7. Systems Design in Metropolitan agriculture

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7.1 Introduction

This chapter describes the Wageningen UR research and its potential on system design. This research area contributes to significant increases in eco-efficient and highly productive agriculture by designing new agroproduction systems (on different scale levels) in cooperation with stakeholders. These systems are especially designed to operate in situations with competing claims on available resources and have the ambition to realize multtargeted production. Such design processes result in broadly based developments that can set the agenda for subsystem innovations. In order to achieve its goal to "explore the potential of nature to improve the quality of life" Wageningen UR follows an interdisciplinary approach combining natural and social sciences and humanities while keeping an eye on economic feasibility. System design methodology can be applied on different scale levels, from the genoom level to farm, chain and regional level, of which examples will be given in this chapter. This approach can offer solutions in any competing claims situation (urban, rural, peri-urban) but is especially useful in situations with high claims intensity as for example in the Dutch context of metropolitan agriculture.

7.2 Metropolitan agriculture

Figure 7-1 Population density and the 100 biggest metropoles (Stichting Onderzoek Wereldvoedselvoorziening van de Vrije Universiteit Amsterdam, 2009). The graph shows the expected growth of the world population and the rural and urban share of it. The transition towards more urban life will also greatly affect the worlds rural areas.

The world is urbanising. Already now half of all human beings live in cities. In a few decades the urban share will approach three quarters of what then are 9 billion people (Figure 7-1). Cities are where the world's economic growth is centred. The Northwest European lowlands are a frontrunner in urbanisation since the 14th century (Wallerstein, 1974) but the massive

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growth of metropoles in our times is taking place in Asia. The result is an explosive growth of
the urban middle class with an increasing purchasing power. They have their own home,
advanced means of transportation, their children at better schools, proper health care, and
their jobs secured. They eat well and dress well, have time for sports, amusement, culture,
take holidays abroad. They work hard to improve their position, and enjoy the rightful
proceeds of their hard work with great gusto.
Purchasing power growth revolutionises consumption patterns, food consumption no less
then other sectors. For food, the difference is not so much in the quantities, but first of all in
the quality. Urban middle class workers need fewer calories from staple food as rice, wheat,
potatoes. They consume much more fruit and vegetables and meat and fish and drink milk
products, fruit juices, soft drinks, beer, wine and spirits. They do not accept health hazards
and demand perfect freshness and excellent taste. Their food must be easy to purchase and
prepare, and must be according to the latest fashion.

These changes in pattern and quality generate much more added value in the whole food
chain than the traditional system based on non-processed staple foods, traded by middle
men. While volumes of food do not change much, the value keeps increasing. So the general
growth of the total purchasing power of the middle class will certainly also manifest itself in
the food sector. And in the same way as middle class development is an urban phenomenon
in general, the major part of this explosive growth in purchasing power with regard to food will
concentrate in urban areas too.
The development of Metropolitan Agriculture (Smeets, 2009) in Northwestern Europe shows
that as a response to the changes in food demand, a transition to highly productive, land
independent agriculture is taking place, large parts of which are embedded in the fabric of the
metropole itself. The development started in Flanders and The Netherlands in the 15th and
16th century (Wallerstein, 1980) and was boosted at the end of the 19th century (Bieleman,
1992) and after the second world war. Greenhouses, intensive livestock and dairy farms are
the modern expressions of metropolitan agriculture and they are inside the metropoles or in
the green space surrounding it. What cannot be produced in these metropoles themselves
(fodder, concentrates, staple foods), is being supplemented by imports, while products
particularly suited to the area, and hence abundantly available, are exported in return. In this
way megacities establish another global network of agro-food chains that are integrated in the
urban structure, from primary production of an enormous variety of food stuffs, via all kinds of
processing activities, to trade and distribution. All along this chain added value is created, the
more so when the highest standards of quality and market responsiveness are attained in
each link. Metropolitan agriculture can be defined as the system of agroproduction with the
ambition of being able to satisfy the changing and competing demands of the urbanised
population on a sustainable basis through new and intelligent connections inherent to the
network society (between producers, sectors, raw materials, energy flows and waste flows,
between stakeholders and between their value systems).
The most important limitation in western society for the further development of metropolitan
agriculture is the societal debate on industrial agriculture. Sloterdijk, 2006) describes this as
the inhibitive context of modern metropoles in the western world, where “every impulse is
stilled by reactions, often before they have been really able to develop. Everything that wants
to move forward, that looks into the distance, that wants to build, is, long before the first
project has been started, reflected in protest, objections, counter proposals, swan songs –
most reform proposals could be realised with a twentieth of the energy applied to their
reformulation, watering down and temporary postponement (….) Governments are these days
groups of people who are specialised in appearing to be able to energetically improve a
country within this inhibitive context.”
This inhibitive context is to a large extent fed by the resistance inherent to the development of
modern agriculture in western society. The distrust from society towards modern agriculture is
also due to earlier and partly still existing bad performance of agriculture in environmental
issues and climate change (Anon., 2008). And also a majority of European farmers faces the
end of their existence as a farmer. They and the organisations by whom they are represented
often oppose ongoing scale increase (Denktank varkenshouderij, 1998).
The inhibitive context is a barrier that must be overcome by the implementation and thus in
the systems design towards sustainable development of agriculture. As will be discussed
further on in this chapter, this implicates that this design process must also include these aspects, that are in the domain of politics, social sciences and psychology. The need for showcases, that can act as examples for the necessary development of metropolitan agriculture worldwide and the inhibitive context in Northwestern Europe within which they need to be developed, motivate the KENGI-approach (i.e. Knowledge Institutes, Entrepreneurs, NGO’s and Governmental organisations that together make system-innovations): only with the political support of all relevant stakeholders, these system innovations can materialize. The design of the stakeholder participation process therefore becomes as important as the technical design of the innovation (Van Mansfeld and Smeets, 2009; Verkaik, 1998).

7.3 Research Directions: Wageningen UR and Metropolitan Agriculture

Figure 7-2 presented by Rabbinge and Slingeland, 2008) depicts the object of the Wageningen UR research, that embroades a wide arrange of interactions between natural and social sciences. Moreover, when turning scientific inventions into innovations in society, also aspects of humanities play an important role, such as design-theory, communication sciences, history, psychology and philosophy. The Wageningen UR scientific approach can therefore be characterised as interdisciplinary and in its co-operation and participatory practice with other stakeholders as transdisciplinary (Tress et al., 2004).

Figure 7-2: The goal of Wageningen UR to "explore the potential of nature to improve the quality of life" is elaborated by an interdisciplinary approach combining natural and social sciences and humanities

System design towards sustainable development is based on a transdisciplinary approach, in which co-operation between science and stakeholders in society is essential. The aim of the work of Wageningen UR on metropolitan agriculture is to generate these system innovations in different places around the world. Research by design or co-design (De Jonge, 2009) is applied as a form of engineering with regional designs as the end-products, where scientific research may take the form of feasibility and suitability studies, as well as process evaluations concerned with the generation of greater generic knowledge. The research is interdisciplinary; it covers both the natural and the social sciences, while also taking account of aesthetics, cultural history and communication. The design produced in co-design is not only aimed at technological systems but also at the generation of inventions and interventions, leading ultimately to the system innovations required for agriculture to link up with the new challenges of globalisation and the network society. Since this consistently involves practical spatial planning situations in which scientific knowledge is in an ongoing process of iteration with the practical know-how of the various participants in the concrete projects, it comes down to transdisciplinarity in practice.
7.4 Examples of systems design on different scale level.

Within this broad framework of regional planning, the introduction of innovations on other scale levels is very attractive. In the following section examples will be given on the level of molecules, greenhouse, stables and integrated agroparks, that all show these characteristics of co-design with KENGi-partners in a metropolitan context, in which the inhibitive context plays an important role.

**Molecule and cell level: Cis-genesis in apple**

In 1998 the Dutch government formulated the ambition to reduce the use of pesticides with 95% in 2010. The Dutch pip fruit chain is one of the biggest users of pesticides and for the biggest single crop, apples, applescabies is the most important disease. The consumption of Dutch apples is significantly decreasing. Its price is high partly because of strict environmental regulations but also the taste of Dutch fruit is decreasing in competitiveness. The development of new apple strains, using traditional growing techniques, would take at least 20 years; which is far too long, given global competition. The development of new apple strains can be speeded up to 5 years by using the innovative ‘cisgenesis’ technique in which genes of wild apple species that generate resistance against the disease, are combined with the genes of the existing species. This in contrast to transgenesis where genes of different species are combined. The cis-genetic design aims at reduction of the environmental burden but can also be applied for generating new and different tastes.

However the question is whether and how the difference between cis-genesis and transgenesis would contribute to a better social acceptance of apples of which production, due to their lower phytosanitary vulnerability would need less pesticides. The design aiming at this innovation therefore not only needed to aim at the technical invention of cis-genesis but also needed to address and influence a discussion in society about the acceptance of this technology. This discussion partly takes place in the domain of politics where new regulations need to be implemented that allow cis-genesis to be applied in the fruit sector. But it is also in the public domain where consumer organisations and other NGO’s oppose the introduction of genetic modification in food (Transforum, 2010b).

Different players in the Dutch fruit sector founded a joint innovation company “Innovafruit” to deal with the demand for more and more swift innovations. Innovafruit joined with researchers of Wageningen UR in 2004 and started a project “Healthy Pip Fruit Chain”, that aims at the systems innovation of introducing the cis-genesis in the development of new competitive apple varieties. In doing so this systems design project combined efforts in three directions: (i) the technological invention of introducing genes from wild apple varieties that generate resistance against apple scabies into existing commercial varieties; (ii) a discussion with the Dutch government and EU-legislators to get cis-genesis excluded from the heavy and very strict regime regarding introduction of genetically modified crops (Schouten et al., 2006, Schouten and Krens, 2006, Commissie Genetische Modificatie, 2006); (iii) consumer research to the perception of genetic modification in general.

General characteristics of system innovations also apply to this specific project: although the technology of cis-genesis, applied to the design of new apple varieties is complex, this hardware problem is relatively easy to solve in comparison with orgware issues (change of regulation) and software issues (change of consumer perception).
Product and field level: Innovative greenhouses

Figure 7-3: Principle of heat and cold storage in aquifers below greenhouses

Dutch greenhouse horticulture owes its leading international position to ongoing knowledge development. However, it is also responsible for approximately 10% of total natural gas consumption in the Netherlands. The future of this sector would be more sustainable if its dependency on fossil fuel could be reduced and the use of it could be made much more efficient. From 2000 onwards researchers at Wageningen UR and innovative growers joined hands to develop new inventions to realise this ambition. One basic idea was to use a completely closed greenhouse and store the heat surplus during summer through a heat exchanger in an aquifer and to do the same with cold surplus in wintertime. The surplus heat can than be used in wintertime to heat the greenhouse and the surplus cold can be used to cool during summer months (Figure 7-3). By doing so the greenhouse can minimise open air ventilation during summer and this adds significantly to the efficiency of CO\textsubscript{2} application for stimulating growth and of biological pest control. And moreover: In dutch climatic circumstances the greenhouse creates a surplus of heat on a yearly basis (de Zwart et al., 2007). At the moment this concept of heat and cold storage in aquifers is being succesfully applied by a number of growers in The Netherlands (Anon., 2009).
Figure 7-4: Greenhouse and power production. Combination of greenhouse and small scale power production can be made very efficient during different periods of light intensity throughout the year.

Another innovation that is being applied on a fairly large scale by greenhouse growers is the combination of crop production and power production by a small scaled power generator on natural gas in a greenhouse (Figure 7-4). The main purpose of the power production is not the power but the clean carbon dioxide that comes as a byproduct, but that is used within the greenhouse to stimulate the growth of the crop. The other byproduct of power production: heat, can be used during cold periods for heating of the greenhouse. In many cases the power is used for assimilation lightning of the crop during dark periods but deliverance to the grid is as least as attractive. Since CO$_2$ and heat both can be stored for longer time the grower can choose to produce and deliver power to the grid at the moments when the price he gets is at the highest. This results in a high price for the produced power but also in a very efficient and flexible power production without the waste products (heat and CO$_2$) that come with traditional power production in large scale power plants (Knies and Raaphorst, 2005).

For the knowledge management concerning innovations in energy-efficient greenhouse production the project ‘SynErgy’ has been set up (Transforum, 2010c). By joining forces, innovators are encouraged to share knowledge and early adopters are induced to follow. A learning network has therefore been set up of innovative growers and researchers. Synergy has created a learning network of growers, greenhouse constructors and knowledge workers, who are at the forefront of energy-efficient greenhouses. The network is now evolving into a Community of Practice (Wenger and Snyder, 2000). New knowledge about energy savings in the greenhouse horticulture sector is being developed and distributed at a high pace and in a demand-driven way. The Community of Practice has formulated several research projects that focus on different aspects of crop production systems in closed greenhouses. All these efforts have generated enthusiasm among early adopters among the growers towards investing in closed greenhouse systems (Bakker et al., 2009).
Product and building (and chain) level: Integrated broiler system

As part of the agropark project New Mixed Company, an integrated broiler production and processing facility has been assigned by Kuipers Kip. It is a system innovation in many aspects, if compared to the existing poultry producers (Figure 7-5).

- Integration reduces transport and veterinary risks
- No transportation before slaughtering: Better meat quality because of stress reduction:
- Reduction of contamination and prevention of loss of taste
- Added value stays with primary producer
- Large scale and industrial mode of production enables radical environmental technology:
  - Smell reduction
  - Ammonia emission reduction
  - Fine dust reduction

Figure 7-5: Integrated poultry chain of Kuipers Kip as part of New Mixed Farm Agropark

In contrast to traditional broiler producers, this facility will integrate egg-production, breeding, broiler growing, slaughtering and processing on one location and in doing so it strongly reduces transportation between these chain elements. But most importantly, a much larger part of the added value in the whole chain, specifically the financial margin of slaughtering and processing, will be kept by the grower/processor. To make slaughtering profitable a minimum delivery of 2000 broilers per hour during at least 8 hrs/day is necessary. Given a growing period of 7 weeks, this results in a minimum scale of 1 mln broiler places in primary production.

The broiler production stable will be completely closed with biological airwashers that eliminate ammonia, smell and fine dust before emission. This reduces the environmental burden of the primary production but also greatly improves the air condition inside the stable, leading to more healthy broilers.

The growing of broilers takes place on a conveyor belt. At the end of their growing period this conveyor belt is switched on and transports the broilers direct to the inhouse slaughtery, taking out the gathering and transport of broilers, that is seen as the worst aspect of broiler production with regards to animal welfare.

In the system design the broiler manure together was projected to be processed in a co-digester to produce biogas and turn that into power, CO₂ and heat. The CO₂ was projected to be delivered to a nearby greenhouse complex, while the heat and power were to be used inside the New Mixed Farm Agropark (see also Figure 7-8) (Broeze et al., 2006).

The hardware plans for the New Mixed Farm have been presented in 2004 for the first time. In many evaluations it has proven to contribute substantially to sustainable development of agriculture (Kool et al., 2008). Since 2004, the entrepreneurs have been trying to acquire all the licences and permits they would need to construct this farm. However, the concept of New Mixed Farm has become the subject to the national debate on the future of intensive livestock farming. It was heavily opposed by local citizens that expressed great concerns about the...
expected inconveniences (smell, heavy traffic, fine dust) A number of environmental and animal welfare organisations used this case in their national campaign against the further development of industrial livestock farming. Despite these protests the local government decided to approve the project, that is now being implemented. (Hoes et al., 2008; Smeets, 2009).

**Product and building level: Cow garden**

The Dutch dairy industry is under pressure from the possible abrogation of European support measures. At the same time, society has set high standards for animal welfare, product quality and quality of production. Farmers seek to provide working conditions that meet these current standards. This calls for new production systems that meet these challenges and demands while also enabling profitable operation.

The 'Dairy Adventure' project experiments with new concepts of enterprises in order to determine the required scale and intensity of production in order to ensure the industry's viability. These concepts are being elaborated around central themes such as stable design, pasture systems, slurry processing, landscape management and the creation of added value. The focus is not only on the technical aspects but also on the co-operation models and on the development path that existing family farms can follow. The project also aims at developing and stimulating new competences farmers need in order to balance society's demands with an operating profit, and at the social and policy conditions, that are required to turn businesses of this type and scale into a success. (Transforum, 2010a).

One of the outcomes of the Dairy Adventure project is the Cow Garden design (van Kasteren, 2009: Figure 7-6)

![Figure 7-6: Animation pictures of the cow garden design, an innovative cow stable concept aiming at maximal animal welfare.](image)

In order to further explore solutions that meet the growing concerns in society on animal welfare in livestock husbandry, the designers changed the perspective for stable design to that of the cow. How would a stable look like if it were designed completely from a cow’s perspective? This resulted in a series of terms of reference to be taken as a starting point for the design:
The resulting design is a synthesis between a greenhouse and a traditional cow stable of which a first pilot version is now being build by a farmer, with support of the Ministry of Agriculture, Nature and Food Quality and several organisations that stimulate innovations in the dairy sector.

Ecosystem and regional level: Agroparks in Intelligent Agrologistic Networks

![Diagram of an agrologistic network serving the needs of a metropole and consisting of consolidation centres, agroparks and rural transformation centres.](image)

Agriculture and logistics are very closely connected within metropolitan agriculture. An ‘intelligent agro-logistic network’ (Figure 7-7) is composed of a number of agroproduction chains, that are connected through logistical operations and flows of knowledge and information. Typical components of the network are, at one end of the chain, production regions, centred on 'rural transformation centres', then at the other end 'consolidation centres' directly servicing metropolitan or export markets, and in between 'agroparks' forming the linking pin between the two. In consolidation centres products, both raw and processed, coming from the rural environment or from specialised agroparks, are combined with import flows, if necessary be processed further, and then recombined and distributed. Perfect freshness and compliance with the highest quality standards are the key issues for operation. For that purpose consolidation centres need to be close to the metropoles. Rural transformation centres work as collection points from where primary products are transferred to other parts of the network. Rural transformation centres are the nodes where the inputs for the whole network can be sourced and where trading facilities will be located. They will also be the contact centres for contract farming and for training and education of farmers.

Of all the elements of the network, agroparks are the most innovative, linking supply and demand flows in entirely new ways. An agropark is a spatial cluster of high-productive plant and animal production and processing units in industrial mode combined with the input of high levels of knowledge and technology. The cycles of water, minerals and gases are skillfully closed and the use of fossil energy is minimised, particularly by the processing of various flows of residual- and byproducts. An agropark may therefore be seen as the application of industrial ecology in the agrosector (Figure 7-8). What is not available from the primary production areas around the rural transformation centres, will either be supplemented by concentrating import flows on the agropark, or intensive, high-tech production within the agropark itself. The third component of the agropark are its trading and distribution functions. These are closely related to the agropark's central point from which all information flows are directed, for the whole intelligent agro-logistic network of the metropolitan region.
The co-design activities of Wageningen UR on agroparks started in 2000 when a first design (Deltapark De Wilt et al., 2000) was launched to start a societal discussion on the pros and cons of this approach. Smeets (2009) gives an overview of a number of designs that have been produced and the research that came with it. Some of these designs have already been implemented (Biopark Terneuzen (Boekema et al., 2008), WAZ-Holland Park in China (Smeets et al., 2004)) while others are under construction (IFFCO Greenport Nellore in India (Smeets et al., in prep.)). In several regions of the Netherlands spatially concentrated agricultural activities are implementing elements of industrial ecology, inspired by the insights that have been produced in this co-design (Agropark Bergerden in Huissen, Agriport A7 in Wieringermeer).

Figure 7-9 shows the existing agroparks, the locations of agroparks in planning and other sites with high potential. Around these projects a large KENGi-network has been established, that from 2002 until 2006 has been actively supported by the Platform on Agrologistics, a cooperation between the Dutch ministries of Agriculture and Transport (Kranendonk et al., 2006).
7.5 Contribution to high-technological and eco-efficient agriculture:

Apart from the extended specialised natural sciences aspects that form the large knowledge base of the above presented designs, there are three overarching theories that are key for the research-by-design or co-design that is characteristic for all mentioned examples.

**Resource Use Efficiency**

The first of these is the resource use efficiency theory (De Wit, 1992). An agropark is primarily concerned with production and the processing of plant and animal products and with the efficient management of the residual and byproducts of these processes. The resource use efficiency theory in its basic form holds that the amount of nutrients needed increases with increasing yield level when expressed per hectare, but decreases with increasing yield level when expressed per unit yield. That means that the efficiency of the agroproduction process in a chain increases the greater the yield per hectare. It also increases with the level of integration: the number of controlled factors as well as their intensity. The theory was originally formulated and illustrated for single crop fields. It has also been applied to integrated systems of plant and animal production. In the report “Ground for Choices” (Wetenschappelijke Raad voor het Regeringsbeleid, 1992) the theory was successfully applied in formulating land use strategies for the European Union.

The innovative greenhouse concepts and the integrated broiler chain concept, that have been discussed in the section before are a striking example of the application of the Resource Use Efficiency theory.

By expanding the greenhouse with heat and cold storage in the aquifer below the greenhouse, the precondition for the use of sunlight for heating and of winter low temperatures for summer cooling is being created. But the system is only productive if the greenhouse is closed, which only makes sense for high productive systems (de Zwart et al., 2007).

By changing the character of power supply from an external input to an internal produced asset, the growers are able to catch the benefits of what is waste in the classical power production: heat and CO₂ and then turn it into a major cost reduction (Knies and Raaphorst, 2005).

The integration of different chain elements in broiler production, needed in order to keep a larger part of the total added value in the chain, is only possible on the basis of a large scale primary production facility. But it also strongly reduces transportation costs and it enables the industrial application of air washers and they again add to the productivity of the whole (Kool et al., 2008).
The Resource Use Efficiency theory clearly has not been the starting point for the design of the Cow Garden. This stable design maximises not on an integrated set of preconditions but favours one in particular: animal welfare. It is to be expected that the application in practice of the concept will be governed much more by a more integrated set of preconditions.

The analysis of seven agropark projects carried out by Smeets (2009) shows the theory also to be applicable for agroparks. Clustering results in transport reduction. Waste processing reduces costs and produces energy. Reduction of emissions, efficient use of water, energy and raw materials reduce the environmental impact. Added to these profit and planet aspects of sustainable development there is the improvement of animal comfort and improvement of labour conditions. Moreover the theory also encourages the high productive use of space for agriculture in metropolitan areas. The reverse conclusion is that within the metropole low productive agriculture should be prohibited. Applied to the resource knowledge, the theory is a plea for maximising the input of the explicit and tacit knowledge of different stakeholders resulting in transdisciplinarity.

**Landscape theory**

The second theory concerns the three-dimensional landscape as formulated by Jacobs, 2006). A landscape is at the same time matterscape, powerscape and mindscape. Landscape is a concept in natural sciences, social sciences and humanities (Figure 7-10).

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<thead>
<tr>
<th>MATTERSCAPE</th>
<th>POWERSCAPE</th>
<th>MINDSCAPE</th>
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<tbody>
<tr>
<td>Physical reality</td>
<td>Social reality</td>
<td>Inner world</td>
</tr>
<tr>
<td>Objective</td>
<td>Intersubjective, normative</td>
<td>Subjective</td>
</tr>
<tr>
<td>Facts</td>
<td>Norms and rules</td>
<td>Values</td>
</tr>
<tr>
<td>Natural sciences</td>
<td>Social sciences</td>
<td>Humanities</td>
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**Figure 7-10:** Design aspects of the three dimensions of landscape: the matterscape dimension is hardware design, the powerscape dimension is orgware design, the mindscape dimension is software design.

Even the discussion in society on genetic modification is partly taking place on the level of the landscape. Although the technology intervenes on the level of genes and molecules, citizens fear its effects partly on the landscape level. They are afraid that modified species spread in an uncontrolled way and mix up with local species. The fears are clearly mindscape and mix up with regulatory aspects in powerscape.

Greenhouses and cow stables are important elements in metropolitan landscapes. Where ever they are being planned or are enlarged, they are heavily discussed (Gies et al., 2007)
The Intelligent Agrologistic Network (IAN) is functioning on the level of the global network society but also on the level of the landscape where it connects Rural Transformation Centres, agroparks and Consolidation Centres in a region. The design of an IAN on this landscape level should take the three dimensions of the landscape in full account. The first dimension is that of natural sciences with aspects such as soil, water and vegetation, the crops, livestock and the physical infrastructure (the matterscape). The second dimension is that of the social sciences and it covers the balance of power between people and groups in the region and the related economic aspects (the powerscape). The third dimension is that of subjective aspects such as aesthetics, history and communication forming part of the humanities (the mindscape). In terms of the theory of the three-dimensional landscape an IAN is regarded as a landscape in which matterscape, powerscape and mindscape each play an important role and must be specifically designed.

An important finding of Smeets, 2009, in his analysis of seven agropark design projects, is that in these design processes the attention of the designers tends to be focussed on the hardware aspects. But it is in the domain of orgware, where the decisive discussions are taking place on the implementation of these designs. The software aspect is in many cases determining the critical path of implementation: training and educating the people that are needed to operate a greenhouse, a modern cow stable or an agropark takes more time than building them.

Process theory
The third theory concerns the design process itself. What conditions must the design of a complex system innovation like an agropark satisfy for it to be a realistic prospect in present-day society? Verkaik, 1998 states that a system innovation is impossible to reach without the co-ordinated effort of all so called KENGi-partners. They have to co-operate in order to reach that complex objective. What are the steps from invention to implementation? De Jonge, 2009 introduced the concept of Co-Design as working method executed by experts who (on the basis of extensive expertise in transdisciplinary design situations) are able to deal with the uncertainties that come with system innovations. They work in an iterative mode, using scenarios and other advanced design techniques. The basic characteristic of a co-design process is its openness. The dialogue with the other KENGi-stakeholders takes place in a ‘free space’, where participants have an open mind, allowing them to seize opportunities outside the ‘dialogue space’ as they come by.

7.6 Quantitative potential
The application of Resource Use Efficiency Theory on European land use (Wetenschappelijke Raad voor het Regeringsbeleid, 1992), showed that in Europe agricultural productivity can still be significantly improved by intensifying agriculture and performing agriculture in the most productive regions. This would hold even more for the relative inefficient agriculture in countries like China and India.
Ex ante evaluations of agropark projects show significant cost reductions (with transport reduction and reduction of fossil fuel use as most important single factors) and large contributions to other aspects of sustainable development (reduction of environmental emissions, of space use, increase of employment and improvement of quality of labour) (Smeets, 2009)

The most important contribution from Landscape Theory on the hardware aspect is a strong improvement of the spatial organisation of agroproduction. Fourty agroparks of 1000 ha in the Netherlands would be able to fully take over all production of intensive livestock, dairy production and greenhouse production. This would not only reduce the direct and indirect space use of these sectors but also improve the quality of space in large parts of the metropolitan green space that would no longer suffer from smell, emissions of ammonia and fine dust and of the heavy traffic that the current spatial organisation brings.
From the orgware perspective of landscape theory a strong plea can be derived to design the masterplanning as well as the implementation of systems-innovations as an open innovation process in which all future stakeholders participate from the beginning. If professionally
organised the extra time investment in the early development stages of this participatory process will be more than compensated with the speed in procedures later on. The same holds for the software development

Application of Co Design Process theory combined with careful monitoring and evaluation will greatly improve the learning attitude of the partners involved and strengthen their ability to generate ongoing system innovations.

7.7 Limitations

To summarize: The strong improvement of resource use efficiency that can be reached is the most important contribution of metropolitan agriculture. System design processes are necessary methodological steps to realise the innovations in products, in production modes, in chains and in networks, adapted to this context. Furthermore in western countries an important improvement can be expected of the spatial re-organisation of industrial agriculture in these densely populated areas, where space is scarce. In emerging market countries as well as developing countries metropolitan agriculture will be able to meet the demands of the growing middle class in terms of more diverse and better quality food. It will generate a large flow of added value and will generate employment for the rural poor who migrate to these metropoles.

7.8 Short and medium term products

The most important result that Wageningen UR and the entrepreneurs and governmental organisations will deliver on metropolitan agriculture in the coming four years are proofs of practice. In different countries around the world Intelligent Agrologistic Networks are being designed and implemented and get connected. They will not only be system innovations that greatly contribute to sustainable development in practice but because of their strong performance in terms of immanent control and transparency they will act as a research base for continuous improvement and innovation of this practice (continuous co-design). The network will also be the practice where education institutes, that are already involved in these designs, will educate students for the jobs that are provided in the network, from farm factory floor workers to the top management. For this knowledge management system aiming at R&D and education, the foundation TransForum, established by the Dutch government to promote sustainable development of agriculture, has established a worldwide network, called the innoversity on metropolitan agriculture.

7.9 Aspects underexposed

A large part of the funding for the research of Wageningen UR is coming from the Dutch Ministry of Agriculture, Nature and Food Quality. No wonder that the research agenda is dominated by the issues that are dominating the societal debate in the Netherlands. The cow garden design is a typical example of an answer to this discussion, expressing the emphasis on animal welfare in the debate on the future of animal husbandry. Worldwide, Dutch agriculture is regarded as a frontrunner on many aspects (Ministerie Landbouw Natuur en Voedselkwaliteit, 2004; Porter, 2001) and there are high expectations on the potential of knowledge export, not only for Wageningen UR but for the whole transdisciplinary network, including the entrepreneurs and the government, that knows how to innovate the regime in which modern food production can take shape.

It would therefore be wise to broaden the research agenda with a number of global issues such as hot and humid climates, robust systems that can operate in less clean environments, systems that address massive water shortages and societies where high-tech logistics and infrastructure are not yet in place. But not only matterscape of The Netherlands is different and sometimes quite unique. There are powerscape differences that matter too: The strong emphasis that animal welfare gets in Northwestern Europe was already mentioned. In some parts of the world animal welfare is not such an issue and investments in it are not understood nor supported. In these cases it helps if direct benefits of animal comfort on productivity can be emphasised (Leenstra et al., 2007). On the other hand, in India, a cow is regarded as holy in Hindustan religion and this demands for specific solutions with regard to cow replacement and treating of calves. Another example of a totally different powerscape is
the public debate and government attitude towards genetic modification. It will be very difficult for Wageningen UR to keep its place as a global frontrunner regarding this aspect, if the European regime is taken as the reference in the long term.

Despite the mentioned attention for training and education, great care should also be taken that this aspect is not becoming the Achilles heel of metropolitan agriculture. There is a general tendency to focus on the hardware aspects of metropolitan agriculture (stables, greenhouses, industrial ecology, infrastructure) and to get stuck in the orgware of it (investors, organisation structure, who has the power?). When finally the agropark opens, there may not be enough trained staff available to deal with the complexity of it. Hence training and education are essential.

7.10 Recommendations

Dutch agricultural enterprises (especially primary producers but also many processors) who are willing to participate are typically small or medium sized. They deserve more support to take the risk of developing metropolitan agriculture worldwide not only from government but also from research institutes. When they succeed in exporting the innovations to countries like India and China, they contribute significantly in showing the innovative power of the industry behind them (greenhouse and stable constructors, ICT developers, large scale processing industry, logistical enterprises) and to the most innovative sector of Dutch economy as a whole.

Moreover, The Netherlands as a worldwide leading country in agriculture and Wageningen UR as its leading knowledge institute should put more emphasis on the establishment of showcases. It is not wise to only take the Dutch policy debate as the one and only benchmark, given the international context in which the sector as a whole and the knowledge institutes that belong to it, operate.

A more effective innovation infrastructure might also need a different orgware: in its report on innovation in the Netherlands, the scientific council of the government points to the need of so called “third spaces” (Wetenschappelijke Raad voor het Regeringsbeleid, 2008; Wissema, 2009). These are virtual or physical organisations aiming at interactions between university and enterprises that are partly connected and partly are preserved from universities and enterprises to protect exploration against too big commercial pressure and at the same time to protect exploitation against the unstoppable preference of researchers to continue exploration. A third space often is needed to enable the interdisciplinary and transdisciplinary research and innovation that the disciplinary organised universities are unable to generate themselves.

7.11 References

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