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New EU-scale environmental scenarios until 2050 – Scenario process and initial scenario applications

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ABSTRACT

Understanding uncertainties and risks can be considered to be the main motivation behind environmental scenario studies to assess potential economic, environmental, social or technical developments and their expected consequences for society and environment. The scenario study presented in this paper was designed to contribute to the question of how natural capital and ecosystem services may evolve in Europe under different socio-environmental conditions. The study was conducted as part of OpenNESS, an on-going EU FP7 research project. We present the iterative participatory scenario process, the storylines and drivers, examples for regional applications, as well as initial feedback from stakeholders.

In a participatory iterative approach four scenarios were developed for the period to 2050, involving regional and EU-level users and stakeholders. Subsequently, scenarios were successfully contextualised and applied in regional place-based studies under widely differing socio-environmental conditions. Regional teams used different approaches to adapt storylines and drivers to the regional contexts. In an internal evaluation process among regional stakeholders some participants expressed concerns about the scenario method. Suggestions are made how to overcome these limitations. However, most participants approved the scenario method, especially in terms of provoking discussions, and confirmed the usefulness and applicability of the approach.

1. Introduction

Understanding uncertainties and risks can be considered to be the main motivation behind 'Futures Thinking' or 'Futures Studies' to assess potential economic, environmental, social or technical developments and their expected consequences on society and environment (Lempert et al., 2004; Liu et al., 2007; O'Neill et al., 2015; Raskin et al., 2002; Tversky and Kahnemann, 1974). A broad range of approaches such as forecasting, predictions, scenarios, trend and uncertainty analysis is used to assess future developments and their consequences on economy, society or the biophysical environment (Bernarie, 1988; Bishop et al., 2007; Hulme and Dessai, 2008; Lempert et al., 2004; Webster et al., 2003). In the

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context of environmental and climate change studies, scenarios seem to be the dominant approach for assessing uncertain futures, such as the IPCC RCP/SSP scenarios, the scenarios of the Millennium Ecosystem Assessment, UNEP's Global Environmental Outlook and others (MEA, 2005; O'Neill et al., 2015; Raskin et al., 2002; UNEP, 2007; van Vuuren et al., 2012, 2014). Many approaches and methods can be combined, which is frequently done in practice. In many studies participatory approaches and mathematical models have been applied in a combined way, which some authors see as an integral step of scenario analysis (Alcamo, 2001; Biggs et al., 2007), while others highlight qualitative or semi-quantitative aspects, depending on the purpose of the study or the preferences of the intended users (Bohunovsky et al., 2010; Henrichs et al., 2010; Kok, 2009).

The scenario study presented in this paper was conducted as part of OpenNESS, an on-going EU FP7 research project (http://www.openness-project.eu/) and builds on existing broad-scale and global scenario approaches. However, a recent scenario review (Hauck et al., 2015) revealed significant shortcomings of existing broad-scale environmental scenarios, in terms of not addressing the future of ecosystem services (ES) explicitly, except the Millennium Ecosystem Assessment (MEA) scenarios (MEA, 2005). However, two aspects were considered as limiting. (i) The MEA scenarios all assume the sustained provision of ES, with a strong focus on demand and supply of provisioning services, and (ii) they make very explicit assumptions about policies, e.g. the pro- or reactive policies involved to achieve the final states of the scenarios.

The new scenarios intend to fill some of the thematic gaps in existing broad-scale environmental scenarios (Ferrier et al., 2016), e.g. to assess conditions leading to increasing or decreasing ES levels. They have been developed as an integrated environmental scenario study contributing to assess futures of natural capital (NC) and ES under different socio-environmental conditions at different scales. Furthermore, they intend to support approaches which try to answer the question of how the ES concept can be operationalized, and providing a framework to evaluate different governance/policy options, e.g. concerning their robustness under different future conditions. In this paper, we present the scenario development process, the storylines and drivers, as well as examples for regional applications. Finally, we present initial stakeholder feedback evaluating scenario process and products and discuss strategies to overcome some of the limitations identified by stakeholders.

2. Methods

2.1. Scenario process

The thematic framework of the scenarios was defined by the focus of the OpenNESS project on the concepts of natural capital (NC) and ecosystem services (ES). In the scenario context the objective implies an exploration of future changes of NC and ES and the biophysical and socio-economic conditions or driving forces leading to different futures.

The conceptual framework and methods for integrative scenario development mainly followed the work by Priess and Hauck (2014). They based their participatory scenarios on three components of a scenario framework: (i) user and stakeholder participation, (ii) knowledge integration, and (iii) quality control, all of which are considered prerequisites to developing integrative scenarios that serve as common boundaries for place-based studies as well as for decision-making needs at different levels. Scenarios are typically developed in a series of steps, e.g. the procedures suggested by Alcamo (2001) or Kok (2009). Similarly, a six-step participatory and iterative approach has been used in OpenNESS: (1) establishing a scenario team – (2) review of drivers – (3) selection of drivers (and indicators) – (4) development and review of storylines – (5) application of scenarios at EU/case study levels – (6) synthesis and feedback to case studies and EU level. In this paper we present steps 1 – 5 and provide initial feedback from stakeholders based on an evaluation of the scenario and other key methods applied in the project.

First, the scenario team was established, covering a broad range of thematic and methodological expertise and ensuring the participation of modellers and leaders of regional place-based studies as key end-users (see section Participation for more details). After establishing the scenario team, an ex-ante survey among the 27 OpenNESS regional studies was conducted to assess their perceptions of key drivers of ecosystem and ecosystem service change at the (i) European and (ii) case study level (an overview of results is presented in Appendix A). Second, an additional component was included at the beginning of the scenario process in the form of an extensive review, which was conducted to assess the range of quantified assumptions of existing global and European environmental scenarios with the objective of providing guidance on the drivers for the new scenarios (Hauck et al., 2015).

The scenario team considered a generic set of EU level scenarios in the form of storylines followed by a process of driver quantification as the most useful approach. Previous studies and scenario manuals repeatedly pointed out that a low number of scenarios (3–6) is advantageous in participatory processes to avoid overburdening participants, scientists, and also the scenario team (Henrichs et al., 2010). In OpenNESS, four scenarios were developed along two axes of uncertainty. Based on the preferences and recommendations of intended users from science, the broader public and policy-making, it was decided that the OpenNESS scenarios should explicitly address mid-term (to 2030) and long-term changes (to 2050); scientists tended to focus on the long term while preferences from the public and policy making arenas tended towards the short- to mid-term period.

Different methods or combinations of methods can be used to develop scenarios, e.g. explorative vs. normative scenarios involving *backcasting, visioning, storytelling, fuzzy cognitive maps*, or other methods (Alcamo et al., 2008; Keune et al., 2014; Kok, 2009; Kok et al., 2011). Based on the inputs from the survey, the scenario review and the expertise of the team, a normative approach which included backcasting methods was used. In scenario processes, backcasting is often used to assess the pathways to desired futures or undesirable ones to be avoided. In this scenario process, it was applied in a general way to identify trajectories and characteristics, which (parts of) society may want to avoid, such as overexploitation of natural resources and declining levels of ES supply.

2.2. Participation

Different potential users and stakeholders were identified by the scenario team. One of the core objectives of this scenario process was to provide a common set of assumptions and constraints (common boundary conditions) for those of the 27 regional case studies which planned to use scenarios (n = 14). Many examples are available of studies deriving boundary conditions for regional and local environmental change assessments, interpreting regional storylines from global or European levels (Rounsevell et al., 2006; Rounsevell and Metzger, 2010; Kaljonen et al., 2012) and downscaling and contextualising broad-scale scenarios for regional or local levels (Zurek and Henrichs, 2007; Alcamo and Henrichs, 2008; Metzger et al., 2010; Kaljonen et al., 2012). While the 27 place-based studies participating in this project were organised in different ways, all of them had OpenNESS representatives and advisory boards or additional forms of public participation, ensuring the representation of different views and perceptions of the broader society. Several leaders of place-based studies were members of the scenario team.

The second group targeted in the scenario process were modellers, predominantly working with aggregated European or global-scale models, and modellers using a broad range of different approaches at regional level in the place-based studies. Several modellers were participating in the scenario team, and additional modelling and thematic expertise was involved during the process of driver quantification and in the iterations to assess the consistency between storylines and (semi-)quantified drivers.

The third group targeted in the scenario process were representatives of NGOs, economic sectors, authorities and policy-makers at the European level. Stakeholders were identified based on an analysis of policy sectors relevant in the operationalisation of the concept of ecosystem services (Bouwma et al., 2018). Representatives from the respective European Directorate-Generals as well as non-governmental actors representing different interests in the policy sectors were invited to a stakeholder workshop in Brussels once the first scenario drafts were established. The main objectives were to discuss storylines and uncertainty axes, enriching them with a broad range of EU-level views on drivers and storylines, and to ensure their relevance and applicability at the EU level.

Involving different stakeholder and user groups at different points in time was the pragmatic answer to conflicting objectives within this scenario process. On one hand, the scenario team was aware of the benefits of a time-demanding, co-development process with envisaged stakeholder and user groups (Kok et al., 2007, 2011); on the other hand, an early delivery of the scenarios was needed to ensure their applicability for instance for place-based studies and modellers during the project. Thus, the team aimed for a moderate level of stakeholder participation, corresponding to level 2–3 on the IAP2 five-level participation scale (IAP2, 2014) or 2–3 on Haklay's four-level scale (Haklay, 2013).

2.3. Knowledge integration

For the development of scenarios different sources and inputs can be used, e.g. based on stakeholder or expert consultations during workshops, interviews or questionnaires, and also using input from other scenarios or literature in general. During the scenario process all sources mentioned above were used, originating from different scales (local to regional: place-based studies; EU: stakeholders, scenario review and policy analysis; global: scenario review and policy analysis) and a broad range of contributors (scientists: case studies, scenario team, literature, external experts; stakeholders: case studies; EU level). Ensuring knowledge integration of the different domains (Acreman, 2005; Kok et al., 2011; Biggs et al., 2007; Mahmoud et al., 2009; Palomo et al., 2011) was part of the iterative and consensus-based scenario process. This involved experts and place-based studies representing all major ecosystem foci (agricultural, coastal, forest, wetland, urban) providing feedback on the storylines, and at a later stage, feedback on the quantification of scenario drivers. Knowledge integration of regional and EU/global views of different team members was needed, for instance, in the discussions about the relevance and representation of drivers at different scales and in different regions, or between different disciplines/expertise, such as when discussing the level of detail of policy assumptions in the scenarios. During the process of driver quantification, the team faced the challenge to ensure that the world views of the scenarios were not only represented in the quantified drivers, but also adequately transformed into the parameterisation of the two EU-scale (CLIMSAVE) and global-scale (IMAGE-GLOBIO) models to be employed to quantify the impacts of the scenarios. Knowledge integration was also considered a key aspect to ensure legitimacy and relevance of the scenarios for the intended users (Alcamo et al., 2008; Kok, 2009; Priess and Hauck, 2014; Hauck et al., 2014).

2.4. Quality control

When designing a process to develop and apply scenarios, it is indispensable to include means of quality control including criteria to measure the success of the scenario exercise. Below we present the various elements of quality control applied in this process, and highlight the monitoring process to test the success of the scenario method at regional scale.

The iterative cycles mentioned in the previous paragraph also served as an important component of quality control, namely the review process of key assumptions and storylines and the subsequent quantification of drivers. The narratives and the driver quantification each underwent two review cycles. The reviews involved not only members of the developer team, but also modellers, external experts (e.g. of JRC scientists to comment on links between the EU and the global economy) and case study representatives to comment on the translation from the results of the ex-ante survey of drivers to the scenario narratives (see Appendix B). Additionally, comments and suggestions on the scenario drafts from an EU-level stakeholder workshop held in Brussels in January 2015 were used to improve and partly broaden the key uncertainty axes and the scenario assumptions for instance concerning the policy integration axis or assumptions about drivers such as economic development or rewilding. Furthermore, we used the ranges and rates of change of key drivers considered plausible in existing environmental scenarios as guidance for the OpenNESS scenarios, presented in the review of scenario drivers by Hauck et al. (2015).

The success of a scenario process can be evaluated by analysing to which degree the intended users or stakeholders regard the scenario process and/or products (Henrichs et al., 2010) as applicable, useful, relevant, etc. (Hulme and Dessai, 2008; Pulver and VanDeveer, 2009). The intermediate successfulness was monitored in a stakeholder survey covering the scenario method and other key methods used in the project. The results are labelled "preliminary" as the project was still on-going at the time of the survey and several place-based studies were not yet advanced enough to answer (see next section). Notwithstanding the preliminary character of the monitoring, strictly assessing quality and success are considered key elements of this scenario process.

3. Results

3.1. Scenario design

Similar to the IPCC SRES or the GEO4/5 scenarios, drivers and uncertainties were organised along axes of key uncertainties, focussing on the key objective of OpenNESS, which aims at the operationalisation of ES, e.g. the integration in various policy domains at different scales:

European Policy Axis: Concentrated Responsibilities vs. Dispersed Responsibilities

Policy Integration Axis: Sectoral Policies vs. Cross-Sectoral Policies

The four scenarios WealthBeing (WB), UnitedWeStand (UWS), EcoCentre (EC) and RuralRevival (RR) were developed populating the quadrants of the uncertainty axes (see Fig. 1), based on the drivers of change identified in the case study survey (see SI), the scenario team, the EU-level stakeholders and the driver review (Hauck et al., 2015). All storylines follow the same structure (see left column of Table 1). A short section on triggers of change provides a general overview of what could have initiated the change. In the

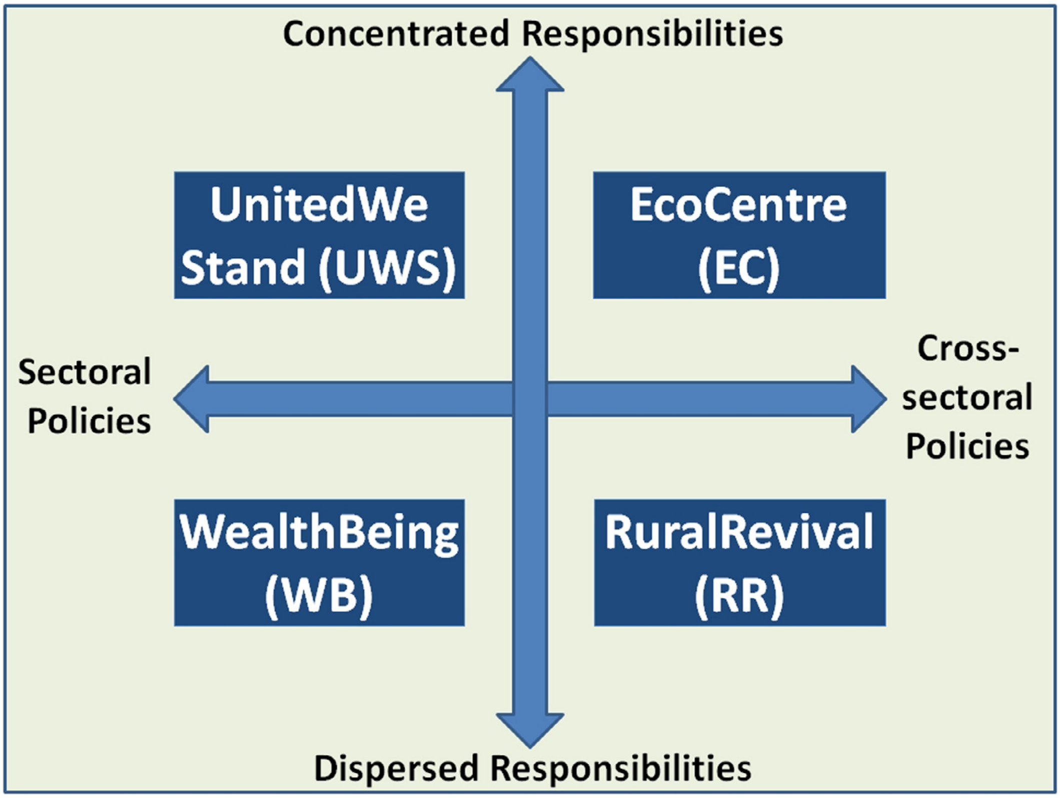

Fig. 1. Axes of key uncertainties and the OpenNESS scenarios developed for each quadrant.

next sections mid-term developments to 2030 are described in detail. We further assume that turning points occur in some scenarios, which are partly related to the overexploitation of ES explained above or to changes in lifestyles/value systems. Each storyline ends with a section on long-term developments to 2050.

3.2. Factors driving changes in natural capital and ecosystem services

The set of factors considered relevant to drive changes in natural capital and ecosystem services was guided by the results of the drivers identified in the ex-ante survey by the OpenNESS case studies at local to regional and European to global scales (see electronic Appendix A for details) and the recent scenario review looking into direct and indirect drivers of change (Hauck et al., 2015). Drivers in the scenario review were based on the STEEP categories (social, technology, economy, environment, policy). In the driver survey among the 27 case studies, it turned out that positive and negative changes in ecosystem service supply and demand were also seen as drivers of change rather than merely being affected by drivers by the case study stakeholders. The large uncertainties about future trajectories of ecosystem service supply and demand is reflected in the scenarios using widely varying assumptions about the factors driving future levels of ecosystem services and natural capital.

Unlike other environmental scenarios (e.g. the Global Environmental Outlook 4 (UNEP 2010) or the Millennium Ecosystem Assessment scenarios (MEA, 2005)), a very limited number of policy drivers were addressed in the OpenNESS scenarios, for instance, addressing the spatial extent of protected areas. The operationalization of NC and ES in different policy frameworks is addressed in a follow-up paper by Hauck et al. (2017).

The set of qualitative assumptions about the changes of driving forces was developed together with the storylines. Drivers were quantified in a follow-up process (Table 2) undergoing the same iterative cycles and review processes as the storylines.

3.3. Scenario applications

The OpenNESS scenarios were developed to facilitate assessments of NC and ES under various boundary conditions and at different scales. In the following sections, we provide two examples of applications at the regional level, as well as the results of a survey among regional stakeholders monitoring their perceptions of the scenario method.

Note that EU-level applications of the new scenarios are addressed in separate papers (i) focusing on simulating the impacts of the new scenarios on land use change and ES provision using the scenario drivers for model parameterisation (Veerkamp et al., 2017) and (ii) assessing the operationalization of NC and ES and the robustness of different policy frameworks (Hauck et al., 2017a,b).

3.3.1. OpenNESS scenarios contextualised by regional place-based studies

Place-based studies used various strategies to develop their regional (participatory) scenarios based on the OpenNESS scenarios, depending on the stage of the projects, level of participation, role of the scenarios in the regional context and other case-specific conditions. Below, we exemplarily present results of two contextualisation approaches based on the new scenarios.

The Scottish study (see example 2) considered all four scenarios as plausible and relevant in their regional context, while the Lower Danube study (see example 1) accepted only three storylines, but rejected the RR scenario. The latter was intensively debated but finally perceived implausible because the storyline was interpreted to cause an unrealistic complete restoration of the Lower Danube wetlands (at the expense of agricultural land).

The list of drivers was accepted and applied in both regional studies but with different levels of contextualisation. While the Scottish study applied the drivers in the same quantification

Table 1
Key assumptions of the OpenNESS scenarios.

Policy area	WealthBeing WB	UnitedWeStand UWS	EcoCentre EC	RuralRevival RR
General tendencies				
	Large political and economical differences between member states but also globally; sectoral EU policies, national legislation strengthened; deregulation of markets.	Joint EU policy approaches, sectoral policies; economically, EU and the world are developing at a comparable, moderate pace.	Cross-sectoral EU policy integration; EU leads mainstreaming of ES and changes towards eco-friendly lifestyle, other countries follow.	Large differences between member states; cross-sectoral integration; economically EU falls behind the rest of the world.
Mid-term developments until 2030				
Political, societal and economic change	Economic success, and growth of export sectors; unequal distribution among member states; high demands and prices for resources and energy; reduced social and environmental standards.	Prosperity of all member states and citizens; Euro-centric visions and policies; strong belief in technical solutions for environmental problems; substantial investments in education and social policies; neglect of environmental concerns.	EU-wide campaign for environmental education and awareness raising; reduced consumption; environmental justice; participatory (environ-mental) decision-making; 'Genuine Progress Indicator' introduced to account for environ-mental and social factors.	High popularity of green, idealistic citizen and 'back to nature' and 'simple life' movements; cooperative and less wealth-oriented policies; local manufacturing; EU institutions dwindle; high outmigration;
Urban, rural and grey infrastructure development	Rural infrastructure and settlements neglected; strong urbanisation and urban sprawl.	Strong development of industries and infra-structures; urbanisation and urban sprawl.	Urban green development and gardening; Open-source mentality; strongly increasing efficiency resource use.	Rural areas regain socio- economic importance; different types of work and sustainable life-styles develop.
Land use and environmental conservation	Intensification of agriculture and forestry; high demand for renewable energy and materials; Consumerism as leading lifestyle; alliances between agrarian and industrial lobbies weaken environmental policies.	Consumerism as leading lifestyle; importance of regulating ES decreasing, due to technical solutions; increase in GHG emissions, land use change and exploitation of mineral resources; decreasing environ-mental concerns.	Agricultural production is converted into organic farming or sustainable integrated farming; pressure on land resources; environmental conservation with the idea of "rewilding". Protected areas increase.	Cooperatives and farmers diversify production; lower land-use intensity and mechanisation; EU imports of agricultural commodities; Protected areas increase, their role is debated hotly.
Long-term developments until 2050				
	Degradation of agricultural and aquatic systems due to high demand for ES; prices for all land intensive commodities continue to rise;	Degradation of ecosystems pushes technical solutions to their limits; transition from fossil fuels to renewables; growing demand for provisioning services from outside EU.	Unsuccessful trials of participatory EU policies, due to high bureaucracy and low efficiency; EU continues to be a strong actor but also facilitates regional developments.	General focus on sustainable management strategies; large multi-national companies and agro-industries either adapt or move out of EU; less organised regions are left behind; revival of traditional, well adapted varieties of crops, vegetables, fruits, old livestock races.

(= rates of change) as developed for Europe, the Lower Danube study accepted the list of drivers, but adapted many of the quantifications to regional conditions. In the latter study, two regionally important drivers were added complementing the EU-level list (hydro-energy production; water transport). See Appendix C for the complete list of regionally adapted drivers.

Example 1 (*Lower Danube region, Romania*). **Purpose of scenario exercise:** Developing regional scenarios by integrating the regional socio-ecological system and key messages of the OpenNESS scenarios. The regional scenarios are intended as tools to establish options for analytical and operational frameworks, enabling the design, elaboration and long-term implementation of integrated (holistic) and adaptive management of the Lower Danube – Northwestern Black Sea region, which is regarded as a socio-ecological system.

Steps of local scenario development:

- Use historical data to identify key issues, drivers and potential future pathways of the integrated and hierarchical organisation of the regional socio-ecological systems
- Allocate OpenNESS scenarios on the regional key uncertainty axis and link regional socio-environmental targets to the EU-level scenarios
- Develop qualitative/quantitative assumptions for processes of change and targets for the scenario period or the endpoint in 2050
- Adapt and complement drivers and targets of the European-scale scenarios relevant for the Lower Danube regional scale

The sub-regional and regional socio-ecological systems (SEcS) used in this exercise are located on the Romanian side of the Lower Danube Catchment. The perspective of nested spatial organisation helped to identify and better understand the complex interactions within and between the nested sub-systems. The perspective of nested SEcS facilitated to identify and select key internal and external drivers and to assess and understand long-distance and cumulative effects on biophysical structure, functions and service flows and changes of natural capital. It also helped to assess the relevance of the EU-level scenario assumptions for the regional scenarios as well as to adapt and contextualise the list of quantified drivers. Two different historical phases (1960–1990 and 1990–2013) have been identified and analysed; the first phase led to severe deterioration of natural capital, while the second phase resulted in a de-structured economy and society. A major conclusion of this analysis was that regional SEcS would strongly benefit from mid-term targets addressing wetland restoration. To cope with the complexity and uncertainties, it was considered feasible to adapt the EU-level scenarios in an iterative discussion process.

Based on the medium and long-term challenges perceived to be most urgent, it was decided to focus the regional scenarios on wetland restoration (including rehabilitation) as a strategic target and to assess the impacts of each scenario in a qualitative fashion. For the WB-Danube scenario, the team assumed restoration and development of irrigation infrastructure, technical facilities and very large farms for intensive crop and meat production; increased diffuse and/or point nutrient outflows comparable with records from the 1980s from agricultural areas; preserving about 95% of formerly established polders and restoration of built infrastructure

Table 2
Selection of drivers of the OpenNESS scenarios – qualitative and quantitative assumptions. Drivers as qualitative indicators address changes from strongly negative (−−) to strongly positive (++) changes relative to current (=2012/13) levels; arrows (→) indicate changes in trends during the scenario period; quantitative changes address % levels in the year 2050 relative to current levels.

Category/Driver	Scenario			
	WealthBeing WB	UnitedWe Stand - UWS	EcoCentre EC	RuralRevival RR
Social				
Population change (% from current)	+ 10%	+→0 +1%	0→− −6%	−− −16%
Change in dietary preferences for meat (% from current)	++ +20	+ +10	 −20	−− −40
Household preference for urban (U) or rural (R) settlements (U++ = strongly prefer urban; R++ = strongly prefer rural; 0 = no preference)	U++	U++	0	R++
Water savings due to behavioural change (% from current)	−− −30	− −20	++ +50	+ +30
Technological				
Change in agricultural mechanisation (% from current)	++ +75	++ +75	− −10	−− −25
Water savings due to technological change (% from current)	+ +30	++ +45	++ +40	0 0
Economic				
Change in agricultural yields (% from current)	++ +50	++ +50	0 +15	- −10
Change in food imports (% from current)	− −20	0→+ +10	0→− −10	0→− −20
GDP change (% from current)	++ +70	+ +35	−→0 0	−− −30
Change in irrigation efficiency (% from current)	+ +30	++ +60	++ +60	0 0
Oil Price ($/Barrel)	++ 200	+ 150	0 80	0+ 100
Environmental				
Compact (C) vs. sprawled (S) urban development	S++ Low	S+ Low	C+ High	0 Med
Change in bioenergy production *from crops* (% from current – proportion of arable crops used for bioenergy)	+ +10	0+ +0	++ +20	+ +10
Political				
Changes in protected areas (relative to Natura 2000 in 2012)	- −50%	0 0	++ +100%	++ +100%
Set aside (%)	−− 0	− 1	++ 10	+ 6

(dykes, irrigation and drainage). Based on the above assumptions, it was considered impossible to achieve the objectives for biodiversity conservation in protected areas as well as economic targets (e.g. in tourism or fishery). UWS-Danube and EC-Danube scenarios were assumed to broadly reflect WB assumptions but strongly differ in wetland restoration, assuming 800 km^2 for UWS-Danube and 2200 km^2 for EC-Danube, leading to a more balanced restoration of wetlands and agricultural landscapes in the latter. The regional scenario team considered the UWS scenario for mid-term and the EC after 2030 as most appropriate to overcome regional environmental challenges. RR assumptions were supposed to cause an almost complete restoration of the Danube floodplain, and the scenario was therefore considered implausible for the Lower Danube after very intense debates.

Example 2 (*Cairngorms National Park, Scotland*). **Purpose of scenario exercise:** Assess the potential impacts of climate change on future land use change in and around the Cairngorm National Park (for this example Appendix D provides a report on the outcomes of using the OpenNESS scenarios in combination with a simulation model at regional scale).

Steps of local scenario development:

- Prepare spatial land cover data and climate scenarios for the Cairngorm region
- Adapt the drivers of the new OpenNESS scenarios (note: storylines have not been modified)
- Use the CLIMSAVE-Scotland model to simulate land cover and land use change and impacts on ES
- Discuss results with stakeholders to derive climate change adapted management strategies.

In the study conducted in the Cairngorms National Park, the majority of the OpenNESS drivers with the recommended parameterisation were selected except the drivers concerning protected area status and size. The study was focused on land use change and the possibility that the protected status of the national park would change was considered not relevant for the study, which means that the original drivers were all adapted to protected areas of constant size. The study also focused on climate change. The socio-economic boundary conditions for the European scenarios were considered relevant for the region. It was assumed that this may also allow comparison with other regional studies using the new scenarios.

The CLIMSAVE model parameterised with the four scenarios predicts significant change in land use and the associated ecosystem services. The area currently consists primarily of unmanaged land and extensively farmed land. Unmanaged land is projected to continue to be the primary land cover as the area is dominated by a mountain massive in the centre (the focus of the original protected status). These lands are the primary source of the majority of the rivers (regulating services) but also provide multiple cultural services. In terms of quantity, the lower altitude slopes and valley bottoms provide the majority of the provisioning services of the park, i.e.

timber, sheep and cattle meat. It is the land use in these areas of the park which were predicted to change most, and as these are the human-dominated areas they are also of great interest to the park authority which focuses on both socio-economic development (provisioning services) and wildlife conservation (cultural and regulating services) of the area. The results of the CLIMSAVE model parameterised with the new scenarios predicts the largest amount of change in the managed forests and extensively and intensively farmed lands, resulting in projected increases or decreases in the ecosystem services provided by these land use classes.

3.3.2. Survey on the scenario method among stakeholders participating in the place-based studies

In early 2016, a survey was conducted among all 27 place-based studies to monitor and understand stakeholders' perceptions on usefulness and applicability of key methods provided by the project, including the scenario method (see Dick et al., 2018 in this special issue for detailed information on the survey). The survey revealed that 4 out of 24 responding studies had already applied scenarios, while the remaining 10 of the originally 14 place-based studies who stated their intent to apply scenarios two years earlier, were either behind schedule or had changed their mind.

Regional stakeholders and advisory board members (N: 16–21) responded to the 12 questions related to the scenario method (see Table 3). On a scale of 1 (strong disagreement) to 5 (strong agreement) the scenario method on average achieved good levels of agreement from 2.9 (local data availability, applicability) to 4.8 (method encourages discussions). The lowest levels of agreement, which were related to (local) data availability for the scenario study, were also reflected in critical remarks by some respondents addressing for instance (i) limited data availability perceived to be limiting scenario work, (ii) the high complexity of the scenario approach, especially when linked with simulation models, or (iii) limited possibilities of stakeholders in their current positions to initiate changes based on insights from the scenario process. Note that we singled out critical remarks here, but in general most of the remarks were positive, mainly reflected in the scoring of the survey.

4. Discussion

4.1. Scenario development process

As reported from other scenario processes (Alcamo et al., 2008; Priess and Hauck, 2014), the scenario development benefitted substantially from the multiple iterative cycles foreseen for this approach. The cycles were also urgently needed to ensure the knowledge integration from local and EU-level stakeholders in our consensus-oriented approach and to consult additional experts to increase the consistency of scenario assumptions. However, the rigorous procedure also had a price. We observed (i) a clearly larger than expected timeframe and workload for the scenario team and the collaborating experts and stakeholders, (ii) a certain fatigue of the repeatedly contacted case study partners and (iii) more importantly of the EU-level stakeholders, several of whom reported a continuously increasing number of similar stakeholder meetings, forcing them to be very selective and strongly limit the number of attended workshops. The latter statements confirmed the approach of the scenario team to involve EU-level stakeholders at a strategic point in the scenario process, enabling them to contribute to storyline and driver assumptions while minimising use of their time.

Scenario development additionally benefitted from the mix of teleconferences and meetings in person, which were held during the annual meetings and additional workshops across Europe, during which also representatives of the place-based studies were present and were able to interact with the scenario team. Thus, on one hand, representatives of the place-based studies were contributing regional knowledge as intended users to the scenario process, on the other hand support and methods were provided during meetings to facilitate the contextualisation and regionalisation of the scenarios.

As the contextualisation of broad-scale scenarios with regional stakeholders was known to be time-consuming (Oteros-Rozas et al., 2015 reported periods of 2–60 months and a mean of 16 months), the development of storylines and quantified drivers had to be finished after 24 months, including the ex-ante driver survey and the iterative cycles in the team and with the stakeholders. Based on additional expert feedback minor refinements were applied thereafter to driver quantifications. The strict timeline left 30 months for contextualisation and application by the place-based studies of the OpenNESS project, which was well above the average period reported by Oteros-Rozas et al. (2015).

4.2. Scenario products

4.2.1. Set of quantified drivers of change

Based on the storylines, the survey, the EU-level stakeholders and the scenario review (Hauck et al., 2015), the set of drivers of change was established and their expected changes were assessed

Table 3
Stakeholder survey: evaluation of scenario method. Lowest mean levels of agreement are highlighted in red, the highest in green; scale: 1 (strong disagreement) to 5 (strong agreement); see Dick et al., 2018 this SI, for a detailed overview of the survey.

Statements (addressing the scenario method)	No. of respondents	Min	Max	Mean	Std. dev.
The results were believable	21	2	5	4.2	0.7
The results were easy to understand	21	2	5	4.3	1.0
The method was easy to use	20	2	5	3.4	0.9
The assumptions underlying the method are clear	20	2	5	4.0	1.0
The results are easy to communicate to others	21	2	5	4.0	0.9
The method encourages discussion	20	4	5	**4.8**	0.4
The availability of data was not limiting	16	1	5	**2.9**	1.3
We could apply this method without external assistance	19	2	5	**2.9**	1.1
The results from this tool identified something I didn't already know	21	2	5	3.9	1.0
I will do something differently as a result of this method's results	20	1	5	3.3	1.1
I would encourage others to use this method	21	2	5	3.8	0.9
My perceived practical usefulness of the scenario method is	20	2	5	4.2	0.8

in a semi-quantitative fashion. After several rounds of discussions and two rounds of revisions, the list of recommended quantified scenario drivers was delivered as a product. The term "recommended" was used to indicate that the quantification reflects the changes and developments assumed in the storylines. However, modifications/adaptations of some of the drivers were needed to parameterise the simulation models to be used to simulate the scenarios such as their impacts on land use and ES. Knowledge integration such as the scenarios' "world views" or the regional knowledge available in the team, was complicated by the fact that the representation of processes and spatial units partly differed between the models. On the other hand, the iterative process of integrating qualitative aspects and assumptions in the storylines and their quantification in model parameters improved storylines as well as the quantification of drivers and model parameters, e.g. assumptions of trade or regional consumption preferences. Simulation results based on the new scenarios using the CLIMSAVE model (Dunford et al., 2015; Harrison et al., 2016), and IMAGE-GLOBIO, which is part of the global modelling framework IMAGE v 3.0 (Alkemade et al., 2009; Stehfest et al., 2014) are presented in Veerkamp et al. (2017). The contextualisation of the drivers in regional place-based studies is discussed in the next section.

4.2.2. Contextualising the scenarios at regional scales

Several procedures of downscaling or contextualising global or broad-scale scenarios for instance to a sub-national level have been described (e.g. Zurek and Henrichs, 2007; Alcamo and Henrichs, 2008; Kaljonen et al., 2012; Metzger et al., 2010). The scenario developer team offered support for the local teams to adapt the EU-scale scenarios to the regional scales, e.g. providing information on downscaling, co-development, back-/forecasting or other methods (Alcamo and Henrichs, 2008; Ash et al., 2010; Durham et al., 2014; UNEP, 2008). In addition, mainly as support for local studies, a handbook for scenario development was elaborated, adapting published literature on scenario typologies such as Börjeson et al. (2006) and Bishop et al. (2007) and scenario development processes and analysis, including process and product aspects (Alcamo et al., 2008; Cork et al., 2012; Lempert, 2013; Priess and Hauck, 2014).

As shown in the two examples above, users contextualising and adapting the OpenNESS scenarios for regional place-based studies followed very different strategies. The Scottish study in principle considered the set of EU-scale drivers to be relevant at their scale, adapting just the drivers addressing the spatial changes of protected areas, and used them jointly with regionalised climate scenarios to drive an adapted Scottish version of the CLIMSAVE model. The study concluded that land use will inevitably change along with the changing climate. However, the socio-economic context, marked by political decisions and the priorities of the population as addressed in the scenarios, will decide the magnitude of change. In the Romanian study, the contextualisation of the scenarios was much stronger based on regional results, especially the trajectory of change of the Lower Danube catchment, into which the EU-scale scenarios were "embedded". The two examples demonstrate that the new EU-level storylines and drivers have been helpful to address changes of land use as well as a broad range of ecosystem services under strongly contrasting socio-environmental conditions. Unlike Vaclavik et al. (2016), it is too early to assess whether the common boundaries provided via storylines and drivers really facilitate comparisons of changes in NC and ES provision, or to assess transferability of strategies across a larger set of place-based studies.

4.3. Stakeholder perceptions of the regional scenario processes

While monitoring was reported for less than 50% of the 23 participatory scenario studies by Oteros-Rozas et al. (2015), this study was participating in a regional stakeholder survey focussing on the evaluation of the scenario and other key methods used in the project. The respondents provided valuable insights into their perceptions of the scenario method, agreeing or strongly agreeing to 10 of 12 evaluation questions (see Table 3), but also addressing potential limitations of this scenario approach. For instance, regional data availability was perceived to be limiting by some respondents. Data gaps are a well-known phenomenon in the context of the work with scenarios and models as highlighted by IPBES (2016). The IPBES report provides some suggestions such as encouraging data holders and institutions to consider improving the accessibility of well documented data sources and working in close collaboration with research and observation communities (including citizen science) and communities working on indicators to fill gaps in data collection and provision. This could go hand in hand with efforts to improve the collection of and access to data for quantifying environmental status and trends to overcome regional data limitations.

Furthermore, some stakeholders were concerned about the need for external assistance for scenario development and some perceived the scenario process as (too) complex. In this study, we used a science-oriented approach with an intermediate level of stakeholder involvement integrated across disciplines and scales. Complexity and the need for external support may be reduced by applying more qualitative or process-oriented participatory scenario planning methods (Kok et al., 2007; Palomo et al., 2011; see also Oteros-Rozas et al., 2015 for an overview of PSP approaches).

5. Conclusions

Ferrier et al. (2016) classified different types of scenario approaches based on their position in the policy cycle. The scenarios presented in this paper are considered agenda-setting/explorative (Ferrier et al., 2016), developed to address future trajectories of NC and ES.

The scenario process benefitted from the iterative development procedure and from including different stakeholders and a broad range of expertise in the scenario team. The new EU-level scenarios were successfully contextualised under differing socio-environmental conditions in regional place-based studies using different approaches. A survey about monitoring the scenario method among regional stakeholders revealed that some stakeholders were concerned about limitations of the method, e.g. its high complexity, which may be less limiting in studies focusing on more qualitative participatory scenario planning methods. Nevertheless, new environmental scenarios were considered a useful, believable and discussion-provoking method for assessing NC and ES by the majority of respondents.

Furthermore, the widely differing assumptions presented in storylines and drivers of change, motivated follow-up simulation studies about future impacts on land use and ES, as well as policy analysis assessing different levels of ES operationalisation and implementation in existing or future policy frameworks.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ecoser.2017.08.006.

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