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ABSTRACT

Scenarios are a useful tool to explore possible futures of social-ecological systems. The number of scenarios has increased dramatically over recent decades, with a large diversity in temporal and spatial scales, purposes, themes, development methods and content. Scenario archetypes generically describe future developments and can be useful in meaningfully classifying scenarios, structuring and summarising the overwhelming amount of information, and enabling scientific outputs to more effectively interface with decision-making frameworks. The Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES) faced this challenge and used scenario archetypes in its assessment of future interactions between nature and society. This paper describes the use of scenario archetypes in the IPBES Regional Assessment of Europe and Central Asia. Six scenario archetypes for the region are described in terms of their driver assumptions and impacts on nature (biodiversity) and its contributions to people (ecosystem services): Business-as-Usual, Economic Optimism, Regional Competition, Regional Sustainability, Global Sustainable Development and Inequality. The analysis shows that trade-offs between nature's contributions to people are projected under different scenario archetypes. However, the means of resolving these trade-offs depend on differing political and societal value judgements within each scenario archetype. Scenarios that include proactive decision-making on environmental issues, environmental management approaches that support multifunctionality, and mainstreaming environmental issues across sectors, are generally more successful in mitigating trade-offs than isolated environmental policies. Furthermore, those scenario archetypes that focus on achieving a balanced supply of nature's contributions to people and that incorporate a diversity of values are estimated to achieve more policy goals and targets, such as the UN Sustainable Development Goals and the Convention on Biological Diversity Aichi targets. The scenario archetypes approach is shown to be helpful in supporting science-policy dialogues for proactive decision-making that anticipates change, mitigates undesirable trade-offs and fosters societal transformation in pursuit of sustainable development.

KEYWORDS

Nature, Biodiversity; Drivers; Nature's contributions to people (NCP), Ecosystem services; IPBES; Impacts, Scenario archetypes

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INTRODUCTION

Nature and human society interact in complex ways. For example, nature underpins and contributes to people's quality of life but, at the same time, human development has caused significant losses in biodiversity through overexploitation and other drivers of change, such as policy/institutional change or climate change (Díaz et al. 2015, Hauck et al. 2015, Rounsevell and Harrison 2016). The complex interactions result in large uncertainties that make it difficult for societies to resolve an appropriate course of collective action to adapt to or to mitigate change and to pursue sustainable livelihoods (Rounsevell et al. 2010). Despite these uncertainties and complex interactions, it is important to understand at least key interrelationships to develop effective management and policy strategies (Luck et al. 2009).

Scenarios and models provide a means for exploring uncertainties about how different drivers of change might develop in the future and for considering how those changes might impact nature (biodiversity) and its contributions to people (ecosystem services), and alter society's vulnerability and ability to take action. This improves understanding of the range of plausible futures in a region, alerts decision-makers to undesirable future impacts, and enables exploration of the effectiveness of policy options and management strategies (IPBES 2016a).

However, the number of scenarios has increased dramatically over recent decades, with a large diversity in temporal and spatial scales, purposes, themes, development methods and content (Priess and Hauck 2014, Kok et al. 2018). To synthesise findings from the plethora of existing scenario studies, scenarios may be grouped into “scenario archetypes” according to their underlying assumptions, storylines and characteristics (Gallopín et al. 1997, Hunt et al. 2012). Here, we define a “scenario archetype” as scenarios that share similar assumptions, storylines or logics, which are in turn reflected in similar types of quantifications. This definition is very similar to the description of a scenario family, and the two have been used interchangeably (Gallopín et al. 1997, Hunt et al. 2012, van Vuuren et al. 2012; see also Oberlack et al. this issue). Scenario archetypes describe different general patterns of future developments and can be useful in summarising and harmonising the overwhelming amount of information in individual sets of scenarios. This approach has been previously applied by scenario reviews at multiple scales. For example, at the global scale, a review by van Vuuren et al. (2012) proposed six scenario archetypes (referred to in the paper as “scenario families”). In another study, Rothman (2008) provided a detailed and conceptually grounded overview of a number of archetypes found in environmental scenarios covering a broad range of sectors, scales and types. Both of these are in general agreement with other similar studies (e.g. Busch, 2006; Westhoek et al., 2006; Zurek, 2006). In addition, there are scenario archetype studies that predominantly review sub-global studies, for example, a review of more than 160 scenario studies by Hunt et al. (2012).

The scenario archetype approach has been recognised by the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services (IPBES) to help synthesise findings from scenario and modelling studies within the four IPBES regional assessments (Harrison et al. 2018a). In addition, the use of scenario archetypes facilitates a coherent comparison of scenarios across the IPBES regional assessments (see Sitas et al. this issue) and their further synthesis in the IPBES global assessment (IPBES 2015). All of the review studies presented above largely agree on similar, comprehensive sets of four to seven scenario archetypes. Furthermore, they all

single out one particular set of scenarios in their analysis, namely the “global scenario group” scenarios of van Vuuren et al. (2012), as being helpful for structuring scenario studies. Consequently, the IPBES Scenarios and Models Thematic Assessment (IPBES 2016a) proposed a set of six global scenario archetypes based on the scenario families described by van Vuuren et al. (2012): Business-as-usual; Economic optimism; Reformed markets; Regional competition; Regional sustainability; and Global sustainable development. These were adapted for the regional context of the Europe and Central Asia Assessment by (i) omitting “Reformed markets” since, at the sub-global level, it is mostly synonymous with a change to more sustainable policies, and therefore falls within the Global sustainability development archetype, and (ii) adding the “Inequality” scenario archetype to reflect the growing importance of this archetype in the scenario literature, particularly through the Shared Socioeconomic Pathways (O’Neill et al. 2015) aligned with the Intergovernmental Panel on Climate Change.

The scenario archetype approach applied in this study relates to the general archetype approach (sensu Oberlack et al. this issue) in a number of ways. First, individual scenarios here are understood as cases, and scenario archetypes are used as their typology (see also Eisenack et al. this issue and Sietz et al. this issue). Thus, similarities are identified between entire cases (scenarios) based on their attributes, and each case (scenario) is then categorised in exactly one archetype. This is in contrast to the “building blocks” approach to archetypes, where any single case of the phenomenon of interest can be characterised by one or a combination of several archetypes (Oberlack et al. this issue). Second, the archetype approach was applied as a means to distinguish and classify existing scenarios. The scenario archetypes were not constructed from the underlying data (i.e. they were not applied in an inductive way) (Oberlack et al. this issue). On the contrary, the final set of scenario archetypes was decided upon and selected as a classification scheme based on existing analyses, i.e. before the IPBES review of scenario and modelling studies started. However, it was informed by an early rapid assessment of the scenario sets included in this paper, which resulted in some adaptations to the pre-existing set of scenario archetypes. This approach is, thus, closer to the deductive use of archetypes as a tool to diagnose cases based on knowledge previously established by preceding research (Oberlack et al. this issue). Nevertheless, by further developing the scenario archetypes for the context of Europe and Central Asia, based on the information from reviewed scenarios, we went beyond a strictly deductive approach to archetype analysis.

Analyses of scenario archetypes and their impacts on nature and its contributions to people can provide information to evaluate whether policy goals and visions that are essential to our quality of life are likely to be achieved. International policy goals to ensure human well-being and sustainable development recognise the fundamental value of nature and its conservation (Convention on Biological Diversity n.d.). This is reflected in the strategic vision of the Convention for Biological Diversity (and its associated 20 Aichi targets), which states that “by 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people”. It is also reflected in the 2030 Agenda for Sustainable Development (and its associated 17 Sustainable Development Goals (SDGs)), particularly SDGs 14 (Life below Water) and 15 (Life of Land). Furthermore, Geijzendorffer et al. (2017) showed that 12 of the 17 SDGs relate to ecosystem services, whilst Rounsevell et al. (2018) showed that 11 of the SDGs address the importance of nature to humans.

This paper provides a synthesis of the scenario and modelling studies that were reviewed as part of the IPBES Europe and Central Asia Regional Assessment. The analysis and discussion focuses on three research questions: (i) What range of plausible futures for nature and its contributions to people in Europe and Central Asia are indicated by existing scenario and modelling studies?; (ii) In what ways do scenario archetypes help us understand future impacts on nature and its contributions to people to inform science-policy processes?; and (iii) To what extent do scenario archetypes usefully link plausible futures to biodiversity targets and sustainability goals? The paper first provides background information on the IPBES regional assessment process, the reviews of scenario and modelling studies that were undertaken and the development of the scenario archetype approach for synthesising findings. Each scenario archetype is then described in terms of its underlying driver assumptions and how they result in particular impacts for nature and its contributions to people. An illustration of how the scenario archetype approach can be used to assess policy goals such as the Aichi targets and the SDGs is then presented. Finally, we compare across the scenario archetypes focusing on the synergies and trade-offs in impact indicators, and discuss the advantages and limitations of the scenario archetype approach.

IPBES uses the terminology of nature, nature's contributions to people (NCP) and a good quality of life to broaden the scope of the widely-used ecosystem services framework to extensively consider diverse worldviews on human-nature interactions (see Díaz et al. 2018a, for further information). Thus, this paper consistently uses the IPBES framework and terminology, rather than biodiversity, ecosystem services and human well-being. The term 'biodiversity' is in itself complex in its use (see Mace et al. 2012 for a thorough discussion) and we apply the term 'nature' whenever this common, general notion is relevant, but use biodiversity for specific scientific (e.g. species/habitat diversity as a feature of nature) or policy notions (Mace et al. 2012). NCP and ecosystem services are considered as nested terms (rather than near-synonyms as proposed by some authors (de Groot 2018)), with NCP embracing and broadening the ecosystem service concept (Peterson et al. 2018, Diaz et al. 2018b), embedded into the legitimate and mandated policy context of IPBES.

METHOD

The IPBES Regional Assessment for Europe and Central Asia involved over 120 leading international experts from 36 countries and took place between 2015 and 2018. The Europe and Central Asia region encompasses 54 countries in the four IPBES sub-regions of Western Europe, Central Europe, Eastern Europe and Central Asia (see Appendix #1). This paper draws on Chapter 5 of the Regional Assessment, which focused on "Current and future interactions between nature and society" (Harrison et al. 2018a). The overall aim of Chapter 5 was to synthesise knowledge related to possible future dynamics of nature and ecosystem functions that affect their contribution to the economy, livelihoods and quality of life in Europe and Central Asia. The assessment was refined based on 7000 review comments (over 550 for Chapter 5) by external experts and governments over three rounds of review.

Two linked reviews were undertaken to gather evidence in the Europe and Central Asia region on: (i) exploratory scenarios, which examine a range of plausible futures based on assumptions

about a range of trajectories of indirect and direct drivers; and (ii) modelling studies, which translate the driver assumptions in exploratory scenarios into projected consequences for nature, NCP and quality of life. The reviews and subsequent analysis were restricted to exploratory scenarios, i.e. future outlooks that address the question ‘what could/would happen?’ and that aim at maximising diversity within a set of scenarios in order to analyse uncertainties in the development of key drivers (Henrichs et al. 2010). This contrasts with the use of normative scenarios that address the question ‘what should happen?’ and predictions that assess ‘what will happen?’ (see Coreau et al. 2009), which were out of the scope of this study.

The review of exploratory scenarios had two parts – a formal review of peer-reviewed scenario literature using the Scopus database, and an informal review of grey literature using the knowledge of the author team (see Appendix #2 for the review protocol). Both reviews focused on environment-related scenarios from 2005 until the present. Articles were screened for ten aggregated groups of drivers (indirect drivers: demography, economy, technology, cultural and institutional; and direct drivers: climate change, land use change, natural resource extraction, pollution, and alien invasive species). Studies including only single drivers and studies with subnational spatial coverage were excluded from the review. These constraints were put in place to focus on multiple driver combinations and on spatial scales relevant to the sub-regional and regional levels. A total of 436 scenarios in 143 studies from both the formal and informal reviews met the review criteria and were assessed.

The review of modelling studies focused on integrated modelling approaches that combine modelling of multiple environmental, social and economic system components and their interactions. Such approaches provide essential support to guide planning and decision-making by highlighting critical interdependencies and potential synergies and trade-offs between NCP under different plausible futures. Similar to the scenarios review, the modelling review consisted of a formal review of the peer-reviewed literature using the Scopus database, which was complemented by extensive searches using the IPBES expert network, additional efforts by the author team to reduce gaps (i.e. for Central Asia and marine ecosystems) and suggestions to include additional studies by external reviewers (see Appendix #3 for the review protocol). Articles were limited to those studies that included projections of future impacts of multiple drivers on multiple components of nature and NCP. As the majority of impact assessment studies still rely on single component models (Harrison et al. 2015), only 37 articles were found from both the formal and informal reviews that met the review criteria. Nevertheless, these 37 articles led to a total of 3,151 entries in the review database representing different combinations of integrated approaches, scenarios, regions and modelled system indicators for nature, NCP and quality of life. The final set of reviewed articles included local (a few hundred square kilometres), national, regional (EU wide, Central Asia) and global (which provided information for Europe and Central Asia) modelling studies.

The individual scenarios from the exploratory scenarios and modelling review databases were screened for multiple attributes (Table A3.2 and A2.3), which were extracted for each scenario and entered in the database. Subsequently, based on the storylines of the scenarios, their underlying logic and assumptions, as well as the qualitative and quantitative values of scenario attributes, the individual scenarios were matched to the six scenario archetypes for Europe and Central Asia using the classification provided by Hunt et al. (2012). This covered all global

scenario sets and a large share of the European-scale scenarios. For those scenario sets not assigned to any of the Hunt et al. (2012) scenario archetypes, the qualitative or quantitative descriptions of changes in indirect and direct drivers were compared with the broad assumptions, storylines and characteristics for the archetypes as described in van Vuuren et al. (2012) and O'Neill et al. (2015). In addition, the information extracted from the scenarios was used to further develop the regional specificity of the scenario archetypes for Europe and Central Asia.

The scenario archetypes were then linked to policy goals using expert opinion to estimate the extent to which SDGs and Aichi targets may be reached under the different scenario archetypes. It should be noted that the scenario timeframes extend beyond those of the SDGs and Aichi targets, ranging from 2030 to 2100. Relative estimates of success (projected positive impacts) and failure (projected negative impacts) were based on: (i) the review of integrated scenario and modelling studies; and (ii) the extent to which SDGs and Aichi targets prioritise diverse values of nature, NCP and good quality of life (IPBES 2016b, Díaz et al. 2018). The reliability of the estimates was based on the number of articles citing a projected impact and the consistency of the projected impact in terms of direction of change (positive or negative).

RESULTS

Overview of the review database

The majority of studies in the scenario and modelling reviews originated from Western Europe (64% and 57%, respectively). Central Europe had a reasonable coverage in the scenarios review (30%), but not in the modelling review (6%). Few studies were found in both reviews for Eastern Europe (5% and 6%) and Central Asia (1% and 6%). Most studies involved multiple sectors, with the agricultural sector often featuring in various combinations with water management, nature conservation, forestry, tourism and energy. Combinations between fisheries, aquaculture, water management and conservation were also observed.

The six archetypes were not represented equally in the literature for Europe and Central Asia. The business-as-usual type of scenario was often used (30% of scenarios), but few of these studies developed a storyline of how indirect and direct drivers are projected to change over time (only three studies); rather they simply assumed no change in current trends. Economic optimism was well-represented (24%) possibly due to its overlap with Business-as-usual and the popularity of downscaled regional versions of the IPCC SRES A1B and A1FI scenarios (Nakicenovic et al. 2000). Regional competition (17%), Global sustainable development (15%) and Regional sustainability (12%) were reasonably well represented in European and Central Asian scenario studies. By contrast, Inequality, as a relatively new scenario developed as part of the recent IPCC-related SSPs (O'Neill et al. 2015), was only covered in 2% of scenario studies.

Description of the scenario archetypes for Europe and Central Asia

Projected future changes in the different indirect and direct drivers represented within the exploratory scenarios for Europe and Central Asia are summarised in Figure 1 for each scenario archetype. Projected impacts of each scenario archetype on indicators of nature, NCP and quality

of life are summarised in Figure 2. A description of the specific driver assumptions and their associated impacts is given in the following sections for each scenario archetype.

Business-as-Usual

Continuation of current social, economic and technological trends results in moderate but uneven population and economic growth, with persisting inequality and societal stratification (Stocker et al. 2012, O'Neill et al. 2015) (Figure 1). International markets and institutions are mostly stable, but function imperfectly. Technological development proceeds but fundamental innovations are not achieved, and the use of fossil fuels does not substantially decrease (O'Neill et al. 2015). While environmental issues are perceived as important, society and industry are reluctant to adopt environmental policies that would lead to substantial improvements (Haines-Young and Potschin 2010). The intensity of climate change is moderate to high (Fronzek et al. 2012, Hickler et al. 2012, Dullinger et al. 2015). In terms of land use, woodlands expand while the area of grasslands decreases at the European scale (Mitchley et al. 2006, Sheate et al. 2008, Partidário et al. 2009), while land homogenisation trends differ across countries (e.g. high countryside homogenisation in the UK vs. low in Croatia; Haines-Young and Potschin, 2010, Pukšec et al., 2014). Levels of pest outbreaks and alien species invasions across Europe increase (Seidl et al. 2008, Haines-Young and Potschin 2010, Chytrý et al. 2012).

In general, northern parts of Western and Central Europe are likely to benefit from enhanced material NCP such as food production and forest yield, while their provision declines in southern Europe, and the production of food remains stable but the forest area decreases in continental parts of Europe (Harrison et al. 2013, Dunford et al. 2015, Kirchner et al. 2015) (Figure 2). A focus on enhancing material NCP with market value comes at the cost of environmental condition and regulating NCP with non-market values (Hirschi et al. 2013, Verkerk et al. 2014, Dunford et al. 2015). Water stress increases in most of Western and Central Europe, except for the northern regions (Harrison et al. 2013, Dunford et al. 2015). Trends in regulating NCP in Western and Central Europe (e.g. carbon sequestration, nitrogen leaching) vary across sub-regions and the time period considered (Hirschi et al. 2013, Dunford et al. 2015, Krkoška Lorencová et al. 2016). However, European citizens benefit from stable NCP such as recreational activities, tourism and landscape beauty (Hirschi et al. 2013, Verkerk et al. 2014, Dunford et al. 2015).

The condition of nature remains stable or deteriorates (e.g. species diversity and vulnerability, ecosystem functioning indicators), however, the trends vary substantially across sub-regions (Hirschi et al. 2013, Lazzari et al. 2014, Kirchner et al. 2015). Particularly southern regions of Western and Central Europe as well as Alpine species and forests become increasingly vulnerable (Dunford et al. 2015).

Quality of life remains generally stable, with sustained levels of food provision but increasing water management issues. Although landscapes become increasingly homogenised and intensively used in some parts of Europe, the overall opportunities for tourism, recreation and landscape experiences remain stable.

Economic Optimism

Global developments steered by high economic growth across the majority of European countries (Koch et al. 2011, Reder et al. 2013) result in a strong dominance of international markets with a small degree of regulation and a high level of international cooperation (Garrote et al. 2016). Population growth is generally low in Europe and Central Asia (Fischer et al. 2011, Stocker et al. 2014), but with national variability (e.g. high growth in Sweden, Milestad et al. 2014). Lifestyles in both Europe and Central Asia are resource-intensive, with high meat and material consumption (Haines-Young et al. 2011, Stokral et al. 2014, Kok and Pedde 2016). A reactive attitude towards environmental management prevails (Kok et al. 2011, Reder et al. 2013), with rapid technological development focused on efficiency (Koch et al. 2011, Stocker et al. 2014), including increasing agricultural productivity (Seitzinger et al. 2010, Stokral et al. 2014, Kok and Pedde 2016). Consequently, the scenarios assume substantial increases in natural resource consumption, utilisation of biofuels (Milestad et al. 2014, van Wijnen et al. 2015), fertiliser usage (Reder et al. 2013, Stokral et al. 2014) and water consumption (Okruszko et al. 2011, Flörke et al. 2012). These assumptions have implications for environmental degradation and pollution (Kok et al. 2011, Reder et al. 2013). They are also associated with high levels of climate change (Okruszko et al. 2011, Reder et al. 2013).

The focus of this archetype on economic growth is reflected by an increase in the provision of most material NCP, such as food production in Central Asia (Bobojonov and Aw-Hassan 2014) and Europe (Schröter et al. 2005), timber production (especially in higher latitudes; Eggers et al. 2008, Forsius et al. 2013) and fisheries production in Nordic countries (Blanchard et al. 2012, Merino et al. 2012). However, there are also declines in Central Asian cotton production (Bobojonov and Aw-Hassan 2014), wetland products in Western and Central Europe (Okruszko et al. 2011) and an overall reduction in fish provision in Europe and Central Asia (Merino et al. 2012). Due to the archetype's general preference for marketable over non-marketable NCP (Briner et al. 2013, Hirschi et al. 2013, Schirpke et al. 2013), there are important trade-offs between material and regulating NCP, leading to widespread decreases in many regulating NCP, such as carbon sequestration (Okruszko et al. 2011), erosion control (Palomo et al. 2011), climate regulation (Hirschi et al. 2013) and protection against natural hazards (Schirpke et al. 2013). Nevertheless, there may be short-term increases in carbon fluxes to Western and Central European lands due to increased net primary production enhanced by increased atmospheric CO₂ (Schröter et al. 2005).

The challenges posed by the environmental limits within these scenarios result in general declining trends in the majority of the nature indicators, especially in coastal and wetland aquatic ecosystems (Okruszko et al. 2011, Forsius et al. 2013) and the southern waters of the Europe and Central Asia region (Blanchard et al. 2012, Merino et al. 2012, Lazzari et al. 2014), birds in Western and Central Europe (Okruszko et al. 2011) and mountainous and Mediterranean species in Western Europe (Schröter et al. 2005).

As a result of these trends in nature and NCP indicators, quality of life will be negatively affected at various scales and in all sub-regions of Europe (Hirschi et al. 2013, Palacios-Agundez et al. 2013, Galli et al. 2017) and Central Asia. However, there are improvements in learning, inspiration, and physical and psychological interactions with the environment, as society invests

in education, recreation and tourism, but declines in indicators related to supporting identities as society becomes more globalised.

Regional Competition

Social fragmentation, competition and failure of market mechanisms result in inequality, declining social cohesion and human capital across Europe and Central Asia (Kok et al. 2011, Kok and Pedde 2016). Violence and instability challenge international trade and cooperation (Kok et al. 2011, 2013, Kok and Pedde 2016) and shift emphasis to self-sufficiency (Thaler et al. 2015). Due to barriers to collaboration, technological development is generally low or failing (Reidsma et al. 2006, van Meijl et al. 2006, Latkovska et al. 2012). Population growth projections are variable across countries (Pereira et al. 2009, Neteler et al. 2013, Ozolincius et al. 2014) and with contradictory trends across the European Union (Seitzinger et al. 2010, Neteler et al. 2013, Milestad et al. 2014). By contrast, economic development is assumed to be generally slow (van den Hurk et al. 2005, Eliseev and Mokhov 2011, van Slobbe et al. 2016). The predominant approach to environmental issues is reactive (Kok et al. 2011). Climate change is expected to be relatively severe (Bourdôt et al. 2012, Neteler et al. 2013, Kelly et al. 2014), whilst land use change differs among countries, in terms of intensification (Seitzinger et al. 2010, Haines-Young et al. 2011) and homogenisation (Haines-Young et al. 2011, Milestad et al. 2014). Conflicts regarding natural resources are expected to increase, with substantial use of local energy resources (Haines-Young et al. 2011). Projections of the likelihood of invasions by alien invasive species are predominantly high (Ozolincius et al. 2014).

Impacts on material NCP (food, feed, biofuel and wood production) are regionally variable with general increases in northern parts of Western and Central Europe (Schröter et al. 2005, Forsius et al. 2013, Dunford et al. 2015) and Central Asia (Bobojonov and Aw-Hassan 2014), but decreases in southern (Palomo et al. 2011, Harrison et al. 2013, Palacios-Agundez et al. 2013) and western (Harrison et al. 2013, Lamarque et al. 2014) parts of Western and Central Europe. Regulating NCP also vary by region and scenario study with some EU studies projecting declining soil organic carbon stocks (Schröter et al. 2005, Hattam et al. 2015), but others projecting increases in carbon fluxes to lands and seas, and increases in total carbon stocks of forests (Schröter et al. 2005, Eggers et al. 2008, Hattam et al. 2015). In southern and western parts of Western Europe carbon storage is projected to remain stable or decrease (Palacios-Agundez et al. 2013, Lamarque et al. 2014), nitrate leaching to remain stable, and pollination and pest regulation to decrease (Palomo et al. 2011, Lamarque et al. 2014).

Biodiversity is generally negatively impacted in both land and marine ecosystems in northern parts of Western and Central Europe, including increased mortality in fisheries, decreases in species richness and decreases in species of recreational interest such as seals and cetaceans (Harrison et al. 2013, Hattam et al. 2015). Biodiversity is also more vulnerable in southern parts of Western and Central Europe, particularly the Mediterranean basin (Harrison et al. 2013, Palacios-Agundez et al. 2013, Lazzari et al. 2014).

Quality of life and health is, in general, negatively affected (Hirschi et al. 2013, Palacios-Agundez et al. 2013, Galli et al. 2017). However, two studies in Spain project increases in recreational activities, good social relations, aesthetic and spiritual value, and local identity

(Palomo et al. 2011, Palacios-Agundez et al. 2013), whilst in Kazakhstan and Tajikistan, farmers benefit from increased income due to increased crop yields (Bobojonov and Aw-Hassan 2014). These results are, however, limited to a small number of studies and countries.

Global Sustainable Development

A high degree of international cooperation and top-down governance result in a globalised world with a high level of proactive regulation in favour of the environment. Population growth is low to moderate across the EU (Ozolincius et al. 2014, van Slobbe et al. 2016) and moderate in Central Asia (Kok and Pedde 2016), whilst economic development varies greatly between scenarios within this archetype from slow (Kok et al., 2011, Louca et al., 2015) to rapid (Gálos et al. 2011, Haines-Young et al. 2011, Kok and Pedde 2016) (Figure 1). Technological development is rapid, focusing on green and resource-efficient technologies (Kok et al. 2011, Kok and Pedde 2016), biotechnology and sustainable technologies (Haines-Young et al. 2011). High levels of social respect and cohesion lead to strong increases in human and social capital in both Europe and Central Asia (Kok et al. 2013, Kok and Pedde 2016) and low material consumption, with some exceptions of increased consumption of local goods (Haines-Young et al. 2011, Kok and Pedde 2016). The proactive attitude of policy-makers and the public at large towards environmental issues results in relatively low levels of climate change (Fischer et al. 2011, Ozolincius et al. 2014, Scholten et al. 2014) and low to medium dispersion of invasive alien species due to extensive control programmes (Fischer et al. 2011, Haines-Young et al. 2011, Chytrý et al. 2012).

Impacts of the Global Sustainable Development archetype are largely positive for most indicators of nature, NCP and quality of life (Figure 2). In particular, regulating NCP such as regulation of climate (Schröter et al. 2005, Dunford et al. 2015, Hattam et al. 2015), air quality (Palomo et al. 2011, Palacios-Agundez et al. 2013), soil erosion (Lorencová et al. 2013, Palacios-Agundez et al. 2013) and natural hazards (Palacios-Agundez et al. 2013) increase across Western and Central Europe. Food (Harrison et al. 2013, Brown et al. 2015) and timber (Dunford et al. 2015; Eggers et al. 2008) production are enhanced as a result of increases in temperature and from greater afforestation efforts in northern parts of Western and Central Europe. However, decreases in water availability in southern countries of Europe and Central Asia lead to increases in forest fires (Schröter et al., 2005) and higher water insecurity (Schröter et al. 2005, Palomo et al. 2011, Palacios-Agundez et al. 2013).

The condition of nature generally improves, particularly in the north-western part of Western Europe where both marine (Hattam et al. 2015) and terrestrial diversity increases (Dunford et al. 2015). However, biodiversity vulnerability is expected to be greater in southern and Alpine areas of Europe (Harrison et al. 2013, Brown et al. 2014, Dunford et al. 2015), although ecosystem functioning in the Mediterranean Sea remains stable (Lazzari et al. 2014).

Various indicators of good quality of life, such as the number of species of recreational interest, aesthetic and spiritual value, nature and beach tourism and recreational activities increase (Palomo et al. 2011, Rodina and Mnatsakanian 2012, Hattam et al. 2015). However, local identity and traditional knowledge declines due to the global nature of the scenario archetype (Palacios-Agundez et al. 2013).

Regional Sustainability

Decision-making shifts towards local and regional levels with a focus on welfare, equality and environmental protection delivered through local solutions (Haines-Young et al. 2011, Kok et al. 2011). A proactive attitude to environmental management prevails, increasingly influenced by environmentally aware citizens. International collaboration is poor causing problems with technology transfer and obstructing coordination to solve global issues such as climate change (Cork et al. 2006). Population growth is moderate (Reidsma et al. 2006, van Meijl et al. 2006), whilst economic development is slow to moderate (Kok et al. 2011, Stokal et al. 2014) with uneven economic growth among countries (Seitzinger et al. 2010). Technological development is also at a medium level but uneven across countries (Reidsma et al. 2006, van Meijl et al. 2006, Latkovska et al. 2012) with a focus on energy-related technologies (Koch et al. 2011) and clean and resource-efficient technologies (Thaler et al. 2015, Louca et al. 2015, Stokal et al. 2014). Consumption patterns are oriented towards local products and food self-sufficiency (Fazeni and Steinmüller 2011, Milestad et al. 2014). Highly diverse and heterogeneous patterns of land use occur within individual countries (Haines-Young et al. 2011, Milestad et al. 2014) and across Europe (Bolliger et al. 2007). Higher standards for environmental protection and strong conservation policies (Bolliger et al. 2007, Koch et al. 2011) lead to reductions in pollution in terms of fertiliser use (Nol et al. 2012, Stokal et al. 2014), O₃ emissions (Jiménez-Guerrero et al. 2013) and nutrient emissions (Ludwig et al. 2010). There is also low dispersion of invasive alien species and reductions in invasions due to stricter border control (Haines-Young et al. 2011).

Regulating NCP particularly benefit in this scenario archetype as all parts of Western and Central Europe show positive trends in, for example, carbon sequestration (Eggers et al. 2008), air quality (Schröter et al. 2005) and soil stability (Schirpke et al. 2013), as well as water regulation, natural hazard regulation, soil fertility and pest regulation (Palomo et al. 2011, Palacios-Agundez et al. 2013). Impacts on material NCP are highly area dependent with both increases and decreases for food and feed (Hirschi et al. 2013, Palacios-Agundez et al. 2013, Schirpke et al. 2013). However, there is a notable increase in timber production in Western and Central European countries, leading to increased wood quantity and quality (Schröter et al. 2005, Eggers et al. 2008). Bioenergy crops also increase substantially in northern countries of Western Europe (Schröter et al. 2005, Eggers et al. 2008). No modelling studies were available for Eastern Europe and Central Asia.

Impacts on nature indicators are not consistent among the studies conducted in Western and Central Europe, with some studies projecting an increase in habitat diversity (Hirschi et al. 2013) and biodiversity (Palacios-Agundez et al. 2013), and others a decrease of biodiversity in terms of number of species and habitats, which is especially significant for birds, Mediterranean and mountain species (Schröter et al. 2005, Okruszko et al. 2011).

Good quality of life indicators generally show improvements, including increases in recreational activities, nature tourism, aesthetic and spiritual values, health and satisfaction with the state of biodiversity (Palomo et al. 2011, Palacios-Agundez et al. 2013).

Inequality

Power becomes concentrated in a relatively small political and business elite across the globe leading to increasing economic, political and social inequalities and fragmentation both across and within countries. In Europe population declines whilst economic development is generally high (Kok et al. 2013, Kok and Pedde 2016), with some exceptions in Central Europe (Hanspach et al. 2014) (Figure 1). In contrast, population increases in Central Asia up to the middle of the century when it stabilises and economic growth remains stable (Kok and Pedde 2016). There are increasing disparities in economic opportunity, leading to substantial proportions of the population of Europe and Central Asia having a low level of development. Political regimes in Central Asia become increasingly authoritarian and repressive, with growing incidence of social unrest, conflicts and ethnic clashes (Kok and Pedde 2016). Technology develops unevenly across countries, but the EU initiates a shift towards a high-tech green Europe (Kok et al. 2013). Environmental issues are addressed only to a limited extent, focusing on local or key transboundary issues, particularly in relation to water and energy supplies (Kok and Pedde 2016). These socio-economic conditions combined with intermediate levels of climate change lead to an intensification of agricultural land use in some areas where large collective farms are established controlled by multinationals (Hanspach et al. 2014) or elites (Kok and Pedde 2016), and agricultural abandonment in less productive areas. Forests and biofuels increase in Europe due to the focus on green technology. Pollution and invasive alien species are only strongly regulated when advantageous to the elites (Kok and Pedde 2016).

Only two modelling studies were found for the Inequality scenario archetype, both on Western and Central Europe (Harrison et al. 2013, Brown et al. 2015). Regulating NCP, such as the regulation of floods and other natural hazards, decrease. Material NCP, such as food and timber production, generally increase in northern parts of Western and Central Europe, but decrease in southern parts; this latter finding being partly related to severe increases in water stress. The overall state of the nature indicators is stable, but is clearly area-dependent. Nature is more vulnerable in the northern and western parts of Western Europe and more resilient in the eastern and southern parts of Western and Central Europe. No studies addressed good quality of life indicators.

Relating the scenario archetypes to policy goals

The estimated success or failure in achieving the SDGs and Aichi targets under the six scenario archetypes, bearing in mind the different timeframe of the scenario archetypes, is shown in Figure 3. Positive trends are shown in greater than half the archetypes for 11 out of 17 of the SDGs (1, 2, 4, 5-9, 12, 13 and 17), most commonly in the two sustainability archetypes (Regional sustainability and Global sustainable development) and Economic optimism. The Aichi targets have fewer positive trends across archetypes with 12 out of the 20 targets showing more archetypes with negative trends than positive.

The fragmented world of Regional Competition is associated with failure to achieve the majority of the SDGs and Aichi targets. Business-as-Usual also leads to failure of most of the SDGs (13 out of 17) and Aichi targets (12 out of 20), whilst Economic Optimism is estimated to have a mixed level of success in achieving the SDGs (8 out of 17 achieved), but would fail to achieve the majority of the Aichi targets (16 out of 20). This may be because such scenario archetypes

tend to lead to trade-offs between material NCP and regulating and non-material NCP through prioritising market values. Their focus on instrumental values (the value that something has as a means to a desired or valued end) and individualistic perspectives, with little acknowledgement of relational (the relationships between people and nature, which can be collective or individual) or intrinsic values (the value that an entity has in itself, which is non-anthropocentric), are unlikely to offer effective sustainable solutions to environmental and social challenges (Jacobs et al. 2016). In contrast, the “sustainability” scenario archetypes (Regional Sustainability and Global Sustainable Development) are estimated to achieve the majority of SDGs (14 out of 17) and Aichi targets (14 out of 20). Such scenarios attempt to provide multiple NCP and aspects of a good quality of life. Thus, they represent a greater diversity of values, but sometimes at the expense of lower, or less intensive, production of material NCP.

It should be noted that the evidence base from the review is highly variable depending on the indicator, with projected indicators of non-material NCP and quality of life, which are important for assessing the likely achievement of many SDGs, being relatively rare (most entries have less than 10 papers, see Figure 2). Evidence tends to be greater for nature and material NCP, supporting estimations of some SDGs (e.g. SDG 1 – no hunger) and the Aichi targets, as biophysical impacts of future scenarios are more commonly modelled and assessed.

DISCUSSION

Impacts of multiple indirect and direct drivers on nature, NCP and quality of life have been synthesised for six plausible futures for Europe and Central Asia using a scenario archetypes approach. This allowed a large diversity of individual scenario and modelling studies to be classified and grouped to inform the IPBES science-policy process about the range of plausible futures in the region and how these relate to the achievement of policy goals and targets. Here, we highlight the key messages from the analysis of the scenario archetypes in relation to the three questions posed in the Introduction.

What range of plausible futures for nature and NCP in Europe and Central Asia are indicated by existing scenario and modelling studies?

The scenario archetypes exhibit varying trends in the indirect and direct drivers. Business-as-Usual, Economic Optimism, Regional Competition and Inequality show negative trends in most direct drivers of nature and NCP, including climate change, natural resource use, pollution and alien invasive species. Among these archetypes, the only positive trend is in the indirect driver of technological development under the Business-as-Usual and Economic Optimism archetypes, which is, however, often outweighed by unsustainable consumption and natural resource exploitation. In contrast, the Regional Sustainability and Global Sustainable Development archetypes show positive trends in most drivers in relation to nature and NCP. Climate change is assumed to increase to various extents under all scenario archetypes and thus represents one of the most pressing challenges.

These assumptions about changes in drivers under the different scenario archetypes result in contrasting impacts on nature and NCP for Europe and Central Asia. Generally, the indicators related to nature, NCP and good quality of life show more positive impacts under the Global

Sustainable Development and Regional Sustainability scenario archetypes than under the Economic Optimism, Regional Competition, Inequality and Business-as-Usual scenario archetypes. This is particularly noticeable for the set of NCP indicators. These broad variations in impacts under different types of scenarios have been discussed by various authors. For example, Schröter et al. (2005), Palomo et al. (2011) and Palacios-Agundez et al. (2013) showed that in general terms, the provision of NCP is predicted to be more negatively influenced under socio-economic scenarios which are associated with a reactive governance of environmental issues (e.g. Economic Optimism or Regional Competition) than under the proactive environmental policies that are found in sustainability scenario archetypes (e.g. Global Sustainable Development or Regional Sustainability).

Furthermore, the main objective of the “sustainability” archetypes is to promote a more holistic approach to managing human and environmental systems that supports multifunctionality and multiple NCP. Alternatively, the Economic Optimism, Regional Competition and Inequality scenario archetypes are motivated by economic growth or national security. These archetypes focus more on the self-interest of individuals or ‘elite’ groups in society and tend to promote a more limited number of NCP, particularly material NCP such as agricultural and timber production. This is supported by studies that examined trade-offs between NCP and showed that increases in food provision (generally associated with the expansion of agricultural land or the intensification of livestock production and fish captures) were linked to decreasing provision of regulating NCP (e.g. prevention of soil erosion, regulation of water quality and quantity) and nature values (e.g. ecosystem functioning and compositional intactness indicators) (Posthumus et al. 2010, Palomo et al. 2011, Briner et al. 2013, Harrison et al. 2013, Dunford et al. 2015). Similar trade-offs have also been identified between other material NCP (e.g. timber extraction) and regulating (e.g. carbon storage) and non-material NCP (e.g. aesthetic value). For example, Schirpke et al. (2013), Verkerk et al. (2014) and Dunford et al. (2015) found that increasing wood extraction reduces the value of forests as a carbon sink and ultimately leads to highly managed forest that are aesthetically unattractive (decreasing its cultural/recreation values) and/or biodiversity poor.

Trade-offs were also apparent under the sustainability scenario archetypes, particularly in relation to the use of land and water (e.g. effects of agricultural extensification or increases in bioenergy croplands on other land uses and nature) (Harrison et al. 2018b). However, such scenarios proactively deal with such trade-offs through, for example, political choices aiming to maximise synergies through mainstreaming and multifunctionality (Global Sustainable Development) or through societal choices to live less resource-intensive lifestyles and, hence, reduce demand for material NCP (Regional Sustainability) (van Vuuren et al. 2012, Kok et al. 2013, Milestad et al. 2014).

In what ways do scenario archetypes help us understand future impacts on nature and NCP to inform science-policy processes?

Scenario archetypes can be a valuable tool to provide a means to structure a plethora of plausible futures into a manageable number of differentiated futures in a systematic way to inform decision-making. Such archetypes have persisted in time in the scenario literature (Boschetti et al. 2016), and have utility within global (e.g. van Vuuren et al. 2012) to continental (e.g. Busch

2006, Westhoek et al. 2006) to local (e.g. Hunt et al. 2012) scenario assessments. Typically, up to seven scenario archetypes are proposed. Even if used only qualitatively, this is a first step in providing a more nuanced, operational, multi-dimensional scenario framework (Carlsen et al. 2016b, 2016a), by building on multiple diverse scenario studies. At the same time, they enable, within a science-policy process where clear communication is important, manageable and informative comparisons across different types of futures, and across regions, that are particularly relevant for understanding future impacts on nature and NCP.

This study has classified scenarios into archetypes to differentiate the resulting impacts on nature and NCP at a broad level. However, a presumption of the archetype framework applied within IPBES was that the variability in the impact indicators arising from the drivers in individual scenarios classified within a single scenario archetype should have some differentiation from that within alternative archetypes (e.g. Brown et al. 2015). Whilst this has to some extent been evident with the differentiation in the direction and magnitude of the scenario drivers (Figure 1) and impacts (Figure 2) associated with each archetype, the diversity (and number) of drivers, spatial extents, scales and indicators within individual scenario studies reviewed has precluded a systematic confirmation of this.

A detailed discussion about the pros and cons of applying the scenario archetype approach is given in Sitas et al. (this issue). Although a key disadvantage of scenario archetypes described by Sitas et al. (this issue) is a loss of detail, which would be expected from any level of scenario aggregation, a greater challenge to the use of archetypes pertains to the lack of requisite driver information within sub-global scenarios for classification within a globally-oriented archetype. In particular, categorisation of scenarios at sub-regional or local scales may be problematic because the rationale of a global archetype may not hold under a local context and/or be difficult to be unambiguously reconstructed without detailed, specific information. Scaling of scenario archetypes is therefore a priority challenge for sustainability research if global and local/national future agendas are to be aligned and assessed using comparable assessment frameworks (Kok et al. 2017).

This study used existing, predefined archetypes as a means to distinguish and categorise scenarios. This has the drawback of relying on past scenario exercises where certain scenario sets (e.g. IPCC SRES) dominate, whilst more recent scenarios (e.g. the SSP4-related Inequality archetype) are underrepresented. This could be overcome in future applications of a deductive approach to archetype analysis by including the “currency” of scenarios as a classification criteria or by defining the original set of scenario archetypes with a greater emphasis on theory (Oberlack et al. this issue). Alternatively, an inductive approach could be employed by constructing scenario archetypes from the review database, rather than predefining them. This would imply a loss of comparability with other assessments in the example of IPBES, but a better representation of the information in the database and the possibility of new archetypes and novel insights.

Furthermore, as many past scenarios have been developed to be used as inputs to global Integrated Assessment Models and climate models, scenario archetypes have tended to be tailored to the temporal, spatial, and sectoral approaches most relevant to understanding greenhouse gas emissions and climate change. Climate change is, however, one among many

more immediate (and destructive) drivers exerting cumulative impacts on nature and NCP, with habitat modification and exploitation being the dominant driver of global biodiversity loss (WWF 2016). This clearly highlights that scenario studies including a comprehensive set of driver assumptions for ecologically relevant subsystems and analyses are lacking (Harfoot et al. 2014). Future scenario work should therefore take caution when fashioning archetypes from literature overwhelmingly focused on climate change as a driver.

Finally, in aggregating scenarios there is an implicit assumption that certain drivers will behave in a more or less uniform manner throughout the archetype. While this is a useful heuristic, in practice there are a near infinite number of combinations of indirect and direct drivers sufficient to foster an environment conducive to a particular goal. Classifying scenarios to concrete archetypes should therefore not have the unintended consequence of discounting radical or transformative change propelled by drivers characterized by high levels of uncertainty (e.g. sociocultural) which are often underrepresented in the scientific literature (Pichs-Madruga et al. 2016).

To what extent do scenario archetypes usefully link plausible futures to sustainability goals?

Our analysis clearly highlights that different futures are associated with different estimations of success and failure in the achievement of policy goals such as the SDGs and Aichi targets, whilst recognising the different timeframe of the scenario archetypes (often 2050 or later) to those stated in the SDGs and Aichi targets (2020 or 2030). We show that continuing current trends under the Business-as-Usual scenario archetype is estimated to lead to failure in achieving most of the SDGs and mixed effects in achieving the Aichi targets, whilst Economic Optimism is estimated to have a mixed level of success in achieving the SDGs but would fail to achieve the majority of the Aichi targets. Regional Competition is estimated to have widespread failure of all goals and targets. In contrast, Regional Sustainability and Global Sustainable Development are estimated to achieve the majority of SDGs and Aichi targets. This analysis shows that priorities for future sustainable development are more widely achieved under scenario archetypes that attempt to provide multiple NCP and aspects of a good quality of life through considering a diverse range of values (Harrison et al. 2018a, IPBES 2016b).

These results are consistent with an assessment of the future annual monetary value of ecosystem services under four global scenarios by Kubiszewski et al. (2017). The authors show that total annual ecosystem service values (in economic terms) decrease the most under the Fortress World scenario (part of the Regional Competition archetype), change little from current 2011 values under the Policy Reform scenario (part of the Global Sustainable Development archetype), and substantially improve under the Great Transitions scenario (part of the Regional Sustainability archetype). The authors conclude that the Great Transitions scenario (and to a lesser extent the Policy Reform scenario) embodies many of the SDGs, and that, therefore, achieving the SDGs would deliver greatly enhanced ecosystem services, human well-being and sustainability.

The scenario archetype approach was useful for highlighting how the choices made by decision-makers and societal actors lead to large differences in future impacts on nature, NCP and good quality of life within Europe and Central Asia, and thus to the likely achievement of

sustainability goals. More positive impacts are projected under scenario archetypes that assume proactive decision-making on environmental issues and promote a more holistic approach to managing human and environmental systems which supports multifunctionality and multiple NCP. Furthermore, those archetypes where environmental issues are mainstreamed across sectors are projected to be more successful in mitigating undesirable cross-sector trade-offs, resulting in positive impacts across a broad range of nature, NCP and good quality of life indicators, whilst those archetypes which include cooperation between countries open up possibilities to mitigate undesirable cross-scale impacts and capitalise on opportunities. Such information from scenario archetypes, combined with research on alternative pathways of actions and strategies that decision-makers can take to move society away from undesirable scenario archetypes towards more sustainable outlooks (Harrison et al. 2018a), provide an essential evidence base to support the development of national and regional sustainable development plans as well as the post-2020 global biodiversity framework of the Convention on Biological Diversity.

CONCLUSION

This study has shown that scenario archetypes can be successfully applied for summarising and harmonising the overwhelming amount of information in individual scenario and modelling studies within large-scale science-policy assessments such as IPBES. Although context-specific details maybe lost through the aggregation process, the approach allows high-level messages to be drawn from a large and diverse evidence base and clearly communicated to decision-makers. The assessment highlights the importance of political and societal choices in determining the consequences of multiple drivers of environmental change on nature and its contributions to people. It also emphasises that decisions related to resolving trade-offs are likely to be needed under all scenario archetypes, even sustainable futures. Such trade-offs would be more likely minimised if decision-making adopted a holistic (i.e. not siloed) approach that takes account of multiple drivers, diverse values and competing interests across sectors and regions. Thus, the scenario archetypes approach can be helpful in supporting proactive decision-making that anticipates change, mitigates undesirable trade-offs and fosters societal transformation in pursuit of sustainable development.

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