



Methodological Guidelines for Mapping and Assessment of Grassland Ecosystem Services



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Introduction

Ecosystem services (ES) mapping and assessment have become high on the agenda of all EU Member States after the adoption of the EU Biodiversity Strategy to 2020¹. In line with the Action 5 of the strategy, mapping and assessment of the ecosystems and their services in national territories would have to be carried out by 2014 and the economic values of ES have to be assessed by 2020. This is conforming to the our national strategic objectives set in the Sustainable Development Strategy of Latvia until 2030², where it is said that Latvia wants to become the EU leader in the preservation, increase and sustainable use of natural capital, and possible solutions are based on the estimation of the national natural capital and integration of the natural capital approach in the environmental, economic, spatial and regional development and land policies. Also the mid-term National Development Plan 2020³ says that natural capital has to be managed in a sustainable way.

Ecosystems have potential to supply a range of services that are of fundamental importance to human well-being, health, livelihoods, and survival (Costanza et al. 1997, Millennium Ecosystem Assessment (MEA) 2005, TEEB Foundations 2010, TEEB Synthesis 2010). However, the supply of ES strongly depends on land cover and/or human-chosen land use and additional human-made inputs. Spatial information about existing ecosystems, their provided ES and human demand for ES is needed not only for national accounting in the European Union member states in the nearest future (EU Biodiversity Strategy, Maes et al. 2012 and 2014), but is also needed for smart planning at landscape level, natural resource use or nature conservation management.

These methodological guidelines focus on grassland ES mapping and assessment, since the grassland ecosystems ask for special attention and management to be maintained in Latvian natural conditions. Due to changes in lifestyle, rural regions are experiencing depopulation and land abandonment, which result in overgrowing of former extensively managed grasslands. These natural and semi-natural grasslands are still hosting high biodiversity although are threatened by succession and a resulting loss of grassland biodiversity.

The main goal of the methodological guidelines is to increase the capacity of Latvian experts in the assessment of ES provided by grassland using one of the simplest, relatively cheap and scientifically accepted ES assessment methods based on expert valuation. The guidelines contain:

1. Overview on grassland ES including the concept of ES, trade-offs between ES, classification of grassland ES and assessment methods.
2. Guidelines on ES mapping and assessment at the local or municipal level, which include guidelines for basic spatial data needs, simplest ES quantification method, as well as assessment of ES supply and demand.
3. Guidelines for expert-based valuation of grassland ES at the local level.
4. Key lessons learned from testing the expert-based valuation and mapping of grassland ES in the Sigulda municipality in Latvia.

The methodological guidelines are developed by the Baltic Environmental Forum – Latvia in the frame of the Latvian Environmental Protection Fund co-financed project “Assessment and mapping of grassland ecosystem services in the Sigulda municipality” (original name „Zālāju ekosistēmu pakalpojumu apzināšana un kartēšana Siguldas novadā”, No. 1-08/179/2014).

¹ <http://ec.europa.eu/environment/nature/biodiversity/comm2006/2020.htm>

² <http://www.varam.gov.lv/lat/pol/ppd/?doc=13857>

³ <http://www.pkc.gov.lv/>

1. What are grassland ecosystem services and how to assess them?

1.1. Concept of ecosystem services

The ecosystem service (ES) concept has become more and more popular during the last decades among scientists and decision makers. An important milestone in ES evaluation was de Groot's publication "Functions of Nature" (in 1992) for landscape ecology and planning. The development of the concept was further promoted by Costanza et al. (1997) and Daily (1997), which were further milestones for ES research in a global context (Burkhard et al. 2009). The ES concept has become especially famous when the United Nations published the "Millennium Ecosystem Assessment" in 2005 (MA)⁴ and it's Environment Programme, the "The Economics of Ecosystems and Biodiversity (TEEB) in 2010"⁵.

Different ES definitions and classifications have been developed up to know. The currently probably most popular definitions are developed by MA and TEEB. The MA defines ecosystem services as the benefits that people obtain from ecosystems, TEEB defines them as the direct and indirect contributions of ecosystems to human well-being.

More recent definition states that ES are the contributions of ecosystem structure and function - in combination with other inputs - to human well-being (Burkhard et al. 2012b).

Most commonly, ES are divided into three categories: provisioning, regulating, and cultural services. All categories of ES contribute, in combination with ecosystem functions (or sometimes referred as supporting services), and other factors, to human well-being (MA, Costanza et al. 2014), for example security, basic materials for good life, or health (see Figure 1).

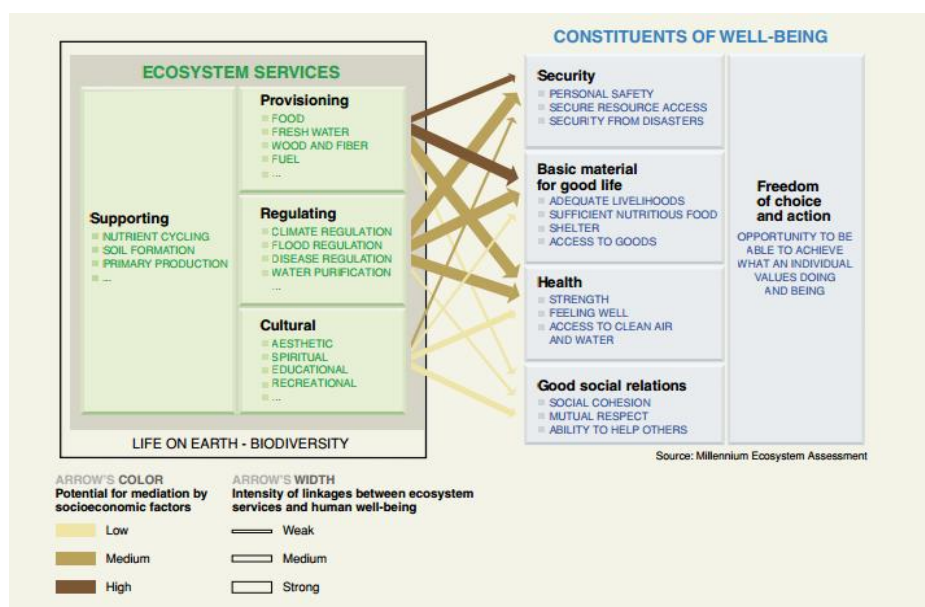


Figure 1: Ecosystem functions, biodiversity, services and constituents of well-being (from MA 2005).

⁴ Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington, DC.

⁵ The Economics of Ecosystems and Biodiversity for Local and Regional Policy Makers (2010).

It has to be understood that the ecosystem cannot provide any benefits to people without the presence of people (human capital), their communities (social capital), and their built environment (built capital). Built and human capital (economy) are embedded in the society, which is embedded in the nature (Costanza et al. 2014) (see Figure 2).

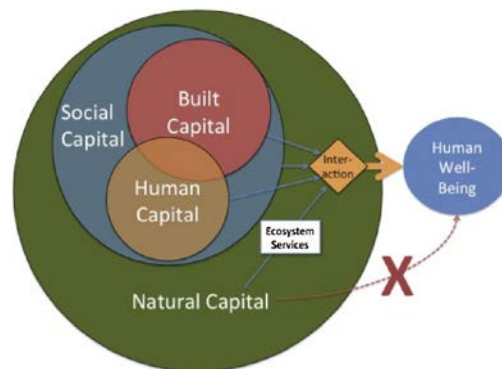


Figure 2: Interactions between built, social, human and natural capital required to produce human well-being (from Costanza et al. 2014).

Most of ES include natural capital and additional human inputs before they contribute to human well-being, i.e. ES do not flow directly but added inputs of humans are needed. Further, there are also ecosystems which cannot exist without people activities, although they play a significant role by providing multiple benefits to humans. In the Latvian case, this includes most of the grassland ecosystems (see grassland ES in chapter 1.3).

According to the Burkhard's et al. (2014a) developed conceptual model of ecosystem functions, services and human benefits (Figure 3), ecosystem functions (ecosystem integrity influences by land cover/land use) provide a specific ES potential, which is the hypothetical maximum yield of selected ES (Burkhard et al. 2012a). This ES potential can be activated, often in combination with additional human inputs (such as fertilisers, machines, knowledge; their way and amount depend on existing functions and expected services) to provide actual ES flows and related yields of ecosystem services. A distinction between the ES potential and ES flow can relatively easy be made for many of the provisioning ES, such as timber provision (service flow) from a stock of trees (ES potential) in a forest. For many regulating as well as cultural ES, this distinction and respective indicator derivation tend to be more difficult (Burkhard et al. 2014a). ES potential and flow together form the ES supply. More about ES supply and demand, their relations and assessment indicators see in chapter 2.3.).

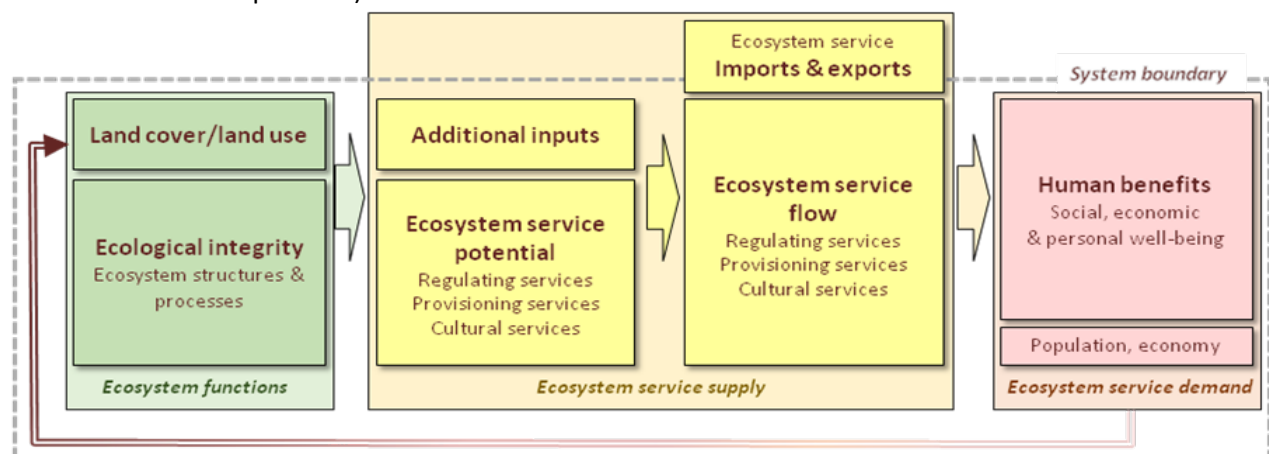


Figure 3: Conceptual model showing relations of ecosystem functions, services and benefits (from Burkhard et al. 2014a).

1.2. Ecosystem service trade – offs

ES trade-offs arise from management choices made by humans, which can change the type, magnitude, and relative mix of services provided by ecosystems. Trade-offs occur when the provision of one ES is reduced as a consequence of increased use of another ES. In some cases, a trade-off may be an explicit choice; but in others, trade-offs arise without premeditation or even awareness that they are taking place (Rodriguez et al. 2006). For example, the management of a forest for tree production (a provisioning service) may deteriorate water quality (a regulating service) and/or decrease the value of the landscape aesthetic which can impact recreation and other cultural services.

Figure 4 demonstrates trade-offs of ES depending from human-chosen land use in a simple way. Each “flower” diagram is made for separate land use/land cover and they show the condition of each ES indicated along each axis (each petal of the flower). An unmanaged forest (a) is able to provide a range of ES where no additional human inputs are needed., Intensively managed agricultural land (b) with large human-based additional inputs significantly reduces the range of ES supply. In opposite, sustainable or ES-based-managed agricultural land (c) maintains the whole range of ES supply in increased amounts. The ES trade-off here is the often reduced crop productivity.

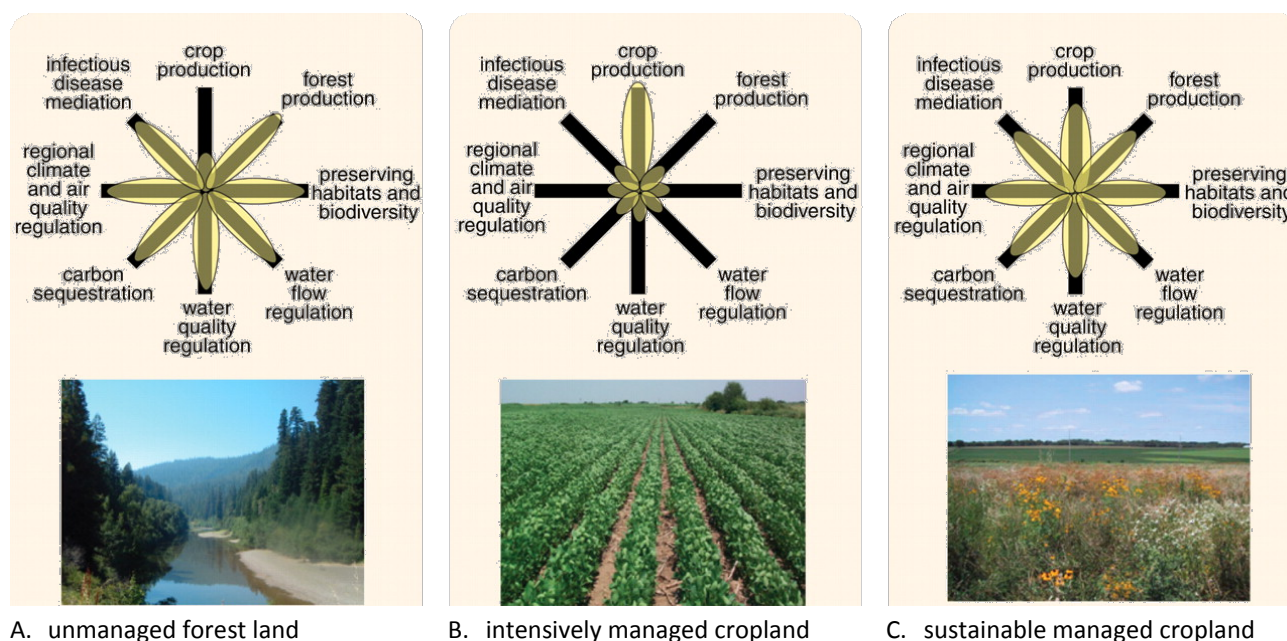


Figure 4: Conceptual framework for analysing trade-offs between ES (from Foley et al. 2005).

ES trade-offs can also take place in areas remote from the site of changed land management. Often, the effects of such management decisions have to be borne by others than those who are benefiting from the enhancement of a targeted ES. For, example, a reduced habitat suitability to support pollination as a result of grassland intensification might also affect the adjacent landscapes, not only the habitat, which underwent a land use change.

1.3. Classification of grassland ecosystem services

Several classifications of ES have been developed. The EU promotes the Common International Classification of Ecosystem Services⁶ (CICES), which has been built on the MA and TEEB classifications. In the CICES system, services are either provided by living organisms (biota) or by a combination of living organisms and abiotic processes.

All grassland-related ES can also be divided into the three previously mentioned categories of provisioning, regulating and cultural services. These categories can be divided into divisions and groups according to the characteristics of the respective service. The classification of grassland ecosystem services adopted from CICES (2013) can be seen in Table 1.

1.3.1. Provisioning grassland ecosystem services

According to the CICES classification, provisioning services include all material and biota-dependent energy outputs from ecosystems. They include tangible goods that can be exchanged or traded, as well as consumed or used directly by people for manufacturing further products. Grassland provisioning ecosystem services provide nutrition, materials and energy mostly based on biomass quantity and quality. Grasslands are an important source for animal forage and related provisioning ES output production. Although pastures on managed grasslands usually provide forage of better quality and higher quantity than semi-natural grasslands, there is some evidence that semi-natural grasslands have added value by positively affecting the quality of the products from reared animals. For example, sensory properties and textures of cheeses and food value (content of microelements and vitamins) of meat can be linked to botanical diversity of grasslands, particularly semi-natural grasslands (Coulon et al. 2014, Hopkins 2009). Concerning forage quantity, several studies have provided the evidence that species-rich grasslands may achieve higher biomass and hence higher hay yields (Hooper et al. 2005, Bullock et al. 2007).

Semi-natural grasslands provide also food for people by wild plants (berries and mushrooms), herbs valuable for medicine and maintain the diversity of genetic material, which can be used also for biochemical industry and pharmacy.

Energy provisioning by combustion of biomass from grasslands is an alternative use of grasslands and, like in the Latvian case, probably one of the most practical solutions for farmers who are managing semi-natural grasslands and receiving subsidies for cutting and removing grass. Although herbaceous biofuels contain more ash producing mineral compounds and nitrogen than wood fuels and therefore their combustion contributes to air pollution. Nevertheless, the use of the local energy recourses, which have to be collected anyway, has to be considered as an advantage.

1.3.2. Regulation and maintenance grassland ecosystem services

In general, regulation and maintenance ES are the services that ecosystems provide by being mediators and acting as regulators of ecological processes, e.g. regulating the quality of air, water and soil or by providing flood and disease control. All regulation and maintenance grassland ES are divided into 3 divisions:

1. Mediation of waste, toxics and other nuisances – by biota or by the whole ecosystem.

⁶ The Common International Classification of Ecosystem Services. <http://cices.eu/>

2. Mediation of flows - provides the flow regulation of matter (e.g. control of erosion rate), liquid (e.g. runoff, water recharge) and gaseous substances/ air (air ventilation). For example, grasslands can reduce water runoff by 20 % in comparison with cropland and by 50 % in comparison with urban areas (Hönigová et al. 2012).
3. Maintenance of physical, chemical, biological conditions – services, which provide maintenance of lifecycle for living beings as well as protection of habitats and the gene pool. For example, grasslands provide an important habitat for many wild plant and animal species, including wild pollinator species, such as hoverflies, bumblebees or feral bees. There are already appearing evidences that the decline in natural pollinator diversity and intensity can result in decreased yields of agricultural crops. Semi-natural grasslands play an important role in the intensity of pollination services. Grasslands have also potentials for the control of pests and diseases, as well as the regulation of water chemical quality, and the regulation of soil and atmospheric composition.

1.3.3. Cultural grassland ecosystem services

Grasslands play important roles in recreation, human aesthetics and in traditional cultures. Many outdoor activities, such as bird-watching, hunting, hiking and general enjoyment of nature are related to open landscapes. Natural grasslands on hills and wild flower crowns typical in midsummer festivities have special values in Latvia and other Nordic countries.

According to the CICES classification, cultural grassland ES can be divided into two divisions: services, which give physical and intellectual interactions (science, cultural heritage, aesthetic, recreation), and services, which provide spiritual, symbolic and other interactions to humans.

Table 1: Classification of grassland ecosystem services adopted from CICES (2013) for Latvian conditions.

Section	Division	Group	Examples of grassland related ecosystem services
Provisioning	Nutrition	Biomass	Cultivated crops
			Reared animals and their products: meat, dairy products (milk, cheese, yoghurt), honey etc.
			Wild plants: berries, mushrooms
	Materials	Biomass	Fibres and other materials from plants for direct use or processing
			Plants and animals for agricultural use: fodder, fertilisers
			Herbs for medicine
	Energy	Biomass-based energy sources	Genetic material (DNA) from wild plants and animals for biochemical industry and pharmacy
		Abiotic energy sources	Biomass-based energy sources: timber, woodchips, hay for burning and energy production
Regulation/Maintenance	Mediation of waste, toxics and other nuisances	Mediation by biota	Wind
		Mediation by ecosystems	Bio-remediation by micro-organisms, plants and animals
			Filtration/sequestration/storage/accumulation by micro-organisms and plants
	Mediation of flows	Mass flows	Filtration/sequestration/storage/accumulation by ecosystems
			Mediation of smell/noise/visual impacts
			Control of erosion rates: vegetation cover protecting/stabilising terrestrial ecosystems
	Maintenance of physical, chemical, biological conditions	Liquid flows	Hydrological cycle and water flow maintenance: recharging of groundwater by land coverage that captures rainfall
		Gaseous / air flows	Natural or planted vegetation that enables air ventilation
		Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal
			Maintaining habitats for plant and animal nursery and reproduction
		Pest and disease control	Pest and disease control , including invasive alien species
		Soil formation and composition	Weathering processes: maintenance of bio-geochemical conditions of soils including fertility, nutrient storage, or soil structure
		Water conditions	Chemical condition of freshwaters: maintenance / buffering of chemical composition of freshwater column and sediment by denitrification, /re-mineralisation of phosphorous, etc.
		Atmospheric composition and climate regulation	Global climate regulation by greenhouse gas/carbon sequestration by terrestrial ecosystems
		Micro and regional climate regulation	Modifying local/regional temperature, humidity, wind fields
Cultural	Physical and intellectual interactions with ecosystems and landscapes	Physical and experiential interactions	Experiential/sensual use of plants, animals and landscapes: e.g. bird watching, landscape photography
			Physical use of landscapes (recreation): walking, hiking, and leisure hunting
		Intellectual and representational interactions	Scientific
			Educational
			Cultural heritage
			Entertainment: ex-situ experience via different media
			Aesthetic: sense of place, artistic representations of nature/landscape
	Spiritual, symbolic and other interactions with ecosystems and landscapes	Spiritual and/or emblematic	Symbolic: Emblematic plants and animals e.g. national symbols
		Other cultural outputs	Sacred and/or religious: e.g. Midsummer traditions
			Existence: Enjoyment provided by wild species, wilderness, ecosystems, landscapes
			Bequest: willingness to preserve grasslands for future generations

1.4. Assessment of ecosystem services

Assessment of ES can be very complex and several biophysical, social and economical assessment methods and indicators have been developed (e.g. Maes et al. 2014, Burkhard et al. 2014a, Martínez-Harms & Balvanera, 2012, Bartelmus 2008, Liu et al. 2010). All methods have their specific advantages and disadvantages. Biophysical assessments are based on quantitative biophysical measurements, monitoring data, spatial data, modelling indicators and mapping by characterisation of ecosystem structures and functions and relations to ES provisioning. Comparing to other assessment methods, the biophysical assessment is time-consuming and expensive, but scientific exactness is often higher (Figure 5).

Social ES assessments are based on different social-scientific survey methods (e.g. interviews, focus group discussions (FGD), participatory (GIS) involving stakeholders and assessing the importance of particular ES for different stakeholder groups. Economic ES assessments are based on different economic valuation methods (e.g. market value analysis, avoided damage costs, contingent valuation, willingness to pay) often leading to an assessment of the total value of a particular ES in monetary terms. The scientific exactness of these methods is varying and the normative loadings for decision making are high.

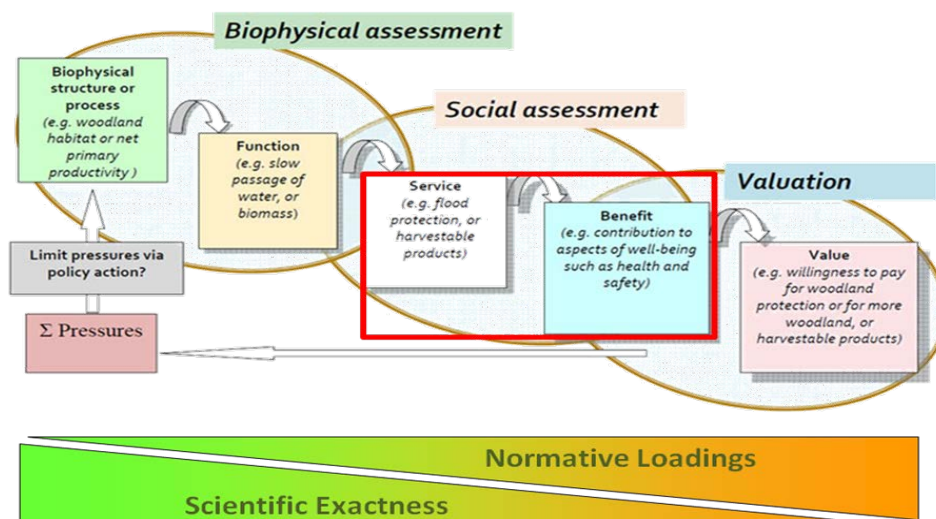


Figure 5: The ecosystem service 'cascade' model and relations of scientific exactness and normative loadings (after Haines-Young & Potschin, 2010, Burkhard 2014b).

ES-based sustainable management strategies and related landscape management measures can often not wait for high levels of certainty and precision (Burkhard et al. 2012b). Thus, ES-research and practice have to balance between scientifically detailed analyses and pragmatism in the context of information needed rather fast for appropriate decision making (Jacobs et al. 2014). Therefore, expert elicitation has become a very prominent tool in order to deliver information about complex phenomena rather quickly. Expert assessments deal with the urgency-uncertainty dilemma by harnessing best available knowledge, validating methods and adding data (Jacobs et al. 2014; Helfenstein & Kienast 2014; Kienast et al. 2009). Expert interviews are based on a manageable number of experts with sufficient knowledge about ES and the study region. The target here is not to collect information from as many interviews as possible, as it would be the case in most social scientific surveys (for more details about the method, see chapter 3), but to harness the existing knowledge available from respectively selected experts

2. Guidelines for ecosystem services mapping and assessment at the local level

Due to the complex and comprehensive character of ecosystem services themselves, their mapping requires flexible approaches. Tiered mapping and assessment approaches, from simple to complex methods, integrating less sophisticated expert- and land cover-based approaches (such as Burkhard et al. 2012a) with the use of existing ES indicator data bases and more comprehensive ES models provide appropriate solutions (Maes et al. 2014).

The quality of ES mapping study results are strongly related to the used quantification and mapping methods, input data and end-user needs. Therefore, all studies should be carefully documented including:

- mapped ES;
- ES type that the accounting refers to - ES function, ES potential, ES flow, ES demand;
- the service providing unit (SPU) (for example, a type of ecosystem located in certain area) and the service benefitting area (SBA);
- used ES indicator and quantification unit (including quantity, area, time);
- used data source – e.g. model output, measured/primary, aggregated statistics, expert scores;
- used quantification method;
- spatial details - scale, extent, resolution;
- the year or period of mapping;
- the purpose of the study.

For a detailed description of how to systematically report on ES mapping studies, see Crossman et al. (2013).

ES quantification and mapping are based on the biophysical (ecological) ES quantification including the identification, measurement and evaluation of ES for understanding how ecosystems function and which species, processes and functions provide ES (Sagoff 2011). Related indicators and quantification units refer to process rates (e.g. erosion regulation) or absolute values (e.g. amount of water supply). Provisioning and regulating ES can be assessed relatively well with biophysical quantification units, whereas cultural ES assessments are often based on personal preferences and respective proxies.

2.1. Basic spatial data needs for biophysical mapping of ecosystem services

For biophysical ES mapping at the local level, the most suitable approach(es) can be selected and, depending on data and resource availability, combined. The most basic data needed for ES mapping must include geospatial reference units such as **topographic** map information about locations of, for example, forests, water bodies or settlements. Despite the high spatial accuracy of topographic map data, their thematic resolution, in most cases, will not be sufficient for the identification of ES supply

units. Therefore, **habitat** maps or **land use/land cover (LULC)** data can be seen as minimum data requirement for ES mapping. Data originating from remote sensing (e.g. satellites such as Landsat TM, SPOT or aerial photos) or ground-based investigations (habitat mapping, land survey) are most commonly used.

The CORINE⁷ land cover data from the European Union provide classified spatial land cover data in GIS format (ArcGIS Shape) for free and are ready for use. The data include 44 land cover classes for artificial surfaces, agricultural areas, forests and seminatural areas, wetlands and water bodies with a minimum mapping unit of 25 ha for the years 1990, 2000 and 2006. These features and its availability across all EU member states make CORINE one of the most commonly used spatial data sets for ES mapping studies. However, for studies on local levels, the relatively coarse spatial resolution may, depending on the heterogeneity and structure of the landscape, not be sufficient. In that case, the use of or a combination with other spatial land information (habitat maps, survey data, specific land use information from cadastral data, forestry or agriculture) is recommended (Kandziora et al. 2013).

For more comprehensive assessments, the land cover data should be combined with data on hydrological and soil conditions, fauna, elevation, slope and climate as well as information on human impacts. Human impacts mainly refer to land use activities but include also emissions, pollution or species removal and introduction (Burkhard et al. 2012a). Human activities can have impacts, especially on grasslands, depending on their use, for example, as pastures, for fodder or as protected areas. Some grassland types occur only as the result of human actions such as cutting or fire.

Working on the local/municipality level demands, compared to studies on larger regional or national spatial scales, on the one hand data with more detail, higher spatial resolution and a better integration of local knowledge (ground truthing). On the other hand, data acquisition and validation are often easier than for large-scale studies.

2.2. Quantification and modelling of ecosystem services

Quantification

Besides the spatial landscape information, which already can be helpful for the identification of ES (the supply of some ES is typically bound to specific land cover types, e.g. crop provision on agricultural areas), further data are needed for ES quantification. In a tiered ES mapping approach, the most rapid way to collect comprehensive information about multiple ES is to make use of expert knowledge (Helfenstein & Kienast 2014). In the approach described in Burkhard et al. (2009, 2012a and 2014a), a broad set of ES can be assessed in combination to their supply capacities in different land cover types in an ES matrix. At the matrix intersections, the capacities of the different land cover types to supply particular ES are ranked on a scale from 0 (no relevant capacity of the particular land cover type to supply the selected ES) to 5 (very high/maximum relevant capacity).

⁷ <http://dataservice.eea.europa.eu>

The scores for different ES in different LULC classes can then be attributed to spatial data in order to compile ES maps (see Figure 6).

The use of expert knowledge for comprehensive ES assessments, which otherwise would demand large resources in terms of time and personnel, has become more and more popular and accepted within the scientific community. Advantages and disadvantages of the matrix-based approach have recently been elaborated in Jacobs et al. (2014).

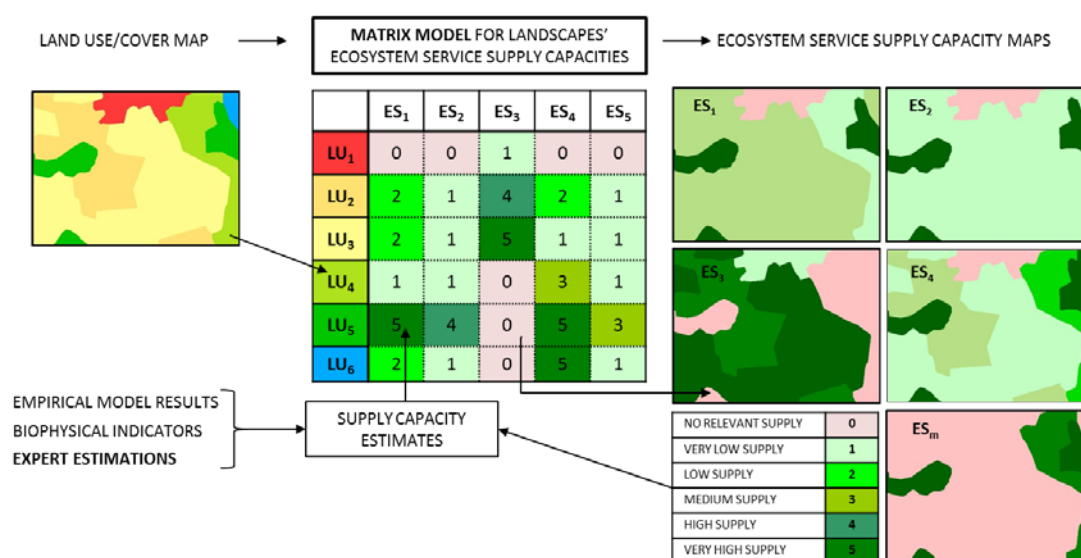


Figure 6: Schematic concept of the ES Matrix model as described by Burkhard et al. (2009; 2012a; 2014a): Based on expert estimations, biophysical quantifications or empirical model results, estimates for ES supply capacities are attributed to land use/cover (LULC) classes. The matrix allows comparison and clustering of ES (columns) as well as LULC classes (lines). The matrix can be used to explore spatial aspects of supply capacities by deriving maps per ecosystem service (Figure from: Jacobs et al. 2014).

For more complex ES assessments, data from statistics (e.g. about agricultural or forestry production such as FAOSTAT⁸) or existing studies with relevant information should be harnessed.

Modelling

ES modelling is one of the most complex ways to assess ES and several promising approaches exist. Bagstad et al. (2013) provide an overview and test of the most commonly used ES quantification and valuation models. A widely applied ES tool is InVEST, a freely available GIS-tool collection developed under the Natural Capital Project⁹. InVEST is based on separate models for different ES and can be used to analyse spatial patterns of ES supply and effects of land cover changes. One disadvantage of InVEST is that for some ES it needs rather comprehensive input data in a specific format. Model outputs include ES estimates in biophysical or (in some cases) monetary units. ARIES, the ARTificial Intelligence for Ecosystem Services¹⁰, is a web-based ES mapping and valuation tool based on

⁸ <http://faostat3.fao.org/faostat-gateway/go/to/home/E>

⁹ <http://www.naturalcapitalproject.org/InVEST.html>

¹⁰ <http://www.ariesonline.org/>

Bayesian networks to analyse ES flows. SolVES, the Social Values for Ecosystem Services¹¹, is a GIS tool to assess, map, and quantify perceived social ES values, e.g. landscape aesthetics, biodiversity or recreation.

Spatial and temporal scales

All information and data used for ES quantification and mapping should be as detailed as possible and needed in a relevant resolution and at appropriate spatial and temporal scales (Burkhard et al. 2012a). However, in flexible mapping approaches, also the definitions of scales need to be sufficiently flexible in order to account for peculiarities of different study areas and socio-economic settings. According to Burkhard et al. (2014a), spatial scales include:

- local scales - communities, farms, ecosystems;
- regional scales - administrative districts, watersheds, landscapes;
- continental scales - Europe, Asia;
- global scales.

One common problem in ES mapping studies is regularly occurring mismatches between geobiophysical spatial units (e.g. land cover types, soil associations, watersheds) and administrative units (such as states, counties, communities). Most ecosystem functions and regulating ES relate to specific spatial process units such as water catchments, whereas statistical data are often collected on administrative units' scales. Consequently, the data cannot easily be linked to the same spatial units and mismatches occur.

Similar problems/mismatches can occur regarding temporal assessment scales. ES can be quantified on:

- short-term scales - events, peak flows;
- seasonal scales - harvest rhythms, tourist or growing seasons;
- annual scales - sums, yearly average values;
- medium-term scales - decades;
- long-term scales - generations, centuries, millennia.

Therefore, it should be checked for each ES individually, which is the relevant spatial scale (the "service providing unit" SPU) of ES supply, and which is the relevant temporal scale of ES supply. In order to keep assessment/computation efforts reasonable, scales should be chosen in order to reflect most important features of the supply of the respective ES and the purpose of the study. Too detailed scales can lead to time and labour efforts disproportional to the gains in information.

Topographic map data should have a scale of at least 1:25 000 – 1:100 000, when working on local scales. The spatial resolution (minimum mapping units MMU) defines which elements are still visible on the map. In remote sensing-based data (such as CORINE with an MMU of 25 ha), the elements smaller than the MMU (also linear or point elements) will not be presented in the map. Topographic maps and other 'classical' map products are generally more accurate, including smaller elements in forms of symbols.

¹¹ <http://solves.cr.usgs.gov/>

Regional assessments can also be based on data of larger spatial scales. Their purpose is mostly to provide an overview instead of giving detailed information on exact location. For most provisioning ES, annual values will provide sufficiently detailed information. Regulating ES can manifest themselves rather suddenly (e.g. during flood or erosion events) or can be more relevant in the long-term (e.g. global climate regulation). Cultural ES can show high seasonal varieties (e.g. tourism seasons) or be based on generational changes (e.g. knowledge systems, trends, cultural heritage). For detailed descriptions of ES mapping scale issues, see Burkhard et al. (2014a), for grassland ES mapping check Lorencová et al. (2013).

2.3. Assessment of ecosystem services supply and demand

Most of the existing ES mapping approaches focus on the supply aspect of ES (see Crossman et al. 2013; Martínez-Harms & Balvanera 2012; Egoh et al. 2012 for reviews). However, it is needed to take a closer look how ES actually are being supplied and used, and to integrate societal needs for goods and services (ES demand). Both are urgently needed to improve existing, often function-oriented landscape planning approaches and environmental management strategies (Burkhard et al. 2014a).

Indicators

For proper identification and quantification of ES supply, clarification is needed, whether the assessment primarily focuses on potential ES supply (ES stocks) or on ES flows (actually used ES). ES potentials refer to hypothetical maximum yields of ES (Burkhard et al. 2012a), whereas ES flows try to quantify *de facto* used set (bundles) of ES and other outputs from natural systems in a particular area within a given time period (Burkhard et al. 2014a). In a forest, for example, the trees as standing stock of wood biomass represent a high potential for the provisioning ES timber. But at first, the harvesting of wood activates the flow of this ES to the society. Like in many human-modified systems, several non-ecosystem-based anthropogenic additional inputs are needed to harness the (natural) ES potential. Additional inputs refer, for example, to fertiliser, energy, pesticide, technique, labour or knowledge use (Burkhard et al. 2014a). This accords with the more recent definition of ES as “contributions of ecosystem structure and function – in combination with other inputs – to human well-being” given by Burkhard et al. (2012b). ES demand refers to ecosystem goods and services currently consumed or used in a particular area over a given time period, not considering where ES actually are provided (Burkhard et al. 2012a). Tables 2 and 3 give overviews of grassland ES potential, flow and demand indicators. Looking at the numbers of relevant ES, it becomes obvious that regulating ES are especially relevant in grassland ecosystems.

Based on ES supply and demand quantifications, regional or local ES budgets can be calculated, providing information about ES under-/over- or balanced supply (see the example by Nedkov & Burkhard 2012; Burkhard et al. 2012a).

Table 2: Overview of exemplary grassland ES potential, ES flow and ES demand indicators (based on Burkhard et al. 2014a).

Ecosystem Service		Exemplary Service potential indicators	Exemplary Service flow indicators	Exemplary Demand indicators
Regulating	Global climate regulation	Amount of methane, carbon dioxide and water vapour stored in vegetation and soils (t C/ha)	Amount of methane, carbon dioxide and water vapour taken up by vegetation and soils (t CO ₂ /ha per year)	Greenhouse gas emissions by industry, traffic, households (t CO ₂ /ha per year)
	Local climate regulation	Temperature (°C); albedo (%); precipitation (mm); wind (Bft); evapotranspiration (mm)	Temperature amplitudes (K); precipitation; wind or evapotranspiration deviation from surrounding areas (%)	Excess heat, rain or storm performance (°C, mm, Bft) or periods (d/a)
	Air quality regulation	Leaf area index, difference between open land and throughfall deposition (kg/ha); emission concentrations (ppm)	Aerosols or pollutants removed (kg/ha per year); air quality standards amplitudes (ppb)	Level of pollutants in the air (ppb); air quality standards deviation (ppb); critical loads exceedance (kg/ha per year)
	Water flow regulation	Water storage capacity (m ³ /ha); groundwater recharge rate (mm/ha per year)	Water released for hydrological process use, e.g. plant or animal uptake, soil processes (m ³ /ha per year); available water content (v%); amount of excess water (m ³ /ha per year)	Periods at permanent wilting point (d/a); soil field capacity (v%); periods of excess water or floods (d/a)
	Water purification	Water quality indicators: sediment load (g/l); total dissolved solids (mg/l)	Elements removed from water (kg/m ³ per year); water quality standards amplitudes (ppb; mg/l)	Level of pollutants in the water (ppb); water quality standard deviation (ppb; mg/l)
	Nutrient regulation	Nutrient turnover rates of, e.g. N, P (y ⁻¹); soil potentials (CEC; SOC; texture)	Nutrients available for plant uptake (kg/ha per year); amount of excess nutrients (kg/ha per year)	Periods of nutrient deficit or excess (d/a); fertilizer needs (kg/ha per year)
	Erosion regulation	Vegetation cover (%); loss of soil particles by water and wind (kg/ha per year); USLE factors for assessment of potential soil loss and landslide frequency (n/ha per year)	Amount of soil retained or sediment captured (kg/ha per year); amount of prevented erosion events (n/a)	Number of erosion events (n/ha per year); soil loss by erosion (kg/ha per year)
	Natural hazard protection	Water-storage potential (m ³ /ha); natural barriers (dunes, hedgerows, trees) (%; m/ha; ha)	Number of prevented hazards (n/a); Prevented fatalities, damage to property or infrastructure (n/a; €/a)	Number of hazards and fatalities (n/a); damage costs (€/a)
	Pollination	Species numbers and amount of pollinators (n/ha); potential habitats for pollinators (ha/ha; %; n/ha)	Amount of pollinated plants (n/ha per year; %/a; kg/ha per year)	Amount of plants demanding pollination (n/ha per year; %/a; kg/ha per year)
	Pest and disease control	Populations of biological disease and pest control agents (n/ha); Potential habitats for control agents (ha/ha; %; n/ha)	Number of prevented pest and disease outbreaks or predator and parasite actions (n/ha per year; %/a)	Number of pest and disease outbreaks (n/ha per year); plants and animals damaged (%/a; n/a); yield losses (%/a; €/a)
	Regulation of waste	Amount and number of decomposers (n/ha); immobilization potential in plants and soils	Decomposition rate (kg/ha per year); Pollutants recycled or Immobilized (kg/ha per year)	Level of organic material in soils (ppb); environmental standards deviation (ppb)

Table 3: Overview of exemplary grassland ES potential, ES flow and ES demand indicators (based on Burkhard et al. 2014a).

Ecosystem Service		Exemplary Service potential indicators	Exemplary Service flow indicators	Exemplary Demand indicators
Provisioning	Fodder	Standing stock +/- or net primary production (t C/ha + t C/ha per year; kJ/ha + kJ/ha per year)	Fodder plant harvest (t/ha, kJ/ha per year); yield (€/ha per year); area used for harvesting fodder (ha)	Fodder use for domestic animals (kg/livestock per year)
	Livestock (domestic)	Number of animals (n/ha; kJ/ha); animal production (t C/ha per year; kJ/ha per year)	Respective animal products (t/ha per year); yield (€/ha per year)	Meat consumption (kg/person per year); related products consumption (kg/person per year)
	Wild food, semi-domestic livestock and ornamental resources	Amount of respective items available; stock +/- or growth of respective wild species (n/ha; kg/ha; kg/ha + kg/ha per year; kJ/ha + kJ/ha per year)	Game taken (kg/ha per year); harvested plant biomass (t C/ha per year); yield (€/ha per year)	Wild food consumption (kg/person per year); ornamental item sale (n/region per year); business volumes (€/a)
	Biochemicals and medicine	Amount or number of substances useable for medicine, biochemical, cosmetics (kg/ha; n/ha); Stock +/- or net primary production (t C/ha + t C/ha per year; kJ/ha + kJ/ha per year)	Yield of respective products (€/ha per year)	Substances used (kg/ha per year); products sale (€/region per year)
	Freshwater	Fresh- and/or process water availability (l/ha per year; m ³ /ha per year); total amount of water (m ³ /ha); groundwater recharge rate (m ³ /ha)	Water withdrawal (l/region per year; m ³ /region per year)	Water use (l or m ³ /person per year; l or m ³ /industrial sector per year)
	Abiotic energy sources*	Areas and natural settings potentially suitable for energy conversion (ha/ha; n/ha; GW/ha)	Converted energy (kWh/ha per year); produced electricity (kWh/ha per year); yields (€/ha per year)	Energy use (kWh/person per year; kWh/industrial sector per year)
Cultural	Recreation and tourism	Number of facilities (e.g. hotels, restaurants, hiking paths, parking lots; n/ha); Results from questionnaires on nature and leisure preferences (wildlife-viewing, hiking, sports)	Number of facility visitors (n/facility per year); Turnover from tourism (€/ha per year)	Results from questionnaires on holiday plans and expectations
	Landscape aesthetic, amenity and inspiration	Evaluations from questionnaires; Scenic beauty estimation via landscape metrics	Number of paintings/ illustrations, songs, products portraying the resp. landscape/ecosystem (n/landscape type); results of travel cost or willingness to pay estimations	Results from questionnaires on landscape preferences and expectations
	Knowledge systems	Number of environmental educational-related facilities (n/ha)	Number of environmental educational-related events and number of their users (n/a)	Requests for environmental education (n requests/a)
	Religious and spiritual experience	Number of spiritual facilities or items (n/ha)	Number of visitors of spiritual facilities or items for performance of rituals and maintain the relationship with ancestors (n/facility per year)	Requests for religious and spiritual experience (n requests per year)
	Cultural heritage and cultural diversity	Areas and natural settings potentially suitable for traditional land use (ha/ha; n/ha); Results from questionnaires on local people's personal preferences	Number of traditional land use forms (n/ha); Number of employees in traditional land use forms (n/ha)	Number of job applications and trainees in traditional land use forms (n/a)
	Natural heritage and natural diversity	Potential habitats for endangered, protected and/or rare species (n/ha)	Abundance of endangered, protected and/or rare species (n/ha)	Relevant guidelines for nature protection (n/ha)

* Abiotic outputs from natural systems (after CICES)

Spatial localisation of ecosystem services supply and demand

ES supply is related to specific service providing units (SPU). SPUs are spatial units that are the source of an ecosystem service (Syrbe & Walz 2012) where it has been assessed. They include the total collection of organisms and their traits required to deliver a given ES (Vandewalle et al. 2009) as well as abiotic ecosystem components (Syrbe & Walz 2012). ES benefiting areas (SBA) are the complement to the SPUs. The structural characteristics of a SBA must be such that the area can take advantage of an ES (Syrbe and Walz 2012). SBA often commensurate with areas of demand for certain ES (Crossman et al. 2013), but several intermediate steps related to complex supply and trade schemes may be included (Burkhard et al. 2012a and 2014a). SBAs may be located distant from related SPUs. These spatial relations describe the relationships between the place of ES production and where the benefits are realised (Fisher et al. 2009; Syrbe & Walz 2012). Several categories for such SPU - SBA relation have been suggested (see Figure 7), for example:

- *in situ* - SPU and SBA are realised in the same location (i.e. the service is provided and benefits are realised in the same area; e.g. soil formation, provision of raw materials);
- omni-directional - SPU in one location, SBAs in the surrounding landscape without directional bias (e.g. pollination, carbon sequestration ES);
- directional - SBA in a specific location to the flow direction from the SPU (for example water regulation services provided by forested slopes);
- decoupled - ES can be traded over long distances, e.g., many provisioning ES (after Fisher et al. 2009).

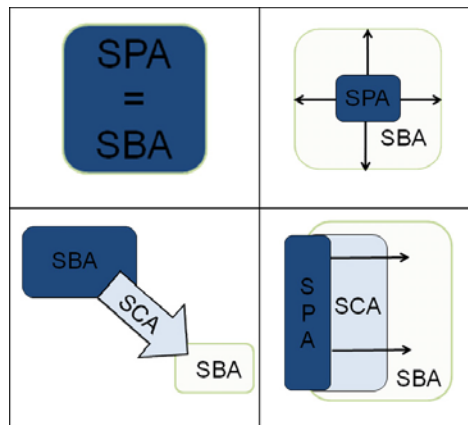


Figure 7: Categories for spatial relationships between service providing area (SPA), service benefiting/ES demand areas (SBA) and service connecting areas (SCAs): *in situ* (upper left), omnidirectional (upper right), directional with slope dependence (lower left) and directional or decoupled (lower right) (from Syrbe & Walz 2012, Fisher et al. 2009).

2.4. Challenges/limitations of grassland ES mapping

All points described above are relevant for the mapping of grassland ES. Grasslands are highly diverse ecosystems, providing multiple ES. Highly relevant regulating ES include global climate regulation (by carbon sequestration) and erosion/nutrient regulation (Lorencová et al. 2013). Provisioning ES supply is strongly dependent on management measures (and related additional

system inputs; see above) taken/not taken in the respective system. If grasslands are used as pastures, livestock and fodder supply will be relevant. Hunting can be a source of game provisioning ES on grasslands. If the grasslands are accessible for humans, recreation and knowledge generation can be relevant. On natural or extensively used grasslands, biodiversity and natural heritage values can be higher than on more intensively used systems.

Expert-based assessments can be used to identify and qualitatively assess ES supply on grasslands. Results from grassland monitoring, measurement or modelling can be used to improve the results and reduce uncertainties of ES assessments. When applying the ES matrix approach (as described above) with focus on grassland ecosystems, a suitable number of representative grassland types has to be identified and their specific ES supply has to be distinguished. Nevertheless, in order to get a manageable number of ecosystem types, generalisations of the high variety of existing grassland ecosystems and the multiple ES they supply have to be accepted.

3. Guidelines for expert-based valuation of grassland ecosystem services at the local level

3.1. Setting the framework for expert-based grassland ES valuation

The assessment framework can be built on experience and methods from existing ES studies but needs to consider the specific focus on grassland ecosystems and their characteristic ES. The definition of assessment areas, their spatial and temporal scales, as well as the selection of experts to be interviewed, have to reflect the special character of different grassland types.

The first step to **categorise the different grassland ecosystem types** could be used to distinguish between natural and human-modified/used grasslands. In the next step, the ecosystems could be grouped according to natural settings (e.g. wet, humid, dry or oligotrophic, mesotrophic, eutrophic), species richness (species-poor to highly diverse) or use levels (protected, extensively used, intensively used). The **spatial delineation** should be based on these natural system borders or/and anthropogenic system characteristics. Depending on the size of the systems to assess, a spatial data **resolution** (e.g. pixel size of GIS LULC data) appropriate to reflect the most relevant characteristics (but at the same time allowing acceptable computation efforts) has to be chosen. Also the **temporal assessment scale** has to be chosen to reflect the most relevant features of ES supply. Some processes take place rather slowly (e.g. nutrient regulation, timber growth) whereas others occur suddenly (erosion or flood events, crop harvest). For most provisioning and cultural ES, annual ES supply values may be sufficient, although information on seasonal patterns may get lost (see Burkhard et al. 2014a).

It is recommended in integrative ES assessments to compare ES values to each other (one grassland system with the other/s) or to a reference state. Also temporal dynamics can show interesting developments in ES supply and demand, delivering relevant results for decision making (i.e. for progress reports or future scenario development). The distinction between grassland ES potential and actual flow (see above) is relevant, especially in human-modified/used grassland systems. The differences between ES potentials and flows are normally highest within the group of provisioning ES, which are mainly supplied and used in anthropogenic ecosystems. In natural (especially in strictly protected/non-used grassland ecosystems), mainly regulating ES and (if accessible for humans) cultural ES are supplied. The distinction between ES potential and flows is not trivial in these two latter ES categories (see Schröter et al. 2014; Burkhard et al. 2014a).

3.2. Methods

Materials for the interviews

For expert-based valuations of grassland ES on the local level, time for preparatory studies should be foreseen before interviewing experts. According to this method, the following materials should be elaborated before the interviews:

- classification of different grassland ecosystems located in the study area;
- a list of relevant ES supplied and/or demanded in the studied ecosystems;
- a matrix with studied grassland ecosystems and supplied and/or demanded ES
- a base map (for needed basic spatial data, see chapter 2.1.) for the spatial localisation of ES supply and/or demand;
- a list of selected experts to be interviewed.

The grassland ecosystem classification should include clear definitions of the different types, enabling reproducible distinctions between them based, for example, on their natural settings or human activities.

The list of ES should include a clear categorisation of all relevant ES (e.g. according to the commonly used categories of provisioning ES, regulating ES, and cultural ES), clear definitions of individual ES, exemplary indicators for their quantification (see ES indicator lists in Kandziora et al. 2013 or Burkhard et al. 2014a) and a distinction in ES supply and demand (see the ES documentation system suggested by Crossman et al. 2013). Information about additional inputs needed for respective ES supply is adding value to the assessment. Such information can, however, be too detailed for most ES assessments.

The matrix should include the types of grasslands chosen for the study and supplied or demanded ES. The ES are on one and the grassland types on the other axis of the matrix (Figure 8). In order not to overload the interview and avoid fatigue of the interviewees, it is recommended (as a rule of thumb) to limit the number of the fields to be filled to a maximum of 100 cells (e.g. 10 ES by 10 LULC types). At the same time, the most typical and relevant (in terms of ES supply) features should be included anyway. In case both ES supply and demand are to be assessed, two different assessment matrixes need to be prepared and respective expert-based valuations need to be collected.

	Regulating services						Provisioning services					Cultural services	
	Local climate regulation	Global climate regulation	Flood protection	Air quality regulation	Erosion regulation	Pollination	Crops	Livestock	Timber	Freshwater	Wild foods	Recreation	Landscape aesthetics
Grassland type 1													
Grassland type 2													
Grassland type 3													
Grassland type 4													

Figure 8: Example (empty) ES matrix to be filled out during expert-based assessments (grassland ecosystem types in the rows and selected ES in the columns).

As **base maps**, most often land use/land cover (LULC) maps (e.g. EU CORINE data) in GIS format are used. Their advantage is that the results of the ES evaluation (e.g. based on the ES “matrix” method described above) can easily be linked in the GIS in order to compile ES maps. However, their spatial or thematic resolution may not be sufficient to distinguish different grassland ecosystems (e.g. only one type “3.2.1 Natural grassland” in CORINE). In that case, more specific habitat maps or spatial data based on remote-sensing should be used. The interviews can also be supported by aerial photos or satellite images (e.g. freely available Google Earth images) in order to get a better understanding of the study areas. The experts should also be able to recognise “their” region, its structures and peculiarities within the base map. Therefore, the base map shown to the experts should be a compromise between being sufficiently detailed but not too complex.

For **the selection of experts** it has to be considered that for the relevance of the results, the quality of the experts (especially their knowledge and experience but also openness for ES in general and particularly the ES matrix approach) is more important than their quantity (number of interviewed persons). Although it is difficult to provide a generally valid number, 8-12 experts may be sufficient in most cases. It has to be considered that the interviewed persons need to be (at least) familiar with the region. A background in ES science and application is highly advantageous but can (due to the novelty of the approach) not be expected in all cases. Then, the concept and the aim of the grassland ES assessment need to be clearly explained (best based on prepared material and commonly accepted definitions).

The interviews

Due to the complex nature of the ES concept itself and the ES matrix method (demanding a rather high capacity for abstraction), a minimum education level will be necessary for the interviewees. The integration of representatives of the concerned society as well as of local stakeholders in the expert evaluation is desirable as it can improve the reliability and acceptance of the results. However, like in all sampling methods, the target should be to find a representative group of experts familiar with the region, grassland ecosystems and their services and willing to deal with complex questions.

Different forms of interviews such as individual interviews, group sessions, focus group discussions (FGD) and participatory GIS (PGIS; see Fagerholm et al. 2012) methods are conceivable.

In **individual interviews** as well as in group sessions, each participant/expert is asked to provide her/his own statement and the results will be analysed later. Thus, individual interviews provide a high number of samples (expert scores). The idea of **focus group discussions** is to get, after discussions and consensus finding within the group, one common score for each ES per each LULC including the opinions of all participants. Free discussion among participants on the interview subject is an essential prerequisite of focus group discussions (Chan et al. 1991). Although the time needed for individual interviews may be shorter due to the lack of group discussion and consensus finding, the total time needed for all interviews and data analysis may actually be longer. Group sessions have the advantage that the concept and method need to be

explained only once. The key point of **PGIS** application is to get information about the areas of ES supply and demand directly from the benefitting people. The method works best in societies with closer relation to nature, i.e. societies based on self-sustaining livelihoods in developing country context. In 'developed' countries, ES supply and demand take place rather decoupled via goods dealers such as supermarkets, sophisticated water and energy supply networks or long-distance transport.

The following course of **five actions** has been proven to deliver sound results in expert-based interviews for ES matrix-based assessments.

Action 1: Introduction

The introduction aims at giving background information about the aim of the whole action and to create a familiar atmosphere of mutual trust and sympathy.

Action 2: Metadata collection

The collection of metadata about the interviewees can also help to create a better atmosphere and to increase the interviewees' confidence. The collected metadata can later on be analysed in order to discover patterns in the ES evaluations based on different criteria. This can deliver important information about the reasoning behind the ranking, which again can be important for decision making.

Action 3: Explanation of the ES concept

A systematic elaboration of the ES concept, the chosen ES and LULC/ecosystem types (perhaps supported by pictures from the different systems) and the assessment method need to be given in order to provide a logical, comparable and reproducible background for all interviews.

Action 4: ES evaluation

The ES evaluation itself is the core of the whole interview process. Here the experts are asked to evaluate the different ES according to their supply (potential or flow) or demand within the different ecosystem/LULC types and the given temporal scale. In the ES matrix approach, the individual ES are ranked for each ecosystem/LULC type on a relative scale from 0-5 (see above) in a matrix table. The evaluation can either take place as individual interviews or as group results after discussion and consensus building. For comparison reasons, it is recommended that each expert assesses the whole set of ES in all ecosystem/LULC types. However, if an expert does not feel comfortable/competent to evaluate a specific ES (i.e. ES is outside the field of competence), certain fields may be left empty. In any case, this (and all other specific issues emerging during the interviews) should be documented carefully. If, however, individual interview results clearly show that the question or problem was not well understood, i.e. with obviously erroneous results, statistical methods can be applied to clear out such outliers. In general, such data manipulation should be reduced to a minimum or, in the case of cultural ES such as landscape aesthetics where a broad range of opinions and thus diverse possible answers are realistic, be accepted and commented respectively.

Action 5: Open questions

After the evaluation is finished, there is the chance for open questions in order to collect further information about ES in the study region and the method itself. All results should be stored systematically (e.g. as MS or Open Office Excel or Access files) for further processing and analyses. Eventually emerging issues (disturbances during the interviews, specific questions) should be documented carefully and included in the study report because they can deliver important information about results' uncertainty.

3.3. Problems and uncertainties

Complex expert-based ES assessments are related to several uncertainties. The advantage of delivering information and data rather quickly is accompanied by problems such as selection of relevant ES to be assessed, finding representative experts available and willing to be interviewed or integration of expert-based information with data acquired by measurements or modelling. Hou et al. (2013) provided a systematic checklist (Table 4) of technical and thematic uncertainties related to each assessment step of the ES matrix method suggested by Burkhard et al. (2009, 2012a and 2014a).

If Step 4 (quantification of ES indicators) is carried out based on expert evaluation alone, additional uncertainties emerge related to the experts' potential subjectivity (e.g. preference of certain ecosystems or ES), background knowledge or socio-economic and emotional arguments that can bias the assessment of particular ES. These issues need to be addressed by:

- a representative expert selection;
- an appropriate explanation of the purpose of the study and the method;
- a systematically developed interview concept;
- a careful documentation of methods, the interview process, results and related uncertainties.

One way to indicate related uncertainties is to provide uncertainty measures with each result. Such measures can be on a qualitative scale such as from "high certainty" to "highly uncertain" referring to different ES scores.

Table 4: Overview of the different steps of ES matrix-based assessments and related uncertainties (modified after Hou et al. 2013).

Step	Assessment step	Technical uncertainties	Thematic uncertainties
1.	Selection of study areas	<ul style="list-style-type: none"> • Information availability and data access 	<ul style="list-style-type: none"> • Representativeness • Specific local natural and cultural settings • Definition of reference states • Management measure vagueness • Changing system conditions (e.g. climate change, social dynamics)
2.	Selection of relevant LULC/ecosystem types	<ul style="list-style-type: none"> • Generalization and categorization of complex landscapes into a limited number of types 	<ul style="list-style-type: none"> • Aggregation/differentiation of land cover vs. land use types, also depending on spatial data resolution and study area • Different landscape scientific approaches
3.	Spatial LULC and biophysical data acquisition	<ul style="list-style-type: none"> • Inaccuracies in spatial data • Suitability of spatial and temporal scales 	<ul style="list-style-type: none"> • Inaccuracies in thematic data
4.	Selection of relevant ES indicators	<ul style="list-style-type: none"> • Appropriate indicandum-indicator relations • Indicators which are robust, scalable and sensitive to changes 	<ul style="list-style-type: none"> • Which ES are really <i>relevant</i> in the study area? • Various indicators are needed for ES trade-off assessments
5.	Quantification of ES indicators	<ul style="list-style-type: none"> • Mismatches of geobiophysical data and statistical data spatial units • Lack of appropriate data for quantifications • Model, measurement and statistical data quantification uncertainties 	<ul style="list-style-type: none"> • Limited knowledge about complex ecosystem functionalities • Indication of ecosystem functions, regulating and cultural (intangible) ES not well-developed
6.	Interlinking LULC/ecosystem types ES in the assessment matrix using the relative 0-5 capacity scale	<ul style="list-style-type: none"> • Comparability of different data • Averaging and potential double-counting of ecosystem functions/services over space and time (i.e. weighting system needed) • Integration of data of varying quality and quantity as well as expert assessments • Spatially heterogeneous ES supply 	<ul style="list-style-type: none"> • Aggregation of data, models and indicators without losing relevant information • ES supply potential vs. ES flow, what to quantify? • Subjectivity in scoring procedures
7.	Linkage of assessment values to spatial biophysical and/or administrative units (mapping)	<ul style="list-style-type: none"> • Lack of appropriate biophysical data (soils, hydrology, vegetation, etc.) • Mismatches of spatial units • GIS software problems • Map layout issues might cause interpretation problems 	<ul style="list-style-type: none"> • Limited knowledge about complex human-environmental linkages, service providing units and ecosystem service flows • Difficulties in allocating services to land cover (e.g. for cultural services) • Multiple ES representation: 2D maps only allow the presentation of one service or averages/sums of services
8.	Interpretation of results	<ul style="list-style-type: none"> • Data and mapping shortcomings • Model and map validation • Insufficient end-user interfaces • Data extrapolation to different or larger regions 	<ul style="list-style-type: none"> • Data and map misinterpretation, also due to lacking study area knowledge • Lack of expert knowledge, e.g. concerning interactions between landscape management and ecosystem service supply • Information too complex and too aggregated • Transferability of results to other regions

4. Key lessons-learnt from testing the expert-based valuation and mapping of grassland ecosystem services in Sigulda municipality in Latvia

Two expert meetings were organized on 21 November and 3 December 2014 during the Project “Assessment and mapping of grassland ecosystem services in the Sigulda municipality”. Within the meetings, the experts assessed grassland ecosystem services in Sigulda municipality applying expert-based valuation method. The obtained experience allows drawing the first conclusions.

In general, it can be concluded that the expert-based valuation method could be considered as very promising in Latvian conditions, particularly taking into account the lack of experience and limited resources for the valuation of ecosystem services. Following key issues were clearly highlighted during the exercise that shall be addressed performing similar assessment in future:

- Assessment purpose must be clearly defined for each area when starting ecosystem services valuation. Objectives may vary depending on local socio-economic and natural conditions, the size of the area as well as the scale of assessment.
- It is important to be aware of data availability for each area, which, to a large extent, determines the valuation methods to be performed in the area, as well as the selection of ecosystem services and related indicators.
- Understanding of the natural conditions of the selected areas is an important factor to clearly distinguish the evaluation units among others.
- Knowledge of local conditions is essential prerequisite for choosing valuation units. Desk studies (work with maps, pictures and written information) may not be enough for distinguishing; therefore, site visits are also recommended to confirm whether the distribution of valuation units is correct or not.
- On a local scale, the possibilities of using coarse-scale cartographic materials are limited. E.g., CORINE LandCover maps were used for illustration purposes only in Sigulda municipality.
- Whenever possible, soil maps should also be used for distinguishing assessment units. This is particularly important in small areas because the soil is largely determining also the type of vegetation.
- The peculiarities of each area, available data and expert knowledge shall be taken into account when defining the list of ecosystem services.
- It is recommended to apply a minimal number of indicators (optimally - one) for characterization of each ecosystem service when using the expert-based valuation method. It will also help to keep sufficient attention of the experts to the task
- Precise definition of assessment indicators and valuation scale, as well as certainty on their common understanding is necessary to obtain most accurate results. In Latvian conditions, the availability of data for many indicators is problematic.
- Discussion of the results is a very important step of the valuation, which brings harmonization of the results among the experts.
- Overall, representation of different sectors is essential in the expert-based valuation; nevertheless, it is important to have experts with in-depth knowledge of specific ecosystem services in the group.

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