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– (2) data availability and selection of indicators

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Climate change damage functions in LCA – (1) from global warming potential to natural environment damages

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1. Introduction

Climate change will alter the environmental conditions for terrestrial as well as aquatic ecosystems. Individual species and populations will experience new and stronger stress impacts, in some cases beyond their adaptive capacity. This may lead to loss of fitness, die-back and extinctions (1). Other plants and organisms may acquire competitive strength outside their current geographic distribution range and become successful invaders. Significant changes in ecosystems across current bioclimatic vegetation zones are foreseen e.g. in Dynamic Global Vegetation Models (2). Ecosystem services (i.e. provisioning, supporting and regulating services) may depend on stable, undisturbed ecosystems, but some of these services may also be robust in a changing and disturbed environment.

In this paper we address this ambiguity by introducing differently shaped hypothetical climate change damage functions in life cycle impact assessment (LCIA) for terrestrial ecosystems. Here, 'damage' is not a definitive term, but vaguely described as environmental change or rate of environmental change referring to the Area of Protection "Natural environment" considered in LCIA. Changes (and damages) to our natural environment are a result of industrialisation including homogenization and intensification of agriculture and forestry, mining and fishing industry. These changes are directly and indirectly driven by global population and wealth increases.

From this multitude of interacting drivers, the direct effects of climate change expressed as damages to the natural environment cannot easily be singled out. For a start, scenarios are required that build on assumptions of socio-economic and technological developments such as the Millennium Ecosystem Assessment (3) and IPCC's Special Report on Emission Scenarios (4), or (now more freely defined) as representative concentration pathways for atmospheric greenhouse gases (5). Fig. 1 shows the route from product-related GHG emissions to future climate damages. In the life cycle inventory (A), emissions of greenhouse gases are assessed and converted into the midpoint indicator 'global warming potential'. Scenarios of cumulative GHG emissions (B) over the next 100 years range from about 700 to 2500 Gt C (~2.6 to 9.1 Tt CO_2) depending on scenario assumptions (4).

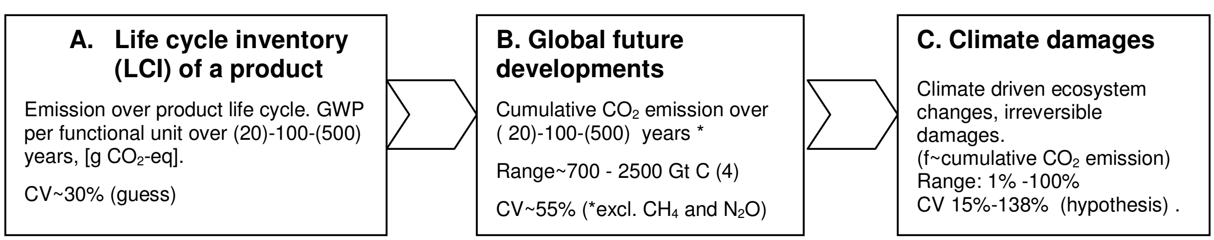

Figure 1: From GWP (midpoint) to damage on the natural environment (endpoint). CV ~ coefficient of variation (σ/μ, see Fig 2.

$CV^2(A*B*C)=CV^2(A)+CV^2(B)+CV^2(C)$, assuming (incorrectly) that A,B and C are not correlated.

The resulting climate changes from global atmosphere-ocean general circulation models followed by regional climate models depict changing means and variances of temperature, precipitation, and climate extreme events. The climate change related environmental damages (C) depend on specific sensitivities of organisms and ecosystems. Climate – carbon cycle feedbacks are an integrated part of C (Fig. 1).

The responses of terrestrial ecosystems to multi-factorial changes in the growth environment for plants and other organisms are widely unknown. So is their ability to adapt to these changes. They are therefore studied theoretically, e.g. (2,6), but also experimentally. Effects may be additive, or include antagonistic or synergistic interactions. State-changing tipping points may be surpassed. It is thus clear that the impacts from a product system being studied in an LCA must be seen on the background of the changing future background situation.

Here, we study the influence of the uncertainties of the LCI itself, of future human development scenarios, and of climate-biosphere responses in climate damage functions.

2. Results

2.1. A set of differently shaped climate damage functions

At this point in time the magnitude of the future emissions and their effects are unknown. The uncertainties in the biological and biogeochemical responses to climate change may be illustrated by differently shaped damage functions, where relative damage is a function of cumulative CO_2 emission up to the year 2100 (Fig. 2). Next to a linear response (F1), also regressive (F2, F3) and partly progressive (F4) damage functions are sketched and two more extreme cases showing a very sensitive (F5) and a very robust (F6) response are shown. The CV (vertical variation, σ/μ) of the relative damages varies at different levels of emission (138%, 64%, 16% and 15% for the cumulative emission scenarios of respectively 700, 1000, 1500 and 2500 Gt C in year 2100) (4). The range represents the total emission range of the 40 SRES scenarios from the lowest (B1) to the highest cumulative CO_2 emission (A1F1) (4).

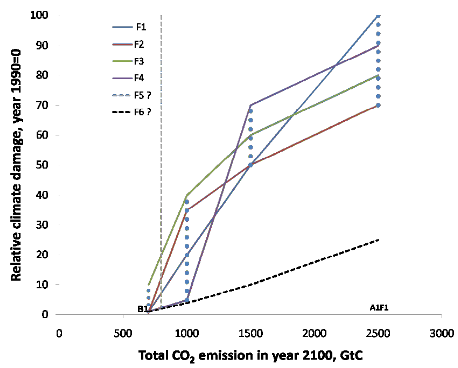

Figure 2: Climate damage functions expressing sensitivity (of a species, process, or other) as a function of total CO_2-C emission (methane and nitrous oxide not included)

2.2. Sensitivity of the climate damage characterisation factor

The relative variation (CV^2) in characterisation factors for the impact category global warming will be the sum of the squared CV's in Fig. 1 assuming (incorrectly) that A, B, and C are not correlated. The emissions estimate for the individual product (depending on the system, typically 30% on the LCI), the global emissions (55% on the emission scenarios) and the uncertainty in Fig. 2 in estimating ecosystem damage (15% - 100%) yields a CV of at least 64%-152%. The global warming potential (GWP) of a product life cycle is extremely small in comparison with the cumulative GHG emissions of different global future scenarios, Fig. 1. The GWP at the midpoint constitutes a fraction of10^{-18} to 10^{-12} of the cumulative emissions in 2100 for a midpoint GWP in the range 1 g to 10^6 g CO_2-eq. The differently shaped damage functions will be linked with the currently established evidence for climate change damages to particular biomes, and one or more common metrics for this will be developed. With this approach no incorrect precision or detailed cause-effect chain is postulated. The characterisation factors will depend on the shape of the chosen damage function.

3. References

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