Towards a sustainable future: Ecology in a changing world

Vision for Ecology at Wageningen University

Report of the taskforce Ecology, September 2014

Preface

This report is the product of a number of meetings of the Taskforce Ecology that has been installed in June 2013 by the Boards of the Graduate Schools PE&RC and WIMEK.
The Taskforce is composed of representatives of Wageningen University groups working in the field of ecology (see below), to explore the future of ecology at WU. This Taskforce has specifically been asked to reflect on the strengths and opportunities of ecology at Wageningen University over the next 5-10 years, given the focus and quality of ecology in its immediate (NIOO, Alterra, Plant Research International), national (other Dutch universities) and international (especially European) environments.

Groups active in Ecology in four science groups (ESG, PSG, ASG and AFSG) have contributed to the final version of the report.

Composition Taskforce:

- Niels Anten (PE&RC, Centre for Crop Systems Analysis, PSG) – chair
- Theo Jetten (PE&RC) – secretary.

PE&RC:
- Fred de Boer (Resource Ecology Group, ESG)
- Gerlinde de Deyn (Soil Biology and Biological Soil Quality, ESG)
- Jeroen Groot (Farming Systems Ecology, PSG)
- Liesje Mommer (Nature Conservation and Plant Ecology Group, ESG)
- Marc Naguib (Behavioural Ecology Group, ASG)
- Erik Poelman (Laboratory of Entomology, PSG)
- Pytrik Reidsma (Plant Production Systems group , PSG)
- Pieter Zuidema (Forest Ecology and Forest Management group, ESG)
- Bas Zwaan (Laboratory of Genetics, PSG)

WIMEK:
- Egbert van Nes (Aquatic Ecology and Water Quality Management, ESG)
- Juul Limpens (Nature Conservation and Plant Ecology group, ESG)
- Lars Hein (Environmental Systems Analysis group, ESG)
- Detmer Sipkema (Laboratory of Microbiology, AFSG)

Table of Contents

Summary

Ecology aims to understand the performance, distribution and abundance of organisms, as well as their interactions with their (a)biotic environment. With its focus on the functioning and resilience of individuals, populations and ecosystems, ecology provides the basic knowledge required to address key fundamental scientific questions on ecosystem functioning, and the insights to tackle important applied problems related to ecosystem management, health, agricultural production and biodiversity conservation. Environmental changes induced by a growing human population, e.g. land conversion, habitat destruction and climate change, cause dramatic losses in biodiversity and subsequent changes in ecosystem functioning. Unravelling the ecological mechanisms by which these environmental changes will affect ecosystems and human wellbeing is a major scientific challenge. An equally large challenge is to develop adaptive strategies of resource use and conservation that allow coping with these effects of environmental change. Tackling these challenges requires a substantial input from Ecology. Ecological research at Wageningen University, 'Wageningen Ecology', is ideally positioned to address these challenges. Wageningen Ecology combines scientific excellence with critical mass. It is one of the few places in the world where ecological research is so closely connected to applied fields such as agriculture, forestry, fisheries, nature conservation, spatial land- and aquatic use planning and health. This document provides a strategic vision for Wageningen Ecology for the coming 10 years, highlighting the strengths and current and future research topics that are required to address these challenges.

Strengths of Wageningen Ecology

Wageningen Ecology is the largest centre (37% in terms of scientific staff) in the field of Ecology and Evolutionary Biology in the Dutch university system. It has strong links with the Netherlands Institute of Ecology and institutes of the Contract Research Organization such as Alterra, PRI and IMARES. Wageningen Ecology is a world leader in ecology, which is reflected by the large number of prestigious awards (i.e., three Spinoza laureates), personal grants (12 ERC/NWO personal grants in the last 5 years) and top publications of Wageningen ecologists. Research and education within Wageningen Ecology are very well integrated and often multi-disciplinary: the dense network of collaboration creates a vibrant scientific and educational atmosphere. The research areas at Wageningen University have a strong focus on those fields (e.g. sustainable agriculture and aquaculture, natural ecosystems, resource conservation and disease management) in which ecology will achieve important fundamental breakthroughs and in which it finds its most relevant applications (Figure 1). The combination of fundamental and applied research places Wageningen Ecology in a strong position to obtain funding to address questions that are highly relevant to society.

Proposed research themes

The Task Force Ecology of Wageningen University highlights five major research themes, which are highly relevant to tackle the abovementioned environmental problems, and represent fields of ecology where major scientific breakthroughs and developments are expected. They bring together the fundamental challenges of understanding the drivers of this change, assessing its consequences on biodiversity, ecosystem functioning and human well-being, and the development of adaptive strategies in terms of planning of use of natural resources (land and water), health and nature conservation. Together, these

themes cover the full breadth of Wageningen Ecology and are well connected to the three major focal areas of Wageningen University: food, health and environment. The themes are:

(i) Ecology for sustainable natural resource use
(ii) Ecosystem resilience in a changing world
(iii) Disease ecology
(iv) Spatial ecology
(v) Species adaptation to a changing world

Key recommendations

In order to capitalize on the unique strengths and ambitions of Wageningen Ecology the taskforce has formulated the following recommendations:

1. Focus on the ecological aspects of current environmental change along the lines of the above-mentioned five key research themes. To this end, this report should be used as an integral part in the decision making process towards new appointments, development of future chair plans and other policy decisions associated with Ecology at Wageningen UR. In addition, the task force could be maintained as an advisory panel to be consulted by e.g. the Graduate Schools for issues regarding Ecology.
2. Stimulate and facilitate an intensification of collaboration within Wageningen Ecology. Developing the abovementioned research themes requires that collaboration among Wageningen Ecology groups is intensified and – in some cases – structurally embedded. This could be achieved by fostering the creation of virtual centres (such as the Centre for Soil Ecology) related to the 5 abovementioned themes, the strategic appointments of special chairs (also with the Contract Research Organization or NIOO), tenure trackers between (science) groups and by integrated funding programs (e.g. through funding tools of NWO and ERC or through Wageningen funding tools such as INREF, IPOP, see further recommendation 4). These collaborations should be developed in a bottom-up manner.
3. Develop and facilitate sharing of key expertise and technologies: Ecology is increasingly benefitting from novel and complex technologies. The increase in size and scale of ecological research in combination with the costs and logistical challenges associated with acquiring and maintaining research facilities necessitate developing and sharing large-scale research facilities and associated expertise. Advances in molecular biology, DNA sequencing technology, bioinformatics, remote sensing, animal tracking, large-scale (field) experiments/data collection and computer modelling are of particular interest in this respect.
4. Increase funding possibilities. Both the public and private sectors are increasingly aware of the importance of ecological research in addressing the effects of environmental change on human wellbeing and in the search for smarter solutions for sustainability. To further stimulate funding, the following actions should be taken: (i) place Ecology & Sustainability more prominently in the profile of Wageningen University; (ii) a stronger lobby to place ecological issues on the (inter)national research agenda; (iii) increase the visibility of Wageningen Ecology in the public debate on the consequences of environmental changes; (iv) develop showcase projects & facilities to strengthen attractiveness for large funds (see

point 3); and (v) develop a more focussed policy to stimulate acquisition of personal grants (VVV and ERC), for example providing seed money for promising researchers (e.g. those that are close to obtaining large personal grants).

5. Integrative activities within nature conservation and management. The multi-disciplinary approach of nature conservation and management asks for an integrated research approach with inputs from different (science) groups. University groups should join forces with NGOs and other (conservation) organizations to develop a research centre for International Nature Conservation.

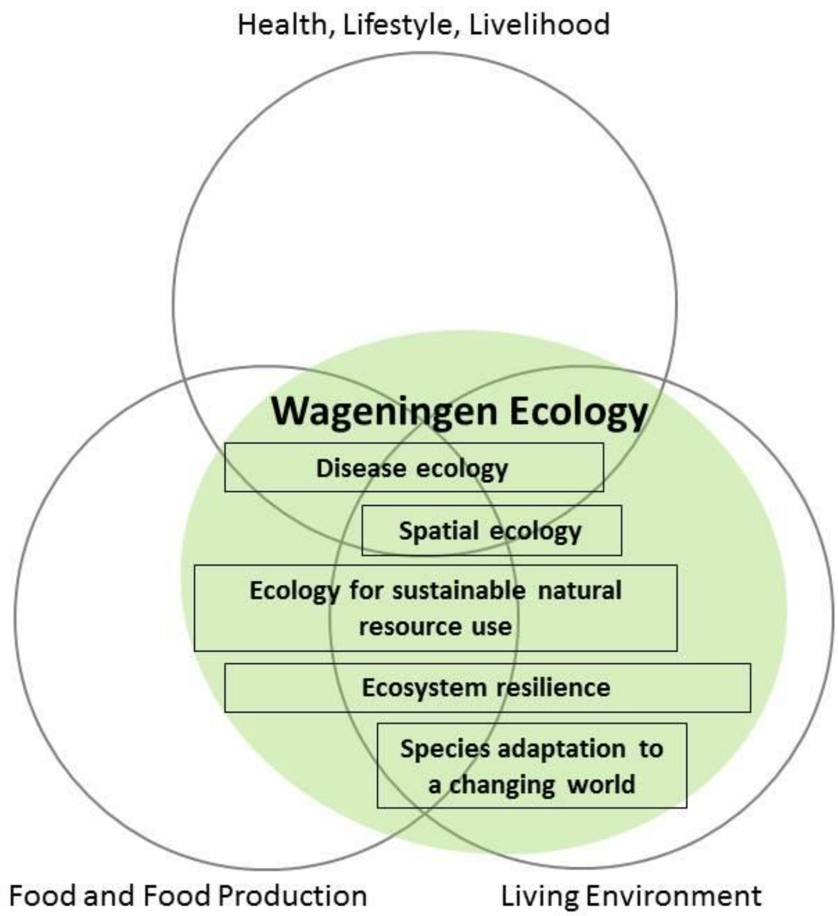

Figure 1[1]: The position of Wageningen Ecology within Wageningen University with five major research themes highlighted by the Task Force Ecology which and represent fields of ecology where major scientific breakthroughs and developments are expected.

[1] The three spheres represent three interconnected subdomains within the domain of Wageningen University, from: Towards an International University with Global Impact; Profile and Performance Agreements Wageningen University (2012)

Introduction

Ecology is a highly multi-disciplinary academic discipline that aims to understand the performance, distribution and abundance of organisms, their interactions with other organisms and with their abiotic environment. With its focus on the functioning and resilience of individuals, populations and ecosystems, ecology provides the basic knowledge to address key fundamental scientific questions as well as applied issues such as how to manage our natural world in order to secure health, production and biodiversity at local to global scale on our planet. To this end, ecological research must be organized in a way that it combines scientific excellence with critical mass that is integrated with applied fields such as agriculture, fisheries, forestry, nature conservation, land- and sea use and health, with strong links to the social sciences given that human behaviour plays a critical role in the successful adoption of (novel) management strategies. Ecological research at Wageningen University (**Wageningen Ecology** hereafter) is uniquely and ideally positioned to meet these criteria.

We live at a time in which finite natural resources are being used at increasing rates while environmental changes such as destruction and fragmentation of natural ecosystems, climate change or invasive species modify our natural environment. In addition, a multitude of novel ecosystems and landscapes (e.g. cities, novel agricultural, and aquatic production systems and the genotypes they harbour) are being created at fast rates. As a consequence the diversity of species, traits and genes is changing, and in general decreasing at alarming rates at local, regional and global scales.

However, the impact of these changes on the functioning of our natural world and human well-being are largely unknown, limiting the development of solutions. Ecology plays a central role in making these unknowns known and in finding solutions to cope with envisaged changes by providing mechanistic knowledge on the functioning and adaptive capacity of species, ecosystems and landscapes. This poses an enormous fundamental scientific task, and resolving the uncertainties of the consequences of the ecosystem changes, exploring the options how to cope with them, and developing highly productive and ecologically sustainable utilization systems are among the major societal challenges of our time. Fortunately, the field of ecology is ideally equipped to take up this challenge.

The ecological consequences of environmental changes in ecosystems cannot be seen independently from societal processes such as shifts in land and aquatic exploitation, increased human population, increasing energy demands, and politics. For instance, habitat destruction of tropical forests or coral reefs and the subsequent loss in biodiversity are largely modulated by socio-economic and political processes. These issues call for the design of optimized multiple land-use and aquatic systems that combine socio-economic demands with ecological sustainability, and for analyses of ecosystem functioning in combination with environmental services. The shifts in (a)biotic drivers associated with environmental change may strongly affect ecosystem functioning in that critical transition points may be reached.

This document provides a strategic vision for the Wageningen Ecology for the coming 5-10 years. It assesses three important issues:

1. The strengths and unique features of Wageningen Ecology

2. The current research areas of Wageningen Ecology that address the key challenges described above and that provide fundamental scientific knowledge and practical solutions for the societal problems

3. Recommendations for the strategy that should be laid out for Wageningen Ecology for the coming 5-10 years to capitalise on the unique strengths and ambitions of Wageningen Ecology

Part I Strengths and unique features of the Wageningen Ecology

The list below outlines a number of key features that give Wageningen Ecology the mass, strength and positioning to address the fundamental ecological questions associated with global environmental change, and to contribute to the knowledge base to address the challenges for society.

- Critical mass: With 126 fte scientific staff Wageningen Ecology is by far the largest among the Dutch universities (constituting 37% of the total across seven universities in the area of Ecology and Evolutionary biology; from "Implementatieplan Nieuwe Biologie 2013"). The ecological groups at Wageningen University are also closely connected to a number of institutions conducting ecological research (e.g. NIOO, Alterra, NIOZ and Imares), which have complementary interests in both fundamental and applied research.
- Scientific excellence: Ecology is one of the fields of excellence of Wageningen University. All Ecology groups at Wageningen University had an average assessment of very good or higher (>=4) within the QANU Research Review Biology, and most a score of 4.5 or higher[2]. Three Wageningen Spinoza laureates are ecologists and Wageningen University Ecologists obtained 7 Veni/Vidi/Vichi and 5 ERC subsidies in this area in the last 5 years.
- Strong links to agricultural production, resource use and health: The mission of Wageningen University is to explore the potential of nature to improve the quality of life. This mission statement implicitly contains the link between ecological research and research on agricultural production, resource use and health. The profound connections of Wageningen Ecology with these fields is unique in the world and provides great opportunities for societally relevant and applied ecological research on present-day dilemmas related to overexploitation of resources and environmental degradation.
- Systems approach: Wageningen is unique in its multidisciplinary combination of experiments and modelling (also dubbed the Wageningen systems approach); quantitative approaches with ample facilities for experimental work and world-leading in a variety of modelling techniques.
- Excellent teaching: The size, breadth and excellence of Wageningen Ecology allows for a strong and multi-disciplinary teaching to meet the demand for well-trained graduate and post-graduate students from all over the world. For the ninth consecutive year, Wageningen University has been announced the 'Best University of The Netherlands', and by the study choice guide Keuzegids. Four programmes related to Ecology ended in 2013 in the top 3 of their category: Plant Sciences (1st place), Biology, Forest and Nature Conservation, Environmental Sciences
- International perspective. Wageningen Ecology actively conducts research in many parts of the world and has strong links with many of the internationally leading groups in Ecology. This international perspective is of crucial importance given the fact that the major environmental issues of our time tend to have regional and often global causes, effects and solutions. In addition, the most vulnerable and diverse systems of the world are located in the tropics, and Wageningen has a strong tradition in tropical ecological research.
- Good funding opportunities: The combination of fundamental and applied research places the Wageningen Ecology in a strategic position to acquire funding, e.g. through the EU. The EU

[2] QANU Research Review Biology. QANU June 2012.

Horizon 2020 programme puts a strong focus on elements in which Wageningen Ecology is active, such as biodiversity and ecosystem services, and ecosystem restoration (partly as a result of the implementation of an EU Biodiversity Strategy[3]). Wageningen Ecology can significantly contribute to at least three of the themes of the EU Horizon 2020 programme within the themes: related to Food security, Climate action, and Health. In the Netherlands, Wageningen has been recognized by the Ministry of Economics, Agriculture and Innovation as an important party within ‘the golden triangle’ in which public and private parties work together with the government, which resulted in a strong position of the Netherlands in what are now called “topsectors”. There is much potential for ecology to play a major role in these themes.

[3]Our life insurance, our national capital: an EU biodiversity strategy to 2020. Communication European Commission Com (2011) 244.

Part II Key research themes of Wageningen Ecology

The introduction stressed the urgency of addressing the ecological mechanisms, potential impact, and adaptations to the current **global environmental change.** The five themes presented here represent a clear choice to focus on the ecological aspects of this change. They encompass the range from a fundamental understanding of ecological and evolutionary effects and drivers of this change, predicting its impacts on natural systems and human well-being (e.g. food supply, clean and safe environments, and health), assessing the resilience of natural ecosystems, and the design of sustainable and adaptive land- and sea-use systems. These themes together strongly link Wageningen Ecology to major societal issues that are central to Wageningen University as a whole: food security, health, lifestyle & livelihood and a clean and safe environment.
The themes are fundamentally challenging, societally relevant, and naturally fit within the strengths expertise and ambitions of Wageningen University described in Part I. The themes do not stand-alone, they sufficiently overlap, are complementary, and together form an integrated research agenda for Wageningen Ecology (Fig. 1).

Theme 1: Ecology for sustainable natural resource use.

The growing world population and increasing demand for food and biofuels call for resilient land use and aquatic systems and management strategies that combine production systems with natural ecosystems in an ecological, economic and social sustainable way. Smarter use of natural resources is required: realising more productive systems while reducing their environmental impact and maintaining and utilizing natural biodiversity and ecosystem services. Ecosystems provide essential services (e.g. food production, pollination, water and nutrient retention, carbon sequestration, climate regulation or coastal protection) determining the functioning and resilience of land-use systems. It is therefore crucial to determine the relationship between these services and the size, biodiversity and spatial configuration of natural and production ecosystems within landscapes. Furthermore, potential synergies and trade-offs among services as affected by land-use types and management need to be explored. The idea of functional biodiversity also plays a key role in this theme: how much and what kind of biodiversity is needed to optimize land-use systems under increasing pressure for instance from a changing climate.

Current key questions:

- How can productivity be increased, while minimizing effects on the environment? Large gaps exist between potential production and actual production, especially in developing countries. In developed regions, productivity is generally high, but the challenge is to increase input efficiency to reduce effects on the environment. Aquatic food production is gaining increasing attention, but the challenge is to increase production while conserving biodiversity. Production ecology can be used to find options for ecological intensification. Given increasing restrictions on the use synthetic fertilizers, pesticides and certain GMOs, alternatively more ecological solutions need to be sought.

- How are ecosystem services altered by changes in biodiversity? Quantifying ecosystem services in relation to biodiversity has been an important research area in ecology for several decades. New challenges arise by placing this research in a dynamic context. Biodiversity is changing (mostly declining) rapidly and will continue to do so in the future. How will these changes affect ecosystem functioning and services?
- To what extent and how do soils provide and regulate ecosystem services? Soils are the primary medium in which we grow our crops. They are also an important source of diversity and provide a suite of additional ecosystem services (e.g. climate regulation, greenhouse gas emissions and carbon sequestration) and these services are mediated through plant-soil interactions.
- What is the role of multi-trophic interactions in the functioning of ecosystems? Multi-trophic interactions are an important evolutionary force and play a key role in driving community dynamics and ecosystem functioning with strong implications for ecosystem services (e.g. pollination and pest control). The full extent of these interactions, their impact and the way the can be utilized however still need to be explored.

Opportunities for Wageningen Ecology:
Addressing the questions outlined above requires a broad ecological approach that transgresses the traditional boundaries that exist between ecological and production oriented fields. Wageningen Ecology is in a unique position to develop such a scope:

- Theoretical foundation. Wageningen Ecology is strong in the theoretical foundation of ecosystem functioning, ecological intensification and ecosystem services.
- Multiple approaches. With strong research on both production and natural ecosystems Wageningen Ecology is ideally positioned to quantify synergies and trade-offs that exist between land use and aquatic systems and ecosystem services, particularly between natural and socio-economic functions. Similarly, we study ecosystem functioning at different scales, and are able to upscale lower level processes to assess impacts at higher levels. These links need to be further stimulated.
- Designing sustainable land-use and aquatic systems. With its strengths in organismal, ecosystems, production and landscape ecology and our focus on a wide variety of resource use, Wageningen Ecology is in the unique position to develop and design sustainable land-use and aquatic systems.
- A virtual centre can be created including ecological and production oriented fields to facilitate collaboration on evaluating and designing sustainable land and aquatic systems.

Theme 2: Ecosystem resilience in a changing world.

Environmental conditions are currently changing at unprecedented rates due to massive anthropogenic activity. Ecosystems experience severe negative impacts of direct stressors caused by human activities (habitat loss, habitat degradation, nutrient inputs, overharvesting, altered pests and disease pressures) and indirect stressors such as climate change and increased atmospheric CO_2 levels. It is crucial to know how these stressors will affect the structure, diversity and dynamics of ecosystems and to what extent ecosystems are resilient to these perturbations. Are ecosystems able to recover from disturbances or change in response to perturbations while retaining the same characteristics and functions, or do they undergo sudden changes (i.e. critical transitions or tipping points) which are difficult to reverse and affect the services they deliver? Understanding what determines the response and resilience of ecosystems to perturbations is highly relevant for ecosystem management, conservation and restoration. Such knowledge is essential to predict future ecosystem dynamics and services. Finally, this knowledge will contribute to the development of new adaptive systems, which may be more resilient to global change.

Current key questions:

- <u>How do multiple stressors due to global change affect ecosystem functioning</u>? Global change involves multiple stressors that have interactive but poorly understood effects on ecosystem properties. In addition, many of the changes are non-linear and involve unknown and complex feedbacks. Understanding the complex effects of multiple stressors on ecosystem functioning is key to forecast ecosystem responses.
- <u>How does ecosystem complexity contribute to resilience?</u> Biodiversity, (a)biotic interactions, spatial configuration and (multi-trophic) ecological networks strongly determine ecosystem functioning. Whether and how these characteristics contribute to the resilience of ecosystems to global change is unclear, but highly relevant for management.
- <u>How are above-below ground and benthic-pelagic interactions affected by global change?</u> These interactions drive ecosystem dynamics in terrestrial and aquatic systems, but it is poorly known how these are altered by global change, and how changing interactions will affect ecosystem functioning.

Wageningen Ecology strategy:

- <u>Applying and integrating multiple approaches.</u> Addressing the above questions requires a combination of thorough theoretical foundation, empirical ecosystem research, experimental studies and practical experience in ecosystem management. Wageningen Ecology uniquely combines these approaches, allowing us to test theoretical predictions experimentally and to develop theoretical insights from experiments and ecosystem management studies.
- <u>Multi-scale integration.</u> We study ecosystem functioning at very different scales (ecophysiology – whole-organism responses – genotypic differences – population ecology – community ecology – systems ecology) and are able to integrate across scales.
- <u>Designing adaptive systems.</u> We will contribute to the development and design of adaptive ecosystems, e.g. climate-smart agriculture, climate-smart landscapes [link to item 1] and disease

control [link to item 3]. Similarly, our studies will contribute to designing practices for nature conservation and ecosystem restoration that are designed for a changing world.

Theme 3: Disease Ecology

Many different biological agents can cause diseases. These agents replicate fast and thus have the potential to evolve rapidly while adjusting to new environmental conditions. Potential hosts, including humans, crops, livestock, and wild animals and plants, are constantly being challenged by new diseases. Infection risk and level of damage by the disease to the host strongly depend on the ecology of the hosts and disease causing agents. The ecology of diseases is strongly driven by their natural modes of dispersal (via hosts, land, water and soil) and by socio-economic and environmental factors, such as the rapid population growth of humans and their livestock, intensification and reduction in diversity of cropping systems, and the unprecedented mobility of humans, plants, animals and their products. These factors increase the risk of new emerging diseases and their rapid spread, a trend that has already seen an unprecedented increase in recent decades. Moreover, the development of new disease control strategies is lagging behind the emergence of resistance of pathogenic organisms to the currently available curative measures (e.g., drugs, pesticides, pest-resistance in crops).
To prevent and control disease outbreaks it is essential that the ecology of infectious diseases is well understood in order i) to come up with realistic risk assessments, ii) to develop sustainable measures to reduce disease severity, iii) to reduce the chance of the emergence of new and old diseases, and iv) to reduce their spread as much as possible. Ecological principles should form the basis for a new, sustainable approach to control diseases as disease agents could be kept in check in a sustainable way by complex dynamic interactions with their biotic and abiotic environment.

Current key questions:

- What are the ecological processes behind the epidemiology of crop, livestock, wildlife and human diseases? Ecological factors have a large impact on disease prevalence patterns, and the manipulation of these ecological factors may contribute to disease control. To what extent does the ecology of (new) vectors, invasive species and pests influence disease outbreaks? What is the role of green (vegetation), blue (water) and red (built) networks behind the epidemiology of diseases? How can we control diseases through controlling their vectors and pathogens?
- How does global change affect disease outbreak patterns? The ongoing change in climate and physical connectivity will modify and likely increase the incidence, distribution and impact of many diseases. But the basic knowledge needed to understand and predict such effects is still clearly insufficient and will need to be further developed to improve accuracy in predicting how diseases will develop and in designing appropriate control actions.
- How important are genetic factors of parasites and pathogens, hosts and vectors to better understand and predict the risks of disease occurrence, of development of resistance to control measures, and to develop new disease control strategies?
- What is the role of biodiversity in regulating disease spread? Current declines in biodiversity could strongly affect the spread and impact of diseases. In addition, diversity itself can be

manipulated (e.g. in agricultural systems, to control diseases), but our fundamental understanding of the relationship between diversity and the ecology of diseases is still limited.

Wageningen Ecology strategy:
Wageningen University is a world-leader in the research on disease ecology and epidemiology. What makes Wageningen unique in this field is that we study diseases in a wide variety of organisms and settings. This research is, in turn, imbedded in the more general research on crops, livestock, wildlife, and humans. This setting enables Wageningen Ecology to address the following pressing questions:

- Development of integrative ecology-socio-economic approaches to disease control. Disease outbreaks often have socio-economic aspects, and the integration of ecological and socio-economic sciences is solidly based at WUR. An integrative ecology-socio-economic approach will enable the development of ethical, biological and socio-economic acceptable control strategies for disease control (e.g., reduction of pesticide use, drugs, vaccination, host mobility, landscape planning).
- Development and use of cutting-edge technologies (sequencing of genes, metabolomes, network studies) and bioinformatics to achieve fast detection and prediction of emerging diseases and to develop control strategies. Success of disease control crucially depends on their early detection, there being a strong need for development of early warning systems and rapid response strategies. Yet, detection methods and taxonomic expertise are strongly lagging behind and need to be further developed.
- Quantification of the role of crop diversification in reducing the spread, impact and resistance development in crop and livestock diseases (links with the theme 4 below).
- Discovery of new antibiotics through studying organism interactions in less well known, species rich environments (e.g., soil microbes, microorganisms in sponges). This includes the understanding and application of the use of microbial community inoculations for promoting animal and plant health (e.g., gut microbe transplants), soil transplantations as a tool in ecosystem restoration, priming of induced defenses in plants via natural vaccination.

Theme 4: Spatial Ecology

Ecology is defined by the interactions of organisms with their environment and any ecosystem is characterized by spatial distribution of organisms and resources. In nature organisms are rarely uniformly or randomly distributed, but rather according to specific spatial patterns. This creates spatial heterogeneity in both the diversity and functioning of natural systems. In addition population dynamics and population genetics are strongly driven by spatial processes (e.g. dispersal) and the movements of animals are an integral part of animal ecology with strong implications also for plant sciences. Finally, much of spatial ecology is closely related to conservation biology, because it emphasizes the study of habitat loss and fragmentation caused by human activities. Thus, the importance of analysing spatial effects at different levels of organization is now widely recognized. Recent advances in remote sensing, animal tracking, geographic information systems, computer technology as well as the availability of more advanced statistical techniques, in the last 10-20 years, have opened up vast new opportunities in this field of spatial ecology.

Current key questions:

- <u>Conservation biology</u>: Merging our understanding of the spatial aspects of human-induced habitat modifications and fragmentation with our understanding of individual, species and community dynamics will aid the development of smart conservation strategies and help to identify proxies for environmental shifts such as tipping points.
- <u>Invasion ecology</u>: The problems of invasive species are increasing dramatically, and include diseases, agricultural pests, and severe impacts on biodiversity both on land and in the sea. The spread and adaptation of invasive species are driven by spatial processes (e.g. dispersal) and landscape heterogeneity (links to theme 3). What strategies should be employed to limit their spread and impact?
- <u>Global change biology</u>: Global climate change has an enormous effect on species distribution, biodiversity and agricultural production. These effects have a strong spatial component (e.g. shifts in habitats and geographic barriers, and the spatial heterogeneity of climate effects). The prediction of the impact of climate change, the spatial dependence of these impacts (what happens here has consequences for what happens somewhere else), and the development of adaptive strategies will thus require a strong spatial ecological input (links to themes 2 and 3).
- <u>Spatial heterogeneity in ecosystems</u>: Environmental conditions within ecosystems are driven by the feedbacks between the external environment and the structure and architecture of individuals and communities within ecosystems. Novel experimental and modelling techniques (e.g. 3D structural- [e.g. FSPM], (micro)climate-, and network modelling, high-tech animal tracking) allow for an explicit analysis of the interplay of organismal physiology, behaviour and architecture, community structure and its interaction with the environment and the anthropogenic activities (links to theme 1, 2 and 5).

Wageningen Ecology strategy:

Spatial Ecology at Wageningen UR has a long-standing tradition building on the breadth, strength and integration of existing groups covering remote sensing, agro-ecology, animal ecology, behavioural ecology and conservation biology with strong links to geosciences and social sciences. Wageningen has strongly contributed to the development of new methodologies (e.g. GIS, functional-structural plant modelling, remote sensing, animal foraging, movement ecology) and concepts (e.g. the concept landscape services) in this field. A strategy to strengthen spatial ecology in Wageningen should include:

- <u>Linking spatial ecology to non-linear ecosystem and landscape dynamics</u>. Wageningen Ecology plays a leading role in the research on the importance of non-linear processes, complex feedbacks, and multiple stressors for ecosystem functioning (<u>Theme 2</u>). These processes tend to have a strong spatial component. For example combinations of habitat fragmentation and climate change will induce complex spatial vegetation-microclimate feedbacks that may induce tipping points.
- <u>From ecosystems to landscape services</u>: Landscapes are heterogeneous agglomerations of different and diverse ecosystems, the services and functioning of which strongly interact on a spatial scale. Landscapes are also an important level of integration for policy and land-use planning and services

need to be assessed at this level. Landscape services are a new concept developed by Wageningen UR that is highly useful in this context. Our strength in spatial ecology in combination with our broad expertise in ecological and socio-economic aspects of multiple land-use planning (links to Theme 1) will enable us to strongly develop this concept.

- Stronger links between organisational levels. Spatial Ecology has often focussed on the landscape level. In light of the importance of linking spatial processes at different levels of organisation, it is essentially that this scope is broadened both towards the organismal level linking spatial ecology to eco-physiology [4] individual organismal responses and the regional/global level as understanding how selection acts on individuals will be essential to understand higher order ecological processes.

Theme 5: Species adaptation to a changing world

An important notion in ecology is that the interaction of organisms with their environment is operating at the level of individuals and that there is considerable genetic and phenotypic variation in traits between individuals of the same species on which selection (by the environment) can act. Evolutionary processes thus shape this trait variation, and the expression of these traits is affected by genetic variation, the environment and by interactions between species including human activities. Thus, both genetic variation and phenotypic plasticity play an important role in community processes, and conversely, these community processes affect evolution of individual species in these communities. Hence, this dynamic interplay between ecology and evolution is crucial in our understanding of the evolution of individual species and at the same time ecosystems functioning and the role human activities play (such as exploitation and climate change).

Human activity may strongly affect ecosystems functioning and resilience by disturbing the within and between-species interactions. This will not only affect community composition, but will exert selection on its community members and consequently, its trait composition. These changes will affect evolutionary and ecological processes of adjacent natural ecosystems. Similarly, introduction of new species (e.g. invasive species; Themes 3 and 4) will affect trait selection in native species through evolutionary community ecology processes. At the same time, these processes may be used to our advantage in sustainable agriculture, aquaculture and nature conservation. Recent advances in whole ecosystems-based analytical tools as well as tools to measure species adaptations and genetic variation now allow for integration of complex ecological processes and species trait variation.

Current key questions:

- Understanding the effect of ecological processes on trait variation. Using a full ecosystems or community approach including indirect species interactions that arise from interaction networks associated with a shared resource will be key in identifying how community properties affect trait variation of community members and evolutionary processes.

[4] By understanding physiological responses of organisms to multiple changes in their environment (e.g. temperature, acidification, eutrophication), changes in spatial distribution may be explained and predicted

- Understanding the role of trait variation in ecological processes. Measuring trait variation in species and its role in ecosystems processes will help us understand the consequences of reduced or altered trait variation in species due to land-use and aquatic-use activities for ecosystems functioning and resilience. It may also provide insights into the relationship between crop trait diversity and the functioning of agro-ecological systems (themes 1 and 2).

- Importance of eco-evolutionary dynamics. To fundamentally understand ecology and evolution it is essential to identify the relative importance of the various (genetic drift, mutation, recombination, and natural selection including human induced selection) evolutionary forces in shaping community and community member variation.

- Heredity: What aspects of heredity (e.g. genetics, epigenetics, G-by-G, G-by-E) underpin the rapid evolution in eco-evolutionary dynamics and how much of this evolution is adaptive for community members and/or the community?

Wageningen Ecology strategy:
Wageningen University is renowned for multidisciplinary approaches of ecological and evolutionary processes with tight links between groups working on ecology, behaviour, genetics and genomics. The whole-systems approach benefits from strong modelling and bioinformatics groups that are crucial for developing and implementing techniques and tools to analyse and integrate large genomics and ecological datasets. A strategy to further develop this area should include:

- Linking community processes to adaptations within heterogeneous environments to understand how community level processes may impose evolutionary forces on individual species taking into account heterogeneity in the land or seascape and spatial limits to species dispersal. This entails linking new developments in molecular science and GIS that allows mapping of genetic variation across environments and entails to elucidate trait-based ecology that focusses on understanding the functional and adaptive significance of traits and ecosystems. This will strongly contribute to predicting environmental change effects on species adaptation and distribution (links to Theme 4). All necessary expertise for this is present in Wageningen and stronger collaboration in this area should be facilitated.
- Sustainable agriculture, aquaculture and conservation policy. Because ecology and evolution are tightly linked in a dynamic interplay, it is crucial to explore how this affects land-use or aquatic-use strategies and to consider them in measures in response to invasive species and nature conservation policy.
- Development of theoretical models linked to experimental research. Development of theoretical models based on evolutionary algorithms that link trait variation and evolutionary forces to community characteristics and functioning. Key here is that these models are developed in a manner that they can be used and validated in real experiments.

Part III A strategy for Wageningen Ecology

In the preceding sections the strengths and unique features of the Wageningen Ecology were laid out and five research themes were identified and described which are scientifically cutting-edge, highly relevant, and in which Wageningen Ecology can continue to excel. This part deals with the strategy for the coming 5-10 years to capitalise on the unique strengths and ambitions of Wageningen Ecology.

Focus: Part II depicts a clear choice to focus on the ecological aspects of current environmental change; dubbed here as the Ecology of Change. This includes fundamental understanding of the ecological and evolutionary drivers and effects of this change, predictions of its impact on ecosystems, and the development of sustainable and adaptive systems, for the use of terrestrial, and aquatic resources. This entails that rather than treating ecosystems as static and isolated, they should be viewed as dynamic and subject to continuous largely anthropogenic change. Understanding the nature of this ecosystems dynamics allows for predicting the impact of unsupervised environmental change, but also to use the dynamics to guide informed decisions on considered environmental change.

Collaboration. Addressing the Ecology of Change requires a strongly multi-disciplinary approach, for which Wageningen Ecology is well positioned. Part II highlights a number of broad areas of collaboration that could be developed in this respect.

- Stimulating further integration between production and environmental thinking: Ecology tends to be divided among those focussing on natural systems and environmental issues (e.g. conservation) and those focussing on resource use and production. But for understanding the impacts of change on ecosystems and designing sustainable and adaptive systems, it is imperative that the integration should be further strengthened.
- Ecology, health and socio-economics: The physiological (health), ecological and socio-economic factors driving the outbreak and spread of diseases are strongly linked and cannot be viewed independent from each other, and stronger links between groups studying these aspects is needed.
- Linking genetics with organismal and community ecology: Understanding adaptation of organisms to changing environments entails research on both the relation between trait variation in relation to fitness and the genetics of this trait variation. However, relatively little research has been done that combines these elements.
- Multi-trophic interactions: Multi-trophic interactions are important in determining the adaptations of different organisms and in driving ecosystem functions. Further understanding of these interactions requires collaborations between groups studying different life forms.
- Spatial ecology: Spatial ecological processes act on scales ranging from the organismal level to the regional/global level, closer collaboration between scientists working on these different spatial levels in close cooperation with remote sensing-experts is important for both terrestrial and aquatic ecosystems.
- Soils, linking the above- and belowground: Soils play a crucial role in determining ecosystem functioning and diversity, and their functioning in turn is driven by a wide variety of organisms

(true soil organism, plants and aboveground animals) and has important feedbacks on aboveground processes. Building on the current Centre for Soil Ecology links to soil interactions with aboveground processes should be built.

- Climate-vegetation feedbacks: The effects of global climate change will strongly depend on how vegetation and climate interact. Vegetation responses can both stabilise ecosystems or trigger positive feedbacks that accelerate ecosystem changes. Big advances can be gained by cross fertilisation between ecology and earth science disciplines such as hydrology and micro-meteorology.

Collaboration in these areas can be fostered for example through establishment of virtual centres in certain areas such as the already existing virtual centre for soil ecology, preferably across science groups. Such clusters should ideally have: a strategic and international profile; a firm base in the chair description of more than one chair group; include different science groups, DLO as well as other (public & private) non-university members; a clear strategy towards joint teaching funding and should be formed in consultation and collaboration with Graduate Schools. They could be fostered and stimulated in several ways. (i) Through the strategic appointment of special chairs or tenure-track positions shared by chair groups, potentially even between science groups. (ii) New areas of collaboration could be explored in dedicated symposia. (iii) Using strategic funding incentives, e.g. in form of funding initiatives that call for collaboration along specific lines or centred around certain themes. Examples include: ERC Synergies, several NWO programs, consortia with private and public sector whereby links with DLO can play a pivotal role or Wageningen based programs such as an IPOP Ecology of change.

Sharing of key technologies towards scale (showpiece) research projects. The trend in ecological research is towards large scale experiments: in terms of replication, time and spatial scale. Financing and conducting such experiments is beyond the means of individual research groups and beyond the career timing of individual scientists, while much mutual benefits can be obtained by collaboratively working on them. Initiatives in this direction should be fostered and stimulated. Funding such projects is difficult as it may require specific infrastructure and large start-up funds. This problem could be overcome by the availability of seed money either at the beginning or at intermediate stages (e.g. when a proposal passes a first or intermediate round)

Advances in molecular biology and in computer modelling are of particular interest in this respect:

Molecular techniques: Technological progress on DNA and RNA based methods has given ecologists a complete new set of tools opening fundamentally new research avenues. Additional new techniques on metabolomics, allows opening up further functional analyses of the genetic signals. Wageningen Ecology is increasingly using these, but should invest in knowledge transfer within the ecological community to use these techniques at best and insure a balance between ecological questions and methodology. Two issues deserve particular attention. (i) The enormous sample sizes that ecologists typically face (in terms of species, genotypes and simply biological replication), make these methodologies prohibitively expensive relative to the funding options. (ii) The bioinformatics required to handle these tremendously large datasets, is a highly complex discipline in itself. Wageningen Ecology should invest in thorough, state-of-art expertise in bioinformatics, available for multidisciplinary projects, as this expertise is not available within individual groups.

Computer modelling: As ecological research becomes more complex and multi-dimensional there is an increasing demand for complex computer models to aid in almost all aspects of research. Wageningen has been a leader in computer modelling for decades, and the university has consistently managed to attract the best and brightest in this field. As models become larger and more complex and multidisciplinary, it will become increasingly difficult for individual research groups to provide both the computational capacity as well as the amount of basic knowledge and analytical and programming expertise needed to run them. There is therefore a need for shared facilities and expertise in this area.

<u>Funding:</u> Ecology plays a central role in addressing the effects of environmental change on human well-being (food production, health and living) and in the search for smarter and more sustainable solutions. Both the public and private sectors are increasingly aware of these issues and are seeking more ecological techniques and processes to achieve their goals. There is clearly a potential for more large scale funding in ecology.

- A stronger lobby to place key ecological issues, such as the importance of ecosystem services and the need to optimize multiple-use landscapes, should play a more prominently role in the research agenda of WU at all levels (Wageningen University, national, international).
- More active engagement of our leading ecologists in the public debate will lead to more visibility of Wageningen Ecology.
- Placing ecology and sustainability more prominently in the profile of Wageningen University. It should be more evident for the outside world that Wageningen is the ideal home base in the Netherlands for scientifically excellent and highly relevant ecological research.
- The development of showcase multidisciplinary projects could strengthen our position for large funds such as ERC synergy.
- A more focussed policy towards acquiring personal grants (VVV & ERC). For example, offering support trajectories for candidates of personal grants. This might include seed money to improve their chances in a subsequent year, when candidates passed the first selection round at ERC or NWO on previous attempts.
- The creation of more virtual expertise centres will facilitate the integration of various disciplines and increases the chances for the successful application for funding.

<u>Integration of nature conservation and management.</u> A large share of the research in Wageningen Ecology is relevant to policy makers, conservation organizations and nature managers. Nature conservation and management is studied and taught by specialists in various research groups. This makes sense as conservation and management advices are often specific to environmental issues (climate change, eutrophication) or ecosystems (forests, grasslands, aquatic systems, oceans). Yet, the multi-disciplinary nature of conservation and management issues in ecosystems, asks for an integrated approach in research. We thus recommend Nature Conservation to be developed as a collaborative field spearheaded by those groups that provide the most relevant expertise (i.e. those groups that have nature conservation and management as a central topic in the chair description) but with input from a

wider set of groups. Particularly a further integration of the production and environmental thinkers and social scientists should be fostered. In addition, there are opportunities for Wageningen to develop as a centre for international nature conservation, a meeting ground for international NGOs, and university research groups involved in this issue. An interesting example in this respect is the REDD@WUR, a diverse Wageningen network of people working on the issue of reducing emissions from deforestation and forest degradation (REDD).

Embedding

In order to implement the activities presented above, an organization structure that initiates and facilitates activities of Wageningen Ecology is necessary, in which the contributions in terms of contents are primarily realized via bottom-up processes across multi-disciplinary groups. This organization structure should include and strengthen the activities of the Graduate Schools that already encompass multi-disciplinary activities (such as done with activities of the Netherlands Ecological Research Network).