

# Challenges and successes in interdisciplinary and transdisciplinary research and education

**WIMEK experiences**

May 2014





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# Preface

The Wageningen Institute for Environment and Climate Research (WIMEK) aims to bring scientifically based front runner understanding and solutions for the worlds emerging environmental questions as raised by society. For this reason a strong interaction with public organisations, national and international governmental bodies and institutes, service providing companies and international industries, is a corner stone of our work. Such a stakeholder interactive type of research is called transdisciplinary research. Within WIMEK we also combine many different disciplines which is indicated as *interdisciplinary* research. The demand for transdisciplinary and interdisciplinary research in the environmental field is strongly increasing. The world population rises to 9 billion people in 2050 and redistributes between rural hinterlands, urbanized deltas and continents. In the past decades the environmental perspective changed from pollu-

tion and climate change to resource depletion. The original focus of the environmental sciences was on loss of biodiversity, eutrophication, chemical pollution, global warming and sea-level rise, and societal adaptive responses to these changes. In addition, we now experience increasing depletion of essential resources. Fresh water and fossil phosphorous needed for food and biobased economy become limiting. Minerals and metals to sustain our ICT-based society become scarce. The foreseen renewable energy potential lags far behind the global demands for fuel, heat, cooling and electric power. Because of scarcity, terrestrial exploitation expands to low production area's and marine systems, issuing new challenges for preserving biodiversity and ecosystem functioning and services. All these developments demand new solutions based on a circular resource economy supported by new societal-technical structures and organisations.

New opportunities arise to support this development: our ICT-based society offers novel options for big-data analysis, monitoring, visualisation, design, steering and stakeholder involvement. New technologies needed for resource recirculation and renewable energy production are in "gold-rush" development. Urban, agricultural and industrial systems can be (re-)designed and engineered towards circular and interactive functioning. In short, in addition to increasing environmental problems and pressures, also the options towards sustainable solutions increase. WIMEK joins in with science-for-impact to make the outcome of these opposing processes positive. WIMEK works with a team of 17 research groups at Wageningen University and Research Centre (WUR), supporting more than 300 PhD and Postdoc researchers. One of our most important approaches is to support our inter- and trans-disciplinary research.

This booklet "*Challenges and successes in interdisciplinary and transdisciplinary research and education* " exemplifies our efforts and achievements herein. It is introduced by an archaeology on inter- and transdisciplinary research in the environmental field. Examples on interdisciplinary and transdisciplinary projects are given in the areas of waste and sanitation in Africa (PROVIDE) and Europe (Sneek, NL), sustainable marine multi-use platform systems (MUPS),

freshwater availability in arid areas, and ecosystem tipping points. Interviews with principal investigators form the basis. Two examples are given how in the educational field, we teach the issues of dealing with uncertainties, and with interdisciplinary and intercultural aspects of societal issues. We end with a short reflection and outlook for future research and education cooperation's in the field of environment and climate research. Throughout this booklet we share with you our lessons learned and successes gained, and we hope to transfer to you some of the inspiration we feel in research and education for a sustainable world.

Professor Huub Rijnaarts  
WIMEK DIRECTOR

## WIMEK aims to support environmental research at WU via the following approaches:

- provide a focal point of environmental research at Wageningen UR and to national and international environmental research institutions;
- safeguard research quality and provide PhD training & education;
- stimulate and support interdisciplinary and transdisciplinary collaboration of researchers from various disciplines on emerging complex environmental issues.

## Introduction

# Confronting the challenges of interdisciplinary work

Since the 1970s the debate on interdisciplinarity has been intrinsically connected with the environmental sciences. At first the idea of Environmental Science (Milieukunde in Dutch) as an integrative science for confronting environmental problems dominated the discourse of the 1970s, particularly in the Netherlands. Interdisciplinarity as discussed in the nation-wide used 'Basisboek Milieukunde' (Boersema et al., 1991) was conceived in terms not just of a shared and collaboratively defined research subject but also in terms of moving beyond existing disciplinary borders. Environmental Chemistry and Environmental Psychology alike were destined to dissolve while being integrated into the new, supra-disciplinary paradigm of 'Milieukunde'. At most Dutch universities, centres for the interdisciplinary study of environmental problems emerged and thrived in the 1980s.

When compared with the 1970's and 1980's, the debate on interdisciplinarity has evolved and changed in character and content. Over the years, the existing borders between well-established academic disciplines appeared to be more robust than expected. Nowadays in the Netherlands at least, most interdisciplinary 'Centres of Environmental Sciences' have disappeared, and the idea of a single, integrative body of knowledge seems no longer the appealing grand idea, which in the early days attracted so many followers. Instead, the debate has become more pragmatic in the sense that interdisciplinarity is now disconnected from challenging the existence of disciplinary fields within mainstream academia. The focus nowadays is on the best way to organize and practice interdisciplinary research and education as a valuable and necessary complement to existing disciplinary fields.

Having lost some ideological feathers, however, does not imply at all that interdisciplinarity has become outdated. On the contrary, over the past decades interdisciplinary research and education is recognized worldwide as an indispensable and well established branch of academic research and education. Interdisciplinarity has proven its ability to generate knowledge and forms of collaboration that are crucial for solving complex societal problems, such as climate change, biodiversity loss, natural resources depletion, global food security, and health risks. Environmental problems are famous for their ability to neglect compartmental divisions as they were set up by newly established academic disciplines around air, water and soil; they tend to beat (spatial) planners when appearing at local, national and international levels at the same time; they are able to cut through existing divisions of power thereby shaking up established configurations of stakeholders; they managed to redefine well accepted definitions of progress, well-being and modernity; and (last but not the least) they make us think about present societies from the perspective of generations that will inhabit these societies in the future. It is because of these powerful characteristics that environmental and climate-change problems tend to pull enlightened researchers into the endeavour of interdisciplinary cooperation in order to more effectively confront the complex challenges at hand.

Within Wageningen UR and its Environmental Sciences' research school WIMEK, the discussion on interdisciplinarity has always been pragmatic with both staff and students showing engagement without entering into strong ideological debates concerning the complex epistemological and methodological issues that tend to emerge as soon as one enters into interdisciplinary, multidisciplinary and transdisciplinary work. This is partly explained by the fact that interdisciplinary and transdisciplinary approaches fit very well within the broader culture of Wageningen University as a university that specializes on the life-sciences with its motto 'Science for Impact'. Interdisciplinary approaches prosper in an academic environment that displays an explicit normative orientation. Wageningen University is a university with a 'mission'. Its explicit aim is to make essential contributions to improving the quality of life for all people on this planet. Pioneering innovative research and education on 'more healthy food', a 'better living environment' and 'more sustainable management of natural resources' brings along a natural inclination to combine disciplinary with interdisciplinary perspectives, and fundamental research with applied, *transdisciplinary* research activities.

In this brochure we use the following definitions (see also Box 1) based on Rice (2013: 2): *Interdisciplinary* approaches integrate separate (natural and social science) disciplinary data,

### Box 1: Various forms of collaboration

**Multidisciplinary:** involvement of several disciplines, but research questions and outputs are formulated from a disciplinary perspective.

**Interdisciplinary:** intensive interaction among disciplines resulting in integrating data, methods, tools, concepts and theories and sometimes creating new methods, concepts or theories.

**Transdisciplinary:** integrating academic knowledge from various disciplines and non-academic knowledge. Throughout the research process academic and non-academic stakeholders are in dialogue.

methods, tools, concepts, and theories in order to create a comprehensive perspective or common understanding of a complex issue, question, problem or challenge. In transdisciplinary research, not only academic researchers from different disciplines are involved but also non-academic participants enter the stage. Transdisciplinary research aims to integrate academic and non-academic knowledge in order to be better able to conduct research on real world problems and to create new knowledge and theories which can be used to improve the present state of affairs. "Transdisciplinarity combines interdisciplinarity with a participatory approach, involving engagement of scientists and non-academic stakeholders throughout the research process" (Rice, 2013: 2).

For a university of life sciences such as Wageningen University making the steps from disciplinary to interdisciplinary research and from interdisciplinary to transdisciplinary research seems a logic and relevant consequence from its main ambitions. These ambitions are to be innovative, to have an impact and to make a difference for the world of tomorrow. The examples of interdisciplinary and transdisciplinary environment and climate oriented research and education as presented in this brochure must be read and understood against this particular background of Wageningen University as an international oriented university with a strong life-science profile and identity.

In this brochure, we illustrate our approach by five interdisciplinary research projects and two MSc courses. Both the research and the education cases are selected from a broad range of projects at Wageningen University. The cases included in this brochure are selected because they highlight interdisciplinary and transdisciplinary academic work in some creative and instructive ways. Throughout the main text, a number of text-boxes are inserted to highlight particular key issues, problems confronted, warnings, successes realized, motivations, do's

and don'ts. The cases and the text-boxes invite to reflect on the experiences gained so far and they hint at useful lessons learned. By presenting and discussing these cases, we explore ways to further improve the WIMEK performance record in the field of interdisciplinary and transdisciplinary academic work in both research and education. Learning by doing, and learning from experiences gained so far has been an important motivation for making the brochure.

We aim to share our experiences with others and to improve ourselves by presenting on-going work and by reflecting on some dilemmas of both theoretical and practical nature that pop-up from this material.

Scientific integration seems to contradict the self-dynamics of scientific progress which can be regarded as a process of differentiation, specialisation and fragmentation. Scientists interested or involved in interdisciplinary and transdisciplinary research might therefore face structural barriers that hinder integration such as limited funding opportunities for interdisciplinary research, restricted career opportunities or discipline-oriented review processes (Rice, 2013). Risks and barriers in interdisciplinary and transdisciplinary research exist, as this brochure shows throughout the series of cases. However, we don't want to outline and emphasize only the barriers and risks but also the opportunities and rewards involved in the process. We tell stories about how persons in real life projects managed to overcome both personal and institutional barriers to interdisciplinarity. In fact many of our examples show that it is very rewarding to get to know new people using different disciplinary and theoretical perspectives, and to get acquainted with these new perspectives (both neighbouring and different). Interdisciplinary and transdisciplinary research can be inspiring and exiting, it can create novel, unexpected achievements and thereby increasing one's scientific portfolio.

## Outline of the brochure

### **Research case 1: INREF-PROVIDE**

The first research case is PROVIDE (Partnership for Research on Viable Environmental Infrastructure Development in East Africa), a programme funded by INREF (Interdisciplinary Research and Education Fund) of WUR. This programme involves the development of tailor made waste and sanitation services for East Africa, a typical wicked problem both for their technical and socio-political dimension. The case illustrates the importance of careful preparation and planning to create a common ground among those involved, a team of 10 PhD-students and their supervisors from different countries and disciplines. Time was needed to make everybody involved familiar with the 'modernized mixtures' approach a new paradigm for waste and sanitation systems that guided the project. The project is a good example of how collaboration between disciplines and stakeholders can bring science into practice. A follow-up project started to disseminate the outcomes of PROVIDE to students and professionals in the field of waste and sanitation in East Africa.

### **Research case 2: Multi Use Platforms at sea**

The second research case illustrates that investigating the opportunities at sea for combining a multitude of functions, triggers new, challenging research questions for both fundamental and applied sciences. Marine governance, marine ecological, agricultural and technological research are new topics for the scientific and policy agenda. Developing Multi Use Platforms (MUPs), combining wind turbines in large scale wind farms with the cultivation of seaweed that can be used for the production of pharmaceuticals, fish feed or bio-fuels in a cost-effective

way, and at the same time trying to improve the local biodiversity, requires scientific input from natural as well as social science. Moreover, the new scientific insights and bodies of knowledge in the making have direct policy relevance. It seems, however, that NGO's, governments at different levels, commercial parties, fishermen, sea-farmers still need to get familiar with these new developments as they are a bit reluctant to get involved.

### **Research case 3: Agro-economic model Brackish Water**

The third research case is completely different in scope and scale, but it shows the enthusiasm of researchers from economics and physical science who collaborated on the development of an agro-economic model for the distribution of brackish water. These researchers became enthusiastic about the model itself as it develops along the way, the problem-solving capacity of the model as well as the new questions for future research it generated. This case also illustrates how interdisciplinary research is highly facilitated when a common language, in this case math and modelling, is available among the researchers involved in the project.

### **Research case 4: New sanitation in Sneek**

The fourth research case describes the implementation of a demonstration project of a decentralised sanitation system. In this system toilet water is treated separately to produce energy (methane gas) and to recover useful nutrients, such as phosphorus and nitrogen. Thirty-two households in the Dutch town Sneek were involved in the demonstration project. The case illustrates that implementing a new sanita-

tion technology requires a smooth cooperation between scientists and stakeholders viz. the municipality, housing cooperation, water board and water company right from the start.

#### **Research case 5: Tipping points**

The fifth and final research case is about the tipping point model which was developed within the chair group of aquatic ecology, but which is used nowadays in many other disciplines. This case illustrates the added value of working across disciplines which stimulates out of the box thinking and brings about unconventional, innovative knowledge which is highly successful and recognized as such by both fellow scientists and society. This case also illustrates that working with other disciplines can result in high impact publications and a crowded future research agenda.

Interdisciplinary and transdisciplinary research and problem solving require specific skills that should be addressed in education. We conclude this brochure with two edu cases, two examples of courses that are part of the MSc programmes at Wageningen University and that specifically train students to work in an interdisciplinary or transdisciplinary setting. These courses are team-taught, use active teaching and learning approaches and innovative educational formats.

#### **Edu case 1: Environmental Quality and Governance**

The first edu case is a course on risk assessment and governance. It aims to show students that separate bodies of knowledge, such as chemistry, toxicology and ecology on the one hand and sociology or political sciences on the other, have their own strategies of coping with uncertainties. For effective risk management and decision making knowledge and understanding of all these fields of science and their interdependencies are needed. An interesting spin off of this course was the development of joint research projects by the involved scientists.

#### **Edu case 2: The European Workshop**

The second edu case refers to a course in which a group of thirty students collaborates to address a sustainability issue commissioned by a governmental or non-governmental organization or a company in an intercultural setting. The course aims to enhance students' awareness of disciplinary and cultural boundaries and to add to their appreciation of using different disciplinary and cultural perspectives in developing sustainable solutions. Students are extremely enthusiastic about this challenging and intensive course.

We hope that the examples in this brochure will inspire scientists, PhD researchers and students that find interdisciplinarity and transdisciplinarity on their way, who at first perhaps perceive more barriers than benefits or think that the initial investment costs are too high. They will not find readily made solutions or sweeping statements on the benefits of interdisciplinary and transdisciplinary work in this brochure. Instead we want to show how and why real people doing real projects became enthusiast, curious and acquired interdisciplinary skills.

## Research case 1

# Tailor made solutions in waste and sanitation for East Africa

**Ten PhD students from different African countries looked at the waste disposal and sanitation problems in Tanzania, Kenya, and Uganda. They described the possibilities of working with mixtures of large-scale and small-scale technological solutions in the context of sometimes newly designed, locally adapted administrative arrangements. The successful project is granted a follow-up.**

Three East African countries border Lake Victoria: Tanzania, Kenya, and Uganda. These countries show relatively good economic performance compared to others in the African continent, which was for a long time underdeveloped. Just as in many countries with developing economies, the population in East Africa grows rapidly, especially in mega-cities, resulting in extra pressures on the environment. "The

increasingly frequent dumping of nutrient-rich wastewater on Lake Victoria will in the long run harm the fishery industry of the three countries and threaten the intake of drinking water for their populations", states Peter Oosterveer, a senior sociologist working in the chair group Environmental Policy (ENP) and managing director of the PROVIDE programme.

The ENP chair group had successfully invested in knowledge and relations in Southeast Asia over the past fifteen years, in countries such as Vietnam, China, and Thailand. At the start of the new millennium, the group decided to look for possibilities to apply their Asian based experiences with sanitation project in Africa as well. "With no less than one million euro from the INREF (Interdisciplinary Research and Education Fund, see Box 2) fund of Wageningen University, we were finally able to initiate an ambitious

## Box 2 INREF a valuable framework

The INREF (Interdisciplinary Research and Education Fund) of Wageningen UR has been and still is very important for developing the structural conditions needed for successful inter- and transdisciplinary research programmes. INREF aims to conduct and trigger innovative, interdisciplinary research, development and education within Wageningen University and beyond. It provides funding, but also a platform for scientists and students with different disciplinary and cultural backgrounds to learn new ways of addressing contemporary issues. Structural frameworks such as INREF can hardly be underestimated for stimulating and advancing inter- and transdisciplinary research.

project for East-Africa”, Oosterveer explains. “To this end, we made extensive use of our existing cooperation with the natural scientists of the WUR”.

To regain control of the sanitation and solid waste flows of urban households that run into Lake Victoria, researchers mapped out the production and processing of solid domestic wastes and faecal matter at a local, regional, and national level in all three countries. “In mapping these material flows, particular attention was being paid to the cultural dimension of the problem, as expressed for example in the way people handle waste in and around their home, in the different ways of managing wastes at municipal levels, and in the different degrees of privatisation of waste-services in the three countries”, Oosterveer says.

The many stakeholders, such as residents and their organisations, municipal authorities, and waste processing companies were the obvious focus of attention for the social science based PhDs in the project. The material and technical dimensions of the problem – size and composition of the waste flows, processing technologies, environmental impacts etc. – were in the domain of the natural science based PhDs. The team consisted of 10 PhD-candidates, recruited from the three African countries. They started working on ‘their project’ in 2006. By the time of writing, all except one student managed to successfully complete their research.

As for the content of the PROVIDE research program, the students were familiarized with the

so called ‘modernized mixtures’ approach as it had been developed in the ENP chair group in particular. “It was clear to all of us that there does not exist a ‘silver bullet’ solution for the complex sanitation and waste problems in developing countries, and we also were aware that simply applying western technologies does not deliver”, Oosterveer argues. “We suggested that a promising route to explore was to be found in the combination of both technological and socio-economic means and strategies, while also thinking beyond the old paradigms of centralized versus de-centralized technological solutions.” During the PROVIDE project, we produced two books and organized two international symposia to scientifically elaborate the concept of modernized mixtures in relation to the challenges of urban sanitation and waste problems in developing countries<sup>1</sup>.

At the chair group of Environmental Systems Analysis (ESA), Professor Rik Leemans gives a striking example. “From a technical point of view, one might opt for applying fermentation toilets in Kibera slum areas, close to Nairobi”, Leemans says. The advantage of this sanitation technology is that you need little amounts of flushing water, with water being a scarce resource in the slum context. Hygiene would also be guaranteed whilst the excrements are readily converted to biogas, which provides people with a fuel source other than the scarce wood that they now burn in their smoke-filled huts. “But this nice story of new, technically easily applicable techniques will not fly when a



One of the slums in Kampala (Uganda) studied by members of the PROVIDE-team. Photo Peter Oosterveer.

certain neighbourhood is primarily inhabited by Muslims. Because they swear by using water to flush their toilets”, according to Leemans. “This example shows that technical solutions have to be embedded in cultural traditions and social contexts in order to be effective.”

The system analyst (co)supervised a PhD student who developed an integrated model with which many environmental impact factors could be predicted, based on growth of the population in combination with an improved socio-economic standing. This model has been developed for and tested on the city of Kampala, Uganda, but can be applied to other cities as well. “During that process, the involved stakeholders were asked which factors they found to be most urgent and relevant. Matters such as the costs of a waste disposal system, employment, improved hygiene, and a decrease in diseases in the nearby environment were found more important than the ecological situation in Lake Victoria”, Leemans says.

The details of both the sanitation problems and their solutions are very subtle and differ between countries and cities, so it is confirmed by Kees Burger who acts as the development economics expert in the PROVIDE program. He

(co)supervised a PhD student who looked into the waste collection system in Uganda’s capital Kampala, right next to Lake Victoria. “The city is experiencing an enormous growth and the municipality cannot keep up with the explosive increase in the flows of domestic wastes. Privatisation of waste collection, where companies invest in containers and lorries, could be a logical step to take”, Burger explains. However, there is a problem with this assumption, since the willingness to pay for the privatized services differs across social classes and neighbourhoods. The rich are willing to pay in order to keep their neighbourhoods clean. In the poor areas, only the developing middle-class population is prepared to do something about the waste problem. “During our research, we arrived at the solution of a hybrid system, in which the government-based system of skips in the poor areas is maintained, whilst the rich neighbourhoods work with privatised waste disposal services. We advocated a solution in which the existing informal waste collectors are included in the new system as intermediaries who are responsible for collection and separation of domestic wastes at household and neighbourhood level”, Burger says. “Informal pickers bring the wastes to the skips,

<sup>1</sup> The books are: B. van Vliet, G. Spaargaren, P. Oosterveer (eds.) (2010) *Social Perspectives on the Sanitation Challenge*. Dordrecht: Springer; and B. van Vliet, J. van Buuren and S. Mgana (eds.) (2014) *Urban Waste and Sanitation Services for Sustainable Development*. London: Routledge.

An illustration of the innovative solutions for sanitation in one of Kampala's (Uganda) urban slums.

Photo Peter Oosterveer.



The PROVIDE team attending a workshop in Kisumu, Kenya.

Photo Gabor Szanto.



while privatised companies are commissioned by the municipal governments to take care of the transport of the skips to the landfill." The proposal could also work for smaller cities bordering Lake Victoria. It has been functioning for a while now in Jinja, the second-largest city of Uganda, and other PhDs in the PROVIDE project investigated the applicability of similar hybrid concepts in Mwanza, Tanzania, and Kisumu, Kenya, on the opposite side of Lake Victoria. What was learned from this research was that social and technical PhD-students could work together in designing new waste collection systems based on new collection technologies like the 'improved skip'. PhD students should

take the opportunity to discuss ideas together. "An environmental technologist could write a paper on a better design of a waste bin and skip, with PhD students in economics and sociology investigating the prices and the willingness to cooperate from the side of households", so Burger suggests. In the PROVIDE program, we had PhDs working on these aspects individually, and we did not yet manage to create a full synthesis. He concludes by stating that "only now that this knowledge is available, we are in the position to deepen disciplinary cooperation in order to create a wider perspective and more integrated solutions."

This sounds like a good and promising strategy

to Joost van Buuren - one of the environmental technology supervisors in the PROVIDE programme- as well. In the seventies, Van Buuren worked on water purification in Mozambique, on separated waste collection in Vietnam, and he already had many relations in Tanzania. "This PROVIDE project is a good example of how different disciplines work together with the aim of bringing science into practice". One of the strong points of the PROVIDE programme was its choice to investigate the waste and sanitation problem at different levels, from the individual households to local neighbourhoods and municipalities, up to national levels of policy making in the three African Countries. He regrets the fact that for practical reasons the international level of development aid and the influence of major donor-countries and organizations had to be left un-researched.

Van Buuren was involved in (co)supervising the activities of three PhD students in environmental technology. "One of them applied the concept of bioreactors in landfills in Tanzania. By recirculating percolation water, the conversion of organic waste to biogas was critically accelerated. Another one looked at sanitation in slums and schools in Dar es Salaam. The third dedicated himself to waste water processing in different types of neighbourhoods in Kampala (Uganda) and Kisumu (Kenya)."

Even though Van Buuren is thrilled about the concept of modernised mixtures, he maintains that empirical research on the topic as yet is rather descriptive. "Only a few connections were being made with future designs and plans and the ideas that came out of the PROVIDE still

have to find their way into practices of academic teaching, policy making, and consultancy." For these transdisciplinary impacts to materialize, he argues that it is crucial "to maintain the relations that we have established in a short period with universities and some local stakeholders in all three African countries". Only sustained efforts in the middle and long term can make it possible for a concept like 'modernized mixtures' to gain ground in academia and society.

It is against this background that Bas van Vliet very much welcomes the money that funding agency INREF granted the PROVIDE-team for a follow-up project directed at the consolidation and further development of the PROVIDE network in East Africa. As senior researcher at ENP, Van Vliet has been actively involved in PROVIDE both in (co)supervision of PhDs and in preparing publications at the programme level.

He is the first editor of both PROVIDE books that resulted from the program. He is about to leave for Africa again, to visit some of the universities and PhDs that were involved in the program. "We are interested in building shared activities for Bachelor and Master-students in Africa. We think it is important that future students in the field of solid waste and sanitation in Africa get to know the philosophy behind and the empirical results from the PROVIDE project". The fact that a number of PhDs who worked for the project now gained important positions in the African waste- and sanitation systems - for example by heading the waste division within the municipal authority of a capital city - is of course very instrumental for the realization of these aims.

### Box 3 Time and careful planning is vital

Research projects that address complex problems require sufficient time and careful planning in order to create a common ground among the actors involved and to disseminate the findings. PROVIDE serves as a successful example. Team members were recruited early and a number of joint activities were organized careful balancing between Wageningen and Africa based. Moreover, energizing field visits and very successful local conferences were organized to create networks, to share methods and to trigger new ideas. An international conference was organized and two books were published to disseminate the research outcomes. A follow-up research network is in the making aimed at capitalizing on the results of the project.

## Research case 2 Multi-Use Platform Systems

# Cleverly combining the practical functions of the North Sea

Offshore wind farms are expected to take up thousands of square kilometres of the much used North Sea soon. A selection of researchers from different disciplines works on a business case of cultivating seaweeds in between the wind turbines. “We want to develop instruments that allow ecosystems to gain a higher economic value and to be granted more importance in policy decisions.”

MUPS is a funny abbreviation for the somewhat complicated acronym ‘Multi-Use Platform Systems’. “When we started back in 2012, we had to get used to the concept”, says project leader Tinka Murk, professor in eco-toxicology at the chair group of environmental technology and the IMARES (Institute for Marine Resources & Ecosystem Studies). When you say ‘platform’,

people tend to think of oil and gas platforms. “Everyone expected something different”, Sander van der Burg of LEI Wageningen UR agrees. Barely two years later, a wide range of scientific fields is concerned with the issue of utilising space at sea for ecosystem services and new types of aquaculture. Experts in ocean currents and coastal erosion, cultivation specialists, sociologists, bio-based researchers, ecologists, spatial planning experts, cattle transport researchers, and economists are all involved in answering the question, whether the space between wind turbines in the large-scale wind farms in the North Sea is suitable for a profitable and ecologically fitting cultivation of seaweed. “The more concrete the casus, the better the cooperation between the natural and social scientists”, Murk declares.

Seaweed cultivation does not occur in the North Sea yet. Even the free space between the turbines is not the least bit open for use. However, seaweed is an interesting crop that can provide a new dimension for ‘sea cultivation’. Different PhD students are currently working on it. Making use of seaweed from the North Sea for fodder can decrease the import of soy. The dependency on scarce and climate-unfriendly fossil oil will diminish when nutrients in seaweeds can serve as the base for plastics or biofuel production. The researchers also ponder how seaweed cultivation looks like technically. “We are now thinking of open systems with ropes that are bound to a pole, such as the pillars of the wind turbines”, Van den Burg says. “The seaweeds grow on the ropes. Apart from that, we think that mussel farming, and collection of mussel seed in particular, can be combined with seaweed cultivation as well.”

The procedure sounds straightforward, but it is actually a real challenge to create a robust system that can handle the strong currents in the North Sea and raging storms from the south west. A PhD student is currently studying the effects on biodiversity.

“There is more than enough space”, states the economist of LEI. “Calculations showed that there is a thousand square kilometres vacant between the wind turbines. With a conserva-

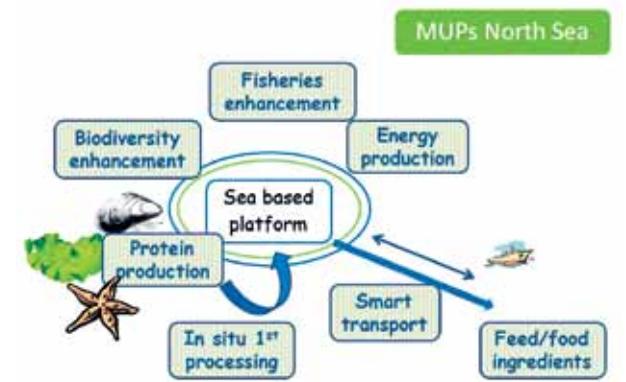


Figure 1: multi-use platform functions.

tive estimate of 20 tonnes (of dry matter) of seaweed per hectare, that could result in two million tonnes of seaweed per year”, Van den Burg says.

Researchers are therefore looking at extraction methods and bio-refineries to discover how high-grade proteins and potential pharmaceutical raw materials can be extracted, after which some matter will remain to serve as fish feed or biofuel. “Seaweed will provide a ‘cocktail’ of products”, according to Van den Burg.

And then there is the aspect of governance. How can the cultivation of seaweed be organised in such a way that marine life will not be harmed and that communities of fishermen,

### Box 4: New sustainable business opportunities

Offshore production of natural resources is often quoted as a sustainable alternative for the dependency on scarce, imported (often non-renewable) resources. The offshore production of seaweed, algae, fish and energy is therefore expected to increase. Wind farms in the North Sea could be transformed into multiple function marine platforms. The private sector is still reluctant to take up these new technologies.

In the TripleP@Sea strategic R&D programme of Wageningen UR natural scientists and social scientists collaborate together and with non-academic stakeholders to assess the feasibility to transform wind farms in the North Sea into multiple function marine platforms. The project aims to inspire researchers, commercial parties, governmental and non-governmental organisation to develop business cases for sustainable entrepreneurship at sea.

Research on seaweed cultivation in aquaria at Wageningen UR.



energy companies, and conservationists will see the benefits? The doctoral research mentioned above, which takes a primarily socio-economic approach, also covers the consequences of the changes in using the sea for the local native population of the arctic Barents Sea. “That is where research is being conducted on the effects of oil and gas drilling that has become possible through the melting of ice shelves. Maritime shipping will also increase and you don’t want an oil tanker disaster in such a vulnerable area”, Murk explains.

In a different project in the Caribbean Sea, people are currently looking at the seemingly conflicting interests of an oil transshipment terminal and its risks of oil spills on the one hand, and touristic and ecological sites such as coral reefs and beaches on the other. “We want to develop a toolbox with which we can assign an economic value to ecosystems and point out the consequences of changes. It can help companies to more clearly define their ‘licence to produce.’” To that end, Tinka Murk, together with other scientists from Wageningen, developed the plan TripleP@Sea for interdisciplinary research a few

years ago through a survey and a workshop. Triple P is the sacred trinity of sustainable entrepreneurship: people, planet, profit. “I wanted to establish a movement of how we can use different disciplines to map out both the natural science aspects as well as the social science aspects of ecosystem services. The P for profit always seems to be the third wheel and it has the image of being in conflict with planet. Instead of protecting the environment and nature with prohibitions and rules, we want to develop tools that really make economic optimisation count in policy decisions, besides ecological interests”, Murk explains.

Within the WUR, many chair groups and research institutes already work on optimising marine ecosystem services and governance. “As a result of the joining of forces, we can be really proud of this. Besides, we don’t want this to be a Wageningen-only party. Institutes that are not from Wageningen, such as Deltares, NIOZ, and TNO, can also join”, Murk says. “Deltares possesses a lot of specific knowledge concerning ocean currents and coastal erosion”, Sander van den Burg adds. “TNO knows how to

make risk assessments, for example regarding possible damage on cultivation systems during a storm in the North Sea. By involving them, we are jointly drawing on various information networks and commercial contacts, which improve the business case and the chances for export.” The bar is set high. “We will have failed if we, after 2016 – at the end of the current project – have not gotten more PhD students to work in this field, have not demonstrated the proof of principle of seaweed cultivation, and have not involved more commercial parties and their investments in MUPS”, Murk says, ambitiously. It is great to see how participating researchers from the different science groups that initially did not know each other well now understand the added value of the other disciplines. They now know how to find each other for new research initiatives and education. “That is the most important gain of the program. Not the temporary investment in research projects, but investment in this new network of disciplines.” The attitude of stakeholders so far is apprehensive, the researchers observe. “Even though the fishing industry gets less and less access to the sea because of wind farms and crowded shipping routes, fishermen still don’t show a lot of interest for seaweed cultivation”, Van den Burg says. It is different for mussel farmers. They are open to alternative methods of mussel seed collection.

The energy companies are also still playing the wait and see game. Of course, they do not want one of their maintenance ships that cost tens of thousands of euros per day to get entangled in ropes full of seaweeds. But the tide is changing. “Businesses and corporations are more open now and advisors of energy companies see opportunities to generate additional revenue whilst undertaking enterprises in a socially responsible manner”, Van den Burg says. One of the options that can be investigated is using maintenance ships during the harvest of seaweed.

The NGO North Sea Foundation (Dutch: Stichting Noordzee) is for the time being “not dismissive” of MUPS. “They are mostly charmed by the idea that the seaweed might take up nutrients such as nitrogen and phosphate. The fertilisers come from the mouth of the big rivers at Rotterdam and are carried to the North Sea by the currents”, Van den Burg explains. This cycle is also being studied at the moment.

The role of the government is still modest. The Ministry of Economic Affairs is waiting for more support from the private sector. Rijkswaterstaat and the Ministry of Infrastructure and the Environment also keep quiet. “Of course, in a period where the government doesn’t have much financial leeway, it’s better to look for financial support for new developments in the market”, Tinka Murk says. “Therefore, we are working on the business cases at full power with all scientific disciplines.”

### Box 5 New networks for research and education

The TripleP@Sea programme illustrates how a complex and practical problem brought together scientists from many different disciplines that did not know each other beforehand. These scientists experienced that working together on a contemporary issue in an interdisciplinary setting can be very rewarding. They experienced that a practical problem triggers many new and challenging research questions, both disciplinary and interdisciplinary. This experience will feed back into their future research and education.

## Research case 3

# Economic modelling for coping with scarce, brackish water<sup>2</sup>

The allocation of scarce water on increasingly saline soils is known to cause problems with cultivating crops. Ecohydrologists and agricultural economists from Wageningen University are combining their disciplines in a model that provides insights into how farmers can achieve the highest yield per litre of water. The model is designed to become a web tool for water authorities and farmers to better manage supply and use of scarce water for irrigation.

What happens when an ecohydrologist, a soil physicist, an agricultural hydrologist, and an environmental economist work together on a model that simulates the allocation of scarce water between farmers? “In the beginning, it took some time to understand each other. We needed to connect physical factors such as soil composition and salinity of water to economic notions and theories about scarcity and allocation: we

use different languages”, says Sjoerd van der Zee of the chair group of soil physics and land management. “At the same time, economists like soil physicists often have to work with quantitative models, so interdisciplinary cooperation in this field is easier than, for example, in fields such as biodiversity or landscape conservation”, says Hans Peter Weikard of the chair group of environmental economics.

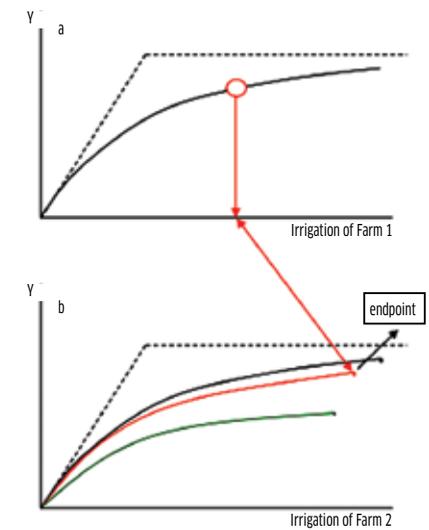
“Besides, these guys are very good at math, so you could say that we very quickly started speaking the common language of mathematics”, Weikard says. It also helps that all four scientists are open-minded. Additionally, Weikard has some basic knowledge of the natural sciences. “During my agricultural sciences studies at the University of Göttingen, I took all agriculture-related courses such as pedology and hydrology in the first two years. Only later, I began to dedicate myself to agricultural economics.”

Van der Zee and Weikard, both with broad-ranging interests, have worked together with Israeli guest researcher Alon Ben-Gal and Pakistani PhD student Hamid Shah on a highly contemporary issue. How to distribute the scarce water of a river fairly among farmers living in the floodplain, not letting everyone have their way, but by achieving ‘more crop per drop’ for all? Moreover, by finding ways to reduce upstream water usage the downstream parts can also be supplied with sufficient quantities of water with less salt.

“One problem in this scenario is that the salt also accumulates in the soil, which affects the harvest”, Van der Zee explains. “Farmers who live upstream have more opportunities to flush the salt out of the soil with water from the river than farmers who live downstream. Those downstream farmers actually have a systematic need for more water for irrigation because of all the salt in the irrigation water that their colleagues upstream have flushed out.”

The problem of salinization and water scarcity is present in many semi-arid regions, such as the south of North America, Mexico, countries in and around the Sahara, parts of China and Central Asia, central South America, and parts of Australia. Precipitation is low, usually much less than 500 millimetres (500 litres per square meter) per year, or precipitation only occurs in a short wet season. “The rivers that spring from the mountains initially supply water of high quality, but that quality decreases downstream because flushed-out salt flows into the river through groundwater flow”, Van der Zee explains. “On the other hand, soils downstream are often more salty and therefore more fertile, than upstream soils”, Weikard adds.

In their model, the researchers have so far worked with just two farmers who have to share water to irrigate one crop (bell peppers). “The harvest details and data come from a field study of Ben-Gal in Israel”, Weikard says. “So the model is a real function of production.”



**Figure 2: Production curves for (a) Farm 1 and (b) Farm 2.** Simulation of a sequential system with two farms. Decision of Farm 1 (use of irrigation water of given quality) dictates production possibilities for Farm 2. Horizontal axis in each frame is irrigation of the respective farm. Vertical axis is relative yield  $Y$ . Different lines in Figure 2b are examples of response curves for Farm 2 based on possible decisions made by Farm 1. This is the figure caption of Figure 2 of the paper by Ben-Gal et al., 2013.



Research of the production of Bell peppers at Gilat Research Center, Israel. Photo Alon Ben-Gal.

<sup>2</sup> Ben-Gal, A., H.-P. Weikard, S.H.H. Shah, and S.E.A.T.M. van der Zee (2013). A coupled agronomic-economic model to consider allocation of brackish irrigation water, *Water Resources Research*, 49, doi:10.1002/wrcr.20258.



Water and salinity trials on bell pepper grown in Israel's Arava Valley used for model calibration. Photo Alon Ben-Gal.

Van der Zee: "Because of the non-linear characteristics of the model, we struggled but were finally able to derive the optimal water distribution, so the highest yield for farmer A and farmer B together", according to Van der Zee. "In other words, we have calculated the highest yield per litre of water." The article on this multidisciplinary model was published in 2013 in the leading journal *Water Resources Research*. This optimisation is useful for a government or a water authority such as a water board. Of course in the reality of a complete river basin, there are not just two but hundreds to thousands of farmers. "And all of them cultivate different kinds of crops, or they use crop rotation schemes", Weikard points out. "And a relatively long river has different soil types along its banks, which is the case with the Colorado River that runs longer than 2,000 kilometres in the southwest of the

United States where downstream enrichment of salts is an issue", Van der Zee adds. To extend the current model with these different parameters and to that larger scale is not that complicated and would be an interesting follow-up research within WIMEK with high added value. After that, sheer computing power is needed to come to a practical water distribution plan for all farmers along the river. "And in that process, we have to take it one step further with multidisciplinary work", Hans Peter Weikard says. "To simulate the issue of distribution well, we will have to cooperate with research experts in the field of operational management and logistics." The researchers will also have to consult with people who work with Geographic Information Systems (GIS) about the application of the model to be able to produce maps of distribution of water for any river and soil type pos-

sible. And of course, there should not be a lack of programmers and web tool experts to make attractive software for easy use by managers and farmers in agricultural practice. "It will be a time-consuming job, but it is definitely feasible", Weikard says.

"We can indeed do it, but unfortunately we have to move to a next project", Sjoerd van der Zee mentions. A model like this is certainly useful for everyday management, the ecohydrologist thinks. The model can also include long term climate changing precipitation patterns. "Rivers can slowly dry up, or flood their banks more and more. We can also incorporate that into the model."

We can perform important scenario experiments with it, Weikard says. "The model uses game theory elements and thus provides the opportunity to imitate negotiation situations. A water authority, for instance, can implement a water legislation measure that gives more rights regarding the use of water downstream than upstream. Farmers that work upstream can also capitalise their rights by selling them to their downstream counterparts."

Van der Zee: "The agro-economic analysis is, for example, able to show that the crop yield of the last one hundred farmers downstream is too little to establish economic viable farming. Based on that, the water authority can shift the allocation of water more towards these downstream farmers making their business also profitable", the ecohydrologist says. "As an alternative, a water authority can also calculate that it may be more profitable to teach the farmer to cultivate more salt-tolerant crops."

Salt-tolerant crop farming is by far past the stage of being practiced only by hobby farmers who experiment with Samphire or sea-lavender, Van der Zee asserts. "I've seen the production figures of experiments with chrysanthemum, a plant that is often considered to be relatively sensitive to salinity. These plants bloomed whilst being watered with seawater that was diluted five times. Other common plants and crops can be reasonably salt-tolerant as well, or they can have tolerant cultivars. Changing parameter values, we make the model applicable for this kind of data, people that are living close to the sea in deltas can also make use of it."

### Box 6 A common language

Interdisciplinary research is highly facilitated when a common language is available among the researchers who participate in a project. In the development of an agro-economic model for brackish water, mathematics and modelling provided such a common language, and facilitated building bridges between economics and physical sciences in particular. More in general, systems analytical tools, such as scenario's and models of all kinds facilitate multi- and interdisciplinary work.

## Research case 4 New Sanitation in Sneek

# Community- on-site resource recovery from toilet wastes

Processing faeces and urine (Black Water = BW) close to the source – just past the toilet bowl – has the future, even in The Netherlands, one of the best countries in the world when it comes to sewerage. 'New sanitation' provides energy and precious minerals such as nitrogen and phosphorus from BW, collected with minimal ( $\leq 1$  litre/flush) water.

"When you want to set up a trans-disciplinary research project, you shouldn't just pick a partner, but you have to very consciously search for people who want to think along in developing the concept", says professor Grietje Zeeman of the chair group of Environmental Technology. Zeeman was a prominent figure in devising the complex topic of 'new sanitation'. Complex, since

it is not just difficult on a technological level, but also particularly complicated because it goes against conventional methods. Faeces and urine have for a long time been flushed with large amounts of water to the sewers. Though hygienic and comfortable this costs a lot of water and leads to tremendous dilution. The subsequent water treatment therefore costs a great deal of energy and chemicals.

In the vision of Zeeman, BW should be directly fermented into biogas, and minerals (N, P) should be recovered – all on-site, close to home, without wasting water, but still preserving comfort and hygiene. To initiate more practical research to this new type of sanitation, Zeeman contacted environmental policy scientists, water technologists of Wetsus, and the knowledge

### Box 7 Collaboration with key stakeholders

The implementation of innovative technologies such as a new sanitation system can only be successful when technologists collaborate closely with social scientists and local stakeholders. The success of the new sanitation project in Sneek was the result of the involvement of relevant and committed stakeholders from the start. The municipality, two housing cooperations, the water board, and water companies were willing to contribute to the project and think along with the scientists. Social scientists were indispensable to investigate the behaviour of the residents and their acceptance of the innovative technology. This collaboration made it possible to develop a novel technology that fitted the local circumstances.

centre of regional water managers, STOWA (Foundation for Applied Research in Water Management, or Stichting Toegepast Onderzoek Waterbeheer in Dutch). She got in touch with toilet bowl manufacturers and water board employees. Particularly the municipality of Sneek, the small housing associations De Wieren and Patrimonium, and the company Landustrie showed enthusiasm. Initially, the municipality of Wageningen seemed to be a logical option for a partner, but that turned out to be like beating a dead horse, according to Zeeman. She did receive an attractive, long-lasting subsidy of economy, ecology and technology from the Ministry of Economic Affairs to support the experiment financially. Also STOWA supported the initiative.

From 2001 on, tests were performed in the laboratory. "From these tests, we arrived at the appealing concept of anaerobic treatment of BW in a UASB reactor." This invention, typical of Wageningen, by Gatze Lettinga from the seventies of the last century produces a liquid with the minerals (nitrogen and phosphorus), a solid with the remaining organic matter, and the energy-rich biogas. The liquid that is rich in minerals is used for the production of an artificial fertiliser, such as the phosphate mineral struvite. Ammonia is currently being converted to harmless gaseous nitrogen that escapes into the air. "We are working on techniques to also retrieve this nitrogen for fertilisers." Meanwhile, a PhD student in the Environmental



Figure 3: 3D-representation of Novel Sanitation in Sneek, Noorderhoek (left panel). The facility treating source separated streams and producing clean water, biogas, electricity, and phosphorous solids, is placed in one central building (right panel) to which the 232 houses are connected.

Policy group was conducting research on the involvement of the residents regarding this new type of sanitation. This research also concerned similar projects in Germany and Sweden. Eventually, the municipality of Sneek was willing to apply a demonstration project in a neighbourhood of 32 houses in 2006. “The municipality and the housing association assigned the houses to an arbitrary group of people that had to move because of the construction of a new road. They said ‘if it will work here, then it will work everywhere’. They communicated that the only difference would be that they would have a toilet that looks like one in an airplane or a cruise ship.”



The UASB reactor for the treatment of black water from 32 households is placed in a garage. Photo: Brendo Meulman.

Sneek was also prepared to do a second demonstration project, but this time in a neighbourhood with 250 houses. In November 2011, the former prince and current king Willem-Alexander opened a block of flats containing sixty housing units including a nursing home in the Waterschoon quarter.

When the economic crisis abates, the entire neighbourhood, including single-family houses, will be build and receive vacuum toilets and kitchen grinders connected to the treatment unit. In the meantime, the ecological research institute NIOO in Wageningen and the Floriade building, Villa Flora, in Venlo also included this ‘new sanitation’ concept.

At the end of 2012, environmental policy researcher Bas van Vliet conducted a survey concerning the first impressions and experiences of the residents of the new building in Sneek. “The people first had to get used to it, but they are satisfied now. It makes them feel good to think that they are helping the environment”, Van Vliet says.

The residents are also pleased with the grinder which brings organic waste in the sink straight to the anaerobic treatment. “They think it’s mighty convenient”, Van Vliet says. It is a fine example of how social and physical aspects can go hand in hand. “Because it’s also favourable for the technical side of the process”, Grietje Zeeman says. “The organic matter from the kitchen increases the production of biogas from the toilets.”

The enquiries of Van Vliet also portrayed a point of criticism. “Both the toilets and the grinder are noisy. Especially the ‘flushing’ of the toilet comes with a loud bang”, Van Vliet reports. He talks about people who did not dare to flush at night. And what to think of the story of a woman who first placed her winter coat over the toilet before flushing? Nonetheless, noise complaints have decreased.

All the same, Van Vliet believes that the new sanitation has a great potential. “Energy produc-

tion from faecal matter can be applied in the neighbourhood itself. And phosphorus is likely to be the first mineral that we really run out of. Mankind therefore has to rely on recycling”, according to Van Vliet. He recommends to also involve the agricultural sector. “Instead of asking them what they can do with this product, we have to ask them ‘what type of product should we make for you’.”

The debate on whether to separate materials at the source (the vacuum toilet) or at the ‘end of the pipe’ (the sewage treatment plant) will continue for some time, Van Vliet says. “For the time being, it is important that these small-scale projects are expanded into sample projects and that new sanitation eventually becomes an option in the building code. Only then, you will be a considerable participant.”

Brendo Meulman, who is actively involved in many parts of the new sanitation in Sneek, shares this opinion. Meulman is the director of the company Desah, he is considering getting a PhD in this field at the University of Wageningen, and, remarkably, Meulman is a resident of the first sample project in Sneek.

He even sacrificed his garage voluntarily, to make space for the treatment plant of the entire neighbourhood where after the first year not only BW but also grey water (from, amongst

others, shower, laundry, and kitchen) was treated. Meulman is a man with a mission. “Every sewer that is currently being renovated or replaced can operate for sixty years. It is foolish to be pinned down for such a long time, because it hinders innovation.

According to Meulman, a small percentage of the total replacement value of 63 billion euro worth of underground sewer pipes can be applied disconnect the entire city of Sneek (with 30 thousand inhabitants) from the sewers. “We would have a real, large-scale experiment in which we can monitor the technology as well as the behaviour and acceptance of residents. I think that we would work on an exemplary project with a reputation like the Afsluitdijk. When we built the Afsluitdijk in 1932, we didn’t have the faintest clue that we would still proudly show it to tourists.”

Meulman thinks that the new sanitation is completed on a technological level. “With all due respect, Grietje Zeeman’s role will decrease in the future, even though every little increase in yield owing to a better functioning anaerobic treatment process is a bonus. The re-use of especially nitrogen can also still improve.” He agrees with Van Vliet that the biggest part of the research lies in creating a business case. “Economists, legal experts, and communication

## Box 8 Transition strategy

‘New Sanitation’ requires new infrastructure. The Netherlands and other industrialized countries are characterized by a high density sewer network connected to municipal wastewater treatment, representing a high monetary value. A gradual replacement is the only feasible way to introduce ‘New Sanitation’ at a larger scale. The development of a transition strategy is required.

## Box 9 Transdisciplinary skills

Scientists involved in transdisciplinary projects require different skills than those who conduct curiosity driven research. The former should be able to use different sources of knowledge. Moreover, they might need to act as a facilitators who help to frame researchable questions and to identify key stakeholders, vital expertise and new approaches.

specialists will have to wrap up the project. When an iconic project such as this has been realised, a market can develop which lowers the costs of the new sanitation.”

Housing association De Wieren immediately saw opportunities in the sample projects. “Being a small participant, we could easily join the demonstration projects. We react quickly and flexibly”, director Henk Heikema van der Kloet says. “We believe in innovation and we would like to serve as guinea pigs.” In the future, he would like to see the project become economically profitable and the planning between the parties improve. “The sewers or the vacuum piping is the municipality’s business, the water board is in charge of the water treatment, and the house owner is responsible for indoor participation. In Sneek, we have gained experience to be able to work together for the first time.”

Grietje Zeeman thinks that both the old as the new sanitation should co-exist for the time being. “I would like to appoint a ‘multidisciplinary PhD student’ to study the factors that determine whether sewage treatment or ‘new sanitation’ is more favourable. Such a ‘transition PhD’ could look at technological developments as well as the economy, social processes, and organisational issues concerning the municipality, the water board, and the housing market.”

## Research case 5

# Less resilience near tipping points of ecosystems

**World fame has accrued to the research group of Marten Scheffer. These ecologists developed a model with which seemingly sudden changes in ecosystems could be described. The group is currently working on refinement of the model. “We would be able to create a type of ‘early warning systems’ and possibly take preventative measures to avoid worse situations.” Remarkably, economists use the model as well, to explain the financial crisis, for example.**

It started with research on shallow lakes. “During the nineties of the last century, we saw that Dutch lakes, such as those around the IJsselmeer, became turbid because of algae and slit particles”, Egbert van Nes recalls. According to well-known theory, the aquatic ecologist knew that this green soup was caused by eutrophication, the ever increasing concentration of nitrogen and phosphate in water. The upwelling of silt particles from the bottom of the lake caused by a strong western wind and fish in the lake contributed to making the lake turbid.

Besides trying to decrease the fertiliser and silt contents, active biological management was also attempted, Van Nes says. “By catching fish such as bream from these lakes, there is less upwelling of silt, aquatic plants get a chance on recovery, and there will be clear water again.” Van Nes together with theoretical ecologist Marten Scheffer found that in some cases the water became clear again, but there were also lakes that returned to the deplorable state of turbid water. However, the researchers discovered something far more important. The water clarity and the concentration of fertilisers do not show a linear and reversible relation. “That means that to get the clear water back, we will always have to lower the concentration of nitrogen and phosphate below the original tipping point at which the water turned turbid.” This longer and often reversed pathway is also called hysteresis. In fact, hysteresis forms an argument for the precautionary principle that is often adopted in environmental policy. After all, it is better to prevent environmental harm because recovery

**A healthy and clear lake.**  
Photo Egbert van Nes.

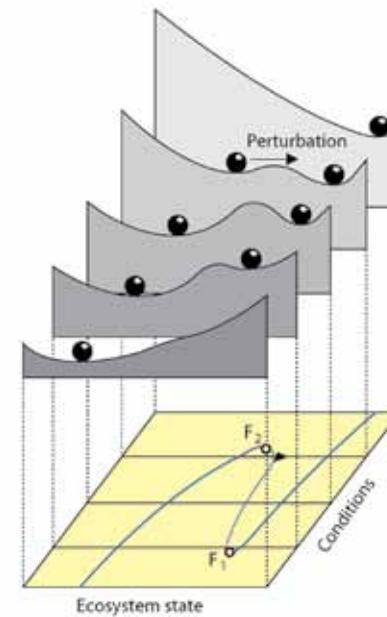


**A turbid lake.**  
Photo Miquel Lürling.



is always more difficult and more expensive. With the measured contents in the shallow lakes, Scheffer and Van Nes built a mathematical model, a characteristic zigzag-curve (see figure). 'Tipping points' quickly became the name of the model. It was published in *Nature* in 2001<sup>3</sup> and it has been cited many times. That was the start of world fame. Because, for the first time, it became clear that ecosystems could resist disturbances and stress factors for a long time, but after a while, they would lose their resilience and their buffer capacity. Subsequently, a new state would arise. "As the tipping

point is being approached, the resilience decreases and the recovery of small disturbances would slow down infinitely. This idea is not new in mathematical models," Van Nes says. The application on ecosystems, on the other hand, is new. The model of these aquatic ecologists from Wageningen also attracted the attention of economists and social scientists. "In the fifties of the last century, the Nile Perch was released in Lake Victoria in Africa", Van Nes recounts. For thirty years, everything was fine, until the fish population exploded in the eighties. "Besides the ecosystem and all its features,



**Figure 4: External conditions affect the resilience of multiple stable systems to perturbation.** The bottom plane shows the equilibrium curve. The stability landscapes depict the equilibria and their basins of attraction at five different conditions. Stable equilibria correspond to valleys; the unstable middle section of the folded equilibrium curve corresponds to hill tops. If the size of the basin of attraction is small, resilience is small, and even a moderate perturbation may bring the system into the alternative basin of attraction (Scheffer, 2001 & 2009).

socio-economic and cultural aspects also play a role here, such as the method of fishing and the differences in fishing cultures between Tanzania, Kenya, and Rwanda that all make use of the lake." The model that was created in Wageningen appeared to be useful for explaining a range of other tipping points. Examples include coral reefs that suddenly collapse due to algal bloom and the abruptly decreasing carbonic acid concentrations found in age-old drilling cores. At present, the model is used to investigate the consequences of melting ice caps and thawing

permafrost and to follow the recovery of tropical rainforests. "We are looking for a way to predict these tipping points with the model", Van Nes says. "We would be able to create a kind of early warning system with the model and take preventative measures to avoid worsening." A bit down the road, in the beautiful building of the Environmental Sciences Group, plant ecologist Milena Holmgren explains how she applies the tipping point theory. Holmgren studies the way plant communities in terrestrial systems respond to disturbances. "We are interested in how plants react to a short period of extreme climatic circumstances", she says. "Think of rainfall in a usually arid region, drought in a tropical rainforest, or hot summers in boreal forests. The effects of the temporary climate changes are influenced by other disturbances such as grazing and forest fires", Holmgren says. Experiments and observations in the field, satellite images, historical data, and statistics make up her toolbox.

As a result of a series of disturbances, vegetation can cross a tipping point and reach a new state. "It concerns, for example, animals that have grazed to such an extent that only solitary trees remain. Or the other way around, grass and trees that after years of drought and a sudden, long period of rainfall start growing very rapidly."

In Chile, in South America, Holmgren demonstrated that the fast-growing and deep-rooting trees of the flowering *Prosopis* genus, roots successfully after a wet El Niño period. "The trees persisted, even when the drought returned." This model could possibly lead to successful replanting of deserts or regions that are threatened by global climate change to undergo desertification, Holmgren says hopefully.

#### **Financial crisis**

It is intriguing that the model of tipping points is also applied outside of aquatic ecology and vegetation science. The tipping point model from Wageningen is used by socio-economic

<sup>3</sup> Catastrophic shifts in ecosystems; Scheffer, M., Carpenter, S., Foley, J.A., Folke, C., Walker, B. (2001) *Nature* 413 (2001)6856. - ISSN 0028-0836 - p. 591 - 596.

and anthropological scientists that follow the financial crisis of 2008, study revolutions in different Arab countries (the Arab Spring of 2011 in particular), or investigate the dot-com bubble at the stock markets in 2000. These are all sudden shifts that occur because a system is slowly losing resilience due to continuously returning stress factors, such as persistent consumer distrust, uninterrupted sale of bad mortgages, or the constantly growing aversion to corrupt political leaders or to leaders of a different religion.

One of these tipping point researchers is Cars Hommes, professor of Economic Dynamics at the University of Amsterdam. Inspired by the tipping point model from Wageningen, Hommes started modelling to try to construct 'irrational behaviour of man'. "Similar to the ecosystems that Scheffer and his co-workers are investigating, the resilience of an increasingly burdened economic system decreases", Hommes says. A couple of bad mortgages can be taken on by a bank, but when all banks start imitating each other, the financial system may collapse.

Hommes repeated a laboratory experiment dozens of times with a group of students to predict the share prices of stocks. "The intriguing thing is that next to looking at rational developments on the market and having a plain aim for profit maximisation, after a while the students start to pay more attention to each other and display erratic behaviour that is not related to economic rationality at all", according to the economist. The nice thing is that this capriciousness and the non-linear relations still show coherence as well, which can be recorded in a complex model as is shown in Hommes' research that was presented to De Nederlandse Bank last year. "Besides the rational paradigm, there is an increasing interest in irrational, or rather 'restricted rational' behaviour", Hommes asserts. "This is fortunate, since many market predictions only consider rational behaviour and they are usually incorrect. When people are insecure, they start to

copy each other's behaviour and, for example, sell their shares en masse. The influence of psychology, communication, and international networks, such as the worldwide microcosm of stockbrokers that trust each other, should be considered to be much more important. And we should also collect much more data, like climate scientists do", says Hommes, who to that end also looks at the stock market crashes of 1929, 1987, and the current banking crisis.

Just as the research group in Wageningen is searching for early warning systems in climate and ecosystems, the economist from Amsterdam is working on predictions and better management for economic crises. "We will have progressed a lot in ten years from now."

#### Spinoza and migraines

At least as intriguing as the multidisciplinary cooperation between the researchers from Wageningen and the economists from Amsterdam, is the cooperation between three recipients of the Spinoza prize. In 2009, Marten Scheffer received this 'Dutch Nobel Prize' for the tipping points theory. Together with the two other winners, neurologist Michel Ferrari and physicist Albert van den Berg, Scheffer conducts research on migraines, which is actually the field of research of Ferrari. Migraines can also be seen as phenomena where a tipping point is reached in the end. It is the first time that recipients of the Spinoza prize collaborate on collective research.

In a recently published paper, the three researchers argue that a migraine attack is preceded by a gradual increase in excitement of neurons in the brain. "This process continues until a point is reached where a very minor change, such as a pulse of light, can induce a 'release'", according to Marten Scheffer, who is hoping to be able to improve predictions of this critical tipping point with the two other researchers in follow-up studies.

## Edu-case 1 Environmental Quality & Governance

# Teaching and learning to cope with uncertainties and conflicting interests

**A course involving an environmental toxicologist and water chemist may seem like a nice fit, but what happens when you put environmental sociology and public administration in the mix? That has been an on-going challenge since the Environmental Policy Group-led interdisciplinary course Environmental Quality and Governance was first given at Wageningen University in 2008. The course revolves around an interdisciplinary approach to risk assessment and management - together called risk governance.**

'The well-done toxic bomb'. Last week, another one of those typical insinuating articles about

the Panga fish was published in a newspaper. Phrases such as 'filled with heavy metals', 'the filthiest river of Asia', and 'large-scale aquaculture' with 'antibiotics' and 'slave labour' can make Simon Bush extremely frustrated. "It's almost one hundred per cent nonsense", says the Environmental Policy scientist.

The Panga (pangasius, *Pterogymnus laniarius*) of Vietnam has a miserable reputation. Bush: "It is correct to say that the Mekong River is not the cleanest river on Earth, that the sediment contains heavy metals, and that part of the fish farms use antibiotics. There is, however, no research that proves that these substances are

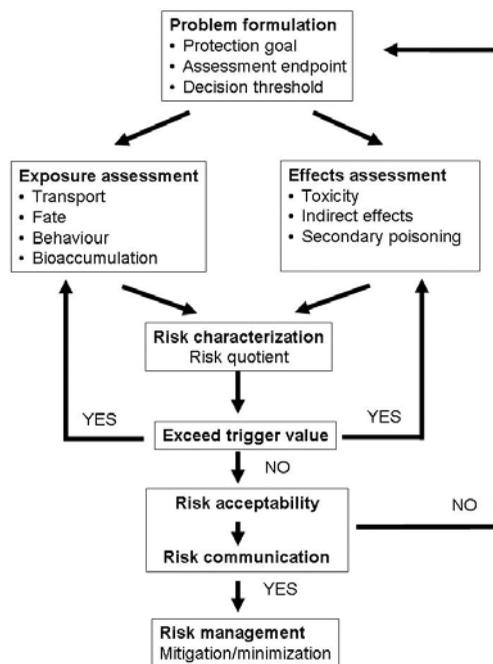


Figure 5: Risk assessment model.

present in this fish in dangerous quantities.” Then how is it possible that the European Parliament, the World Wide Fund for Nature, and eel fishers denounce the Panga, and that journalists speak of ‘toxic bombs’? “That is because the potential hazard of these substances are confused with the actual risk”, Bush responds. Toxicologist Tinka Murk of Environmental Technology also marvels at this ignorance: “A shark is highly dangerous, but if you stay on the beach, the risk that it will attack you is non-existent.” This is the type of reasoning Murk teaches her students. To this end Murk’s students have to calculate ‘how much of a fish needs to be consumed to reach the maximum daily intake standard’. “For eel from the Biesbosch, the maximum daily intake is less than 150 grams due to exposure to primarily dioxin-like micro-pollutants. The ban on eel-fishing in the Biesbosch is therefore justified. For Panga, one would have to eat dozens of kilos to exceed the safety standard. Consuming such quantities

will cause other problems”, Murk asserts. The bad image of the Panga involves conflicting interests, according to Bush and Murk. “The potential dangers are used in improper argumentation to influence policy”, they say. The arguments might come from an NGO that wants a cleaner river, an eel fisher whose reproach of Panga comes from self-interest, or the gut instinct of a lazy journalist. Making students aware of the Panga affair is the start of the course Environmental Quality and Governance. In the first week of this course students learn through a series of lectures about indicators of environmental quality, risk assessments, risk management, and the involvement of society. A key theme running through this course is whether and how different scientific perspectives contribute to a shared understanding of a complex environmental problem. The first week of lectures is followed by two weeks of lab based practical. Students analyse water samples and interpret the results. They gain experience with exposure and effect assessments. Murk: “The social science students are impressed by the pipetting and worry about calculating concentrations.” Next is the undisputed highlight of the course. For two weeks, students participate in a role-play simulating the situation in Rotterdam Harbour, where Common Tern eggs have stopped hatching, possibly because of the dumping of pollution. Together, the students play up to fifteen different roles including directors of the port and of the municipality, toxicologists of the chemical industry, and experts of Rijkswaterstaat (part of the Dutch ministry of Infrastructure and the Environment that relates to water management). Moreover, a trade union is present; an environmental organisation is actively engaged, as well as journalists who write newspaper articles. “It is a great pleasure to see how dedicated the students are and how they identify with their roles”, Murk says. She recounts a student who

diligently played the role of the toxicologist from the chemical industry and meticulously used uncertainties to sway opinions. “She casted doubts amongst everybody and was therefore able to persuade the decision-makers to refrain from taking measures. Afterwards, she came to me and said ‘I’m astonished, because I was only bluffing.’” “The simulation engages students in a form of experiential learning”, Bush says. “Students take on real life roles to solve a so called ‘wicked’ problem with high degrees of uncertainty and poor levels of information. It enables them to learn about values, interests and strategies of different stakeholders involved in policy processes around risk identification, definition, acceptance and management. It is exceptionally valuable to pass this knowledge on to students”, he adds. Sylvia Karlsson-Vinkhuyzen of the Public Administration and Policy Group is also involved in the course. Before she dedicated herself to the science of public administration, she studied biology and ecotoxicology. “The simulation game of the polluted sediment in Rotterdam Harbour ends differently every time. It shows that there is not just one individual in control of decision-making, but that there is a dynamic interaction between changeable and changing opinions influenced by many uncertainties”, she explains. “Look, natural scientists are also not sure why those birds die right now.” And she continues: “Because of the Internet and new social media,

the amount of ‘noise’ has increased and many opinions and assumptions are presented as facts without any scientific proof. This has complicated the role of scientists. Students have to be aware of that. They should learn about the importance of how to communicate the results of a risk investigation. Scientists have to be trustworthy and transparent. The nice thing about teaching this course is making in particular the natural science oriented students aware of the broad context of conflicting interests that their research might end up in.” “At first the group of natural science students has often little interest in the social science aspect of the course, but after sensing how uncertainties can be dealt with and how decisions can be manipulated, social science suddenly starts to make sense”, Murk says. “What has taken me years to find out through trial and error, these students can learn in a few weeks.” Karlsson-Vinkhuyzen emphasises that the Panga affair as well and the dumping of pollution in Rotterdam Harbour are examples of what happens everywhere in the world. “Wherever the student comes from, or wherever he will be employed, it is important that he is aware of how information about environmental hazardous substances is processed in a society with a great number of actors, interests, and networks.” As professor in water and sediment quality Bart Koelmans has worked together with toxicologists and water technicians for years. He is also

### Box 11 Interdisciplinary teaching and learning

Developing an inspiring interdisciplinary course is complicated in particular when the target group consists of students with a diverse disciplinary background. Natural science students usually have only limited interest in social science and vice versa. Finding the right entrance level for such a miscellaneous group and at the same time ensuring sufficient disciplinary depth is challenging. In the course Environmental Quality and Governance students are enthused by a combination of a well-chosen, timely and interdisciplinary topic, challenging and active teaching and learning methods and a team of dedicated and inspiring lecturers who are willing and able to cross disciplinary boundaries themselves.



Not only scientific, but also negotiation skills matter.

Photo Tinka Murk.

one of the lecturers of the course. “It took me some time to get used to teaching social science students. They are often less interested in the practicals and exercises I use in my education. It is quite a challenge to draw their attention and to arouse their interest in the natural science aspects of an issue such as developing an understanding of the intake of hazardous substances by birds and fish, or how those substances accumulate,” he explains. Whenever he can, he tries to start a debate. “I tell them, for instance, that polluted sediments in the port can be excavated, but I also point out relatively new insights such as adding activated carbon to the pollutants. In time, much of the pollutants become less dangerous because of aging processes, but activated carbon stimulates those processes by sucking the pollutants out of the silt, so to speak.”

Just like the other three lecturers, Koelmans also considers the role-play the highlight of the *Environmental Quality and Governance* course. “It is enjoyable to see how the social scientists make students aware of the broader context of risk identification and the importance of communicating research results. I believe it is very good that students gain insights in, for example, the role of the media in a risk-aware society and

how public’s fears take part in it.”

Koelmans thinks it is a great achievement that students receive this information through attractive casuistry and that they are able to actively participate. “We didn’t have that when I was studying environmental chemistry in Utrecht.”

The success of the *Environmental Quality and Governance* course is exemplified by its growth. The course was originally designed for a small group of 25 students enrolled in the MSc Management of Marine Ecosystems. Within five years it became a compulsory course for both the MSc Environmental Sciences and MSc Aquaculture and Marine Resource Management, accommodating around 180 students per year. Moreover there are other unexpected outcomes of this course. Not only have the lecturers engaged in joint teaching, but having learned about the different scientific approaches themselves they also started to develop student research projects and larger interdisciplinary research proposals together. This collaboration feeds back into the classroom, and strengthens the communication and coordination within the two master programmes as a whole.

## Edu-case 2 The European Workshop

# Students practice inter- and transdisciplinary research in an intercultural setting

**Each year several groups of thirty students collaborate to investigate a sustainability issue somewhere in Europe. In the European Workshop they practise interdisciplinary and sometimes even transdisciplinary research.**

“I was studying meteorology in Greece when I heard some good stories about Wageningen University. I was not at all expecting what it turned out to be.” Dimitra Kalosynaki (25) had only received ‘strict education’ in her homeland: physics formulas written on a blackboard with chalk. She just returned from the so called ‘European Workshop’ in Budapest and she’s really thrilled.

“It was very exciting”, she says. “A complex environmental problem, dealing with sustainable mobility in the inner city, discussed in a group of thirty students from eleven countries and a lot of stakeholders from Hungary. It was such an interactive experience.”

Audrey Legat (23) already obtained her master in international relations. She shows the same enthusiasm as Kalosynaki. “We did some very interesting fieldwork in Norway with a group of very motivated students. We investigated various opportunities to reinvigorate a coastal area through the development of aquaculture, wind energy and tourism”, she explains.

Kalosynaki and Legat are two randomly chosen students in their first year of the MSc programme Environmental Sciences at Wageningen University. They have just finished the 2013-edition of the European Workshop. “We developed the didactic model ourselves”, Karen Fortuin from the Environmental Systems Analysis group and coordinator of the workshop, clarifies. “This eight-week course trains students to do problem-oriented research in an interdisciplinary and intercultural setting. From 2007 to 2013 we trained about seventeen groups of thirty students.”

In these eight weeks students work on a consultancy project somewhere in Europe. “They integrate their knowledge and skills in practice and acquire new skills”, Fortuin explains. “They analyse the current situation using different disciplinary theories and methodologies and formulate recommendations for a commissioner. Lecturers from various chair groups facilitate the students during the workshop.”

Several subjects have been investigated in the past. Students went to Prague to study the sustainable development of brown fields (abandoned industrial sites) in the city centre. Another year they went to Budapest to develop scenarios for future uses of the Danube banks to improve the quality of life in the city. Another study involved the promotion of bicycle and public transport to improve the air quality in Madrid.

Together with her team of lecturers Fortuin searches for interesting cases. “We consult

alumni from Wageningen University and colleagues and contacts at other European universities to find a non-governmental organization, a local or regional government or a company with a suitable problem for the workshop.” The workshop mostly provides practice in problem-oriented interdisciplinary work. “Given the involvement of stakeholders such as civilians and companies, the workshop even shows transdisciplinary research features”, she says.

The workshop’s structure is shaped by the so-called matrix. The thirty participating students are distributed over five different areas (for example: five different neighbourhoods or five companies). The participants are also divided over five different fields of expertise determined by the problem under investigation. A management team, also a group of students, coordinates the project (see Box 13). Lecturers facilitate the students and support them to deliver a concise and coherent consultancy report for the commissioner. They guide the students to formulate research questions, collect data in the field and to analyse and integrate these data. “Facilitating the research process of a group of thirty students with such a variety in disciplinary and cultural background is a very interesting but challenging job”, Fortuin explains. “All kind of aspects of collaborative, interdisciplinary research emerge during the project, such as integrating data from various sources. But also decision making, dividing tasks and assigning responsibilities or differences in communication styles are challenging when

### Box 12 European Workshop

Wageningen University promotes the training of T-shaped skills of her students. In the EUW students train their T-shaped skills by executing a consultancy project in an intercultural setting. Students highly appreciate this course as is illustrated by the fact that most students memorize it as the most valuable course element of their MSc programme at their graduation ceremony. The educational institute of Wageningen University also cherishes the course as is shown by the annual financial contribution to this relative expensive course.



During the field work students collect data by interviewing local stakeholders.

Photo Petter Buenglake.

such a big international group works on a common task. We stimulate our students to reflect on these issues during and after the project so that they learn from their experience.”<sup>4</sup> Fortuin considers the intensive two-week field period the workshop’s cherry on the top. “Students leave Wageningen for what is often their first contact with stakeholders with divergent views. They experience the differences between theory and practice, and realise the importance of good planning, management and effective communication skills. In this period they live together and work intensely on the project. This period often creates a strong bond between the students because there is plenty of time for informally getting together. It also makes them aware of their own cultural background and the cultural differences within the group.” Alette Langenhoff, from the Environmental Technology group, shares this experience. This year was the first year she supervised a project. “In the Czech Republic my group addressed traffic problems”, she says. “It was fun to quickly dive into the mobility and infrastructure issues of a business area in Brno. The students contacted at least seventeen involved parties to create a mobility plan and discovered that each party tried to have the others solve the problem.

The key issue the students discovered was lack of communication between the stakeholders.” While the problem’s core was not natural scientific, Langenhoff is still satisfied with her contribution. “It is very rewarding to coach students in their abilities while slowly but surely revealing the communication issue. Thanks to the students from Wageningen stakeholders started to consult each other during the field work. The project thus showed direct results.” Initially she had some trouble with the seemingly abstract matrix but it did clarify the project’s problems. “It is simply a brilliant methodology developed by WUR.” A special website using MS SharePoint was developed for the course. This website supports the organizational structure and facilitates the formal exchange of information between and within the different groups. In general this website worked fine, but a personal touch is important as well. “After a long day of counting cars and traffic movements in heavy rain in Brno, the management team felt the group’s need for an extra pat on the back. The participants found a personal note on their doorsteps that evening. Such events are of great value.” While it was Langenhoff’s first time as a participating teacher, Bas van Vliet from the

<sup>4</sup> For more information about the didactical model of this course see: Fortuin, K. P. J. and Bush, S. R. (2010) ‘Educating students to cross boundaries between disciplines and cultures and between theory and practice’, *International Journal of Sustainability in Higher Education*, 11(1), 19-35.

Environmental Policy group has five years of experience in the project. He appreciates the opportunity to expose students to contradictory information. “After various interviews in the field -in particular the technologically schooled-students are often puzzled and ask me: ‘which stakeholder should we believe, what is the truth?’”, Van Vliet says. Well, and how does their lecturer react? “Welcome to reality”, Van Vliet responds. “In contrast to what the natural science students learn, social scientists know that social reality hardly has a truth. Apprehending this is an important goal for these students”, according to Van Vliet.

Like Fortuin and Langenhoff, Van Vliet also praises the intercultural aspect of the course.

“When we started, many of our projects were in Central Europe. This was convenient as many students came from this region, but there is another advantage of doing the fieldwork outside the Netherlands. Dutch students learn about a totally different part of Europe and become aware of their typical Dutch perspective.” Besides, Dutch students learn to be more patient and to give room to for instance a Chinese student who at first seemed to be a bit shy.” And what has he personally learned? “It is interesting to not only teach in front of the class but also give input from the back row. You can see that the group of students forms an instant consultancy company. For let us be honest, many graduates from environmental sciences at

WUR become scientists working in consultancy or policy. This makes this workshop a valuable element in their MSc program”. Van Vliet feels that it is inherent to Wageningen and WIMEK to work in an interdisciplinary and transdisciplinary way. “The world will not become more sustainable through strong independent analyses. No, a graduate from Wageningen is a knowledge worker whose insights empower others to make the world a better place to live.”

Also, Dimitra Kalosynaki is convinced that the interdisciplinary or transdisciplinary approach in the European workshop contributes to better and more sustainable mobility for the citizens in Budapest. Audrey Legat shares this opinion. “I think we delivered a good report. Of course, our study will not cause radical changes in Norway, but our commissioner, ‘Kysten er Klar’ (Norwegian for ‘the coast is ready or clear’) could find some really interesting ideas. We provided them with a whole spectrum of recommendations for various scenarios for the development of wind energy, aquaculture and tourism in the area.” ‘Kysten er Klar’ is indeed satisfied with the work of the WUR-students. “It is the fourth year now”, says director Leif Harald Hanssen. “Each time the students focus on another part of our region. The students are open-minded and present the community a mirror to look at itself. This year’s most important outcome was ‘be aware of how to take care of the foreigners who (we attract to) work here’. For that it was great that the students from Wageningen also formed a multicultural group.” Michal Veselý, Development Director of Nadace Partnerství (Environmental Partnership) received the recommendations for the mobility plan in Brno and sent an email expressing his appreciation for the students’ work: “We are inspired by your approach. It was for us a kick off towards a bigger development in the field of mobility management. It was highly useful, many thanks once again.”

### Box 13 “The Matrix, a powerful course element of the EUW

An important course component of the EUW is the organizational ‘matrix structure’ in which students work (see below). This matrix enables students on the one hand to work in a disciplinary or expert group and to deepen their knowledge and skills in a specific area of expertise (i.e. the columns of the matrix). On the other hand it forces them to cross the boundaries of their discipline when they work in a field-work team that studies a particular geographical area (i.e. the rows of the matrix). This ‘matrix-approach’ enables intensive group interaction and facilitates the involvement of every student.

Before the start of the EUW, WUR lecturers together with the commissioner draft the Terms of References, the starting document for the EUW consultancy project. Together they define the analyses (i.e. expert groups) as well as the geographical unites (districts of a big city or small municipalities in a rural area, i.e. geo-groups) of the matrix.

#### Expert groups

1.	2.	3.	4.	5.	
Policy analysis	Stakeholder analysis	Technology & infrastructure analysis	Ecosystem services analysis	Scenario analysis	Management Team
1 S1.1 + S1.1 <sup>MT</sup>	S1.2	S1.3	S1.4	S1.5	S1.1 <sup>MT</sup>
2 S2.1.	S2.2 + S2.2 <sup>MT</sup>	S2.3	S2.4	S2.5	S2.2 <sup>MTT</sup>
3 S3.1	S3.2	S3.3 + S3.3 <sup>MT</sup>	S3.4	S3.5	S3.3 <sup>MT</sup>
4 S4.1	S4.2	S4.3	S4.4 +S4.4 <sup>MT</sup>	S4.5	S4.4 <sup>MT</sup>
5 S5.1	S5.2	S5.3	S5.4	S5.5+ S5.5 <sup>MT</sup>	S5.5 <sup>MT</sup>

Geo groups

*S is student - The Management Team consists of students from all groups*

## Reflection

# The future of inter- and transdisciplinarity in the field of environmental sciences

The scientists, who are interviewed for this brochure, are inspired by and very enthusiastic about crossing their disciplinary boundaries. They learned to confront complex problems and to think 'out of their disciplinary box'. The examples in this brochure illustrate this. Having impact and contribute to societal-change processes are strong incentives for researchers to get involved in interdisciplinary and transdisciplinary education and research projects. Moreover, working with decision makers and other stakeholders is very rewarding, also when they do not have a scientific background or

interest per se, but just want to directly, instrumentally and pragmatically benefit from scientific information. The scientists involved in our cases also experienced that crossing disciplinary boundaries and developing different collaborative approaches with non-academics (who are primarily interested in applying the scientific information), requires different skills and inputs compared to conducting traditional research. Scientists reported the need to learn how to confront complex, novel and unique problems that are not described in textbooks or not yet covered and explained by existing theories.

They discovered that non-academic approaches and skills that at first seemed to be scientifically unimportant actually are very relevant. Finally, the cases also illustrate that interdisciplinary and transdisciplinary activities and projects likely generate new knowledge and new research questions, and so also advance traditional research. Collaboration between scientists from various fields is definitely able to uncover a whole new set of researchable questions, both academic and non-academic. When thinking about some key issues that can be derived from the cases and that need further reflection and attention. We suggest to pay extra attention to the following two major aspects when defining the strategic future agenda for WIMEK (and nationally also for SENSE).

Firstly, WIMEK stimulates development and application of multidisciplinary, interdisciplinary and transdisciplinary approaches to address the current complex societal problems. This is thus central to WIMEK research and many interdisciplinary PhD-theses, reports, books and peer reviewed papers have been published and many of them are highly influential. The typical problem-and-solution oriented nature of many WIMEK papers and studies likely contribute to the much higher than average scientific and societal impacts. Such applied research nature must continue to be pursued in the future. This does not mean that fundamental or curiosity-driven research is excluded. On the contrary: problem driven research often determines new research needs and leads to innovative new insights across disciplinary borders. For example, much of the feedbacks, teleconnections, lagged responses and tipping points within complex human-environment interactions are characterized and quantified only after problem-oriented research deemed them important. Studying these interactions is rarely interesting for single disciplines but becomes especially interesting in interdisciplinary contexts.

It often is argued that interdisciplinary publications are less cited than disciplinary papers. This, however, is not the case as is illustrated by the success of WIMEK with interdisciplinary publications in the recent publication and citation analysis of especially the peer-reviewed papers in scientific journals listed by the ISI's Web-of-Science (Gerritsma et al., 2014)<sup>5</sup>. In six disciplinary fields we have published between 100 and 600 papers, in five additional fields between 30 and 100 papers and, finally, in nine other fields just a few papers (Table 1). The relative impact of the papers (i.e. the number of citations divided by the number of papers; the world average is around one) and the number of top 10% and top 1% most cited papers are all high to very high in most fields. This can be explained by the boundary crossing character of many of the WIMEK papers. Interdisciplinary papers attract a broader audience and are cited more frequently. This is especially true for the main WIMEK domains (Table 1, see next page).

Secondly, the actual interdisciplinary and transdisciplinary research and education processes must be documented and reflected upon. WIMEK already published some papers on these issues (e.g. Fortuin et al., 2011, Fortuin et al., 2013) and together with other SENSE-groups has gained much experience with participatory processes to better involve stakeholders (e.g. Hisschemoller and Sioziou, 2013). Tuinstra, for example, pioneered and reflected on stakeholder involvement in environmental policy making (e.g. Tuinstra et al., 2006, Tuinstra, 2008). She clearly showed the importance of cross boundary work and co-production of science and policy as it enhances credibility, legitimacy and relevance with multiple audiences of scientific assessments. Cuppen (2010) further built on these findings and designed approaches to reduce conflicts between groups of stakeholders with different interests, and to enhance collaboration between these groups. These studies reflected

<sup>5</sup> Gerritsma, W., Fest, E. P. M. J. & Van der Togt, P. L. 2014. Bibliometric analysis of SENSE 2007 - 2012. Wageningen: Wageningen UR library.

**Table 1**  
Bibliometric indicators for WIMEK per research field for the period 2007-2012.

The meaning of the columns is indicated underneath the table, the rows are ordered in descending number of publications (Gerritsma et al., 2014).

Research Field	N	C	Wavg	CPP	RI	%T10 (T10)	%T1 (T1)	%NC (NC)
Environment/ Ecology	613	11890	5380	19.4	2.49	28% (170)	6% (39)	5% (32)
Geosciences	324	6066	2349	18.7	2.66	34% (110)	8% (26)	4% (14)
Biology & Biochemistry	114	2743	1405	24.1	1.81	18% (21)	4% (4)	4% (4)
Agricultural Sciences	109	886	568	8.1	1.66	17% (19)	4% (4)	9% (10)
Chemistry	100	1667	925	16.7	1.89	28% (28)	4% (4)	5% (5)
Social Sciences, General	90	1112	327	12.4	3.53	39% (35)	8% (7)	10% (9)
Engineering	72	794	300	11.0	2.70	36% (26)	6% (4)	14% (10)
Plant & Animal Science	59	648	354	11.0	1.80	24% (14)	3% (2)	8% (5)
Microbiology	46	864	576	18.8	1.52	17% (8)	4% (2)	2% (1)
Economics & Business	34	340	164	10.0	2.32	12% (4)	6% (2)	9% (3)
Clinical Medicine	13	171	43	13.2	4.77	54% (7)	15% (2)	0% (0)
Pharmacology & Toxicology	10	179	94	17.9	2.06	30% (3)	0% (0)	0% (0)
Physics	10	297	59	29.7	6.01	80% (8)	20% (2)	0% (0)
Computer Science	8	91	33	11.4	2.87	38% (3)	13% (1)	0% (0)
Molecular Biology & Genetics	6	15	59	2.5	0.20	0% (0)	0% (0)	17% (1)
Materials Science	2	38	4	19.0	9.55	50% (1)	50% (1)	0% (0)
Mathematics	2	20	5	10.0	4.07	50% (1)	0% (0)	0% (0)
Immunology	1	11	8	11.0	1.43	0% (0)	0% (0)	0% (0)
Neuroscience & Behaviour	1	23	15	23.0	1.53	0% (0)	0% (0)	0% (0)
All research fields	1614	27855	12669	17.3	2.44	28% (458)	6% (100)	6% (94)

Where N is the number of peer reviewed publications; C the number of citations to these publications; Wavg the World average citations for these articles; CPP the Average citations per publications; RI the relative impact; %T10 the percentage of articles cited within the top 10% most cited (T10) article on their domain; %T1 the percentage of articles cited within the top 1% most cited (T1) article on their domain.

on the transdisciplinary processes. The lessons learned from these studies help to mainstream transdisciplinary approaches. For example, the new innovative international sustainability research programme 'Future Earth' (<http://www.futureearth.info>) that recently started its activities (Reid et al., 2010, Rockstrom et al., 2013), has both a science and an engagement committee that respectively advice on scientific and research issues, and stakeholder involvement and outreach. Sandra van der Hel, one of the 2013- SENSE honours students, is documenting and evaluating the transdisciplinary processes of Future Earth's emergence and implementation as part of her PhD thesis. Transdisciplinary research is being stimulated in the coming years through calls by funders (e.g. the Belmont Forum: <http://igfagcr.org/belmont-forum-governance>; and EU's Horizon2020: <http://ec.europa.eu/programmes/horizon2020/>), Dutch Top-Sector policy (joint

research programmes with business and industry), additional science-policy interactions (e.g. IPCC and IPBES) and new research projects. Hopefully, this will not only result in better understanding of the complex human-environment interactions and consequently in developing better strategies to address the accompanying problems and challenges, but also to ample opportunities to investigate the "Do's and Don'ts" of transdisciplinary research. Such reflection should not only results in transdisciplinary guidelines but also in the development of a common coherent framework for transdisciplinary research (c.f. Jahn et al., 2012), methodologies for further interdisciplinary integration (Ignaciuk et al., 2012), transdisciplinary research processes and knowledge production (Scholz, 2011), involvement of decision makers and other practitioners, and creating scientific and societal impacts (Brandt et al., 2013, Mauer et al., 2013).

## The role for Graduate School WIMEK and Wageningen University

WIMEK aims at developing an integrated understanding of environmental change and its impact on people, society and nature. This typically requires interdisciplinarity and transdisciplinarity. As a graduate school WIMEK is unique in the world but its research groups have their equivalents elsewhere. Research institutes that also take a comparable integrated interdisciplinary approach, are, for example, the International Institute for Applied Systems Analysis (IIASA), in Laxenburg, Austria, the Center for Environmental Systems Research of the University of Kassel, Germany, the Potsdam Institute for Climate Impact Research (PIK), Germany, The Helm-

holtz Centres for Environmental Research in Leipzig, Jülich and München, Germany, the Institute of the Environment at the University of Arizona, US, and the Stockholm Resilience Centre, Sweden. All these institutes advance research on human-environment interactions systems and sustainability and pioneer integrated models, science-policy assessments and stakeholder involvements. WIMEK researchers already collaborate with these institutes to jointly advance the science on human-environment interactions under the influence of global change and become more successful in international interdisciplinary and transdisciplinary research acquisitions.

WIMEK's unique position in this international network provides an excellent opportunity to further develop interdisciplinary and transdisciplinary approaches. Within this network various issues need to be discussed, including: the value of interdisciplinary and transdisciplinary approaches; the restricted research period of interdisciplinary projects; developing and reflecting on transdisciplinary approaches; difficulties with funding, planning and partners; organizing and facilitating meetings and, finally the scientific productivity. These are shortly discussed below. The added value of interdisciplinary and transdisciplinary research for the integration of natural science disciplines, of natural and social science disciplines, and of natural and social science disciplines with engineering, planning and design disciplines is large. This ultimately leads to a better assimilation of disciplines in research projects. For example, natural scientists often limit the role of social scientists to facilitating stakeholder involvement and communication. In well-integrated projects, social scientists actually advance understanding and synthesising the human dimension (Ignaciuk et al., 2012), while outreach is the responsibility of all involved. Most of WIMEK's interdisciplinary and transdisciplinary research is solution oriented. A major issue is to move scientific knowledge towards applications under real practical conditions. Although some excellent examples illustrate the possibilities in this brochure, the next step is to capitalize on these and other examples. WIMEK's valuable experience must be used to feed this knowledge into successful practice, and to learn from practice to feed theory development. Such new knowledge need to be absorbed and mainstreamed by other scientists so that the problem and solution oriented sustainability science does not remain a distant and unrealistic goal. This also means that such new knowledge and theories must also be incorporated in textbooks, courses and curricula to educate a new generation.

Much of the research is currently organised in projects bounded in time and space. These projects end and many are not further ensued. Reinventing the wheel happens too frequently. Much of the effort invested in (international) collaboration, developing stakeholders networks, building trust and evaluating approaches are lost after a project ends. For example, the Wageningen University INREF projects (c.f. Research Case 1), although successful in building capacity, producing scientific theses and papers, and showing the feasibility of approaches, did not guarantee that all these investments resulted in better and sustainable local livelihoods. Adding collaborations with governments, NGOs and the private sector could help to anchor long-term interests but this is currently rarely done. While there could be large differences between developing and industrialized countries, possibilities to achieve this, have to be explored. Maybe such transdisciplinary collaborations could lead to more stable long-term funding but only when the researchers have fostered thrust that their contributions continue to be valuable to these societal actors.

Although much of the transdisciplinary research originated from participatory approaches in development research, doing transdisciplinary research on complex human-environment interactions and sustainability is different. The 'sustainability' stakeholders are not just local people (as in many development studies), but cross many different scales and institutional actors. Also stakeholders are involved from the start. They also influence the research questions when a co-design and co-production approach is selected (e.g. Mauser et al., 2013). This different framing of research problems can result in questions that require other disciplines or other tools and approaches. Some of the questions can even not be scientifically investigated (e.g. the meaning of life). The role of a leading scientist changes in this process. (S)he becomes more of a facilitator in recognizing different modes of

knowledge production, framing researchable questions and identifying the required expertise and approaches. Utilization of all these different sources of knowledge and expertise requires different skills when compared to curiosity-driven research.

All these skills must be trained and not only at the BSc, MSc and PhD students levels but also at the level of the teaching and research staff (i.e. who is teaching the teachers?). As transdisciplinarity is a new and rapidly emerging field, research experience therefore has to be immediately translated into clear and comprehensive guidelines, textbooks and innovative governing structures of programmes and projects. The establishment of Future Earth's engagement committee (Liverman et al., 2013), for example, is a step forwards to accomplish this. Also journals are needed to publish and review the relevant new insights. Although some journals are already dedicated to this challenge (e.g. Journal of Interdisciplinary and Multidisciplinary Research, Interdisciplinary Science Reviews and The Transdisciplinary Journal of Engineering & Science) and many other journals provide space for these issues (e.g. Ecological Economics, GAIA, Current Opinion in Environmental Sustainability, Global Environmental Change and Climatic Change), much of the research is still published in disciplinary journals.

Finally, there are still major funding issues. The major national science funding organisations, including NWO, are organised along disciplinary lines. More and more, these organisations also invest part of their funds in integrated or interdisciplinary calls, and ask for motivation of societal relevance. Unfortunately, even such problem-oriented research proposals are generally reviewed by disciplinary experts and rarely solely by knowledgeable interdisciplinary experts. This disciplinary heritage of funding agencies slows the mainstreaming of interdisciplinary and transdisciplinarity. This is also illustrated by the successful development of large

scale earth system models or integrated assessment models. Most of them are developed by problem oriented-research institutes (e.g. PBL in the Netherlands, NIES in Japan and Batelle National Laboratories in the US) with long-term legal mandate to assess national energy, land use and environmental problems in their regional and global contexts. Although the recent economic crisis has also affected these institutes' research continuity, they still have almost ideal conditions for long-term interdisciplinary and transdisciplinary research. Establishing collaborations with these internationally renowned research institutes helps to improve interdisciplinary esteem and provides research opportunities in their innovative (model-based) projects and applications.

WIMEK is also imbedded in the progressive Wageningen University and Research structure, which provides funding for strategic research programmes on emerging topics (e.g. IPOP), programmes with PhDs from developing countries (e.g. INREF) and entrepreneurial chairs and researchers, who find their own funding in collaboration with industry, research institutes and NGOs. Many of the resulting projects are interdisciplinary and transdisciplinary and contribute to knowledge generation and experience. Individual initiatives within the university thus remain extremely important. One of the lessons learned from all these projects, is that the planning and execution of such a project require more time because of the involvement of other experts and stakeholders. Not all partners are equally engaged and interested in such research and selecting the best partners thus requires much effort. All these interactions must be organised through dedicated activities (e.g. workshops and meetings, teleconferences, joint fact finding; sessions to share and exchange findings). Someone needs to be responsible to organise these but a (postdoctoral) scientist is not always the best person to accomplish this. Effectively organising these interactions re-

quires facilitator's skills (e.g. structuring, listening, summarizing and synthesising) and often this is best done by a dedicated person, who has no stake in the research process (Tomich et al., 2007). Many EU and UN projects therefore already use experienced specialized companies, such as Prospex or Global Knowledge Initiative. Initially interdisciplinary projects seem to be less productive because the first papers often appear relatively late in the research process. However, there are more opportunities for papers to target different professional and scientific audiences. Ultimately this results in more publications (Hall et al., 2012), a higher scientific impacts and a larger visibility in newspapers and other media.

Interdisciplinary and transdisciplinary research has come a long way but is not yet fully matured. Many successful and failed projects were executed around the world but their legacy has not been fully captured or synthesised. The dilemmas described above relate to a project's extent, its depth versus its breadth and its reach. Such projects can clearly never be accomplished by a single individual but need a team of committed and enthusiastic scientists (and stakeholders). Many recognized interdisciplinary researchers were educated as experts in a single discipline, but learned to solve problems with trial and error through collaboration by others, by continuously asking questions, refrain from using jargon and listening to experts from other disciplines. They are the typical T-shaped skills researchers. WIMEK now tries to educate interdisciplinary researchers almost from scratch in the various PhD-programmes. Although some fail, many of these young researchers prosper and have a broad perspective. They have overcome one or more of these dilemmas and contribute to further developing interdisciplinary and transdisciplinary research and to challenging, addressing and solving the diverse complex human-environment problems that humanity are facing today, locally, regionally and globally.

This contribution builds upon a long integrated research tradition of 'Science for Impact' in Wageningen initiated in the seventies by visionary scholars, like Prof. dr. J. de Wilde, Prof. dr C.T. de Wit and Prof. dr G. Lettinga, and will definitely be recognized as WIMEK's main legacy in the near future.

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## Colophon

*Interviews and original text case studies provided by René Didde, freelance scientific journalist*

### Editors case studies

ir. K.P.J. (Karen) Fortuin,  
Prof. A.J. (Tinka) Murk, Prof. H.H.M. (Huub) Rijnaarts,  
Prof. G. (Gert) Spaargaren, Prof. S.E.A.T.M. (Sjoerd) van der Zee,  
Prof. G. (Grietje) Zeeman

### Preface

Prof. H.H.M. (Huub) Rijnaarts

### Introduction

ir. K.P.J. (Karen) Fortuin and Prof. G. (Gert) Spaargaren

### Reflection

Prof. R. (Rik) Leemans

### Final editing

J. (Johan) Feenstra and ir. K.P.J. (Karen) Fortuin





Challenges and  
successes in  
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research and  
education