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Pathways for agriculture and forestry to contribute to terrestrial biodiversity conservation: A global scenario-study

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A B S T R A C T

If the world stays on its current development path, the state of biodiversity will continue to decline. This is due to projected further increases in pressures, most prominently habitat loss and climate change. In order to reduce these pressures, biodiversity conservation and restoration, as well as sustainable resource use, needs to be an integral part of sustainable development strategies of primary production sectors, such as agriculture, forestry, fisheries and energy. This paper presents a model-based analysis of three alternative pathways described as *Global Technology*, *Decentralized Solutions* and *Consumption Change* to conserve biodiversity. Each of these pathways pursues international biodiversity goals together with a broader set of environmental sustainability objectives, including feeding the world, universal access to modern energy, limiting climate change and controlling air pollution. We show that different combinations of bio-physical measures, ecosystem management changes and behavioural changes can globally substantially reduce biodiversity loss in the coming decades (avoided Mean Species Abundance (MSA) loss is 4.4–4.8% MSA, compared to 9.5% MSA loss in the Trend), although the types of biodiversity conserved in the pathways will be different. The agricultural and forestry sectors together have until 2010 globally caused almost 60% of the total reduction in terrestrial biodiversity in MSA terms and 55% of the expected loss up to 2050. We show that increased productivity by technological improvements, increased use of ecological methods in agriculture and forestry, and consumption changes help to avoid biodiversity loss by 3.1–3.5% MSA. In addition, combinations of pathways, taking into account specific regional contexts, might result in even larger reduction of biodiversity loss. The changes needed in the agricultural and forestry sector to achieve this go well beyond current efforts to reduce their impact on biodiversity.

1. Introduction

The mid-term evaluation of progress towards the attainment of the 2020 Aichi Biodiversity Targets set in the United Nations Convention on Biological Diversity (CBD) shows that, if the world stays on its current development path, the state of biodiversity will continue to decline. While there has been an increase in the societal responses to biodiversity loss, in most cases this will not be sufficient to achieve the biodiversity targets by 2020, let alone to realise the long-term vision of the CBD (Leadley et al., 2014, sCBD, 2014, Tittensor et al., 2014). The latter is formulated as ‘by 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people’ (CBD, 2010).

Analyses have shown that the fate of the world's biodiversity will largely be shaped by activities in the agriculture, fisheries, extraction industries, energy production, water management, and forestry sectors. These sectors exert direct pressures on biodiversity such as land use change, pollution and climate change (Donald et al., 2002; Green et al., 2005; MA, 2005; sCBD, 2014; Spangenberg, 2007; Ten Brink et al., 2010). If current trends continue, the global demand for food, wood, water and energy is projected to increase 1.5–2 fold by 2050 as

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compared to 2010 as a consequence of the expected rise in global population and increasing wealth (OECD, 2012; Riahi et al., 2017; van Vuuren et al., 2015). This paper evaluates the impacts on biodiversity of different response strategies in the agriculture and forestry sectors, all of which aim at achieving similar outcomes for a range of sustainability objectives by 2050.

Often, scenarios are designed to explore how the future could evolve on the basis of pre-set storylines - a set of assumptions - also referred to as explorative scenarios (IPBES, 2016; van Vuuren et al., 2012b). In contrast, in the current analysis we apply scenarios that meet a range of long-term environmental sustainability objectives, including those for biodiversity, and analyse diverse response strategies for the agricultural and forestry sectors to achieve those objectives. This approach, known as back-casting (Dreborg, 1996; Robinson, 1982) or target seeking scenarios (IPBES, 2016), explores how different trajectories towards specific objectives may look and is used to identify short and medium-term priorities and efforts required to achieve long-term goals. The trajectories analysed are referred to as "pathways" in this paper. In the context of global scenario studies for biodiversity this approach has seldom been applied, with notable exceptions of Erb et al. (2016) who explore the biophysical option space for feeding the world without deforestation and Smith et al. (2013a) exploring how much land-based greenhouse gas mitigation can be achieved without compromising food security and environmental goals including biodiversity.

The three pathways analysed in this study were originally designed to meet a broad set of environment related sustainable development objectives and include a Global Technology pathways, a Decentralized Solutions pathway and a Consumption Change pathway. They are described in (van Vuuren et al., 2012a; van Vuuren et al., 2015). Apart from achieving the 2050 vision on biodiversity, the pathways limit greenhouse gas emissions to avoid climate change beyond 2° increase by 2100; eradicate hunger by 2050; and provide universal access to safe drinking water, improved sanitation and modern energy. These objectives are in line with the Sustainable Development Goals (SDGs) that were agreed upon by all countries within the United Nations in 2015 as part of the 2030 Agenda for Sustainable Development (UN, 2009). The pathways are quantitatively analysed using the Integrated Model for the Assessment of the Global Environment, IMAGE (Stehfest et al., 2014) combined with the Global Biodiversity model, GLOBIO (Alkemade et al., 2009; Schipper et al., 2016). The analysis is performed at global level and at the level of large world regions, with a time horizon of 2050.

The pathways were further elaborated to make them more relevant from a biodiversity and agricultural and forestry sector perspective (Kok et al., 2014). The reduction and eventual halting of biodiversity loss as is required to achieve the 2050 biodiversity vision under the CBD, is explored using distinct combinations of technological improvements of production, ecological solutions, land use management options, and consumption changes and waste reduction. These options are levers for sectors to contribute to the reduction of biodiversity loss. The Global Technology pathway emphasizes the potential of technologically advanced, sustainable intensification in agriculture potentially leading to land sparing (see for example Balmford et al., 2005; Ewers et al., 2009; Garnett et al., 2013; Green et al., 2005; Phalan et al., 2011; Tilman et al., 2011). The Decentralized Solutions pathway shows the potential for ecological innovation in mixed land use systems where natural elements are interwoven within production landscapes, potentially leading to land sharing (see for example Hulme et al., 2013; Perfecto and Vandermeer, 2010; Pywell et al., 2015; Tittonell, 2014; Tscharntke et al., 2012; van Noordwijk and Brussaard, 2014). The Consumption Change pathway highlights the potential of lower demand for food and wood products by waste reduction, efficiency improvements and of changing diets (see for example Bajzelj et al., 2014; Erb et al., 2016; Machovina et al., 2015; Parfitt et al., 2010; Stehfest et al., 2009). In all pathways, we assume extensive climate change mitigation measures and pollution is expected to be reduced. Also some other options are included in all three pathways (without further differentiation) that contribute to the realisation of the biodiversity goals, but are primarily inspired by other concerns. These are an accelerated phase-out of traditional bioenergy and simultaneously improvement of access to modern energy (to reduce indoor air pollution).

Together, the three pathways indicate an "option space" to meet biodiversity and environment related sustainable development objectives. They are used here to further explore the potential of agriculture and forestry sectors to reduce their impacts on biodiversity. We restrict ourselves here to an analysis of the potentials of options and pathways to achieve these objectives, without entering into the fundamental question of how such pathways could be realised from a political and institutional perspective. In our analysis, we also do not focus on the potential feedback of the pathways on the economy and demography. These can be important to assess investments and costs and benefits, but are also not necessary for assessing the bio-physical option-space. Furthermore we did not assess the likelihood of realisation of these pathways. It is however clear that the three pathways assume different societal preferences and governance systems between each other and all will be fundamentally different from the Trend. It goes beyond the scope of this paper to delve into that deeper (see for further analysis of these questions Kok et al. (2014)). Synergies and trade-offs among options and targets are briefly explored. This is of particular importance when, for example, climate objectives are met by increasing the share in biofuels with possible detrimental impacts on food production and biodiversity. The "option space" will differ between world regions, as priorities, context and synergies and trade-offs between options vary between regions. The pathways were also analysed for impacts on aquatic biodiversity (see for this Boelee et al., 2017). They also include an analysis of the potentials to overcome water challenges through nature based solutions.

2. Material and methods

2.1. Defining biodiversity objectives as end-points

A back-casting or target-seeking analysis first of all requires the identification of end-points to be met by the pathways. The end-points are in our case a set of environment related sustainable development objectives for 2030–2050, including the 2050 Biodiversity Vision, described in van Vuuren et al. (2015). The quantitative end-point to operationalise the long-term objective for biodiversity was derived from the Aichi Biodiversity Target 5 to 'at least halving or when feasible bringing close to zero biodiversity loss by 2020' and Target 11 'Expanding protected areas to at least 17% of terrestrial area and inland waters by 2020'. Following the intentions of the Aichi targets it is assumed that developed countries halt biodiversity loss by 2020 and developing countries from 2030 onwards, allowing developing countries some more time to meet this target, while also meeting the targets for protected areas in 2020 (CBD, 2010). Based on this, the end-point for biodiversity was calculated and by comparing the Trend with this endpoint the policy challenge was identified and expressed as avoided biodiversity loss to be realised by 2050.

2.2. Trend scenario

The so-called *Trend* scenario shows developments without new policies being introduced to achieve biodiversity or other environmental related sustainable development objectives. The Trend scenario serves as a benchmark to understand the context and challenges to achieve the biodiversity goals in the sectors and is based on the OECD Environmental Outlook for 2050 (OECD, 2012). This scenario represents an intermediate "business as usual" scenario, and has been thoroughly analysed and described, and therefore suits well for comparison with the pathways. As the focus of our analysis is on the pathways, only one baseline is used (and so we do analyse the pathways

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