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SUMMARY OF THE SHARED SOCIOECONOMIC PATHWAYS

Note by the Executive Secretary

1. The Executive Secretary is circulating herewith, for the information of participants in the twenty-first meeting of the Subsidiary Body on Scientific, Technical and Technological Advice, a note summarizing the shared socioeconomic pathways (SSPs) developed by the climate change research community under the mandate of the Intergovernmental Panel on Climate Change (IPCC). The note has been prepared by the UN Environment World Conservation Monitoring Centre with inputs from the Secretariat of the Convention on Biological Diversity, Alexander Popp (Potsdam Institute for Climate Impact Research) and Detlef van Vuuren (PBL Netherlands Environmental Assessment Agency and Utrecht University). The financial support from the United Kingdom of Great Britain and Northern Ireland is gratefully acknowledged.

2. The present note is relevant to the deliberations of the Subsidiary Body on Scientific, Technical and Technological Advice, in particular as it provides additional information relevant to CBD/SBSTTA/21/2, section III C, which focuses on ongoing work related to the development of scenarios on biodiversity, land use, climate change and sustainable development.

3. The report is presented in the form and language in which it was received by the Secretariat.

* CBD/SBSTTA/21/1.

SUMMARY OF THE SHARED SOCIOECONOMIC PATHWAYS

I. INTRODUCTION

1. The Shared Socioeconomic Pathways (SSPs) describe plausible futures for the society and economy of the world, using a combination of storylines and quantified elements (Riahi et al., 2017). The SSPs were developed by the climate change research community under the mandate of the Intergovernmental Panel on Climate Change (IPCC) to facilitate analysis of climate impacts, vulnerabilities, adaptation and mitigation in an integrated way. The SSPs provide researchers from a range of disciplines with a tool to explore the outcomes, and the associated uncertainty, of a variety of socioeconomic drivers. Based on their broad framework, the SSPs are also intended to be used for other sustainable development issues in addition to climate change, allowing linkages across different assessments, including biodiversity and ecosystem services. A program of work currently underway under the mandate of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) to link climate research with biodiversity assessment is described later in this document.

2. The SSP storylines guide the development of quantified projections of socioeconomic drivers including population growth, levels of education, levels of urbanisation, and economic growth. These national-level drivers are interdependent, for example population growth estimates are based upon scenario-specific assumptions on fertility, mortality, migration and education (KC & Lutz, 2017). Urbanisation projections are based on United Nations census data (United Nations, 2009) which details urban populations in 232 countries since 1950 (Jiang & O'Neill, 2017). Country-specific models of urbanisation paths are produced from this data and used to project future trends for all scenarios.

3. The SSP storylines describe different global futures, but the storylines also allow the translation of the scenarios to enable finer scale assessments of local drivers and likely outcomes. The quantified elements of the projections are gridded, where each grid cell is assigned a value, allowing aggregation to global, regional or local scales.

4. Integrated assessment models (IAMs) are the machinery through which the projections are processed with resulting outputs of spatially explicit land use, developments in the energy system, and greenhouse gas and air pollution emissions (Bauer et al., 2017; Popp et al., 2017; Rao et al., 2017; Riahi et al., 2017). The outputs have been tested to ensure that they are broadly representative of the range of plausible outputs proposed by the scientific community (O'Neill et al., 2017).

5. The baseline SSPs do not contain climate mitigation policy. The resulting radiative forcing levels, of around 5-8.7 W/m^2 (Table 1), reveal the forcing levels that might be expected for each of the contrasting futures in the absence of such policy. Radiative forcing in this context estimates the impact that emissions of greenhouse gases, air pollutants and land use change have on the amount of energy that is trapped within the atmosphere, thereby leading to global warming. Within each of the SSPs, it is possible to explore variants that assume climate policy through the integration of the SSPs with the representative concentration pathway (RCP) scenarios. The RCPs explore the impact of long-term climate targets with radiative forcing levels of 2.6, 4.5, 6.0 and 8.5 W/m^2 (1.9 is currently under development). It is important to note that climate change feedbacks are not considered in the IAMs but the production of such projections is being explored (Frieler et al., 2016).

II. STORYLINES

6. At their core, the SSPs contain narrative descriptions, or storylines, of how societies and economies will change into the future. The five storylines reflect qualitatively different futures.

7. **SSP1: Sustainability – Taking the Green Road.** This storyline details a sustainable world where development occurs but, due to policies focussed on human well-being rather than economic growth, environmental boundaries are maintained. With a global recognition of the positive outcomes of inclusive development, inequality is reduced both within and between countries. Due to global improvements in education and health, population growth is slowed leading to reduced pressures on the environment. Environmental technology is prioritised and the use of renewable energies increases. Land conversion, including tropical deforestation, is dramatically reduced through strong regulation, crop yield increases, decreased consumption of meat and less waste. This scenario describes a future where many of the objectives of the Sustainable Development Goals (SDGs) (United Nations, 2017) have been advanced including global improvements in health, education, reduced inequality, poverty alleviation, sanitation, and responsible consumption and production. Although, the achievement of specific SDG targets was not explicitly addressed in the development of SSP1 (van Vuuren et al., 2017) this scenario provides a useful framework in which the advantages of a sustainable future can be explored.

8. **SSP2: Middle of the Road.** The future described by this storyline is one in which some progress has been made towards the SDGs, but progress is slow and uneven. Although population growth has levelled off, much income inequality remains. Fossil fuel dependency decreases slowly as does the intensity of resource and energy use. Global levels of meat consumption continue to increase, leading to the conversion of natural habitats to pasture. The regulation of land conversion is imperfect but incentives for afforestation and avoided deforestation are enacted in 2030 resulting in a levelling-off in the extent of forested areas. The SSP2 scenario details a dynamic system, and is not simply an extrapolation of the current situation, but it is parameterised through historically observed conditions.

9. **SSP3: Regional Rivalry – A Rocky Road.** A segregated globe is envisioned in this storyline. Here countries have become increasingly inward-looking and nationalised with highly protectionist economic rivalry and decreased emphasis on international development. The divide between industrialised and developing nations widens and the lack of multilateral environmental co-operation results in environmental degradation. Developing nations struggle to provide for their citizens, resulting in low levels of education, poor health care and sanitation, and a surge in population growth. The conversion of natural land to agriculture increases due to lack of technological advances, high population growth and high consumption diets.

10. **SSP4: Inequality – A Road Divided.** This storyline details a stratified world where society is polarised into an internationally-connected group and a lower-income, poorly-educated group. This division is seen throughout the world, independent of political boundaries. However, the poorly-educated group is fragmented and unable to lobby for change, even within democratic societies. The divisions seen in this storyline arise from unequal education opportunities, driven by elimination of low-skill jobs through technological advances. The internationally-connected group controls technological development, political institutions, and global investment, and the promotion of low-carbon energy sources occurs as part of the diversification of resources. The regulation of land conversion occurs in high-income countries, and this, along with agricultural advancements, lead to

the protection of natural habitats in high income countries, but the lack of the above in low income countries leads to high rates in the loss of natural habitats, including tropical forests.

11. **SSP5: Fossil-fuelled Development – Taking the Highway.** This is a future where technological advances that benefit the environment arise out of competitive markets. Here investments in human capital and integrated societies are driven by the rapid growth of the global economy. Due to the improvement of global living standards, this storyline envisages population growth declines in the latter half of the 21st century. However, the growth of the economy has occurred through exploitation of fossil fuel resources and has resulted in the normalisation of resource and energy intensive lifestyles. Although high consumption diets are the norm, agricultural innovations drive a shift towards intensive crop and livestock production, and this together with a declining global population results in low levels of land conversion.

III. PROJECTIONS OF SOCIOECONOMIC DRIVERS: POPULATION, EDUCATION, URBANISATION, ECONOMIC GROWTH

12. The SSP storylines are translated into quantified projections of socioeconomic drivers of change. These drivers are population, education, urbanisation, and economic growth. These indirect drivers of biodiversity change are then processed by the IAMs to generate projections of direct drivers of biodiversity change, principally land use and climate change (see Section IV). A summary of the trends in socioeconomic drivers for each of the different SSPs is provided in Table 1 and is further explored below.

13. **Population.** In SSP3 the growth of the global population remains unchecked in developing nations with a resulting global population of 12.6 billion people. In contrast, the eradication of inequality described by SSP1 results in the lowest global population density with about 7 billion people in 2100 (Figure 1). SSP3 is the only scenario which does not result in a static or declining global population by 2100 (KC & Lutz, 2017).

14. **Education.** SSP1 and SSP5 project that global average education level in 2050 will be roughly equivalent to the level found in Europe today. In contrast, SSP3 and SSP4 envisage that the share of the world's population that is illiterate will steadily increase. Under SSP4 approximately 1 in 5 of the world's population is projected to be illiterate by 2100 (Figure 1).

15. **Urbanisation.** Within all SSPs it is projected that the world's population will increasingly reside in urban areas, with four of the five scenarios projecting that at least 80% of people will live in cities by 2100 (Figure 1). Only SSP3 envisages a lower level of urbanisation, with levels remaining relatively stable from present-day to 2100. SSP1 and SSP5 observe rapid urbanisation due to their projected high economic growth. Urbanisation follows historical trends in SSP2, with urbanisation gradually increasing in all regions (Jiang & O'Neill, 2017). Urbanisation is more complex for SSP4, with high income countries undergoing urbanisation due to increasingly attractive urban conditions, and medium income countries pulling workers into cities for work within newly-developed manufacturing centres. However low income countries see populations being pulled to the wealth of cities, but also being pushed out by competition for land (Jiang & O'Neill, 2017).

16. **Economic Growth.** SSP5 and SSP1 experience the highest growth in GDP and GDP per capita (Figure 1), but the growth in GDP in SSP5 comes at the cost of high energy demand (in 2100 the projected energy demand of SSP5 is over twice that of SSP1) (Riahi et al., 2017). SSP3 exhibits the

slowest rate of increase of GDP as nations stagnate in this protectionist and fragmented world. The growth in GDP per capita varies by region, but especially so in SSP3 and SSP4 (Leimbach, Kriegler, Roming, & Schwanitz, 2017). In these scenarios, sub-Saharan Africa lags behind other regions with almost no projected growth in GDP per capita projected to 2100 (Leimbach et al., 2017).

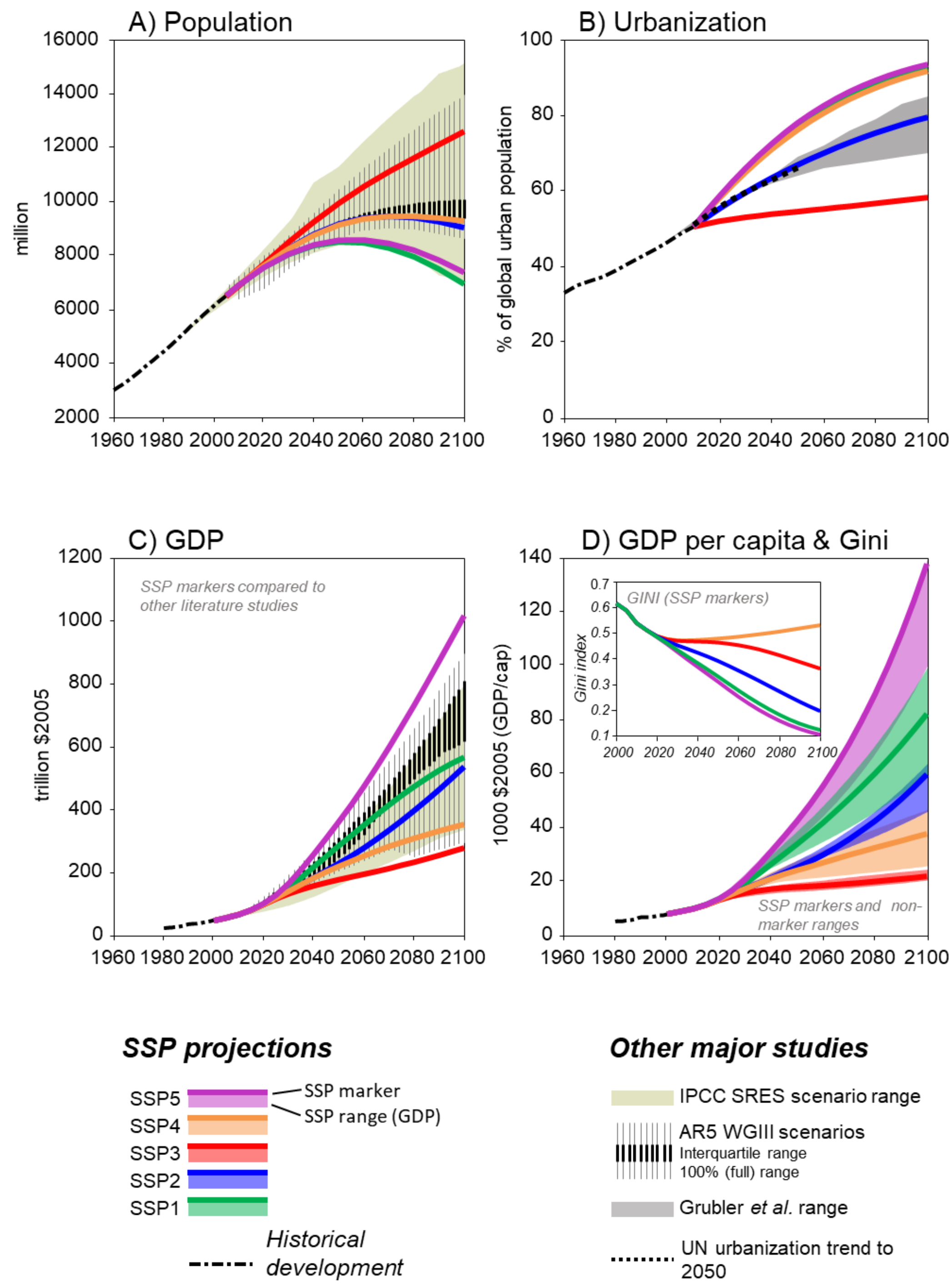

Figure 1. Development of global population and education (A), urbanization (B), GDP (C), and GDP per capita and the Gini index (D). The inset in panel D denotes the development of the global (cross-national) Gini index. Taken from Riahi, et al. (2017).

IV. OUTPUTS OF SSP'S: LAND CONVERSION, ENERGY SOURCES, GREENHOUSE GAS EMISSIONS

17. The quantified projections of socioeconomic drivers are processed by a range of IAMs to project impacts on land conversion, energy use, and greenhouse gas emissions. These differences are explored below.

18. **Land-use change.** Land conversion is one of the main drivers of change in local biodiversity (Newbold et al., 2015). Within IAMs, land conversion results from changing demand for raw materials such as food, timber or bioenergy. The intensity of use of the land is determined by model outcomes and assumptions on productivity/technology and need. The spatial pattern of land conversion is determined by productivity as well as environmental impacts, regulations, and trade.

19. The total amount of land put in use for agricultural production by 2100 varies between the different scenarios and models by hundreds of millions of hectares, but within the intervening years, the amount of converted land also undergoes dramatic rises and falls.

20. The SSP3 storyline reveals the vast proportion of land that has to be converted from natural vegetation to feed SSP3's large population in the absence of environmental protection or agricultural advances in productivity. Most of the conversion occurs in countries in the Middle East, Africa, Latin America and the Caribbean (Popp et al., 2017). The SSP1 storyline reveals a contrasting situation with a focus on high agricultural productivity, within a sustainable system that targets low food waste, and low population growth, resulting in agricultural land abandonment and regrowth of natural vegetation (Popp et al., 2017).

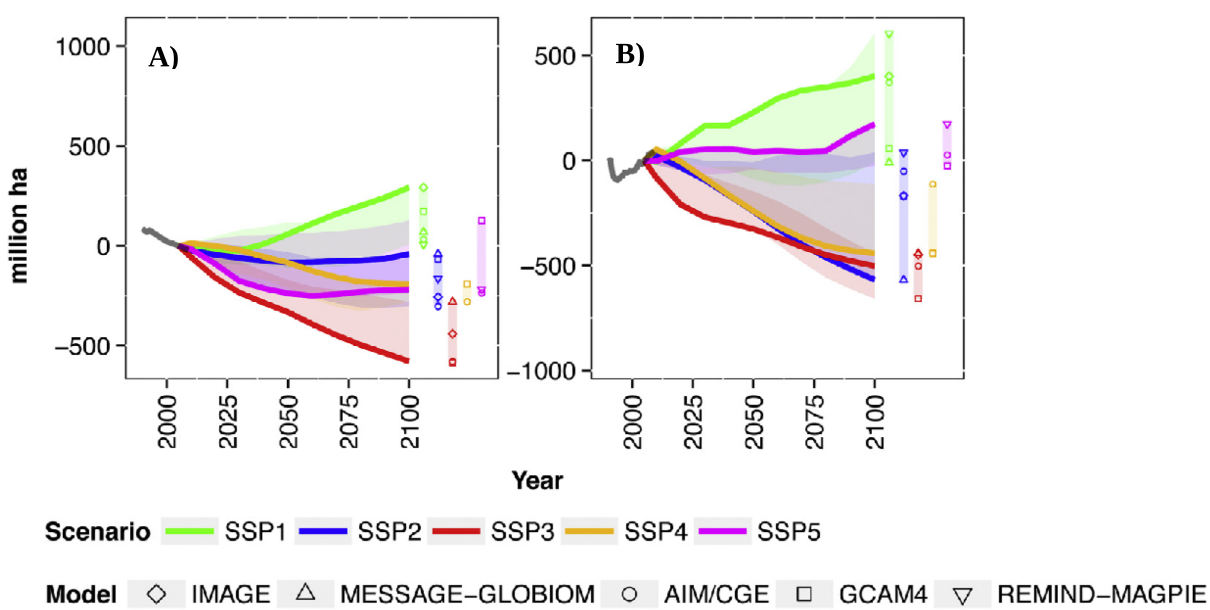

Figure 2. Change in global land for forest (A) and other natural land (B) of the five SSP marker scenarios. Coloured lines indicate the marker model results for each SSP. Coloured bars indicate the range of data in 2100 across all marker and nonmarker projections for each SSP (models are depicted by icon). Grey line shows historical trends based on FAO data (FAO 2014). Adapted from Popp et al. (2017).

21. **Energy system.** Each SSP encompasses specific assumptions about the balance of pressures on the energy system, such as population, land conversion and fuel availability, as well as the mitigation of

pressures, such as technological advances, behavioural changes and focus on environmental policies. These assumptions result not only in the amount of energy required per capita, but also determine the proportion of energy that is taken from renewable sources, oil and gas or coal.

22. SSP2 retains the current global proportion of reliance on energy sources, but energy demand increases due to increasing population. The greatest final energy demand is observed in SSP5, with demand by 2100 approximately three times that of today. This energy is almost entirely sourced from coal or oil and gas. As access to energy is tied to levels of poverty, SSP3 and SSP4 scenarios result in many of the poorest people or nations remaining tied to a reliance on fossil fuels, despite the technological advances observed in the richer groups.

23. **Greenhouse gas emissions.** As CO_2 levels are directly correlated to fossil fuel energy use, SSP3 and SSP5 scenarios exhibit the highest CO_2 emissions and SSP1 and SSP4 the lowest. Methane (CH_4) and nitrous oxide (N_2O) emissions are tied to population and agricultural production, therefore SSP3, with the largest population growth, predicts the greatest increase in emissions, and SSP1, with low population growth and sustainable agriculture, predicts a slight decrease in emissions by 2100.

Table 1. Summary of SSP's. (Calvin et al., 2017; Fujimori et al., 2017; Kriegler et al., 2017; O'Neill et al., 2017; Riahi et al., 2017).

	Population	**Global illiteracy**	**Urbanisation**	**GDP per capita**	**Emissions**	**Land use conversion**	**Energy Demand** **Reliance on non-renewables**	**Total anthrop-ogenic forcing by 2100 (W/m^2)**
SSP1: Sustainability – Taking the Green Road	Low	Low	High	High	Low	Low	Low Low	5.0-5.5
SSP2: Middle of the Road	Medium	Medium	Medium	Medium	Medium	Medium	Medium Medium	6.5-6.8
SSP3: Regional Rivalry – A Rocky Road	High	High	Low	Low	High	High	Medium High	7.1-8.1
SSP4: Inequality – A Road Divided	Medium	High	High	Medium	High	Medium	Medium Medium	6.4
SSP5: Fossil-fuelled development	Low	Low	High	High	High	Medium	High High	8.7

V. RADIATIVE FORCING AND THE REPRESENTATIVE CONCENTRATION PATHWAYS (RCP'S)

24. The emissions projected under each scenario by IAMs give rise to projections of radiative forcing and resulting changes in climate, another major driver of biodiversity change (Bellard et al., 2012). The climate system detailed in each of the SSPs, which do not incorporate any climate mitigation policies, results in a specific level of radiative forcing with levels ranging from 5 W/m^2 to 8.7W/m^2 by 2100 (Table 1). Thus it is necessary to integrate climate change mitigation policies with these baseline scenarios to test the impact of climate change mitigation within these different projected futures.

25. To integrate climate policy with the SSPs, a set of Shared Climate Policy Assumptions (SPAs) were produced. These assumptions further the SSP storylines in their descriptions of how nations and individuals could engage with climate change mitigation, emphasising factors such as the level of global cooperation, and technologies applied. The SPAs can also specify the contribution of different regions (realizing different levels of development).

26. As with the baseline SSPs, the SPAs are quantified and processed through the Integrated Assessment Models (IAMs). This results in a range of forcing levels that can be reached via climate policy for each of the SSPs. The results show that the final forcing level observed in 2100 is to some degree dependent on the SSP. For instance, IAMs were only able identify pathways to attain radiative forcing levels of 2.6W/m^2 by 2100 from SSP1, SSP2 and SSP4. It is possible that mitigation strategies may allow radiative forcing levels to drop further for these scenarios, and this is work that is presently being explored (Riahi et al., 2017).

27. To highlight the interaction between the baseline SSPs, the SPA's and the resulting radiative forcing levels, two contrasting examples are explored in further detail below.

28. **SSP1/RCP2.6**. The SSP1 storyline provides an example of the power of sustainable development, with the best outcomes for global well-being of all scenarios. As discussed, each of the baseline scenarios results in a level of radiative forcing in the absence of climate change mitigation. Even without climate policy, the assumptions in SSP1 already lead to a relatively low level of climate change (the marker scenario results in a radiative forcing of 5 W/m^2 and global rise in temperature of around 3^{o}C by 2100). The baseline SSP1 can be combined with climate policy to reach radiative forcing levels consistent with those described by the Representative Concentration Pathways (RCPs) (van Vuuren et al., 2011). The RCP with the lowest forcing level is RCP2.6, therefore the future described by SSP1/RCP2.6 provides our best guess at what a plausible 'green' future might entail. The effort entailed to reach the radiative forcing level is indicated by the jump in carbon prices required. For SSP1 to reach a radiative forcing goal of 2.6W/m^2 a relatively low increase in carbon prices is foreseen, indicating that the 2.6 W/m^2 goal is more easily attainable than from other SSPs combinations (van Vuuren et al., 2017). Climate mitigation strategies outlined by this scenario benefit the high levels of international cooperation leading to early and effective climate policy, as well as technological development leading to energy efficiency and low resource lifestyles. Fossil fuel use declines in this scenario and renewable energy use increases. However, land conversion for bio-energy crop production is projected to increase in this scenario (as well as in other scenarios) and this has been shown to have detrimental impacts on biodiversity at the local scale (Newbold et al., 2015).

29. **SSP2/RCP4.5**. The SSP2 storyline describes a future based on an extension of historical experience, a middle-of-the-road scenario, with intermediate outcomes for human and environmental well-being. Without climate mitigation, the SSP2 scenario is projected to result in 8.1W/m^2 total radiative forcing by 2100, which would result in a global temperature rise of approximately 4.5^{o}C (Fricko et al., 2017). SSP2/RCP4.5 presents a combination of an intermediate scenario with an intermediate level of climate change mitigation. However, this is not to say that the climate change mitigation is not ambitious, for instance, to achieve a radiation forcing of only 4.5W/m^2 by 2100 in this scenario requires 2050 greenhouse gas emissions to be limited to approximately 2010 levels, and 61% lower emissions to be realised by 2100 (Fricko, Havlik et al. 2017). Land-use CO^2 emissions are limited in this scenario due to increases in productivity. The afforestation included in the climate mitigation of SSP2/RCP4.5 leads to an increase in forested land area compared to the baseline SSP2 scenario. The

decline in the extent of other natural land area is also lower than the baseline SSP2 scenario, as the increase in bio-energy crop production is balanced by a decrease in pasture area (Popp et al., 2017).

VI. RELEVANT USES OF THE SSP'S

30. The SSPs represent a major advance in the projection of plausible storylines which are of use to a broad range of researchers and decision makers. The key focus of the SSPs is the exploration of socioeconomic drivers on the climate. However the focus on protecting biodiversity is at the moment still limited.

31. A group of biodiversity researchers has been brought together with the IAM community by the IPBES Scenarios and Models Expert Group to tackle the lack of focus on biodiversity in the SSPs. This work responds to a call from the Conference of the Parties for IPCC and IPBES to foster enhanced collaboration between researchers working on scenarios and models with those working on biodiversity monitoring and data (CBD 2016). The group aims to investigate biodiversity futures using a combination of the marker SSP scenarios with specified RCPs. The SSP/RCP combinations have been selected to maximise the deviation between different futures and thus allow the exploration of impacts from a range of different socioeconomic drivers. A series of existing biodiversity and ecosystem service models have been selected for this process to facilitate comparison of how different facets of biodiversity respond to the socioeconomic drivers and to quantify the impact on ecosystem services (including provisioning, regulating and cultural services). Using the outputs provided by the SSP framework, primarily land use and climate change, biodiversity modellers will be able to provide spatially explicit maps of the different biodiversity futures over time. It is anticipated that this work will inform the IPBES Global Assessment of Biodiversity and Ecosystem Services.

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