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Synthesis, part of a Special Feature on Archetype Analysis in Sustainability Research

Synthesizing plausible futures for biodiversity and ecosystem services in Europe and Central Asia using scenario archetypes

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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 summarizing 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. We describe 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 (including biodiversity) and its contributions to people (including 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 dialogue for proactive decision making that anticipates change, mitigates undesirable trade-offs, and fosters societal transformation in pursuit of sustainable development.

Key Words: *biodiversity; drivers; ecosystem services; exploratory scenarios; impacts; IPBES; models; nature; nature's contributions to people (NCP)*

INTRODUCTION

Nature and human society interact in complex ways. For example, nature 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 (including biodiversity) and its contributions to people (including 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 2016*a*).

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. 2019). To synthesize findings from the plethora of existing scenario studies, scenarios may be

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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 that can in turn be 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, Oberlack et al. 2019). Scenario archetypes describe different general patterns of future developments and can be useful in summarizing and harmonizing 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). In addition, there are scenario archetype studies that predominantly review subglobal studies, for example, a review of more than 160 scenario studies by Hunt et al. (2012).

The scenario archetype approach has been recognized by the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services (IPBES) to help synthesize findings from scenario and modeling studies within the four IPBES regional assessments (Biggs et al. 2018, Gundimeda et al. 2018, Harrison et al. 2018*a*, Klatt et al. 2018). In addition, the use of scenario archetypes facilitates a coherent comparison of scenarios across the IPBES regional assessments (see Sitas, Harmáčková, Anticamara, et al., *unpublished manuscript*) 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 tend to cite the "global scenario group" scenarios of Raskin et al. (2002) and the scenario families of van Vuuren et al. (2012) as being helpful for structuring scenario studies. Consequently, the IPBES Scenarios and Models Thematic Assessment (IPBES 2016*a*) 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" because, at the subglobal 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. 2019) 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. 2019; Sietz, Frey, Roggero, et al., *unpublished manuscript*). Thus, similarities are identified between entire cases (scenarios) based on their attributes, and each case (scenario) is then categorized 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 characterized by one or a combination of several archetypes (Oberlack et al. 2019). 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. 2019). 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 modeling 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. 2019). 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 recognize the fundamental value of biodiversity and its conservation (Convention on Biological Diversity [date unknown]). 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 on 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.

We provide a synthesis of the scenario and modeling 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 modeling 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?

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. 2018*a* for further information). Thus, we consistently use 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 et al. 2018), with NCP embracing and broadening the ecosystem service concept (Diaz et al. 2018*b*, Peterson et al. 2018), 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 subregions of Western Europe, Central Europe, Eastern Europe, and Central Asia (see Appendix 1). In this paper, we draw on Chapter 5 of the regional assessment, which focused on "current and future interactions between nature and society" (Harrison et al. 2018*a*). The overall aim of Chapter 5 was to synthesize 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 the following: (i) exploratory scenarios that examined a range of plausible futures based on assumptions about a range of trajectories of indirect and direct drivers; and (ii) modeling studies that translated the driver assumptions in exploratory scenarios into projected consequences for nature, NCP, and quality of life. The reviews and subsequent analysis focused only on exploratory scenario and modeling studies, i.e., future outlooks that address the question "what could happen?" and that aim at maximizing diversity within a set of scenarios in order to analyze 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 are out of the scope of this paper.

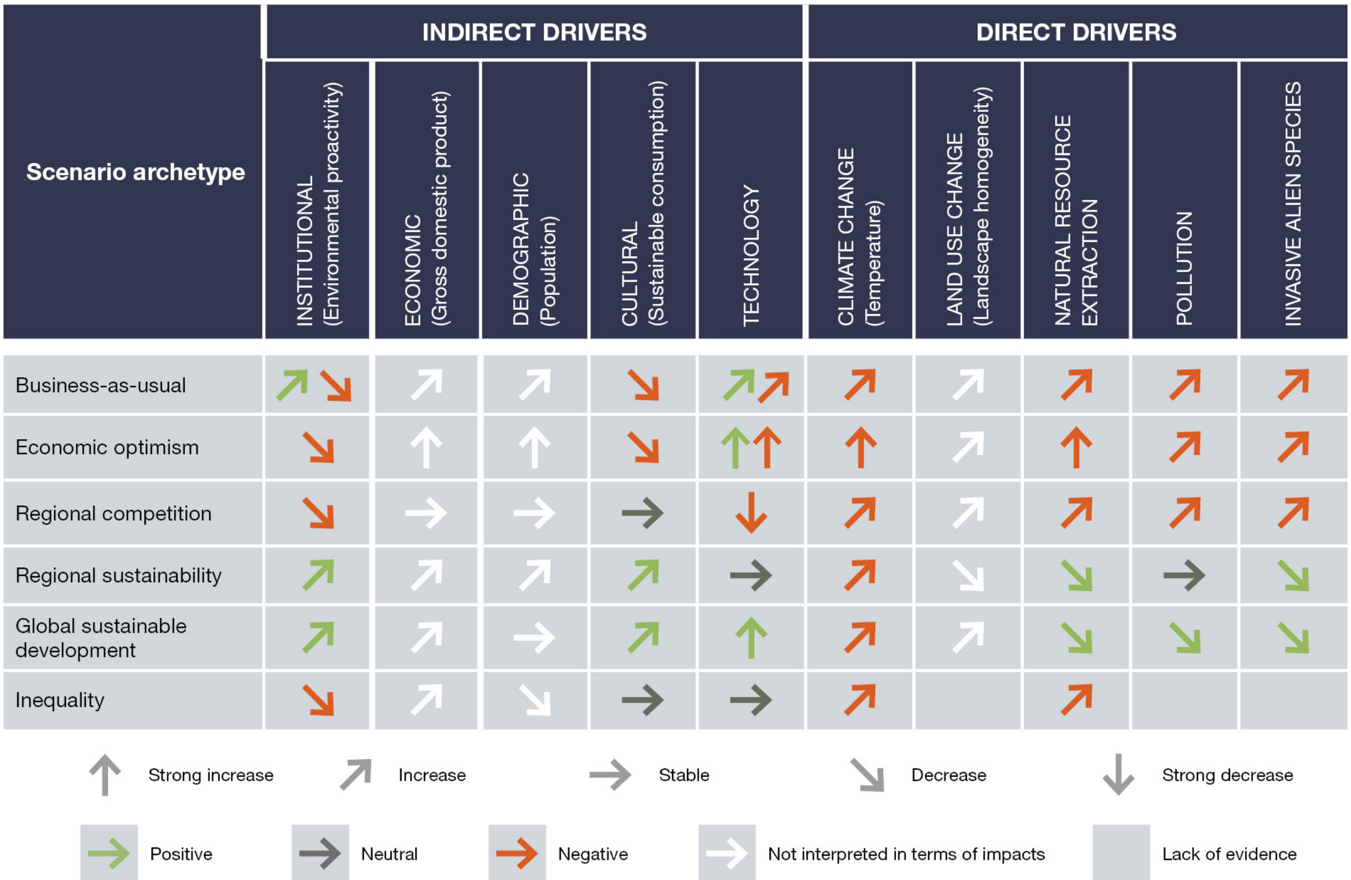
The review of exploratory scenarios had two parts: a formal review of peer-reviewed scenario literature using the Scopus database, and an informal review of grey literature using the knowledge of the author team (see Appendix 2 for the review protocol). Both reviews focused on environment-related scenarios from 2005 until the present. Articles were screened for 10 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 subregional 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 modeling studies focused on integrated modeling approaches that combine modeling 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 modeling 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. Because the majority of impact assessment studies still rely on single component models (Harrison et al. 2015, 2016), 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 3151 entries in the review database representing different combinations of integrated approaches, scenarios, regions, and modeled system indicators for nature, NCP, and quality of life. The final set of reviewed articles included local (a few hundred square kilometers), national, regional (EU wide, Central Asia), and global (which provided information for Europe and Central Asia) modeling studies.

The individual scenarios from the exploratory scenarios and modeling review databases were screened for multiple attributes (Tables A2.3 and A3.2), 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 of over 160 scenarios by Hunt et al. (2012). This involved mapping the Hunt et al. (2012) scenario archetypes to the six IPBES archetypes, which 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 Aichi targets and SDGs may be reached under the different scenario archetypes. It should be noted that the scenario timeframes extend beyond those of the Aichi targets and SDGs, ranging from 2030 to 2100. Relative estimates of success (projected positive impacts) and failure (projected negative impacts) were based on the following: (i) the review of integrated scenario and modeling studies; and (ii) the extent to which Aichi targets and SDGs prioritize diverse values of nature, NCP, and good quality of life (IPBES 2016*b*, Díaz et al. 2018*a*). 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).

Fig. 1. Trends in indirect and direct drivers in the six scenario archetypes for Europe and Central Asia. Arrows in the table represent the expert interpretation of the magnitude of trends in drivers across all reviewed scenarios found within the archetypes. Color coding represents the expert interpretation of the impact of the trend on nature and nature's contributions to people. Source: IPBES (2018).



RESULTS

Overview of the review database

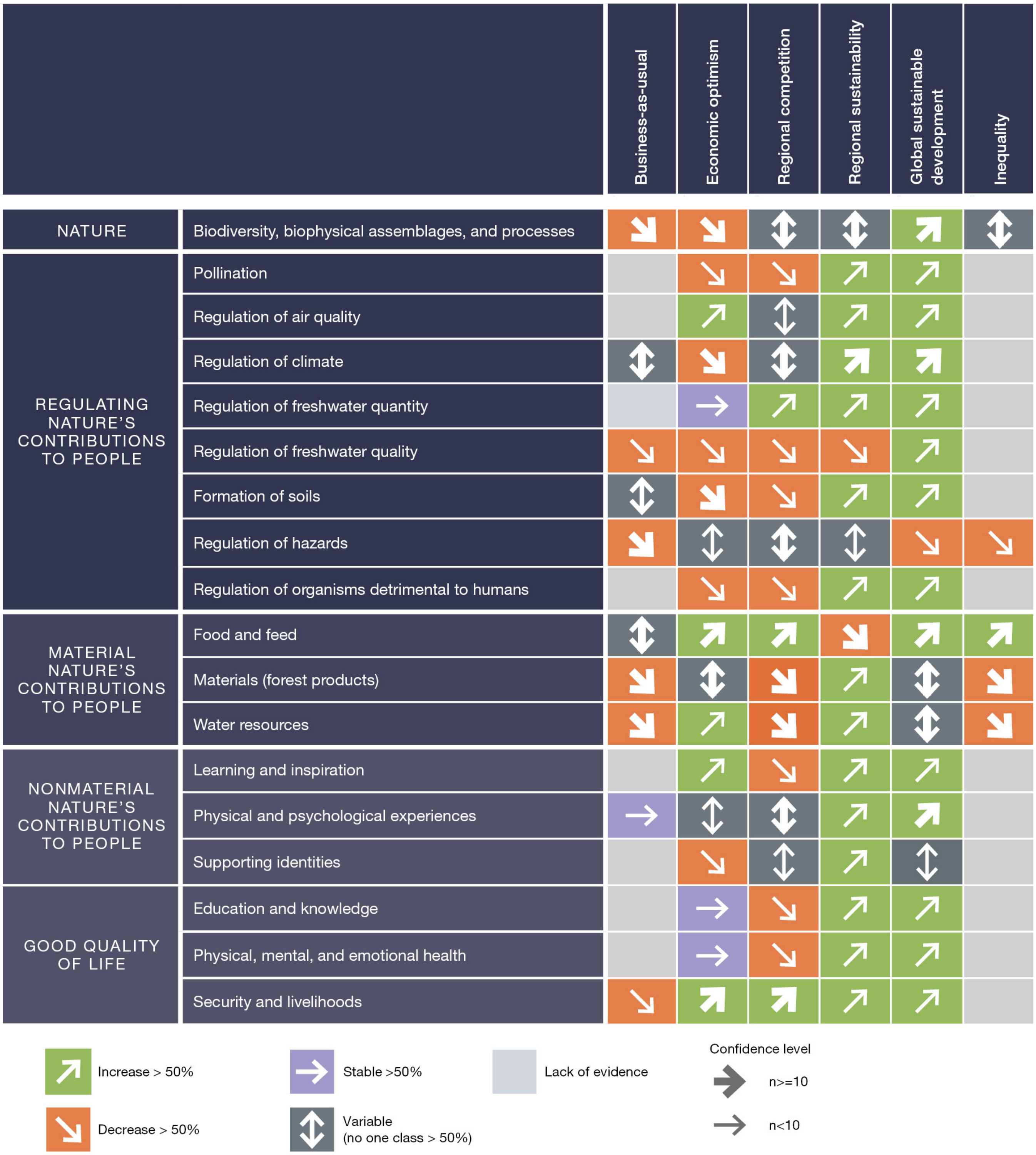
The majority of studies in the scenario and modeling reviews originated from Western Europe (64% and 57%, respectively). Central Europe had a reasonable coverage in the scenarios review (30%), but not in the modeling review (6%). Few studies were found in both reviews for Eastern Europe (5% and 6%) and 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 most 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 because of its overlap with business-as-usual and the popularity of downscaled regional versions of the Intergovernmental Panel on Climate Change special report on emissions scenarios (IPCC SRES) A1B and A1FI scenarios (IPCC 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 shared socioeconomic pathways (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 summarized in Figure 1 for each scenario archetype. Projected impacts of each scenario archetype on indicators of nature, NCP, and quality of life are summarized in Figure 2. A description of the specific driver assumptions and their associated impacts is given in the following sections for each scenario archetype.

Fig. 2. Projected future impacts on nature, nature's contributions to people (NCP), and good quality of life according to the six scenario archetypes for Europe and Central Asia. Green symbols with upward arrow indicate an increase, orange symbols with downward arrow a decrease, and purple symbols with horizontal arrow a stable trend. Thick arrows indicate evidence from the modeling literature review is based on 10 or more model indicators per scenario archetype, thin arrows indicate evidence based on fewer than 10. Source: IPBES (2018).



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; Fig. 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). Although 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 homogenization trends differ across countries, e.g., high countryside homogenization 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; Fig. 2). A focus on enhancing material NCP with market values comes at the cost of environmental condition and regulating NCP with nonmarket 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 or nitrogen leaching, vary across subregions 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 subregions (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 homogenized 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; Fig. 1). 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, Strokal et al. 2014, Kok and Pedde 2016). A reactive attitude toward 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, Strokal et al. 2014, Kok and Pedde 2016). Consequently, the scenarios assume substantial increases in natural resource consumption, utilization of biofuels (Milestad et al. 2014, van Wijnen et al. 2015), fertilizer usage (Reder et al. 2013, Strokal 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; Fig. 2). 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). Because of the archetype's general preference for marketable over nonmarketable 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 because of increased net primary production enhanced by increased atmospheric CO_2 (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 subregions 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 globalized.

Regional competition
Social fragmentation, competition, and failure of market mechanisms result in inequality and declining social cohesion and human capital across Europe and Central Asia (Kok et al. 2011, Kok and Pedde 2016; Fig. 1). 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). Because of 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, Ozolinčius 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), while land use change differs among countries, in terms of intensification (Seitzinger et al. 2010, Haines-Young et al. 2011) and homogenization (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 (Ozolinčius 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 (Fig. 2). Regulating NCP also varies 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), while in Kazakhstan and Tajikistan, farmers benefit from increased income because of 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 globalized world with a high level of proactive regulation in favor of the environment. Population growth is low to moderate across the EU (Ozolinčius et al. 2014, van Slobbe et al. 2016) and moderate in Central Asia (Kok and Pedde 2016), while 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; Fig. 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 toward environmental issues results in relatively low levels of climate change (Fischer et al. 2011, Ozolinčius et al. 2014, Scholten et al. 2014) and low to medium dispersion of invasive alien species because of extensive control programs (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 (Fig. 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 (Eggers et al. 2008, Dunford et al. 2015) 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 northwestern 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 because of the global nature of the scenario archetype (Palacios-Agundez et al. 2013).

Regional sustainability
Decision-making shifts toward 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 (Fig. 1). 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), while economic development is slow to moderate (Kok et al. 2011, Strokal 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 (Strokal et al. 2014, Louca et al. 2015, Thaler et al. 2015). Consumption patterns are oriented toward 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 fertilizer use (Nol et al. 2012, Strokal et al. 2014), O_3 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 because of stricter border control (Haines-Young et al. 2011).

Regulating NCP particularly benefit in this scenario archetype because 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; Fig. 2). 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 modeling 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. Some studies project 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).

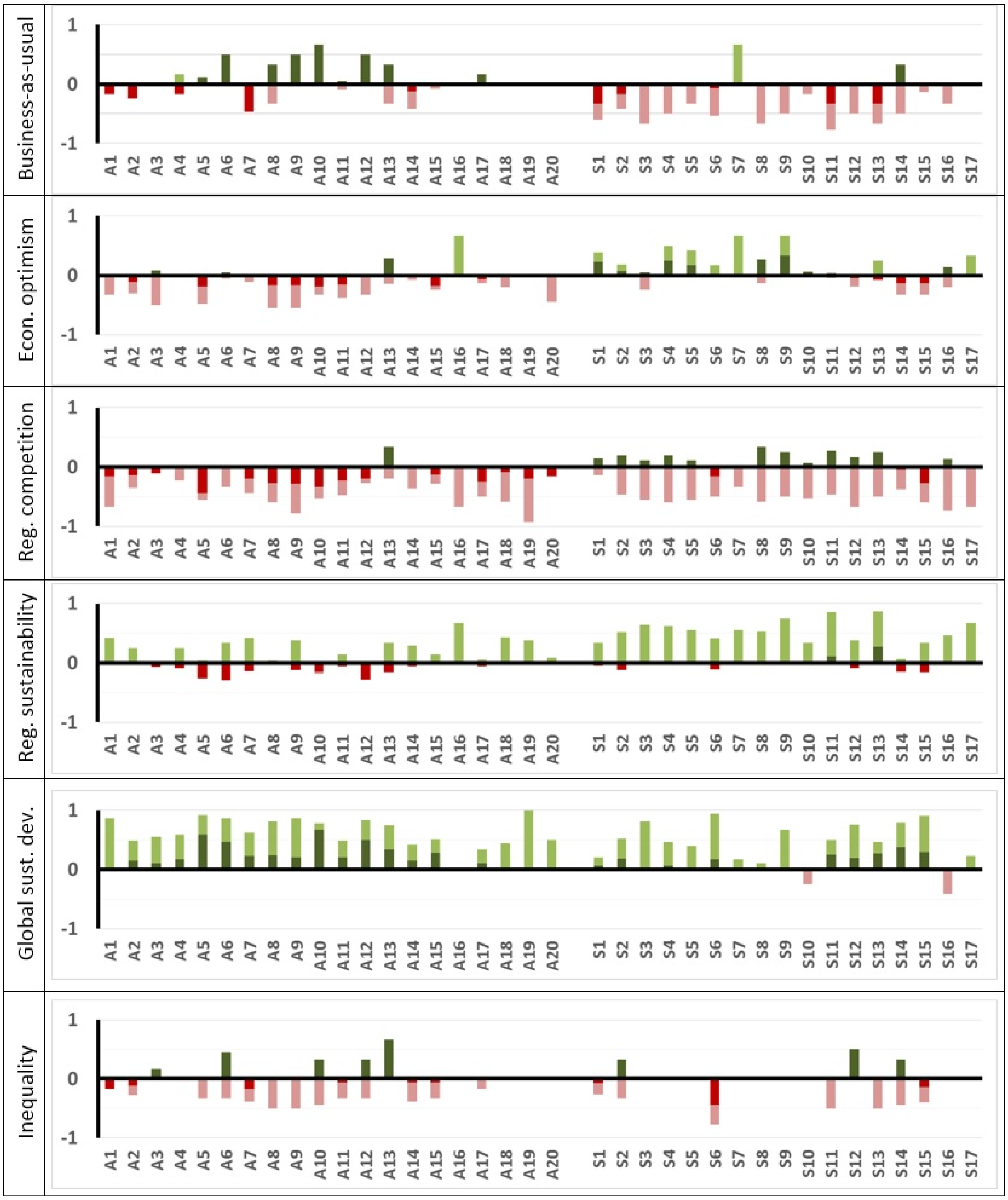
Inequality
Power becomes concentrated in a relatively small political and business elite across the globe leading to increasing economic, political, and social inequalities and fragmentation both across and within countries. In Europe population declines while economic development is generally high (Kok et al. 2013, Kok and Pedde 2016), with some exceptions in Central Europe (Hanspach et al. 2014; Fig. 1). In contrast, population increases in Central Asia up to the middle of the century when it stabilizes 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 toward 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 socioeconomic 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 because of 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 modeling 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 (Fig. 2). 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 Aichi targets and SDGs 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 Aichi targets and SDGs. Business-as-usual also leads to failure of most of the Aichi targets (12 out of 20) and SDGs (13 out of 17), while 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

Fig. 3. Extent to which Aichi targets and sustainable development Goals (SDGs) may be reached under the different scenario archetypes for Europe and Central Asia. The height of the bars reflect the extent to which Aichi targets and SDGs may be reached in a relative scale from 1 (completely reached) to -1 (completely failed). Red (below the line) indicates relative failure in achieving targets/goals; green (above the line) indicates relative success in their achievement. Darker shaded bars are supported with evidence from ≥ 10 papers; lighter shades from < 10 papers. Note that SDGs and Aichi targets with no bars, i.e., a zero value, mean that there was no evidence from the literature to suport that information. Also note that the scenario archetype timeframes extend beyond those of the Aichi targets and SDGs, ranging from 2030 to 2100.



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 nonmaterial NCP through prioritizing 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 nonanthropocentric), 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 Aichi targets (14 out of 20) and SDGs (14 out of 17). 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 nonmaterial 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 Fig. 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 because biophysical impacts of future scenarios are more commonly modeled and assessed.

DISCUSSION

Impacts of multiple indirect and direct drivers on nature, NCP, and quality of life have been synthesized for six plausible futures for Europe and Central Asia using a scenario archetypes approach. This allowed a large diversity of individual scenario and modeling 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 modeling 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 ecosystem services is predicted to be more negatively influenced under socioeconomic scenarios that 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 ecosystem services 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 nonmaterial 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 forests 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. 2018*b*). However, such scenarios proactively deal with such trade-offs through, for example, political choices aiming to maximize 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, multidimensional scenario framework (Carlsen et al. 2016*a, b*), 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). Although this has to some extent been evident with the differentiation in the direction and magnitude of the scenario drivers (Fig. 1) and impacts (Fig. 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, Harmáčková, Anticamara, et al. (*unpublished manuscript*). Although a key disadvantage of scenario archetypes described by Sitas, Harmáčková, Anticamara, et al. (*unpublished manuscript*) 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 subglobal scenarios for classification within a globally oriented archetype. In particular, categorization of scenarios at subregional 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 categorize scenarios. This has the drawback of relying on past scenario exercises where certain scenario sets, e.g., IPCC SRES, dominate, while 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 date of scenario construction as a classification criteria or by defining the original set of scenario archetypes with a greater emphasis on theory (Oberlack et al. 2019). 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, because 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. Although 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 Aichi targets and SDGs, while recognizing the different timeframe of the scenario archetypes (often 2050 or later) to those stated in the Aichi targets and SDGs (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, while 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 Aichi targets and SDGs. 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. 2018*a*, IPBES 2016*b*).

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 the provision of multiple NCP through systemic approaches to managing social-ecological systems. 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, while those archetypes that include cooperation between countries open up possibilities to mitigate undesirable cross-scale impacts and capitalize 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 toward more sustainable outlooks (Harrison et al. 2018*a*), 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

We have shown that scenario archetypes can be successfully applied for summarizing and harmonizing the overwhelming amount of information in individual scenario and modeling studies within large-scale science-policy assessments such as IPBES. Although context-specific details may be 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 emphasizes 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 minimized 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.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/10818

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APPENDIX #1: Definition of the Europe and Central Asia Region

Europe and Central Asia encompasses four sub-regions (see Figure A1.1) and 54 countries (see Table A1.1). According to Rounsevell et al. (2018) these countries vary greatly in size, including the largest and smallest on Earth, have diverse geography and history, but also common properties in terms of geography and climate, history and social systems. The region shares many cultural norms and historical features reflected in some similarities in land use, environmental history, biodiversity and ecosystem services. Nevertheless, the region encompasses high heterogeneity in natural and socio-cultural aspects. The seas that surround the region are also very heterogeneous in terms of temperatures, currents, nutrient availability, depths and mixing regimes.

Figure A1.1: The four sub-regions of the IPBES Europe and Central Asia Regional Assessment. Source: Rounsevell et al. (2018).

Table A1.1: Countries within each of the IPBES Europe and Central Asia Regional Assessment sub-regions.

Sub-region	Countries
Western Europe	Andorra, Austria, Belgium, The Kingdom of Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Liechtenstein, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, San Marino, Spain, Sweden, Switzerland and United Kingdom of Great Britain and Northern Ireland
Central Europe	Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Montenegro, Poland, Romania, Serbia, Slovakia, Slovenia, the former Yugoslav Republic of Macedonia and Turkey
Eastern Europe	Armenia, Azerbaijan, Belarus, Georgia, Republic of Moldova, Russian Federation and Ukraine
Central Asia	Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan

LITERATURE CITED

Rounsevell, M., M. Fischer, F. Boeraeve, S. Jacobs, I. Liekens, A. Marques, Z. Molnár, J. Osuchova, A. Shkaruba, M. Whittingham, and A. Zlinszky. 2018. Chapter 1: Setting the scene. Pages 1–54 *in* M. Rounsevell, M. Fischer, A. Torre-Marin Rando, and A. Mader, editors. *IPBES (2018): The IPBES regional assessment report on biodiversity and ecosystem services for Europe and Central Asia*. Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem services, Bonn, Germany.

Appendix 2. Methodology for the review of exploratory scenarios.

Appendix 2 outlines the steps of the formal review of future exploratory scenarios for Europe and Central Asia. The formal review was conducted using the Scopus database (https://www.scopus.com) and focused on studies published in peer-reviewed research journals before May 2017. The formal review was supported by an informal review of grey literature using the knowledge of the author team and the suggestions of external reviewers during the IPBES review process.

Step 1: The initial search applied combinations of keywords as listed in Table A2.1. We used the boolean operator 'AND' to combine the different queries. The terms [country] and [region] were replaced by the names of countries and regions in the geographic scope of the review (see Appendix #1).

Step 2: In addition, several targeted searches were conducted to identify further scenarios to fill the data gaps which became obvious after the initial search. The gaps and respective search terms are listed in Table A2.2.

Step 3: The studies obtained by the systematic and targeted searches were limited according to the following criteria:

- Relation to biodiversity and ecosystems (thus, e.g. studies addressing the effect of climate change on precipitation levels/river discharge/water levels, production of specific crop or scenario analyses related to energy were not included);
- Time span from 2005 to May 2017;
- Addressing two and more drivers (since the focus of the review was on driver interactions);
- National, sub-regional or regional coverage;
- Semi-quantified or quantified trends in drivers (purely qualitative narratives excluded).

Step 4: A total of 436 scenarios in 143 studies from both the formal and informal reviews met the review criteria and were assessed, out of which 252 scenarios were unique. The scenarios were screened for future trends in direct and indirect drivers of biodiversity and ecosystem services change and their interactions (Table A2.3).

Table A2.1: Search terms used for the literature review.

Keywords		Motivation
scenario AND ([country] OR [region])	analysis ecosystem ecological biodiversity	General scenarios focusing on biodiversity and ecosystem services change
	economic GDP socioeconomic scenario demographic population urbanization technology governance meat consumption diet	Indirect-driver specific scenarios
	invasive species biological control climate greenhouse gas emissions land use land change deforestation restoration LUC AFOLU fisheries resource exploitation acidification pollution fertilizer phosphorus nitrogen	Direct-driver specific scenarios

Table A2.2: Search terms used for the targeted searches.

Query	Keywords	Motivation
1	scenario AND (river OR basin OR watershed OR catchment) AND (Volga OR Danube OR Ural OR Dnieper OR Don OR Pechora OR Kama OR Dvina OR Vychegda OR Oka OR Belaya OR Dniester OR Rhine OR Elbe OR Donets OR Vistula OR Tagus OR Daugava OR Loire)	Freshwater-ecosystem related scenarios: Scenarios related to major European and Central Asian rivers (>1000 km) and their catchments
2	scenario AND (lake OR basin OR catchment OR watershed) AND (Ladoga OR Onega OR Saimaa OR Vänern OR Kuybyshev OR Rybinsk OR Tsimlyansk OR Kremenchuk OR Kakhovka OR Vättern OR Kamsk OR Kallavesi OR Saratov OR Limfjorden OR Päijänne OR Inari OR Vygozero OR Gorky OR Nasijarvi OR Mälaren OR Imandra OR Pielinen OR Sevan OR Topozero OR Votkin OR IJsselmeer OR Beloye OR Oulujarvi OR Hornavan OR Caspian OR Balkhash OR Issyk-Kul OR Sarygamysh OR Tengiz OR Zaysan OR Aral OR Alakol OR Kaptchagay)	Freshwater-ecosystem related scenarios: Scenarios related to major European and Central Asian lakes (>1000 km2) and their catchments
3	Due to language constraints, this gap was addressed by an informal review of grey literature using the knowledge of the author team	Exploratory scenarios for Eastern Europe and Central Asia
4	scenario AND ([scenario name] or [scenario family]) Scenario families and names: ALARM GRAS: 'growth applied strategy' BAMBU: 'business-as-might-be-usual' SEDG: 'sustainable European development goal' BIOSCENE Business as Usual Liberalization Managed Change for Biodiversity Wilding/Natural Processes	Large-scale multi-driver scenarios: Multi-driver scenario families developed within international research initiatives, assessments and large-scale interdisciplinary projects.

Query	Keywords	Motivation
	CLIMSAVE	
	We are the world	
	Icarus	
	Riders on the storm	
	Should I stay or should I go	
	EURURALIS:	
	Global Economy	
	Global Co-operation	
	Continental Market	
	Regional Communities	
	MA	
	Global Orchestration	
	Order from Strength	
	Adapting Mosaic	
	TechnoGarden	
	SCALER:	
	1A	
	1B	
	2A	
	2B	
	SCENES:	
	Economy First	
	Policy Rules	
	Fortress Europe	
	Sustainability Eventually	
	SSP (Shared Socioeconomic Pathways)	
	SSP1 – SSP5 †	
	UK National Ecosystem Assessment (UK NEA)	
	Green and Pleasant Land	
	Nature @Work	
	World Markets	
	National Security	
	Local Stewardship	
	Go with the Flow	
	SRES (Special Report on Emissions Scenarios)	
	A1 (A1F1, A1B, A1T)	
	A2	
	B1	
	B2	

† SSP consistent RCPs were included in the review, however, the primary focus was on the socio-economic scenarios.

Table A2.3: Information extracted from the selected studies for each scenario.

Database field	Details
Descriptive characteristics of scenarios	Stakeholders involvement in the scenario building process (0/1) Notion of values explicitly addressed in the scenario (0/1) Biodiversity explicitly addressed in the scenario (0/1) Time horizon Region or country Ecosystem domain addressed (e.g. forests, grasslands, marine) Activity sector addressed (e.g. agriculture, forestry)
Drivers addressed in the scenario and their respective trends	Demographic (e.g. population growth, urbanisation) Economic (e.g. Gross Domestic Product) Cultural (e.g. diet type, intensity of material consumption, attitude towards environmental issues) Technological (e.g. rate of innovation, agricultural productivity, irrigation efficiency) Institutional (e.g. level of international cooperation, efficiency of institutions, management strategies) Climate change (e.g. radiative forcing, temperature, greenhouse gas emissions) Land use/land cover change (e.g. rate of land cover change, land homogenisation, deforestation, land use intensification) Natural resource use (e.g. rate of exploitation, water extraction, energy use) Pollution (e.g. nutrient emissions) Invasive species (e.g. rate of dispersion)

APPENDIX #3: Methodology for review of integrated modelling studies

Appendix 3 outlines the steps of the formal review of integrated modelling studies for Europe and Central Asia. The formal review was conducted using the Scopus database (https://www.scopus.com) and focused on studies published in peer-reviewed research journals before May 2017. The formal review was supported by an informal review of peer-reviewed and grey literature using the knowledge of the author team and the suggestions of external reviewers during the IPBES review process.

Step 1: The initial search applied combinations of keywords as listed in Table A3.1. We used the boolean operator 'AND' to combine the different queries. The search was repeated changing the query by the names of the regions and countries considered in the Europe and Central Asia Regional assessment (see Appendix #1).

Step 2: In addition, several targeted searches were conducted to identify further integrated modelling studies to fill the data gaps which became obvious after the initial search. The targeted searches particularly focused on Central Asia and marine ecosystems, but also examined studies cited in the bibliographies of studies identified in Step 1.

Step 3: The studies obtained by the systematic and targeted searches were limited according to the following criteria:

- Included projections of future impacts considering uncertainty (i.e. considering two or more future scenarios);
- Included multiple drivers of change;
- Evaluated multiple components of biodiversity and ecosystem services (i.e. assessed multiple indicators);
- Included quantified trends in impacts (qualitative or semi-quantitative impact narratives excluded).

Step 4: Only 37 articles were found from both the formal and informal reviews that met the review criteria. From each article we extracted the information detailed in Table A3.2. This 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 biodiversity, ecosystem services and human well-being.

Table A3.1: Search terms used for the literature review.

Query	Field	Keywords	Motivation
1	Topic	(Scenario* OR model* OR Impact* OR Future*)	Captures modelling studies addressing predictions into the future
2	Topic	(biodiversity OR ‘ecosystem service*’ OR ‘human wellbeing’ OR ‘human well-being’)	Identifies studies evaluating indicators of biodiversity, ecosystem services or human well-being
3	Topic	(system* OR holistic* OR integrat* OR interaction* OR cross-scale OR cross-sector* OR trade-offs* OR treshold* OR tipping point* OR driver*)	Captures multi-driver, multi-scale studies evaluating multiple indicators
4	Topic	(Europe OR Asia)	Sets the geographic context: Europe and Central Asia (see Appendix #1 for country names)

Table A3.2: Information extracted from the selected articles. The right-hand column lists in detail the different categories into which we classified each study within each information field.

Database field	Details
Modelling approach (from Kelly et al. 2013)	*System dynamics models* are particularly good for modelling feedbacks, delays and non-linear effects, and are more commonly found in climate change-related impact assessments. *Bayesian network models* fit probabilistic relationships between system variables, and are therefore often found in modelling assessments where uncertainty needs to be properly quantified, such as for supporting decision-making and management. *Coupled component models* combine models from different disciplines or sectors to derive an integrated outcome. They can incorporate or handle complex representation of system components and their interlinkages *Agent-based models* define interactions between autonomous entities in a system, often humans (individuals or groups), but also other species or biophysical entities (e.g. water). Some entities (usually humans) are agents that share the same resources, can communicate or compete and react to changes in their environment through individual and social learning. *Knowledge-based approaches* encode knowledge elicited from experts using a logic system to infer conclusions. They can be used to encapsulate a wide range of complex feedbacks which are difficult to incorporate explicitly in quantitative methods, but care should be taken in using such approaches where knowledge about the system is uncertain or incomplete. Such approaches are often associated with a larger representation of impact indicators including nature, its contributions to people, and a good quality of life (or a combination of all three), which is possible due to the simplified way in which system relationships are represented.
Scenario archetype	Business-as-usual Economic optimism Regional competition Regional sustainability Global sustainable development Inequality
Country	Country name and corresponding Europe and Central Asia subregion (see Appendix #1)

Database field	Details
Scale/s	Global/EU/Central Asia Regional (e.g. Mediterranean basin) National (e.g. France) Sub-national (e.g. Provence-Alpes-Côte d'Azur in France) Local (e.g. National Park)
Direct Drivers	Climate change Land use change Pollution Change in resource use Change in market value of the ecosystem service Invasive species
Indirect drivers	Indirect drivers explicitly stated in the scenario description
Feedbacks among drivers	Was any feedback among drivers explicitly indicated in the scenario description; how was the feedback included
Economic sectors	Agriculture Forestry Water management Fisheries and aquaculture Tourism Conservation All
Nature (biodiversity) indicator	Biophysical assemblages Biophysical process Biodiversity Maintenance of options Habitat creation and maintenance
Nature's contributions to people (ecosystem services) indicators (NCP)	Classified in one of the following categories: *Regulating NCP:* Pollination and dispersal of seeds and other propagles Regulation of air quality Regulation of climate Regulation of freshwater quantity, flow and timing Regulation of freshwater and coastal water quality Formation, protection and decontamination of soils and sediments Regulation of hazards and extreme events Regulation of organisms detrimental to humans

Database field	Details
	Material NCP: Energy Food and feed Materials Timber and forest products Water provisioning *Non-Material NCP:* Learning and inspiration Physical and psychological experiences Supporting identities
Good quality of life (human well-being) indicators	Education and knowledge Governance and justice (equity) Free choice Good social relations Health and wellbeing Security and livelihoods
Indicator trend	Increase (change > +5% during the period assessed) Stable (change ± 5 %) Decrease (change > -5%)
Synergies and trade-offs	Were synergies and/or tradeoffs among indicators explicitly assessed and discussed in the article