Social-ecological networks

Building connections for sustainable landscapes

Prof. dr Paul F.M. Opdam

Farewell address upon retiring as Special Professor of Landscape in Spatial Planning at Wageningen University on 18 December 2014
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Rector Magnificus, relatives, friends and colleagues, students, ladies and gentlemen,

Most people know the fascinating phenomenon of thousands of starling flocking together and performing a spectacular show in the air. You may find nice films on the internet, for example http://www.dailymail.co.uk/news/article-2514252/Incredible-photos-of-the-moment-TEN-THOUSAND-starlings-fly-formation-Scottish-Borders.html. Starling flocks are a good example of individuals acting collectively. Scientists from Groningen University analysed how these birds manage to perform these air shows (Hemelrijk and Hildenbrandt 2011). They simulated the behaviour of the individual birds in a computer model, and found that this phenomenon can be described as a process of self-organisation. A few rules in the model are enough to generate the flock behaviour. The birds are attracted to each other, they move in the same direction and they try to prevent collisions. It seems that by flocking, the birds exchange information and are better protected against predators. Together the individual starlings create something that is of value to all of them.

The National Nature Network of the Netherlands is another example of cooperation, this time between people. Since 1991 this ecological network is being created in cooperation by land owners, private organizations, governmental bodies and many more actors. Almost 15 years ago, I had the pleasure to talk at this very place about ecological networks, networks based on ecological processes with the aim to conserve biodiversity. I explained the ecological arguments for applying this ecological network concept as a conservation strategy (Opdam 2000). The network exists because of functional connections between the sites. You may say that the sites cooperate, or more precisely that the local populations inhabiting these sites cooperate by exchanging individuals moving across the network. So here we detect a second layer of collaboration.
Figure 1. Schematic representation of an ecological network with performance level of interacting local populations in habitat sites. Intensity of shade indicates performance level. Open circle: not present.

Figure 1 illustrates such an ecological network. Imagine an area with scattered habitat sites, some larger, some smaller, with a few corridors in between. The grey shade indicates how well local populations perform: the darker the shade, the better the performance. The two small sites at the bottom left are too small and to remote to support a local population. The upper right corner has the strongest part of the network. It produces the highest number of individuals moving to other sites. In such a network structure even small populations may have a fairly good performance level. I have been frequently involved in landscape ecological research on such spatially structured populations, or metapopulations, to figure out how their survival depends on the dimensions and configuration of ecological networks (e.g. Verboom et al. 2001, Vos et al. 2001, Johst et al. 2011; Van Teeffelen et al. 2012), and how climate change interfered with this relationship (Opdam and Wascher 2004; Vos et al. 2008; Verboom et al. 2010; Cormont et al. 2012; Cobben et al. 2012; Malinowska et al. 2014). Research based on the ecological network concept provides the knowledge basis for the National Nature Network and for planning such networks in a multi-stakeholder setting (Opdam et al. 2003; Opdam et al. 2006; Gaston et al. 2006; Opdam et al. 2008). The network concept is also applicable at local level in agricultural and urban landscapes (Geertsema et al. 2002; Snep et al. 2006; Billeter et al. 2008; Termorshuizen et al. 2007; Opdam and Steingröver 2008; Snep et al. 2011).
Figure 2. Two examples of networks based on cooperation: a social network of starlings and the National Nature Network based on cooperation of humans, aiming for establishing ecological cooperation between sites of the network.

Figure 2 portraits these two examples of networks: a network of starlings creating a protection against predators, and a network of people creating an ecological network for biodiversity. These examples have in common that individual actors cooperate to achieve a common goal. As such these examples are a metaphor of landscape planning: actors creating common value by collective action. However, there is also a big difference between the examples. The starlings make a show case of self-governance, what you see is not centrally organized. In the case of the National Nature Network the national government had a strong leadership role, it is a case of hierarchical governance.

During the 15 years that passed since my inaugural lecture, the world has changed. Nowadays the national government no longer takes the lead in creating ecological networks. Nature and landscape policies are decentralized. Citizens and companies are invited to take responsibility for the environment, their landscape (Opdam et al. 2013). Thus, the government created space for local initiatives. Hierarchical landscape planning is replaced by landscape governance, calling for innovations in planning science (Beunen and Opdam 2011). In particular, it calls for planning concepts based on the interaction between ecological and social systems. Therefore, in this farewell
address I put the concept of the social-ecological network central. I discuss why and how it can be helpful to develop landscape planning in a changing world. I will especially focus on how we can use this concept to foster collaboration and to create a feedback between the social and ecological component.

What are social-ecological networks?
In the social-ecological system (Berkes and Folke 1998) the landscape with its natural processes is the life support system of the human community. Humans and nature are interacting. People respond to changes in their life support system by creating solutions that ensure a sustainable future. Research suggests that social-ecological systems behave like so-called complex-adaptive systems (Levin et al. 2013). One of the characteristics is that many individual decisions together may lead to a fundamental change, just like in the flock of starlings. I introduce a special case of the social-ecological system: the social-ecological network. By using this term I want to emphasize the spatial structure of the system. Imagine that you walk through the landscape: you see things change. You encounter wet and dry places, you meet green farmers and high tech farmers, you see gardens with green lawns and gardens full of flowers. Places and people vary across space, and so does their interaction.

In figure 3 you find how I imagine a social-ecological network. For the ecological network, think of sites, scattered across the landscape, which have something to share. For example a network of hedges and bushes or a network of sites with flowery grasslands. If these sites are close enough and large enough, they exchange individuals and so create spatial cohesion in the social network. In the social network land owners, land users, inhabitants and visitors, local governments and companies interact. These actors exchange information and knowledge, they negotiate about how to respond to challenges, and they decide about how to intervene in the landscape to create value.

The two networks are interconnected. Firstly by using the benefits of the landscape. People may use firewood or food crops for example, but also regulatory services such as preventing soil erosion or pest outbreaks. By making use of these services, human well-being is improved. Landscape services is a special case of the term ecosystem services which is popular in conservation planning literature (Schröter et al. 2014). In the context of collaborative landscape planning, Termorshuizen and Opdam (2009) proposed that the term landscape services is better understood by local actors. They associate landscape services with the place they live in, whereas ecosystem services is associated with conservation in protected areas. Whether such services are beneficial should not be determined by economists, but by the users of the landscape. Dinnie et al. (2013) have shown that meaning attributed to green space is developed within the
social network by discussions and exchanging knowledge. So the first connection between the social and ecological part is benefiting from landscape services and valuing their contribution to human well-being.

Figure 3. Schematic representation of a social-ecological network.

The second connection is coordinated intervention in the landscape. If actors become aware of how the landscape can contribute to their well-being, they may decide to invest in it, to change it for better value or to prevent loss of value. Thus in landscape planning processes the essence of valuation is that it leads to interventions. An example is a farmer creating a flowery strip to contribute to the ecological network that provides natural pest control, as part of a common management plan developed by a group of farmers and other actors to improve the landscape services they preferred.

Although my imagination of the social-ecological network applies at the local scale, it is obvious that it is part of the complex world of today and influenced by (for example) changes in the world market price of milk and oil, by political measures such as a restriction of trade with Russia, and by climate change.

Examples of social-ecological networks
A first example is taken from a study on the green infrastructure of the city of Stockholm, Sweden. Ernstson et al. (2010) analysed how the green infrastructure in the urban landscape supported movements of birds carrying seeds and bumblebees pollinating plants (Figure 4). The social network was fragmented into small groups of people that are linked to parts of the ecological network, for example a cemetery or a park. Between the groups were few contacts, the social network was fragmented. To create more cohesion, the researchers proposed to appoint scale crossing brokers.
Figure 4. Result of an analysis of a social-ecological network in an urban landscape in Stockholm, Sweden. Adapted from Ernstson et al. 2010.

Figure 5. Social-ecological network in Hoeksche Waard: linking farm level to landscape level and individual farmer to local community. Based on Steingröver et al. 2010.
In a second example (Figure 5), taken from the study in the Hoeksche Waard by Steingrover et al. (2010), researchers provided the local planning group with ecological information about conditions under which natural pest would be effective, both for the farm and landscape level. By applying this information collaboration at the landscape level increased. Farmers enhanced the social network to manage the ecological network. This social network was extended with the water board and a conservation group of citizens. These groups joined because other landscape services were provided by the same ecological network, being water purification, landscape identity and biodiversity. It suggests that by providing several services at the same time, the actors recognized shared interests which enhanced social network relations.

Figure 6. Network of 34 municipalities cooperating on water management. The darker shaded municipalities aim for water purification and tourism, the light shaded ones for water purification only. Size of dots indicate level of cooperation. Quebec, Canada. Adapted from Rathwell and Peterson (2012).

The third example (Figure 6) was published by Rathwell and Peterson (2012). The map shows a 100 km long section of land with 34 municipalities in Quebec, Canada. Two types of municipalities are distinguished: those only interested in water purification in relation to agriculture, and those interested in water purification and landscape scenery for tourists. The municipalities interested in two services collaborate more often with their neighbours than the narrower scoped municipalities. So as in the Hoeksche Waard case this suggests that if several landscapes services come together they intensify social network relations.
Understanding social-ecological networks

From a science perspective the first challenge is to understand how networks function, for example how they respond to external changes. Researchers found that stronger social networks are better in creating adaptive responses to environmental change. Sandstrom and Rova (2010) suggested that networks with more connections had a better adaptive capacity because actors converged better in perceptions, goals and interests. Such high density networks provide arenas for learning and problem solving, in which conflicts are easier solved. Recently researchers have become interested in the spatial structure of the social network, connecting structure to function similar to the example of ecological networks (Figure 1). It seems that social network structure determines information processing and knowledge generation, both important for self-governance. In figure 7 (published by Bodin and Crona, 2009), the bottom left network has one central person. It is efficient in knowledge exchange, but it is also vulnerable: if the central person disappears, the network collapses. In the one on the upper left knowledge exchange is less efficient but the network is more resilient. Such insight raises the question how social network structure determines the functioning of these networks. And if we understand this relationship, how could we use this knowledge to influence the network structure and enhance the capacity of self-governance? Could it be that, for example, information on shared benefits of landscape services has a positive influence on collaborative relationships?

![Figure 7. Four basic structures of social networks. Source: Bodin and Crona 2009.](image)

One way of addressing such questions is by doing experiments with Agent Based Models (Schouten et al. 2013). Anouk Cormont and co-workers from Alterra and LEI Wageningen UR are developing such a model as part of the WUR strategic Complex Adaptive Systems program. The model has similarities with the model for the
starlings: individuals make decisions resulting in a fundamental change in the system. In the ABM model farmers decide whether or not to shift towards the use of natural pest control by investing in the ecological network. But they know that natural pest control is only effective if a cluster of neighbouring farmers collectively make the change. Therefore the individual interests are connected to the common interests. Neighbours influence each other. As in the real world the farmers have different mind sets, some prefer economic values, others also care for sustainability, still others have a relatively strong social orientation. The model experiments aimed to identify under which conditions the farmer community shifted from conventional to sustainable farming. We found that for such a shift, the proportion of sustainability-driven farmers is crucial, as is the costs of the green infrastructure, and the risk that the natural pest control does not work. Once the majority of farmers made the shift, the intensity of social relations is the key factor that stabilizes sustainable farming. It seems that strong social relations are a significant force preventing the system to shift back to the conventional mode.

**Supporting landscape governance practice**
A part from understanding social-ecological networks, as landscape planners we should also consider how the concept may support planning in practice. I discuss two issues: (1) setting goals for landscape adaptation, and (2) fostering social ecological networks.

![Figure 8. Map of demand for and supply of water retention service in Bulgarian mountain area. Source: Nedkow and Burkhard 2011.](image-url)
In order to create collaboration a common vision on the future is a must. Which landscape services have priority, who is going to benefit? Such goal setting is about values: creating new values, retaining present values, saving costs. In research on ecosystem services, many attempts have been made to connect the landscape to benefits and values. An often pursued method is mapping ecosystem services. For example, O'Farrell et al. (2010) published a map of a part of South Africa showing areas important for selected services, for example areas where groundwater accumulates and where livestock can be bred. Such a map may be useful to stimulate awareness about what the landscape can do for you, but it does not inform about specific benefits to specific stakeholders. More interesting is the map shown in figure 8 for a mountain landscape in Bulgaria (Nedkow and Burkhard 2011). It reveals problems with water flooding during heavy rain in the valleys and the potential of the forests in the mountains to retain the water. So the map informs about how the present landscape functions as a storm water buffer and where the demand for this service is located. But for applying such a map in collaborative planning improvements are necessary. We lack for example information about where measures can best be taken to improve the water retention capacity. We also need to make the connection to the social network: who are the key actors in the valleys, who is managing the forests, who makes the costs of interventions, who gets the benefits, what are their interrelations?

I show you these examples to make the point that often scientific results are not ready for use in collaborative landscape planning (Pouwels et al. 2011; Opdam 2013). An important challenge is to determine how value of landscape services can be specified for local actors. There is a vast literature on economic valuation of ecosystem services (Schröter et al. 2014), but most of it is not useful for collaborative landscape planning for various reasons. One reason is that values determined by scientists are often not recognized as legitimate by local actors. A second reason is that value is not static, the recognition of value evolves during the planning process. So I think that valuation of landscape services is still to be invented. The Master student Juichieh Liu and I advocated a new approach in a recent paper (Liu and Opdam 2014), showing that a lot of work has to be done on this subject. This work starts by defining what value of landscape services means to users of the landscape. Let me use an example from our daily life to explain two aspects of value of landscape services. If you buy a vacuum cleaner, you may find two basic things important. It cleans your carpet properly, and it works any time you switch it on. It is the same with landscape services. If you adapt your landscape to provide better pollination for your strawberries, you want pollination to work at a proper level. And you want it to be reliable: irrespective of how cold the winter has been. I will now elaborate on this point a bit further.
Klatt et al. (2014) were able to show the economic value of wild bee pollination in strawberries (Figure 9). Strawberries are produced in three quality classes with parallel prices. There are three ways to pollinate the flowers: by self-pollination, by wind and by wild bees. The experiment shows that with wild bee pollination 48% of the yield is in the highest quality class. This percentage drops to 30% and lower in the other pollination modes. Obviously, the wild bees that provide this added value to the farmer are there because of the ecological network in the surrounding landscape. To find out how landscape relates to value, we first need to understand the role of species diversity in landscape services.

In recent years evidence is accumulating showing that species diversity matters for the performance level of many landscape services (Harrison et al. 2014), including water purification, pollination and pest control. For example, Wagg and co-workers (2014) were able to provide a positive relationship between soil productivity and soil species diversity. As for reliability, Brittain et al. (2013) showed that a higher pollinator species diversity makes pollination more reliable in Californian Almond orchards under variable wind speed. We all know that weather is variable, and so is the number of pollinators. On the pictures (Figure 10) you see that with only honey bees, pollination is limited to a part of the canopy, and even more limited under high winds. With many pollinator species, the whole tree is pollinated, and high winds have a small impact. It shows that species complement each other, just as humans do when they work in a team.
Figure 10. Almond tree flowers in Californian orchards are better visited if many pollinator species are available: with only honey bees a smaller part of the tree canopy is visited, and pollination is highly affected by high winds. Based on Brittain et al. 2013.

So species diversity makes landscape services more effective and more reliable. For planning we need to know how this value can be generated by taking measures in the landscape. Here we return to the literature on habitat fragmentation and metapopulation ecology that I was involved in during the first years of my professorship, but now for other species and species assemblages. The evidence base is still very small (Vos et al. 2014). A nice example was published by Klein and colleagues (2012), again for the Californian almond orchards. They found that the flower visitation frequency by hover flies and wild bees increased with an increasing coverage of semi-natural landscape elements in the surroundings of the orchard. As we have seen that a diverse set of pollinators improves the reliability of the pollination service, managing the surrounding landscape is the key to ensure that pollination provides value to the farmer, as in the case of the strawberries.

There is a great need for research that not only helps to understand how species diversity ensures effective and reliable services, but also makes the connection to what actors can do in the landscape. With such information we can build knowledge chains that inform groups of actors how they can translate desired service levels into solutions that improve the landscape. Figure 11 portraits such a chain of knowledge, connecting desired value of the service to functioning and structure of the landscape system (Termorshuizen and Opdam 2009). Structure is what you can change, within
Choose desired value of preferred landscape services

- Performance level
- Reliability

Know the required species diversity

Chose from a range of solutions the best improvements to the ecological network

Figure 11. Knowledge chain linking two aspects of value of a landscape service (in this example: pollination) to ecological network structure, as an example to show how scientific knowledge should be constructed to be applicable in collaborative landscape planning.

limits, and we need to know these limits, because within these limits is the space for effective and reliable design options. And design options are crucial, because actors in collaborative planning need to negotiate for the best solution (Opdam et al. 2008). This brings us back to the social network.

A second topic in applying social ecological network concept in planning practice is how to foster social networks in the planning process. Social-ecological networks are an important basis for self-governance, for exchanging information and organizing deliberations and collective action. So how could we foster social networks and connect them to ecological networks? One way is to organize a planning process as a collaborative learning process. A nice example is given by one of the projects within the Green Circles program, in which Heineken, the province of SH and Alterra cooperate to initiate a transition towards sustainable land use. Sabine van Rooij and her project team organized three important steps. They brought together a variety of actors who were triggered by the opportunity to create a better environment for pollinators. Second, they organized a workshop in which actors deliberated about a common goal. And thirdly they offered design rules that connected this common goal to measures that could be taken by individual actors at their own place. What is interesting is that these design rules included a minimum area to create a sustainable habitat for a local pollinator community. Most actors could only achieve this minimum area by cooperating with neighbours. Thus the social network was fostered in three ways: by bringing together people with a shared interest, by building a shared vision and by providing a design rule that stimulated cooperating with neighbours. The result is that a regional pollinator network is now being
planned by many actors: each of these actors contributes a piece (Figure 12). Among these actors are the Heineken brewery, the Archeon recreation park, the municipality of Zoetermeer and a developer of office parks.

One way of making collaborative relationships operational is to stimulate demand and supply relationships within the social network. Sabine van Rooij and Judith Westerink are experimenting with an approach to develop a social-ecological network in an agricultural area near Bodegraven (Figure 13). They work with the local farmer groups as providers of landscape services and with three governmental actors as demanders for landscape services. In a process organized by the researchers, individual farmers created a collective offer to improve the water quality and the connectivity for biodiversity at the level of the whole landscape area. Also, the three governmental bodies replaced their usual control role for a role as a demander for landscape services. So we created three types of collaboration: between the farmers, between the governments and between the suppliers and demanders. This is work in progress, and we certainly need a range of such experiments in a variety of areas to understand how this approach facilitates the development of social-ecological networks.
Among the many unexplored aspects of this approach is the role business actors could play. As in our society economic values are often more powerful than social or ecological values, it is of importance that some business actors advocate that sustainable resource use is pivotal to long term economic targets. If a food industry, say a brewery, would demand barley grown without the use of pesticides, such a demand may trigger farmers to shift to sustainable farming. To achieve this goal, they need to extend the ecological network, for example by adding flowery field margins. But this measure provides other services as well: biodiversity and landscape identity, water purification, and water retention. These services are in the interest of for example the province and the water management board. So the demand for a more sustainable barley production chain by the brewer could foster a social network of suppliers and demanders of landscape services. The business actor stimulates ecological and social network building. We are experimenting with this idea in the Green Circles program, jointly with the Heineken in Zoeterwoude and the Province of South Holland and of course many regional actors (www.groenecirkels.nl). This cooperation is a rich source of new insights in how a demand by a business actor may trigger social-ecological network processes.

To conclude
I presented the concept of social-ecological networks and discussed its role in spatial planning. In developing the concept I integrated knowledge from landscape ecology, economy and governance science (Figure 14). As a new planning concept it can be used to obtain insight in how local communities interact with their landscape, and how scientific information and methods may play a role in managing such systems.
What is special in this system is that scientific knowledge is an essential part. The concept is built on collaboration: collaboration between ecological units in the ecological network, and collaboration between human actors in the social network. Ecological and social collaboration are interdependent. Landscape services provide benefits to a range of actors, and if actors become aware that they share these benefits, they may become motivated to collaborate. But it is also clear that for gaining these benefits, the ecological network in the landscape is the appropriate scale level of management. This insight urges collective interventions. Thus, within the social-ecological network two levels of scale are connected, the individual property with the landscape, and individuals with the community.

![Diagram of social-ecological network interactions](image)

Figure 14. Schematic representation of social-ecological network interactions: social and ecological interactions across space within the networks affecting network function, and informational interactions between the networks affecting collaborative relations.

Within the time constraints of this talk I left out important topics. A critical assumption is that humans cooperate if they understand that cooperation is both in their own and common interest. Obviously, conflicts, lack of trust and power relations play an important role in the dynamics of social networks and are of influence on collaborative relationships.

Ladies and gentlemen, this is a farewell address, but I am afraid it sounds more like a research programme for a new professor. That is partly because I am better in looking ahead than in looking back. But I also hope that the many people I have had the pleasure to work with feel inspired by these thoughts. There is a lot to do.

Let me finish by a few words of thank. Much of what I contributed to science was born in Alterra projects I was involved in. That is where we invented new concepts and approaches, that is where we discovered how science can interact with practice. I
am most grateful that I could work with so many nice and motivated people. Those moments in which we together created new ideas are among the highlights in my scientific life. The results are summarized in this farewell address.

Of great impact to my scientific thinking is that I was appointed as program coordinator of several Wageningen UR strategic research programmes: The Kennisbasis programme Sustainable development of the green and blue environment, the Scaling and Governance program and currently the Informational Governance program. I thank Martin Kropff and Cees Slingerland for the confidence in me, all the members of the coordination teams and especially Katrien Termeer for our effective and creative cooperation. Much of what I learned in these programs has been very influential to my thinking, as you may have noticed today.

Working together with PhD’s has been and still is a rich source of inspiration. Their work was often born in an interdisciplinary team of supervisors. Working in between scientific domains can be difficult, but also very rewarding. So behind the PhD’s are their supervisors, and I thank my colleagues Lengkeek, Kropff, Van Bruggen, Van Ierland, Heijman, Hoekstra, and Leemans and all the co-supervisors for building such effective supervising teams. I cordially thank Frank Berendse for hosting me the first five years of my professorship in his chair group Nature Conservation and Plant Ecology.

The last ten years I have had the pleasure to be part of the Land Use Planning Group. With most of the members of this group I co-supervised students, prepared research proposals or wrote publications. I am grateful that I have been able to share my knowledge with yours in such an open way. Coming from an ecological background, I learned from you that there is not just one truth about landscapes. It felt like passing the finish when a few weeks ago I had my first paper accepted in a hard core planning journal.

For those of you who were at the Alterra symposium earlier today, I will not come as a surprise when I thank all the people from practice I had the pleasure to have worked with. My scientific progress has been greatly inspired by the knowledge we shared. You greatly influenced my thoughts about how scientific knowledge can be made useful for practice. Learning science from practice (Opdam 2010).

And finally, I thank my partner Claire, for always keeping me sharp for other important things in life than work.

Thank you very much for listening.
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'Humans adapt their landscapes, their living environment. Sustainable use of the various landscape benefits requires that land owners and users collaborate in managing ecological networks. Because the government is stepping back as the organiser of coordinated landscape adaptation, we need new landscape planning approaches that enhance collaboration by building social networks and link them to ecological networks. In this farewell address I will explain why the social-ecological network is a promising conceptual model for landscape governance.'