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Title: **Differentiating the effects of climate and land use change on European biodiversity: a scenario analysis**

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Supplementary Annex 1. Revision of climate sensitivity of species in the BIOSCORE database.

Butterflies

We assigned a climate sensitivity to each dry grassland and wetland butterfly species in BIOSCORE based on Settele et al. (2008). Settele et al. compiled an atlas of climate sensitivity for the majority of European butterfly species through climate envelope modelling for 2051-2080 using HadCM3 climate data (table 2.1) and three of the four SRES scenarios (SEDG corresponds largely to B1, BAMBU=A2 and GRASS=A1, Spangenberg et al. 2012). Settele et al. (2008) classified butterfly species in different classes of climate vulnerability based on: a) fit of the climate envelope model with the species' present distribution and b) the geographical overlap of the modelled current and climate change distribution. We used the results of the SEDG scenario, equivalent to IPCC/SRES B1, since it is most similar to B2 available for birds and vascular plants and both scenarios project comparatively moderate changes and lead to acceptable consistency.
Area Under Curve, geographical overlap of modelled current and climate change distribution, and climate risk category according to SEDG-scenario in Settele et al. (2008) are available as excel sheet form the authors. Resulting BIOSCORE climate sensitivity scores are also given.

Table 1.1 Criteria for climatic risk categories of Settele et al. (2008), and conversion of these climatic risk categories into climate sensitivity scores in BIOSCORE. AUC = Area Under Curve, an indicator for goodness of model fit.

Climatic risk category Settele et al. (2008)			BIOSCORE
Category	AUC	Overlap	Climate sensitivity score
Potential risk	<= 0.75	-	Not
Low risk	> 0.75	>= 50%	Low
Risk	> 0.75	50% > AND >= 30%	Low
High risk	> 0.75	30% > AND >= 15%	Medium
Very high risk	> 0.75	15%> AND >= 5%	Medium
Extremely high risk	> 0.75	< 5%	High

Birds

Climate sensitivities of birds were assigned using the data of Huntley et al. (2008), who determined the climate sensitivity of the majority of European bird species through climate envelope modelling for the period 2070-2099 using HadCM3 climate data (IPCC/SRES B2 scenario). Huntley et al. (2008) do not directly classify bird species into climate change vulnerability classes, but instead give the overlap between the current and climate change distribution plus the AUC. Thus, like for butterflies, we used the overlap between the current and climate change distribution plus the AUC as presented by Huntley et al. (2008) to classify birds into climate sensitivity classes and we implemented these likewise in the BIOSCORE database (see table 1.1).

Vascular plants
We assigned climate sensitivities for plants in BIOSCORE using Thuiller et al. (2005), who determined the climate sensitivity of the majority of European plant species through climate envelope modelling for the period 2051-2080 using HadCM3 climate data. Similar to butterflies and birds, the geographical overlap between the current and climate change distribution was determined under the B2 scenario and used to classify plant species in climate sensitivity classes. Only the geographical overlap could be derived from Thuiller et al. (2005). Therefore, we dropped one category and assumed sufficient fit (i.e. AUC > 0.75).

Dragonflies
We assigned a climate sensitivity to each dragonfly species in BIOSCORE based on expert knowledge and current distribution (Dijkstra and Lewington, 2006). We decided whether a species would increase or decrease using the following assumptions:

- Species with alpine-boreal distributions will decrease.
- Species with southern European or North African distributions will –at the least- remain stable, as they have opportunities to increase.
- Species that are widespread and common throughout most of Europe will remain relatively stable.
- Species with Atlantic and continental distributions will decrease slightly.
- Species with very restricted or fragmented distributions are most vulnerable to climate change.
- Generalist species are less vulnerable to climate change than habitat specialists (e.g. bog species).

The resulting climate sensitivity plus assumptions are available from the authors.

Supplementary Annex 2. Narrative articulation of the SRES scenarios for use in the BIOSCORE tool based on Berkhout et al. (2002), Lorenzoni et al. (2007), and Westhoek et al. (2006).

scenario	narrative
A1	This scenario has a focus on globalization and economic growth, with less attention for environmental sustainability. Overall, it foresees an affluent, wealthy world. European farmers have to compete in a global market, which favours agricultural intensification in highly productive regions and agricultural land abandonment in more marginal regions. Climate change and associated temperature rise is intermediate in this scenario. Technical progress is rapid in this world. Due to agricultural intensification in highly productive regions and little emphasis on environmental sustainability, eutrophication and pollution are expected to increase in this scenario. Water transparency is expected to deteriorate due to increased temperatures and nutrient inputs. Increased harvesting of crops and a reduced trampling of the soil (i.e. more cattle kept year-round in stables) is expected as part of a more efficient, industrial European agriculture. Climate change is intermediate in this scenario, and variables such as (water) temperature, continentality, temporary water availability, soil moisture and permanent water surface are expected to deteriorate. Overall, water quantity/flow is not expected to change, as extra drought in summer is expected to be offset by additional rainfall in winter. The global focus of this scenario is likely to result in more international transport and shipping, leading to more invasive species.
A2	This scenario also has a focus on economic growth, but with more resistance to globalization than the scenarios A1 and B1. Europe aims to be remain more self-reliant in its food production than in scenarios A1 and B1. As a result, European farmers are more protected by policies and do not compete in a global market. Because there is also little attention for environmental sustainability, this leads to on-going agricultural intensification and much less agricultural land abandonment than in the other scenarios. Climate change and associated temperature rise are high in this scenario. Eutrophication, pollution and the number of crop rotations (harvests) are expected to increase substantially in this scenario due to agricultural intensification. Water transparency is expected to deteriorate significantly due to increased temperature and nutrient inputs. No additional trampling of the soil is expected, as changing the entire agricultural production process (i.e. cattle kept year-round in stables) seems unnecessary as farmers do not have to compete on a global market. More marginal agricultural areas are kept in use. Climate change is high in this scenario, and variables such as (water) temperature, continentality, temporary water availability, soil moisture and permanent water surface are expected to deteriorate. Overall, water quantity/flow is not expected to change, as extra drought in summer is expected to be offset by additional rainfall in winter. Although not really global, this scenario does have a focus on economic growth requiring international transport and shipping. Increasing numbers of invasive species can therefore be expected.
B1	This scenario has a focus on sustainable economic growth. Due to a strong belief in globalization, important steps towards a (fair) global economic market have been taken but within certain boundary conditions to ensure sustainable growth. European farmers have to compete in a global market, which favours intensive agriculture in highly productive regions

	and agricultural land abandonment in more marginal regions. Nonetheless, environmental regulations regarding agricultural production are strict and aim to reduce the negative impacts of intensive agricultural production systems. Global environmental issues (i.e. global warming) are efficiently tackled through global cooperation and agreements. The resulting world is affluent and internationally oriented with less climate change than scenarios A1, A2 and B2. Technical progress is rapid in this world. Although agriculture remains intensive in this scenario, environmental regulations are assumed to change the agricultural production system in a way to limit its' negative impacts. Things such as eutrophication, pollution and the number of crop rotations (harvests) are expected to improve or remain stable. Water siltation is expected to decrease due to less erosion-prone on-farm practices. Forestry practice is expected to comply with high environmental standards, resulting in older forests and more dead wood. Although climate change is less in this scenario than in the scenarios A1, A2 and B2, important variables such as (water) temperature, continentality, temporary water availability, soil moisture and permanent water surface are still expected to deteriorate to some degree. Overall, water quantity/flow is not expected to change, as extra drought in summer is expected to be offset by additional rainfall in winter. Water transparency is expected to deteriorate due to increased temperatures and nutrient inputs. The global focus of this scenario is likely to result in more international transport and shipping, leading to more invasive species.
B2	In this scenario there is more resistance to globalization than the scenarios A1 and B1, and there is an emphasis on sustainable economic growth. Instead of developing towards a global economic market, regional-scale production is supported as dependency on international markets is not favoured. European farmers are protected by policies and do not have to compete in a global market. But environmental regulations for farmers are strict in order to minimize the negative impacts of agricultural production. This results in changes in the agricultural production process, which will become less intensive. To reduce the dependency on global markets, demand and support for European agricultural products remains high. Therefore land abandonment is smaller in this scenario than in the others. Climate change and associated temperature rise is intermediate in this scenario. Although the demand for European agricultural products remains high in this scenario, agricultural production is expected to become less intensive due to environmental regulations promoting environmental sustainability. Things such as eutrophication, pollution and the number of crop rotations (harvests) are expected to improve or remain stable. Water siltation is expected to decrease due to less erosion-prone on-farm practices. Although high environmental standards will be put into place for forestry, the increased demand for European wood (i.e. less dependency on global markets) is expected to be a driving factor for more intensive use of European forests. This more intensive use will partly offset the beneficial environmental effects of high environmental forestry standards on forest biodiversity. Climate change is intermediate in this scenario, and variables such as (water) temperature, continentality, temporary water availability, soil moisture and permanent water surface are expected to deteriorate to some degree because of this. Overall, water quantity/flow is not expected to change, as extra drought in summer is expected to be offset by additional rainfall in winter. Water transparency is expected to deteriorate due to increased temperatures and nutrient inputs.

Supplementary Annex 3. Land use changes from 2000 – 2030 derived from EURURALIS* and modelled in the relevant BIOSCORE scenario runs. Left as percentage and right in km^2.

	%				km^2			
(a) Europe	A1	A2	B1	B2	A1	A2	B1	B2
Urban	25%	7%	6%	3%	45,980	12,115	10,341	4,802
Arable	-11%	0%	-12%	-11%	-130,322	-4,024	-151,572	-130,539
Pasture	-5%	-6%	-13%	-11%	-29,476	-34,557	-72,465	-59,961
semi-natural vegetation	-15%	-27%	-21%	-22%	-70,619	-129,319	-99,954	-104,101
abandoned arable**					32,912	10,835	92,252	82,480
permanent crops	-12%	1%	-18%	-15%	-17,490	1,137	-25,738	-22,098
Forest	10%	10%	12%	13%	138,999	126,912	166,257	174,813
abandoned pasture**					30,016	16,901	80,879	54,604
(b) Continental Europe								
urban	20%	4%	4%	2%	14,649	2,636	2,696	1,451
arable	-10%	-2%	-12%	-13%	-54,572	-10,476	-63,474	-71,133
pasture	-1%	-8%	-11%	-15%	-2,316	-16,029	-22,830	-30,982
semi-natural vegetation	34%	-3%	33%	38%	15,265	-1,176	15,094	17,353
abandoned arable**					10,920	7,479	30,260	45,262
permanent crops	-21%	-11%	-25%	-32%	-3,543	-1,881	-4,302	-5,367
forest	3%	3%	4%	5%	9,564	10,399	14,211	17,276
abandoned pasture**					10,033	9,048	28,345	26,140

*Matchup of the land use types of the CLUE modelling framework (Verburg et al. (2008)) to the CORINE types available in BIOSCORE:

1. Moors, heaths, beaches, bare rocks and dunes have been kept constant in time in the simulations of Verburg et al. (2008) and are therefore kept constant in BIOSCORE.
2. Arable land, pasture, permanent crops, forest and urban are modelled by Verburg et al. (2008), and their percentage change was thus directly derived from Verburg et al. (2008). Subcategories in BIOSCORE (respectively urban fabric/green urban areas and broadleaved/coniferous/mixed forest), were assumed to change proportionally.
3. Verburg et al. (2008) includes (semi-)natural vegetation as a land use type. We assumed this to be equivalent to natural grasslands, sclerophyllous vegetation and transitional woodland-shrub in BIOSCORE, and presumed these to change proportionally.
4. Verburg et al. (2008) includes abandoned land as a land use type, which has no equivalent in BIOSCORE. We assumed that transitional woodland-shrub roughly corresponds (in terms of biodiversity) to abandoned land. As a next step, we therefore adjusted the area transitional woodland-shrub in BIOSCORE to match the increase in abandoned land estimated by Verburg et al. (2008).
5. We used heterogeneous agricultural land as a rest term to keep the above land changes consistent with the total land area, with the prerequisite that its' percentage change should be intermediate between the percentage changes of arable land and pasture. Verburg et al. (2008) does not distinguish heterogeneous agricultural land as a land use type and it is contained within the other agricultural land use types in their simulations.

** These land use types are not included in the input CORINE land use map, and therefore no percentage change could be calculated but only the absolute increase could be given.