Areas of protection and the impact chain

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1. Introduction

A modified scheme of areas of protection (also known as safeguard subjects) by Udo de Haes & Lindeijer (2000) has opened up a debate in the SETAC-Europe Working Group on impact assessment. This paper should be seen as a contribution to this debate, providing some basic concepts and structures for the debate.

2. The starting points: Substance flows and physical changes

Traditionally, LCA operate with a number of other environmental impact categories, such as "radiative forcing (global warming)", "stratospheric ozone depletion", "human toxicity", "eco-toxicity", "photo-oxidant formation", "acidification" and "nutrification" (Udo de Haes 1999).

To avoid double-counting, it is important to make a clear distinction between the different impact categories and between the impacts and the human activities that cause the impacts. Human activities may have several physical and chemical exchanges with the environment:

- Substances emitted to air
- Substances emitted to water bodies
- Substances that are removed from the soil, through wind erosion, run-off from the surface, with crops, or directly by physical removal
- Substances that are left in the soil or on the soil surface
- Physical impacts on humans (accidents) and animals in human care
- Physical changes to the original flora, fauna and soil, including soil compaction and other changes in water infiltration and evapotranspiration
- Physical changes to the surface, including changes in albedo

3. The end points: Areas of protection

Four areas of protection (valuable in themselves or to humans) were identified by Udo de Haes et al. (1999): Human health, man-made environment, natural environment, and natural resources. Natural resources as a protection area reflect the concern of availability to future generations. Natural resources may be any part of the natural environment, but the protection area is only affected if availability to future generations is affected, i.e. through irreversible depletion. In contrast, natural environment as a protection area is defined in terms of its current value (to humans or in itself), and may be affected both by reversible and irreversible depletion.

Since the natural environment (understood in every-day language terms) physically includes natural resources, it may be useful to rename the protection area "Natural environment" into e.g. "Natural Ecosystem", "Ecosystem functions" or "Life-support functions", leaving the irreversibly depletable aspects "Biotic resources and biodiversity (genetic resources)" under "Resources."

Similarly, the protection area "Man-made environment" includes aspects which are of concern to future generations (unique cultural assets), and aspects that are only of current value (e.g. ordinary buildings and current crop yields), which makes it useful to rename (redefine?) the protection area "Man-made environment" into "Man-made structures and ecosystems", leaving the unique cultural aspects under "Resources", which thus becomes not only "*Natural* resources."

Thus, we may outline the following areas of protection (see also figure 1):

- Resources, consisting of:
  - Deposits of materials and energy carriers,
  - Biotic resources,
  - Biodiversity (genetic resources),
  - Land with potential for agriculture,
  - Unique types of landscapes.
  - Unique cultural assets (unique cultures, historical or archaeological sites or structures and other non-reproducible cultural media),
- Health/welfare of humans (and animals in human care – forgotten or intentionally omitted in Udo de Haes et al. 1999?),
- Man-made structures and ecosystems,
- Life-support functions of the natural systems, which includes[1]:
  - UV-protection (by the stratospheric ozone layer),
  - Temperature regulation of air, water and land surface (through the "greenhouse effect", movements of air and water currents and interaction with the hydrological cycle),
  - Regulation of fresh water availability (through precipitation, runoff, evapotranspiration, and soil storage),
  - Regulation of nutrient concentrations (via weathering, photosynthesis, nitrogen fixation, movement by and through organisms, decomposition, and sedimentation)
  - Topsoil formation and preservation,
  - Removal of unwanted substances (by filtering, immobilisation, and biological decomposition).

[1] Several ways of sub-dividing and describing ecosystem life support functions have been suggested, e.g. de Groot (1987, 1992) and Daily (1997). The short list suggested here summarizes these typologies according to functional characteristics.

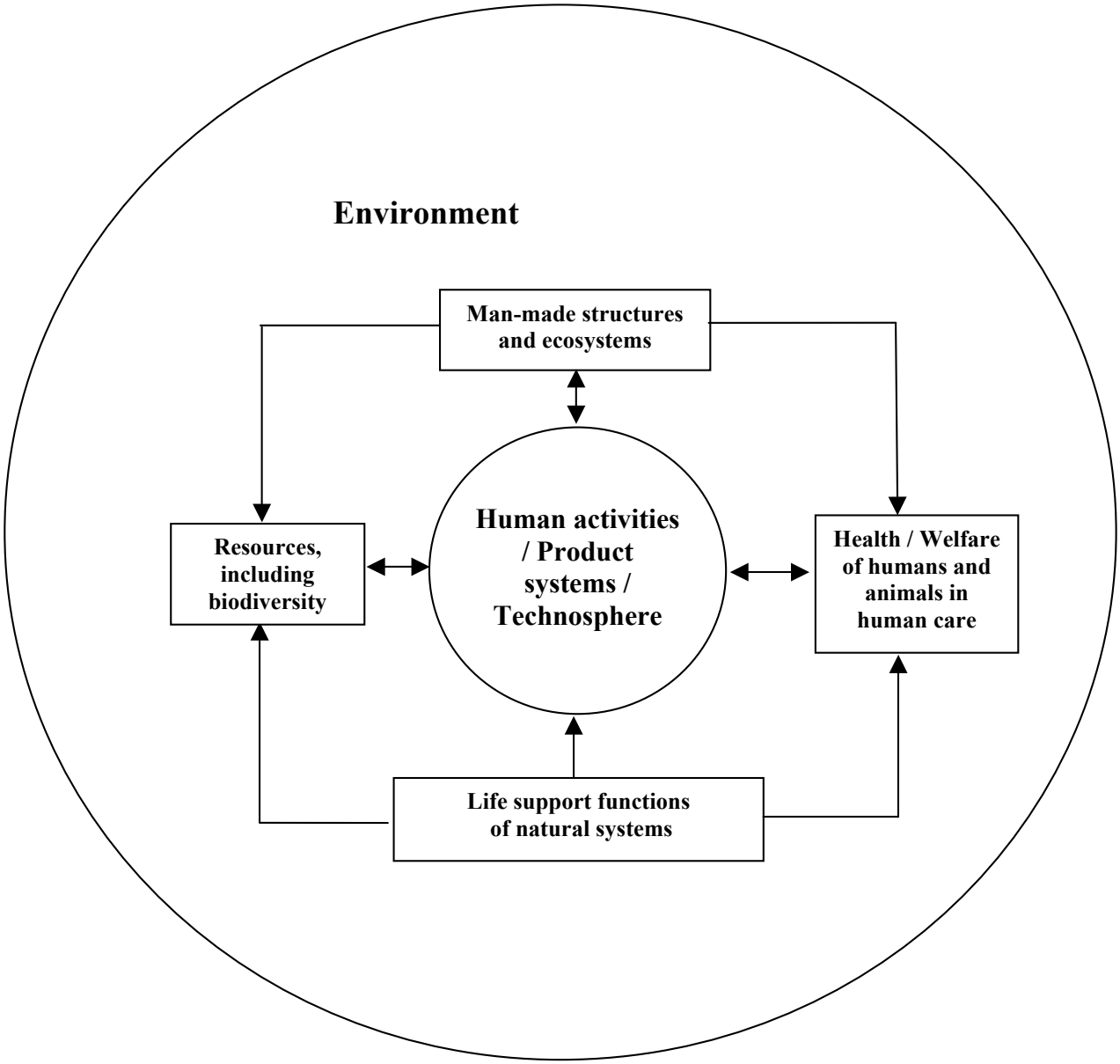

Figure 1. Areas of protection and their relations.

4. Mid-points of the impact chain

An impact chain is a description of how the starting points (substance flows and physical changes) are connected to the above end points. However, as shown by figure 1, the endpoints are not independent, i.e. an area of protection can be an endpoint for the valuation, while at the same time being a midpoint in the impact chain of another endpoint.

Figure 2 provides a rough example of the impact chains with starting point in the physical changes to flora, fauna, soil and soil surface (the physical impacts of land use).

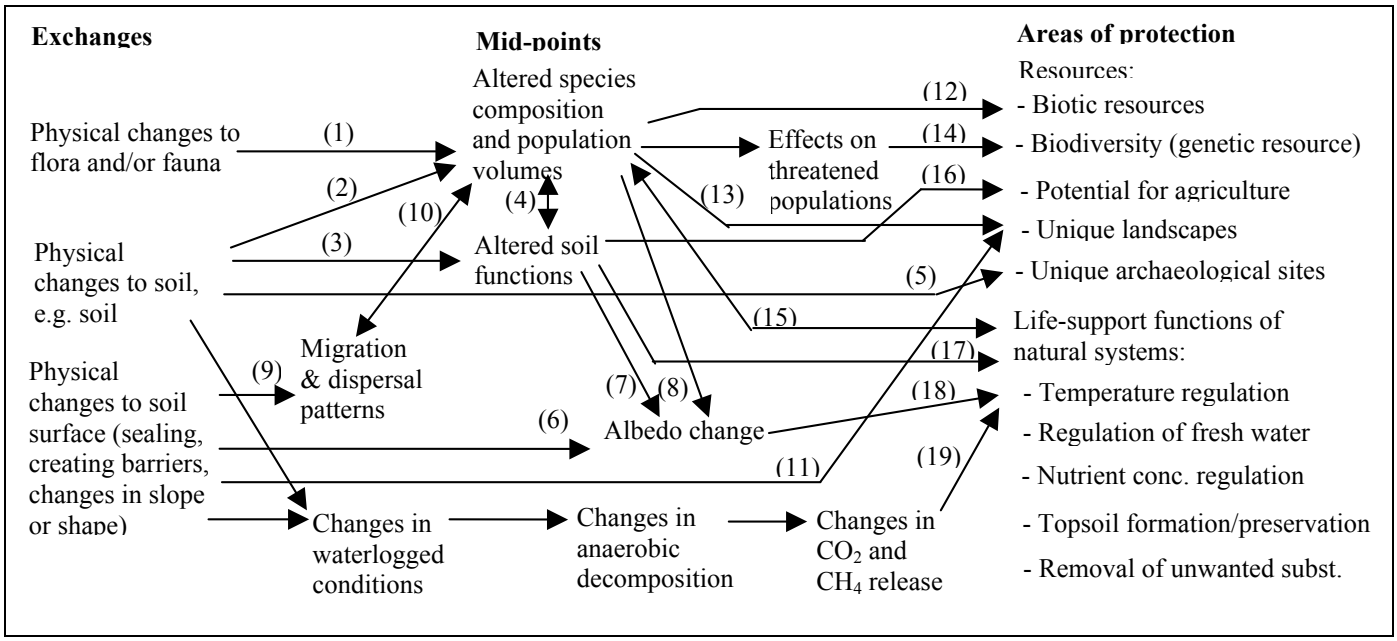

Figure 2. Impact chains for physical impacts of land use

A *physical change to the soil* may also lead to *"altered species composition and population volume"*, either directly (arrow 2 in figure 2) or as a consequence of *altered soil functions*, especially related to water infiltration and water holding capacity (arrow 3). Altered soil functions may itself be caused by altered species composition, thus forming a feedback loop (arrow 4). Physical changes to the soil may also have a *direct impact on archaeological sites* (arrow 5), which is a sub-category under unique cultural assets of the area of protection "Resources", and on *temperature regulation* via changes in waterlogged conditions (arrow 19).

Physical changes to the soil surface may have an impact (arrow 6) on the *albedo* (which may also be affected by the above mentioned altered soil functions and altered species composition, arrows 7 and 8) and on migration and dispersal patterns of flora and fauna (arrow 9), thus interacting with the *species composition* of ecosystems (arrow 10). Physical changes to the soil surface may also directly impact on *unique types of landscapes* (arrow 11), which is a category under the area of protection "Resources."

The mid-point *altered species composition* may be related directly (arrow 12 & 13) to *biotic resources* and *unique types of landscape* of the area of protection "Resources". The relationship to *biodiversity* (arrow 14) is also fairly straightforward, through the mid-point *"effects on threatened populations"*. An altered species composition, especially of the vegetation, may also affect practically all the categories under the area of protection *"Life-support functions of natural systems"* and vice versa (arrow 15).

The mid-point *altered soil functions* can be related directly to the *potential for agriculture* (arrow 16) under the area of protection "Resources" as well as to several categories under *"Life-support functions of natural systems"* (arrow 17).

The mid-point *albedo* relates directly to the *temperature regulation* under the area of protection "Life-support functions of natural systems" (arrow 18).

It should be noted that in addition to the impacts chains of figure 2, the different *life-support functions are interrelated both within themselves* and back to the midpoints *migration & dispersal patterns, altered species composition and population volumes* and *altered soil functions*, thus creating a complicated network of relationships, for which it may appear difficult to find any simple indicator. This issue is touched upon in section 5.

Furthermore, it should be noted that the areas of protection mentioned in section 3 are not in themselves independent, which implies the possibility for further modeling of the impacts, e.g. towards the area of protection "Health/welfare", as shown in figure 1.

In parallel, impact chains can be described for the starting points not included in to the example in figure 2:

- Impacts caused by substance emissions (to air, water, soil or soil surface, including emissions of soil through erosion). Note that the impact chain of substance emissions may affect the same mid-points as addressed in figure 2.
- Impacts from the intended application of substances or from the removal of substances (including soil, water and nutrients), directly or indirectly, typically modelled separately as impacts to the area of protection "Resources."
- Physical impacts to aquatic ecosystems, since the example in figure 2 includes only impacts from terrestrial land use.
- Physical impacts on humans (accidents) and domesticated animals.

5. Indicators for the impact chains

In order to operationalise the impact assessment, it is necessary to find one or more indicators that adequately reflect and preferably quantifies the key aspects of the impact chains. Indicators may be defined at several levels of the impact chain (exchange, midpoint or endpoint).

As an example, the following types of indicators may be distinguished for the impact chains in figure 2:

- Indicators for the biogeochemical *substance and energy cycles*, being part of the impact chains for the life-support functions.
- Indicators for the actual or potential *ecosystem productivity*, relating to the availability of biotic resources, the potential for agriculture, and most of the life-support functions.
- Indicators for the *biodiversity* of the ecosystems, relating directly to the endpoint "biodiversity" under Resources, and also being an indicator for species composition as a mid-point to other areas of protection.
- Indicators for the *cultural value* of the affected sites, in terms of uniqueness of landscapes and archaeological remains.
- Indicators for biotic *migration and dispersal*.

References

Daily G. (ed.) (1997). Nature's services: Societal dependence on natural ecosystems. Washington DC: Island.

de Groot R S (1987). Environmental functions as a unifying concept for ecology and economics. Environmentalist 7(105-109).

de Groot R S (1992). Functions of nature. Groningen: Wolters-Noordhoff.
Udo de Haes H A, Jolliet O, Finnveden G, Hauschild M, Krewitt W, Müller-Wenk R (1999). Best available practice regarding impact categories and category indicators in life cycle impact assessment. Background document for the second working group on Life Cycle Impact Assessment of SETAC-Europe.
Udo de Haes H A & Lindeijer E (2000). Review of Areas of Protection within the Working Group on Life Cycle Impact Assessment. Note to the members of the second working group on Life Cycle Impact Assessment of SETAC-Europe. November 2000.