, and the existing means are not sufficient to cover the steps we aspire to. The *High-tech to Feed the World* roadmap will have to receive much more attention, and structural budget increases. The *Sustainable Food Initiative* has been started by a number of companies and knowledge institutes, and this will boost the food-processing sector.

The formulated ambitions will require cooperation between agri-food businesses, high-tech industry, the IT sector, and technical and green universities and universities of applied sciences. Living labs are being set up with trade organisations and government bodies. Social science and civil society organisations will help with the introduction of new concepts and promoting social acceptance.

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Summary This publication describes eight game changers identified for sustainable production of safe and healthy food, based on the innovative Dutch National Science Agenda (NWA).

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TOPSECTOR

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