Civil-Public-Private-Partnerships (cp³):
collaborative governance approaches for policy innovation to enhance biodiversity and ecosystem services delivery in agricultural landscapes

Methodology to assess spatial and temporal flows of ES in rural landscapes to different beneficiaries

Milestone M.10

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cp³ = civil-public-private-partnerships

ES = ecosystem services

1. General concept of scale

Ecosystem services are supplied to humans at a range of institutional (spatial) scales, from households, to countries to the globe. Ecosystem services are also supplied at a range of temporal scales, from short to long time periods. The term scale is used to refer to the physical dimension, in space or time, of a phenomena or observation (O'Neil and King, 1998), using physical units such as km or year. Carbon sequestration to regulate the climate, for example, is supplied at the long-term global scale, i.e. this ecosystem service benefits people at the whole globe for longer time periods. Cultural ecosystem services supplied by a nature area, on the other hand, benefit only people who visit this area, for the (short) time period they are there. See Table 1 for more examples of spatial scales for regulating services.

Table 1: Most relevant spatial scale for regulating services. Source: De Groot et al. (2010)

Scale	Dimensions	Regulation service
Global	>1,000,000 km^2	Carbon sequestration
		Climate regulation through regulation of albedo, temperature and rainfall patterns
Biome-landscape	10,000 – 1,000,000 km^2	Regulation of the timing and volume of river and ground water flows
		Protection against floods by coastal or riparian ecosystems
		Regulation of erosion and sedimentation
		Regulation of species reproduction (nursery service)
Ecosystem	1 – 10,000 km^2	Breakdown of excess nutrients and pollution
		Pollination (for most plants)
		Regulation of pests and pathogens
		Protection against storms
Plot plant	<1 km^2	Protection against noise and dust
		Control of run-off
		biological nitrogen fixation (BNF)

Note that some services may be relevant at more than one scale. Based upon Hufschmidt, James et al. (1983), de Groot and Wagenaar-Hummelinck (1992), Kramer, Sharma et al. (1995) and Van Beukering, Cesar et al. (2003).

Spatial and temporal scales of ecosystem services can be used to identify so-called spatiotemporal lags of ecosystem services. Spatiotemporal lags, a concept borrowed from landscape ecology, is used to describe the dissimilarities in place and time between the production and use of an ecosystem service. Greater lags imply greater spatial or temporal distances between the ecosystem service producers and users (Fremier et al., 2013). Figure 1 gives examples of spatiotemporal lags.

Understanding the spatial and temporal scales at which ecosystem services are supplied to humans and the spatiotemporal lags is essential for developing landscape-level conservation and land management plans (Raudsepp-Hearne and Peterson, 2016), i.e. to have effective governance for managing ecosystem services.

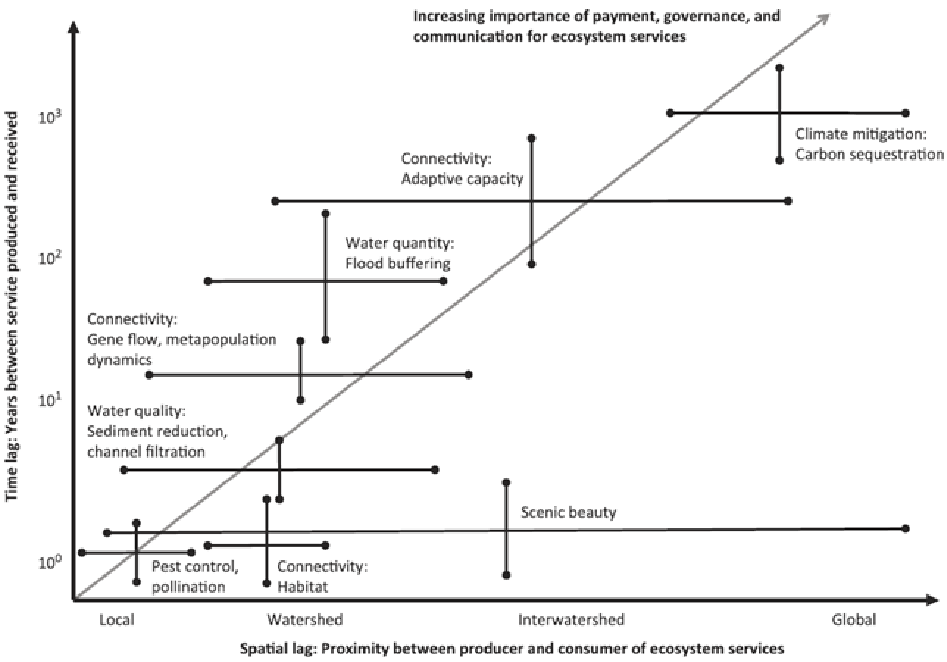


Figure 1: Effective management of ecosystem services requires an understanding of the lags between production and consumption, particularly across well-connected landscape features, such as within river–riparian systems. The grey line illustrates the increasing importance of management or payment for ecosystem services schemes and of matching the scale of the services with that of the organization. Source: Fremier et al. (2013)

2. Spatial aspects of ecosystem services

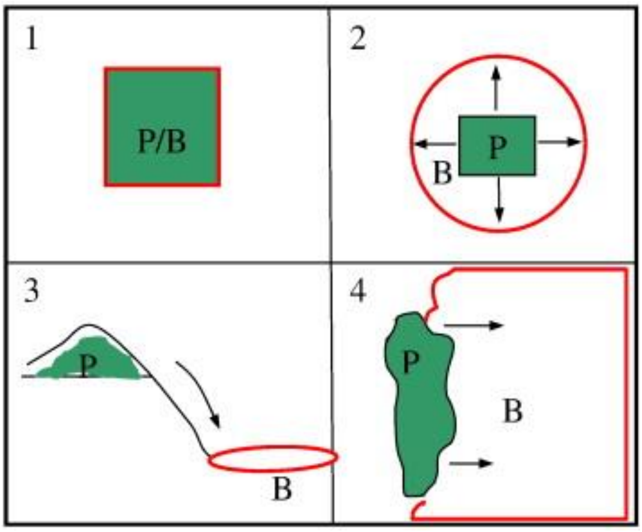
2.1. Spatial aspects of supply

The supply of ecosystem services is influenced by the functioning of ecosystems. This functioning is determined by ecological processes which operate at different spatial scales (Hein et al., 2006). Ecosystems need for example certain areal requirements, i.e. minimum areas, to supply services (Bastian et al., 2012; Kremen, 2005). Or a specific spatial composition or pattern of ecosystems is necessary for the supply of certain services (Kremen, 2005; Bastian et al., 2012).

2.2. Spatial flows: spatial lag between supply and use

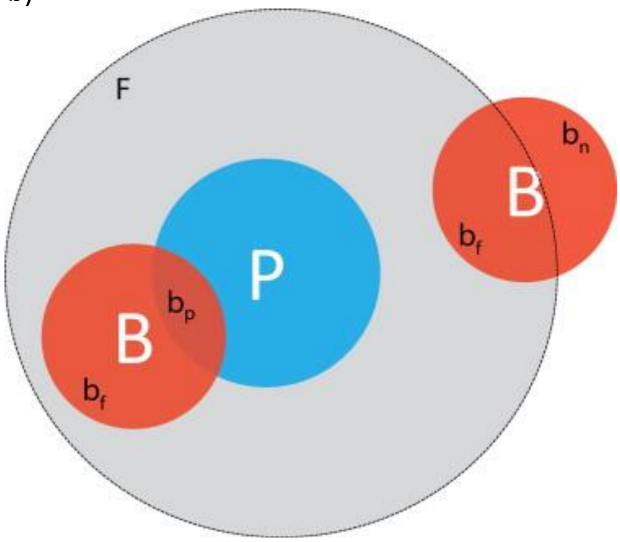
Some ecosystem services are used at the location where they are produced. For other services the location where a certain ecosystem service is produced is not the same as where this ecosystem service is being used, i.e. spatial lags. These spatial dissimilarities result in ‘delivery’ of ecosystem services from provisioning to benefiting areas, i.e. spatial flows of ecosystem services, through either biophysical or anthropogenic actions or carriers. Ecosystem service carrier is the way how a service flows from the location where it is produced to where it is used. To identify locations where ecosystem services are being used, i.e. benefiting areas, it is essential to identify spatially explicit, concrete beneficiaries per ecosystem service (Bagstad et al., 2013). Each service has a specific carrier, which may be matter (water, CO_2 or biomass), information (e.g. aesthetic view quality) or energy (e.g. wildfire) (Bagstad et al., 2013). The distance a service can be maximally transported differs among services (Bagstad et al., 2014; Burkhard et al., 2014; Fisher et al., 2009; Serna-Chavez et al., 2014). In the scientific literature several examples of schematic frameworks to portray spatial flows of ecosystem services exist, see Figure 2.

a)



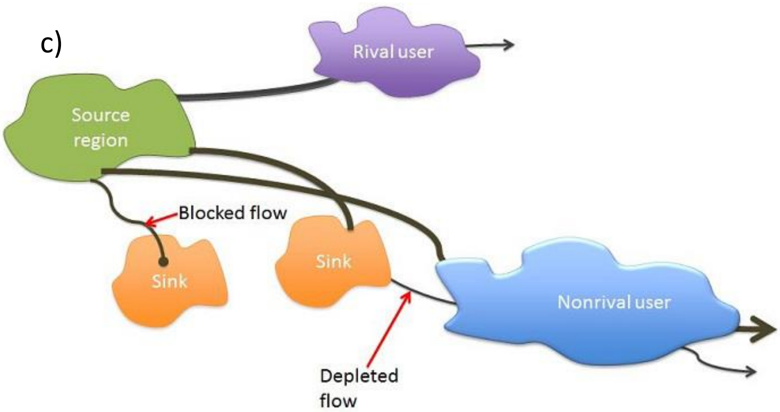
Possible spatial relationships between service production areas (P) and service benefit areas (B). In panel 1, both the service provision and benefit occur at the same location (e.g. soil formation, provision of raw materials). In panel 2 the service is provided omni-directionally and benefits the surrounding landscape (e.g. pollination, carbon sequestration). Panels 3 and 4 demonstrate services that have specific directional benefits. In panel 3, down slope units benefit from services provided in uphill areas, for example water regulation services provided by forested slopes. In panel 4, the service provision unit could be coastal wetlands providing storm and flood protection to a coastline. Source: Fisher et al. (2009)

b)



Framework to analyze and quantify ecosystem service flows. Red circles with B, represent benefiting areas, while blue circle with P represents provisioning areas. F is the flow area within which services from provisioning area can potentially be delivered; b_f is the benefiting area not overlapping with P but within F; b_n is the benefiting area not-overlapping with the provisioning area and outside F; b_p is the benefiting area overlapping with the provisioning area. Source: Serna-Chavez et al. (2014)

c)



Stylized conception of regions of ecosystem service sources, sinks, uses, and flows for a given ecosystem service. Service flows are generated by source regions and depleted by sinks and rival use, but not by nonrival use. Source: Bagstad et al. (2014)

Figure 2: Three examples of schematic frameworks to assess spatial flows of ecosystem services.

3. Temporal aspects of ecosystem services

3.1. Temporal aspects of supply and demand

Besides the discussed spatial aspects, the supply of services is also under influence of time aspects (Bastian et al., 2012; Hein et al., 2016). Flows of ecosystem services can vary over time due to changes in the demand (and use) and supply of services (Rounsevell et al., 2010). Temporal variations in supply can result from changes in biophysical conditions like long-term climatic changes (Holland et al., 2011), but also due to short-term seasonal changes, e.g. the variation in supply of cultural ecosystem services among tourist and non-tourist seasons (Burkhard et al., 2014).

Temporal variability in ecosystem supply can also be driven by human-induced changes, for example land use and land cover changes. Decisions to change land use to promote the supply of one ecosystem service can be at the expense of other services, e.g. the conversion of forests into cropland (Rounsevell et al., 2010). But also short-time management decisions can promote or hinder the supply of ecosystem services, for example fodder harvest from grasslands after meadow birds have finished breeding will result in lower fodder yields, but higher chances for meadow birds to survive (Bastian et al., 2012). Finally, the demand for ecosystem services by society and consequently the use, varies over time as well, influenced by many factors, among which are policies, population dynamics, economic factors, and cultural norms (Hein et al., 2016).

3.2. Temporal flows: time lag between supply and use

As with spatial dissimilarities between supplying and benefiting areas, there are also dissimilarities in timing of ecosystem service supply and use, i.e. time lags. Some ecosystem services are immediately used when supplied, for example soil nutrient cycling, while others show a larger time lag, for example water provision (Fremier et al., 2013), see Figure 1 for more examples.

4. Methodology to determine spatial and temporal flows in the cp³ case study areas

In this part of the cp³ project we aim to characterize and quantify ecosystem services produced within the three case study areas, including spatial flows of these services. We also aim to analyse the change in supply of these ecosystem services over time as a result of land use change, which in turn, could result from changes in governance. The latter analysis will only be carried out for Berg en Dal. Figure 3 gives a schematic overview of the steps to be taken for the two analyses.

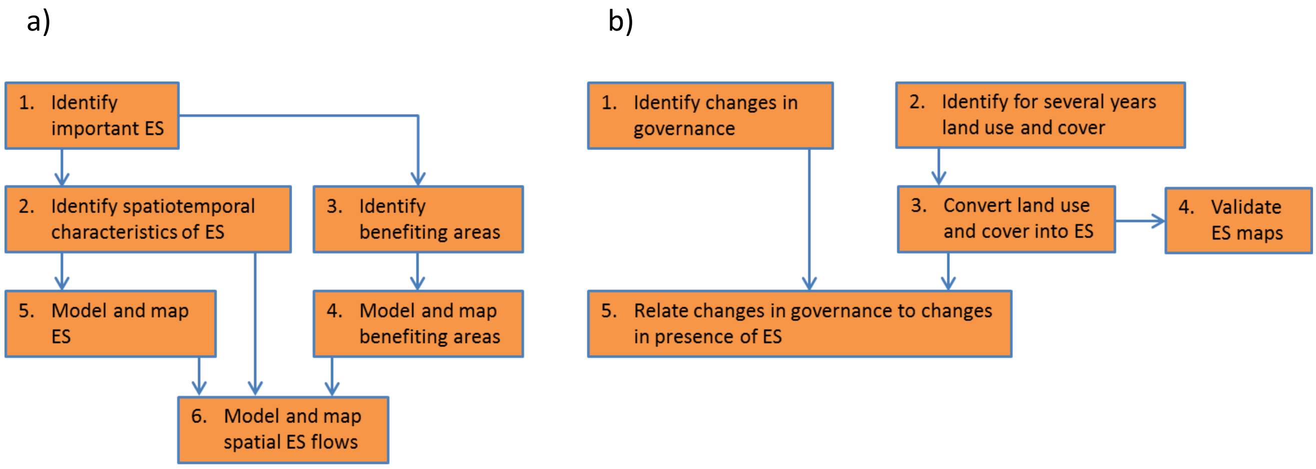


Figure 3: a) schematic overview to assess spatial flows of ecosystem services, b) schematic overview to analyse the change in supply of ecosystem services over time as a result of changes in governance.

4.1. Spatial assessment

4.1.1. Characterization of ecosystem services and beneficiaries (step 1-4 Fig. 3a)

In consultation with cp³ project partners the most important ecosystem services per case study area will be selected from the previously filled out classification and ecosystem service matrices. Per selected ecosystem service information about areal requirements to provide the service, the distance the service can flow, possible carriers and the time-lag will be collected (see Table 2) based on literature research and expert knowledge.

The ecosystem service beneficiaries are those stakeholders who demand a certain ecosystem service, e.g. a farmer demanding irrigation water or someone who is visiting an area as a tourist. To identify spatially explicit, concrete beneficiaries per ecosystem service, information on the location of farmers (arable, horticulture, livestock, and orchard), local businesses, local inhabitants and tourists will be collected and mapped for each case study area, with help of ArcGIS.

Table 2: Draft table to collect spatiotemporal characteristics per ecosystem service

Categories	Sub-categories	Specific services	Unit	Ecosystem providing the service	Spatial relationships between service production and service benefit areas*	Minimum area of ecosystem to provide the service	Maximum distance service can flow	Possible ecosystem service carrier	Time-lag
Provisioning	Food	Fruits	kg/ha						
	Fresh water	Drinking water	m3/ha						
	.....	.....	.....						
Regulating	Air quality regulation	Capture of particulate matter	kg PM10/ha						
	Climate regulation	Carbon sequestration	kg C/ha						
	.....	.....	.....						
.....									

* See Figure 2a

4.1.2. Model and map ecosystem services and spatial flows (step 5-6 Fig. 3a)

Per ecosystem service a tier at which data on ecosystem service can be provided has been defined (see classification and ecosystem service matrix per case study area). Table 3 shows the explanation about the data tiers.

Table 3: Explanation about the data tiers for ecosystem services. Source: personal communication R. Remme (2016)

Tier	Data type	Description	Example
1	Binary	Presence or absence of the ES in the area (yes/no) based on qualitative data	ES tourism available in study area? - YES. ES nursery service available in study area? - NO.
2	Expert judgement	Likert scale system on quantity/importance of ES in the case study area, based on the judgement of (local) experts	ES availability for area: [0- not available, 1- scarce, 2- relatively common, 3- common, 4- abundant]
3	Basic aggregated statistics	Basic quantitative data for ecosystem service, based on a single or a few figures for the whole study area, or for specific ecosystem types. This could be data from literature or national statistics, national average.	Statistics for total timber harvest [m3/yr] or nature tourists [#/yr] in the area.
4	Spatially explicit data	Maps that show the spatial variability of ecosystem services, based on quantified data from field studies or spatial models. Show variation in ecosystem service provision between ecosystems, but preferably also within ecosystems.	Examples of quantified ecosystem service maps can be found at e.g. ANK Netherlands or ESP mapping tool

Per ecosystem service the data will be collected and mapped in ArcGIS. In addition, the location of both natural (e.g. water flows, hedge rows) and human elements (e.g. roads) that are able to transport ecosystem services will be collected and mapped in ArcGIS. The produced maps (providing areas, beneficiaries areas and location of carriers) will be combined and information about the maximum distance a service can be transported and the type of carrier will be used to map the spatial flows of ecosystem services (following to some extent the approach as show in Figure 1b).

4.2. Temporal assessment

The analysis of temporal trends in delivery of ecosystem services as a result of changes in governance will be carried out for the period 1995-2015 for the Dutch case study Berg en Dal. To assess changes in governance a narrative of governance will be constructed. This narrative will be based on interviews with relevant stakeholders (e.g. farmers, the Water board, a policy maker of the municipality Berg en Dal, a member of the association for landscape management and a member of the organisation that implements the regional landscape development plan). Additional data on changes in governance will be collected via literature research.

To analyse changes in the delivery of ecosystem services land use maps of Landelijk Grondgebruiksbestand Nederland (LGN) will be used, which are available for multiple years. The LGN maps have a spatial resolution of 25 by 25 meters. Spatial analyses will be performed using ArcGIS. To identify small landscape elements, these land use maps will be supplemented with information with higher spatial resolution, such as satellite data and information from stakeholders. Land use maps from the available years will be converted into ecosystem services by using the 'table scoring' method developed by Burkhard et al. (2009). This method uses land cover or land use maps as proxies for ecosystem service supply (Burkhard et al., 2009), with help of input from local stakeholders and with help of the previous defined ecosystem services – ecosystem matrices. To assess the accuracy of the applied methodology the developed ecosystem service map of 2012 (the latest year available) will be compared with existing ecosystem service maps (e.g. maps from ANK Netherlands or ESP mapping tool). A land use map for 2015 will be constructed with help of local stakeholders. Finally, temporal trends in governance (type) and in ecosystem service provision will be compared.

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Impressum

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