GLOBAL BIODIVERSITY SCENARIOS FOR THE YEAR 2100: A SUMMARY AND DISCUSSION

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I. Background

In 2000, Sala et al. published a journal titled Global Biodiversity Scenarios for the Year 2100. This study discussed future biodiversity changes in 10 principal terrestrial biomes of the earth based on several scenarios. In addition, there was explanation about few uncertainties as well. Along with this, discussion on related studies are also presented to give wider perspective about other biodiversity changes model.

II. Global Biodiversity Scenarios for the Year 2100

To compose biodiversity changes model, there were four steps to do. First, identify the five most important determinants of changes in biodiversity at the global scale: changes in land use, atmospheric CO_2 concentration, nitrogen deposition and acid rain, climate, and biotic exchanges (deliberate or accidental introduction of plants and animals to an ecosystem). The second step was to calculate the expected change of these drivers in each biome. Third, estimate for each biome the impact that a unit change in each driver has on biodiversity. Lastly, derive three scenarios of future biodiversity for each biome, relative to its initial diversity, based on alternative assumptions about interactions among the drivers of biodiversity change.

Meanwhile, this study has three assumptions. First, there are no interactions among the various causes of biodiversity change. Second, there are antagonistic interactions and biodiversity will respond only to the driver to which it is most sensitive. Third, there are synergistic interactions and biodiversity will respond multiplicatively to the drivers of biodiversity change.

1. Drivers of Change

Five drivers of change explained in the study are changes in land use, atmospheric CO_2 concentration, nitrogen deposition and acid rain, climate, and biotic exchanges. As for terrestrial biomes examined are arctic tundra, alpine tundra, boreal forest, grasslands, savannas, Mediterranean ecosystems, deserts, northern temperate forests, southern temperate forests, and tropical forests. Table 1 below explains business-as-usual scenario generated by global models of climate, vegetation, and land use to estimate the change in magnitude of the drivers of biodiversity change for each biome between 1990 and the year 2100.

Table 1. Expected changes for the year 2100 in the five major drivers of biodiversity change (land use, atmospheric composition CO_2, nitrogen deposition, climate, and biotic exchange) for the principal terrestrial biomes of the Earth (arctic tundra, alpine tundra, boreal forest, grasslands, savannas, Mediterranean ecosystems, deserts, northern temperate forests, southern temperate forests, and tropical forests).

	Arctic	Alpine	Boreal	Grass-land	Sa-vanna	Med	Desert	N temp	S temp	Tropic
Land use	1.0	1.0	2.0	3.0	3.0	3.0	2.0	1.0	4.0	5.0
Climate	5.0	3.0	4.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0
Nitrogen deposition	1.0	3.0	3.0	3.0	2.0	3.0	2.0	5.0	1.0	2.0
Biotic exchange	1.0	1.0	2.0	3.0	3.0	5.0	3.0	3.0	2.0	2.0
Atmospheric CO_2	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5

The second step of the exercise was to evaluate, for each biome, the impact that a unit change in each driver has on biodiversity independently of the expected magnitude of change in the driver as shown in Table 2.

Table 2. Impact of a large change in each driver on the biodiversity of each biome. In this exercise, a unit change of the driver was defined for land use as conversion of 50% of land area to agriculture, for CO_2 as a 2.5-fold increase in elevated CO_2 as projected by 2100, for nitrogen deposition as 20 kg ha^{-1} $year^{-1}$, for climate as a 4°C change or 30% change in precipitation, and for biotic exchange as the arrival of 200 new plant or animal species by 2100. Estimates vary from low (1) to high (5) and result from existing global scenarios of the physical environment and knowledge from experts in each biome (see text).

	Arctic	Alpine	Boreal	Grass-land	Sa-vanna	Med	Desert	N temp	S temp	Tropic
Land use	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Climate	4.0	4.0	3.5	3.0	3.0	3.0	4.0	2.0	2.0	3.0
Nitrogen deposition	3.0	3.0	3.0	2.0	2.0	2.0	1.0	3.0	3.0	1.0
Biotic exchange	1.0	1.0	1.0	2.0	2.0	3.0	2.0	1.5	3.0	1.5
Atmospheric CO_2	1.0	1.0	1.0	3.0	3.0	2.0	2.0	1.5	1.5	1.0

A simple a sensitivity analysis of the model was performed by independently increasing and then decreasing by 10% the expected change of each driver. This analysis resulted in Figure 1.

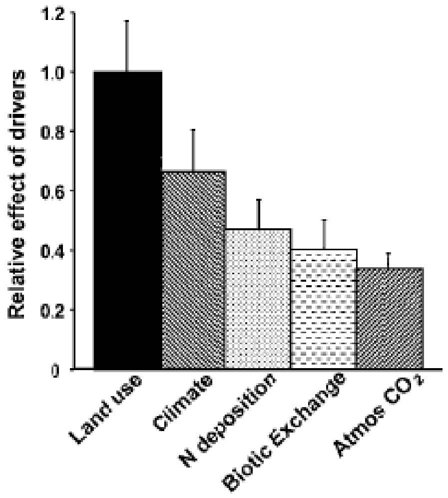

Fig. 1. Relative effect of major drivers of changes on biodiversity. Expected biodiversity change for each biome for the year 2100 was calculated as the product of the expected change in drivers times the impact of each driver on biodiversity for each biome. Values are averages of the estimates for each biome and they are made relative to the maximum change, which resulted from change in land use. Thin bars are standard errors and represent variability among biomes.

2. Variation Across Biomes

There are large differences among biomes in the causes of future change in biodiversity. In tropical and southern temperate forest large change occurres mostly due to changes in land use with relatively small effects due to other drivers. In arctic ecosystems, biodiversity change is influenced largely by a single factor (climate change). Meanwhile, Mediterranean ecosystems, savannas, and grasslands are substantially affected by most drivers. For northern temperate forests and deserts, contributions are shown by all the drivers but most of them are moderate. In freshwater ecosystems, substantial impacts are shown from land use, biotic exchange, and climate.

This study also examined expected changes for lakes and streams. Biodiversity in streams and rivers generally is more sensitive to climate than in lakes because streams have greater responsiveness to runoff; generally, it is less sensitive to biotic exchange because streams are physically harsh and more dynamic temporally.

3. Uncertainties

Regarding future biodiversity change for the year 2100, there are 4 scenarios. First, invasions of exotic species are promoted by human disturbance and changes in climate variability (interaction of biotic exchange, land-use change, and climate change). Second, Elevated CO_2 has the greatest effect on species composition in the presence of nitrogen deposition (interaction of CO_2 and nitrogen deposition). Third, Synergistic interactions may decrease in importance at extreme values of individual drivers of biodiversity change. Lastly, Uncertainties in the magnitude and regional variation in the future changes in drivers and future climate and vegetation.

III. Biodiversity Scenarios: Projections of 21st Century Change in Biodiversity and Associated Ecosystem Services

This publication is a technical report for the Global Biodiversity Outlook 3 made by Secretariat of the Convention on Biological Diversity. There are some key conclusions in this synthesis. Firstly, projections of global change impacts on biodiversity show continuing and, in many cases, accelerating species extinctions, loss of natural habitat, and changes in the distribution and abundance of species and biomes over the 21st century. Second, thresholds, amplifying feedbacks and time-lag effects leading to "tipping points" are widespread and make the impacts of global change on biodiversity hard to predict, difficult to control once they begin, and slow and expensive to reverse once they have occurred.

Third, for many important cases the degradation of ecosystem services goes hand-in-hand with species extinctions, declining species abundance, or widespread shifts in species and biome distributions. However, conservation of biodiversity and of some ecosystem services, especially provisioning services, are often at odds. Lastly, strong action at international, national and local levels to mitigate drivers of biodiversity change and to develop adaptive management strategies could significantly reduce or reverse undesirable and dangerous biodiversity transformations if urgently, comprehensively and appropriately applied (Secretariat of the Convention on Biological Diversity 2010).

IV. Uncertainties in Ensembles of Global Biodiversity Scenarios

While there is a clear demand for scenarios that provide alternative states in biodiversity with respect to future emissions, a thorough analysis and communication of the associated uncertainties is still missing. This study modeled the global distribution of ~11,500 amphibian, bird and mammal species and project their climatic suitability into the time horizon 2050 and 2070, while varying the input data used. By this, uncertainties are explored, originating from selecting species distribution models (SDMs), dispersal strategies, global circulation models (GCMs), and representative concentration pathways (RCPs). The overwhelming influence of SDMs and RCPs on future biodiversity projections are demonstrated, followed by dispersal strategies and GCMs. The relative importance of each component varies in space but also with the selected sensitivity metrics and with species' range size. Overall, this means using multiple SDMs, RCPs, dispersal assumptions and GCMs is a necessity in any biodiversity scenario assessment, to explicitly report associated uncertainties.

This study resulting in several points. In terms of species-level uncertainty analyses, the influence of SDM, GCM and RCP differed with respect to the sensitivity metric and dispersal scenario used. When assuming limited dispersal, the choice of SDMs causes a more than ten times higher deviance in the change of suitable habitats than the choice of the other two components. In other words, the subjective selection of a specific SDM has an overarching influence on the final result compared to the choices of GCMs and RCPs. Meanwhile, pixel-based uncertainty analysis shows that the overall variation originating from the combination of SDMs, GCMs and RCPs markedly differed between pixel-based metrics and among species groups (Thuiller *et al* 2019).

V. Discussion and Conclusion

Scenarios of changes in biodiversity for the year 2100 can now be developed based on scenarios of changes in atmospheric carbon dioxide, climate, vegetation, and land use and the known sensitivity of biodiversity to these changes. This study identified a ranking of the importance of drivers of change, a ranking of the biomes with respect to expected changes, and the major sources of uncertainties. For terrestrial ecosystems, land-use change probably will have the largest effect, followed by climate change, nitrogen deposition, biotic exchange, and elevated carbon dioxide concentration. For freshwater ecosystems, biotic exchange is much more important. Mediterranean climate and grassland ecosystems likely will experience the greatest proportional change in biodiversity because of the substantial influence of all drivers of biodiversity change. Northern temperate ecosystems are estimated to experience the least biodiversity change because major land-use change has already occurred. Plausible changes in biodiversity in other biomes depend on interactions among the causes of biodiversity change. These interactions represent one of the largest uncertainties in projections of future biodiversity change (Sala et al. 2000).

Biodiversity scenarios are not meant to predict the future precisely, but rather to project the range of possible futures allowing to better understand uncertainties and alternative visions of this future. These visions allow for considering how different political options, represented here by the RCPs, might influence the persistence of biodiversity under a wide range of possible futures. However, to be useful, one has to acknowledge also other sources of variations that may influence the overall modelling exercise.

There are different types of biodiversity models, and here while considering only a single type (i.e. statistical SDM), this study shows that different algorithms could lead to substantial variability in the sensitivity metrics used. This variation may blur the utility of using several RCPs to discuss their impact on biodiversity persistence. This issue was long recognized in climate sciences such that it is no longer conceivable to show projected climatic trends from a single GCM only. Rather, ensembles of climate trajectories are usually shown (or least statistics thereof) and offered to users through data portals (e.g. CMIP5). The biodiversity modelling community needs to more consistently follow this path and report and communicate the variability resulting from the different options in biodiversity models (e.g. SDMs, dispersal scenarios) and input data (e.g. GCM, RCP). However, the range of biodiversity model types, algorithms, input data or parameterizations is so large that it seems currently impossible to report the variability even across biodiversity model types. However, it is urged that variabilities originating from modelling algorithms, input data and external forces be assessed and reported comprehensively for better informing science, users and decision-makers in exploring options for the future (Thuiller *et al* 2019).

In conclusion, biodiversity scenarios are needed in order to give policy makers deeper insight related to environmental impacts resulted from policies made, especially from development. Biodiversity is so important that its imbalance may leads to future devastation. Every species has its own special role in ecosystem and keeps world's food chain run well. Also, by modeling global biodiversity scenarios, we can project strategies to prevent species extinction.

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