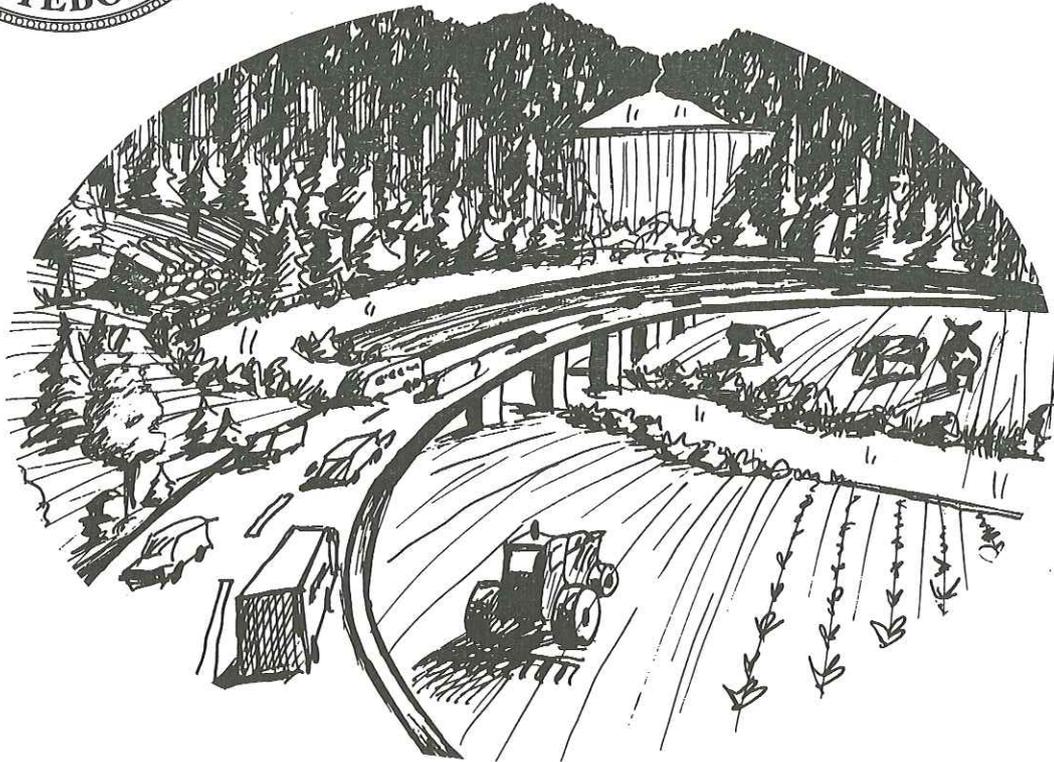


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CHALMERS UNIVERSITY OF TECHNOLOGY



Evaluation of Land Use in Life Cycle Assessment

EDITOR:
Göran Swan



CENTRE FOR ENVIRONMENTAL ASSESSMENT OF
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**Evaluation of Land Use
in
Life Cycle Assessment**

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Foreword

Methodological development for Life Cycle Assessment (LCA) has been substantial during the last ten years. Still there are gaps in the methodology, one of which is methodology for assessment of impacts related to land use.

Centre for Environmental Assessment of Product and Material Systems, CPM, is a national competence center at Chalmers University Technology. CPM is jointly funded by industry, NUTEK, The Swedish National Board for Industrial and Technical Development, and Chalmers. Twelve large Swedish industrial companies participate in CPM.

When CPM was started during spring 1996 the gap in methodology for assessment of land use was recognized. A project was started with the aim to get an overview of the field, and based on that create a framework for evaluating land use as part of an LCA impact assessment. Within CPM the project has been performed in the research area Methodology Development

Land use has high relevance to many of the companies participating in CPM, *e.g.* those active in forestry and hydropower production. Evaluation of land use for factories and production sites is relevant for all types of industrial companies. Since the aim was to develop a framework for impact assessment of land use in LCA that may be generally applicable, the need to consider also agriculture was recognized. The Swedish Institute for Food and Biotechnology and The Swedish University of Agricultural Sciences were thus invited to participate in the project.

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Göteborg December 1997

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Summary

Land use belongs to the technosphere when it comes to the energy inputs needed for silviculture and wood extraction or agricultural activities like fertilizing and harvesting. Such processes are accounted for in the ordinary inventory procedure in LCA and are not dealt with in this report. Beside that the land use management has a direct impact on the landscape itself, which can be described as impacts on its sustainability, by affecting productivity, biodiversity etc.

The goal of the project was to find ways to include these kinds of environmental impacts in the LCA framework, at least in a tentative way, and to make it possible to apply a gradation in between different land use management based on their impacts on the environment.

Land use has in this CPM project been classified according the purpose of land occupation, thus in terms like forestry, agriculture, mining, etc.

Two modes of land use has been treated; ongoing or static land use, and land transition from one kind of purpose to another.

The project group has accepted that man has the right to occupy land for his living, but not to misuse it. Thus the way of land use management and the environmental impacts caused by this should form the basis for the life cycle assessment suggested.

Another basis was the setting of bioquality in a central position. The estimation of the bioquality for each area should also dictate the range of the environmental impact of land use management. This impact can only be a fraction of the total bioquality value. Bioquality is here based on two components, bioproductivity and biodiversity. Both components are built up by parameters defining the essential properties.

The parameters to be used for the bioquality estimation have not been defined within this project, only their nature has been touched upon.

Using a top-down way of reasoning, after having estimated the potential bioquality of the untouched area as well as the actual bioquality in relation to the natural, the effect of different kinds of land use management can be calculated as a result of the quality of the management.

Thus, although a hemerobic or closeness to nature scale is used for the estimation of the bioquality, it is not the distance to the natural, undisturbed bioquality, but the quality of the land use management that will decide the environmental impact reported. This is a "political" decision. The way of estimating the final effect (E), confines this effect to be a fraction of the bioquality value, and depending on the actual bioquality as well as the quality of the management - the better these parameters are, the lower the impact.

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Evaluation of Land Use in Life Cycle Assessment

1. Background

The LCA methodology is still in the development process. This holds especially for the Impact Assessment phase of LCA. Land use is essentially an impact assessment issue. So far, in the literature and in the common valuation systems, only generic values for forestry, farming etc. are used.

Considering the common use of land as part of most activities, and the growing interest in sustainability aspects, this situation is not acceptable when LCAs are made.

The evaluation of different land uses, considering different countries, climatic and fertility conditions, is a very big object. As a CPM project, the suitable goal was decided to be:

2. Goal

To get an overview of the field, and, based on that create a framework for evaluating land use as part of a life cycle impact assessment.

The goal was also to find a methodology allowing "environmentally friendly" land use strategies to be separated from those impairing the environment.

3. Land use - its place in an LCA

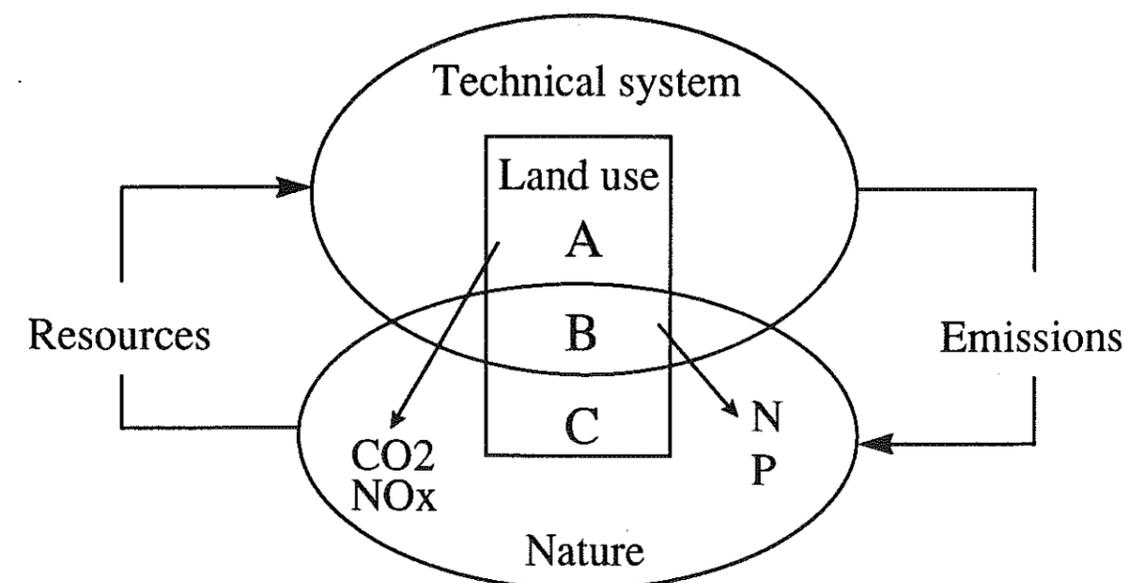


Fig.1. Schematic description of the relation between land use and the technical and natural systems.

Referring to Fig.1, land use is dealt with in:

- The pure technical system, A
- The overlapping area between the technical system and the natural system, B
- The environment, C

In the technical system A, the input of resources and output of emissions from the processes, e.g. planting, cultivating and harvesting of land, are treated. These activities are part of the inventory of an LCA and the impacts can be treated with the normal impact assessment methods. The function of land as a sink for emissions including carbon dioxide is not included here.

These manipulating activities in the technosphere may interplay with the land by causing erosion, leakage of biocides, fertilizers and/or emission of CO₂ or methane etc. Resource depletion as nutritional losses are also part of this interplay. Although this happens in the area called B, most of them can be dealt with using existing methodology for inventory and impact assessment.

A third class C of activities is the manipulation of land areas which influence on the conditions for the flora and fauna to survive and prosper. Or which influence on the other multifunctional uses which characterize especially forest land; the possibilities for fishing and hunting or hiking, but also aesthetic and cultural impacts may be part of this impact.

Thus, many aspects of land use in a wide meaning can be treated in a conventional LCI, and those parts are here limited to the areas A and B. Interventions in the pure technical system A are not to be dealt with in this report. Most interventions belonging to B can also be treated with existing LCA methodology. However, they are for instance often associated with indicators used in the certifications for forestry. Thus, when forest certification is used in an LCA, care must be taken that these indicators are not accounted for twice. The activities belonging to the nature area C will be included in the land use evaluation and are the main scope of this report.

4. Scope and limitations

Land use have many applications, some of which are mentioned below. The main interest in this project will be directed towards forestry and agricultural use, however.

Within the above mentioned goal, the following issues were mentioned:

1. To characterize the main land uses.
2. To make a preliminary inventory of criteria and types of indicators.
3. To arrange the criteria and indicators according to an LCA framework for practical applications.
4. To scrutinize the suggested solution against end user requirements, possibly by carrying through a small example on forestry.
5. To give some practical guidelines to the LCA practitioner.

This pattern was followed during the project, although more work has been devoted to finding and developing the main issues, and less work to the implementation part. Thus especially point No 5 has hardly been dealt with. Instead the implementation of the suggested methodology will be made later in complementary studies. A literature search was included and cited where needed.

Although there has been an ambition to find generally acceptable principles, it is a general experience that indicators and even criteria mentioned in this report often have only a local or regional scope. Thus examples of indicators etc. given in the report often are of Swedish origin, and may therefore not be applicable elsewhere.

As at the end of the project it was found that the number of land use examples increased above initial expectations, the decision was taken to have one general part, followed by individual presentations of the different land use examples.

5. Land use in the literature

5.1 The research view

Sturm and Westphal [1995] notice that there are often conflicts between different uses of land, thus land must be a scanty type of resource. The utilization of land results in different degrees of environmental effects, which then ought to be considered in an LCA study. The authors go on saying that this effect should be put into relation to how far the land use is withdrawn from its natural state (the hemorobic view).

Odum [1988], Krottschek and Narodslawsky [1995] all arrive at land area as a basic unit in ecological evaluation with the following reasoning: "in a sustainable economy the only real input that can be utilized in the long term is solar exergy. Its utilization per se is bound to the surface area. Furthermore, area is a limited resource in a sustainable economy because the surface of our planet is finite" [Odum, 1988]. Fertile soil is also regarded as a production factor with the unit area as its yardstick. Flows entering or leaving a process can then be identified by areas needed to create these flows. If the total area so calculated is divided by the area per inhabitant in the region being relevant to the process, the Sustainable Process Index, SPI, is the result. The SPI, thus is the fraction of the area per inhabitant related to the delivery of a certain product or service unit expressed in its functional unit. Its physical meaning is, how much of the area theoretically available for a person to guarantee its sustainable subsistence, is used up to produce the service or product in question.

Sustainability is based on the use of resources within the carrying capacity of the system. The consequences are twofold;

- (i) the production should preferably be based on flow resources or renewable resources.
- (ii) the emissions should be within the capacity of the ecosystem to assimilate them below the threshold level of non-acceptable impact.

The idea to use area as the yardstick for the environmental load is original, but shall not be dealt with further here. The function of land area as a carrying system for emissions is important to acknowledge, however.

Weidema *et al.* [1996] discussed a number of different aspects of land use that should be included in LCA:

- land use as area occupancy,
- land use causing reversible changes in the input-output relations compared to the original land use,
- land degradation,
- impact on biodiversity,
- aesthetic impact.

A treatment of resource depletion of land is made in LCA - NORDIC, Techn. Rep. No. 10 [1995], where also other authors are cited. In short, this treatment proves that this issue so far was rather underdeveloped.

Udo de Haas [1996] makes a distinction between land use and land transformation (see below). He goes on saying that when the type of land (use) or any change in the characteristics of the land is considered, land should be described as a fund resource (land cannot be depleted, but usually it gives an annual yield).

Ekvall [Ekvall 1997] has made a survey of land use issues in earlier works and has found some details, but on the whole also this review underlines the fact that for land use in-depth studies are lacking.

S. Nilsson, IASA, [Nilsson, 1997] comments: "...most of the concerns as to whether wood, plantation or nonwood crops are the most preferable source of raw material, boils down to the question of the most suitable land use. None of the studies have really analyzed the land-use issue and incorporated it into the traditional environmentally, economically and technologically oriented approaches."

In a very recent paper by Blonk et al [1997], the methodology for taking physical degradation of ecosystems into account in LCA is treated more deeply. The authors separate in between Landscape Degradation and Ecosystem Degradation. Landscape degradation is said to be the degradation of the visual quality of an environment, and was left aside in their life cycle assessment.

5.2 Public guidelines

The United Nations have always taken great interest in environmental issues. The Bruntland commission in 1987 defined the sustainability principles. A landmark was the Rio Conference in 1992, when Agenda 21 was settled, based on the sustainability principles. The main message is that all our activities should be such that we do not limit our coming generations to get the same possibilities. From that follows that flow resources and renewable resources should be used rather than deposit resources. Renewable resources should be used in a sustainable way. Reuse and/or recycling might prolong the life especially for deposit based resources. The natural environment should be preserved as far as possible, as well as the diversity of flora and fauna. Impacts from emissions and use of resources should be minimized.

The Swedish Environmental Protection Agency has declared some overarching goals for the utilization of land and water [NV 1993], e.g.:

- The natural resources should be utilized according to the sustainability principles.
- The production capacity of the forest, its biodiversity and its genetic variation should be protected.
- The cultural, aesthetic and social values of the forest must be protected.
- In the agriculture the demands for a good environment and sustainable long term economizing of natural resources must be fulfilled.
- The environmental goals of the agriculture shall be to maintain a rich and variable farming landscape and to minimize the environmental loads.
- Also here the cultural values as well as the biodiversity shall be maintained.

The Swedish EPA has also defined five safeguard subjects [NV 1995], which were later applied in the Swedish EPS system:

1. The Ecosystem health or resilience
2. The ecosystem production capacity
3. Renewable (fund) and/or deposit resources
4. Human health
5. Aesthetic values

In the Goal and Scope Definition (GSD) phase of an LCA the goal of the study is established. The weight that should be put on different interventions is very often dependent on the goal definition. Thus, it is important to make such statements in the GSD so as to give the practitioner the right inputs for the evaluation stage.

6 Land, terms and definitions

6.1 Global land views

According to Meyers [1990], the global land can be shortly described as follows:

70 % of the earth's surface is covered by seas and oceans. Greenland and the Antarctic taken aside, the rest of the land area is originally characterized as follows: Tundra 6 %, boggy areas 10 %, thin soil cover areas 22 %, dry areas 28 %, poor soil areas 23 %, and forest areas with good agricultural potential 11 %.

The climatic conditions have been decisive for the origin of boreal, temperate, and tropical forests, as well as grassy, bushy or savannalike areas. Thus warm and humid areas forming the tropical rain forests contain 75 % of the earth's phytomass, although they cover only 10 % of the land area, and the soils are pretty low in nutritive substances - practically all is bound to the biomass.

"Once upon a time two-thirds of the land surface of the earth was covered with forests. Today only one third remains. We human beings have gradually pushed back the forests in order to fill our needs of food and fuel. In pace with the increase in global population, the forests have disappeared. The tropical forests are still decreasing with about one percent annually. Yet the most rapid depletion is on dryer forest areas of the savanna and dry forest types. It is from those areas that deserts are formed insidiously and irreversibly" [Remröd 1991].

The areas taken from the forests were used for cattlebreeding and agriculture during most of the millenniums. With the emergence of industrialism and fast growing population, other uses of land grew in importance. Some 70% of ecosystem degradation in Europe is considered to be due to changes in land use [RIVM, 1992].

6.2 Land - a resource.

In the classification part of the impact assessment the input parameters from nature are classified as resources and the outputs are products, or emissions creating different effects on the environment. Land is then a kind of resource.

The resources are divided into:

- **flow resources** (solar energy and derived forms of energy like wind and hydropower), and

- stored forms of flow energy, called **renewable materials**, or **fund resources**. The wording fund resources implies that there is an annual replenishment of the resource. Thus, as long the annual extraction is lower than the replenishment, there is no depletion of the fund. Still a depletion of the soil quality might occur.
- resources which are limited on Earth, as fossil fuels and all minerals. These resources are called **deposit resources**. Some resources are scarce and with a threat to be depleted within a few decades or centuries. Other resources exist in big, and even inexhaustible amounts. The extraction of scarce deposit resources results in resource depletion effects. Land is a limited resource of the deposit type, although unrestricted use leads to degradation rather than to depletion. If acceptably managed, land can be seen as a fund resource, however, see Udo de Haas above.

SETAC suggests the following list of impact categories [Udo de Haes, 1996, Finnveden 1996]:

1. Depletion of abiotic resources; deposits, funds and flows
2. Depletion and competition over biotic resources (funds)
3. Land use and transformation

Individuals of plants and animals belong to renewable resources, but species and specially adapted populations are lost forever if they are threatened until extinction. Thus species and some populations are deposit resources according to these authors. The number of species that share the earth is thought to be between 10 and 40 millions, most of them belonging to the class of insects - 30 millions or more [M.L. Rosenzweig, 1995]. So far, about 1.75 million species have been identified. The great concentrations of this diversity are found in forests, particularly in tropical ones.

Finnveden [Nov. 1996] stresses that resources are input categories. The system boundary decides if wood is a resource. If the boundary is set at the mill, the input of wood is a resource, but if forestry is included in the technical system, solar energy and land use are the resources.

6.3 Definition of land area

The area referred to in land use will in this context be the area on the planet surface including the vertical projection in both directions. Thus it is rather a question of a volume with air, soil and underlying minerals, than a two-dimensional area. Yet, the unit chosen for land use is square meter or hectare (ha), sometimes also with a time dimension, e.g. ha*yr. In this report ha will be used.

6.4 Types of land use effects and land use classification

Land use in LCAs can be further explained by mentioning which are the effects of land use. Lindeijer [1997] has made the following effect list:

- desiccation
- fragmentation
- landscape degradation
- soil degradation
- loss of nature development space
- loss of biodiversity
- impacts on the life support function
- impacts on other functions (local environment, recreation, economy)

Land use classes are frequently mentioned. Most of them are classification after naturalness or so called degree of hemoroby. The start is then undisturbed ecosystems. Over different degrees of forest cultivation and then agriculture, the bottom is reached with a sealed land surface [Giegrich and Sturm, 1995].

Within the project group the following main types of land use were identified and found suitable for the further work:

1. Primitive use by hunters and collectors.
2. Extensive cattlebreeding.
3. Farming.
4. Settlements (including urban roads and other communicational and technical structures).
5. Mining.
6. Forestry.
7. Recreational areas.
8. Landfills.
9. Transports and communication outside urban settlements.
10. Impoundments and their opposites; land claimed from the sea or lakes.

6.5. Land use - modes

As often in the literature, and also below, the use of land will be treated in two modes:

1. **Use of land** of the kind described above. The use is an ongoing process, but the environmental management of the land might be static or change to the better or to the worse.
2. Often shifts are made from one form of use to another, from the natural state to a state of use, or between different forms of uses. This is called a **transition** of land use ("övergång"). OBS Udo de Haas (1996) and Blonk et al (1997) use the word **transformation** ("omvandling")

In the literature a distinction is often made between *land use* and *land occupation*. The latter term then refers to the mere occupation of a scarce resource. As will be discussed later on, land occupation is not considered as an environmental impact in this study.

7. Land use assessment

Above it has been suggested that:

- Land is a scarce resource.
- Land use can be divided into groups depending on kind of utilization, with different environmental effects.
- Two phases are defined; continuous land use and transition from one kind of use to another.
- The continuous use can be static or gradually changing.
- The evaluation of land use must be made considering the Goal and Scope statements

7.1 The need for a baseline

Ideally it should be possible to make comparisons between different kinds of land uses in different countries. To be able to do that, a common baseline is necessary. The project group had to meet the difficulties in finding such an ideal baseline. In the literature the undisturbed, natural land is often suggested.

The group decided to introduce the **potential bioquality W** of the area in question as the baseline. The bioquality has at least two components; bioproductivity and biodiversity. Both should be considered as vectors with a number of parameters. These two components are well known as effect classes or safeguard subjects (EPS). Even if they below will be used only to calculate the bioquality, they should also be registered in non-aggregated states.

The bioquality so defined will be depending on local climatic and soil conditions etc. Thus the bioquality W will differ a lot from low values for deserts, montaneous areas etc. to fertile land areas with suitable climate.

Especially forest and agriculture LCA studies must include areas on the **landscape level** to be able to cover all biodiversity possibilities. Regarding hydropower, the equivalent approach to adopt is the catchment level. In order to arrive at a landscape measure, the corresponding values from the different landscape sectors with internally similar properties, have to be added to an area weighted average value. It is worth noting that bioquality due to the biodiversity component of the expression, never can have a value for individual stands.

Another possibility would be to refer to the time it would take for the area to come back to its original natural state if let alone, that is the relaxation time, see Blonk [1997] or Udo de Haas [1996]. In the latter case the relaxation time supposedly stands for a valuation of the use, substituting the W value.

7.2 The bioquality of land

What is the potential bioquality of an area? It can be the undisturbed, natural state of the area in question, which is not known, but can be estimated. The bioquality of neighboring areas of unmanaged or low intensity cultivated areas with similar soil properties should give indications.

The ideal bioquality potential could also be used as a baseline, which may possibly be higher in value than the natural state. The bioproductivity could be related to practical and well known characteristics, e.g. the indices of fertility for forest or agricultural areas. However, with different kinds of indices for different types of areas there is a risk that comparisons with other land uses are more difficult to carry through. The similar definition of biodiversity may not be

easier, mainly because the biodiversity certainly has to be based on a number of parameters being indicators for different aspects of biodiversity.

The term bioquality is here a complex measure of the biological potential of the area studied. Climatic as well as physiochemical, biological and historical properties will determine both bioproductivity and biodiversity, which here are the components in the "bioquality" concept. Below this bioquality is designated "W", with the EPS dimension format ELU/ha*yr.

Traditionally we have our preconceptions regarding the total effects of different kinds of land uses. Fig.2 is meant to mirror such views, but shown here only to illustrate the base for the further steps in the calculation of the effects of land use.

Thus in Fig.2 the different land use classes and their actual bioquality levels are supposed to occupy the same land area or other areas having the same bioquality W. Each land use has an average level and a spread around that depending on the quality of the land use management.

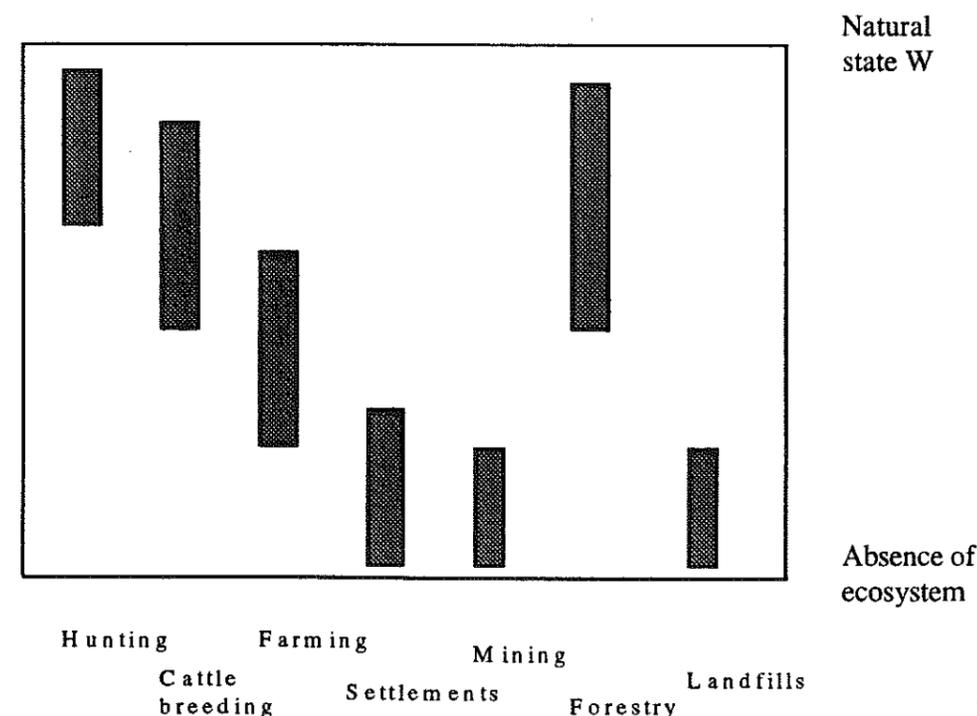


Fig.2. Illustration of actual bioquality levels in different land uses

The bioquality W of an area thus varies from very high values for the most fertile land, rich in biodiversity, to close to zero for deserts and bare mountain areas. In Fig.2 the upper limit stands for one and the same area used for different purposes. It shows the zones within which the actual land uses are thought to bring the land areas. Again it is worth noting that bioquality due to the biodiversity component of the expression, never can have a value for individual stands. Only a landscape based level can tell the biodiversity.

The top of the scale in Fig.2 represents the natural state W . The actual state is somewhere in between the top and the bottom - unless the actual level has not surpassed the natural state level, which is theoretically possible. Introducing p , the actual state is:

$$W_{\text{actual}} = p \cdot W \quad (1)$$

where $0 < p < 1$ normally, but $p > 1$ if the actual bioquality is higher than that of the natural state.

W is given per unit area (preferably a hectare, ha) and year.

7.3 Transitions.

Historically mankind has gradually claimed practically all valuable land for different purposes, especially in the old world.

Very few original forests remain here, most forests are now managed forests, which show different degrees of bioquality. The areas with the highest bioquality often have by transitions been formed into farmland and partly covered by settlements.

A transition of a land area does not change the W value, only the p value in (1). If the transition is from 1 to 2, the difference is as follows:

$$\Delta W_{\text{actual}} = W \cdot p_2 - W \cdot p_1 = W \cdot (p_2 - p_1) \quad (2)$$

If a land transition is carried through - what or whom shall the difference in burden affect? If the transition is more a historical event, the change is suggested to be neglected. But the fact that a degenerated area has a low bioquality may still be mirrored in the estimation of the impact.

If on the other hand the transition is carried through in real time or recently, a kind of allocation of the effect is needed.

One way is to introduce a period of "depreciation", which then should affect the products resulting from the land use during an appropriate time interval.

7.4 Environmental management of land use.

According to the philosophy accepted by the project group, man is part of nature and allowed to use nature. Thus only the misuse, or rather the environmental effects of use, should be recorded as loads and impacts on the environment. The effect of management frequently leads to changes in the actual level of bioquality although the kind of use is the same. This is probably the heaviest part of land use impact, because the type of environmental management is so decisive for the resulting load.

Referring to Fig.2, the effects of environmental management should be confined to parts of the bioquality range. If the horizontal axis is changed to a time scale, the actual bioquality level represented by $W \cdot p$, moves up or down as a curve as a result of the management measures, see Fig.3 below. If the land use management is ideal, the bioquality will in due time increase to W , which is an increase of p to $p=1$. This increase in bioquality is $W \cdot (1-p)$.

As well as $W \cdot p$ describes the actual bioquality in relation to W , we introduce q to show how good the land use management is in relation to an ideal management, which is a management bringing W_{actual} to the W level. Thus $q = \text{Actual management} / \text{Ideal management}$.

Suppose the environmental management quality can be measured and designated by q , where $q=1$ is reached by ideal environmental management, and $q=0$ indicates management leading to zero bioquality. If the effect of the environmental land use management is called E per unit area (ha*yr), it can be defined as:

$$E = W \cdot (1-p) \cdot (1-q) \quad (3)$$

The closer to the ideal management q is, the smaller is E . If q is decreased, E rises, but is never bigger than $W \cdot (1-p)$ per ha. E is in equ.3 an intensive unit describing the impact per ha*yr. Usually the total impact per functional unit is required. If 1 ton of paper requires 5 m³fub of wood, and the yield of wood is 4 m³fub/ha*yr, the needed area A is 1,25 ha.

If an area has been managed in the same way for a number of years, p narrows to q . When the management is changed to the better, as for instance recorded in a certification, $q > p$.

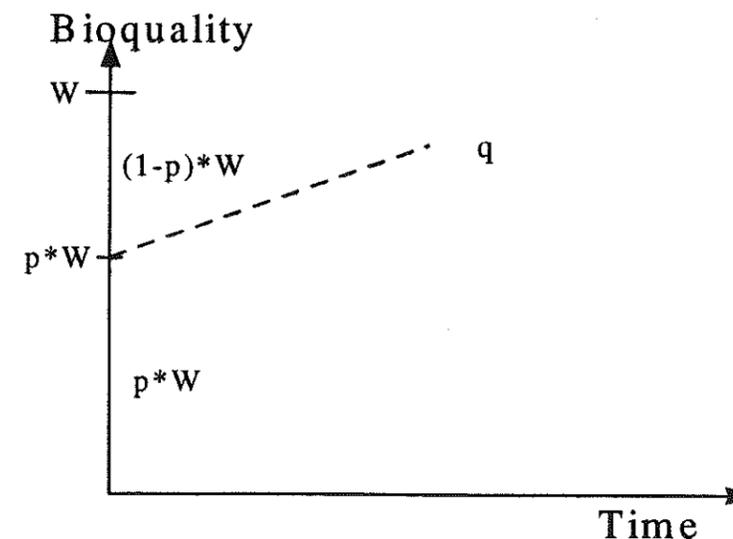


Fig.3 Improved land use management will result in a diminished impact E according to equ.(3).

Although it has been said that "inherited land use impacts" should not be considered, equ.3 has the p term included. Thus, the lower the p value, the higher E will be. However, this value of p is the cumulated value based mainly on the closest time period preceding and up until the time of the LCA inventory. Consequently the situation just before the inventory is considered rather than earlier historical events.

7.5 The LCA framework

The starting point is equ.(3).

In the paragraphs 7.1 - 7.4 a method for the assessment of land use management has been suggested. Here the method will be arranged according to the LCA framework and further discussed.

In the inventory part the constituents of A, W, p, and q have to be defined.

The area A. For practical reasons the area is suggested to be measured in hectare, $ha=10\ 000\ m^2$. When making an assessment or a comparison, the area needed for the functional unit has to be calculated. For instance, 1 ton of paper may require 5 m³sub of wood. If the yield in the forest is 4m³sub/ha*yr, the area required is minimum 1,25 ha for sustainable forestry. Yet the assessment of the impact has to be based on the quality of the landscape, and not only the field where the extraction took place.

The (potential) bioquality W (ELU/ha*yr) is of central importance. The project group visualizes W as having two components, bioproductivity and biodiversity, bioquality being a function of the two. Both components should be looked upon as vectors with a number of scalars, which are analogue to inventory parameters. The parameters supposed to describe bioproductivity should cover climatic conditions, soil quality and the influence of the natural state on the bioproductivity (old forests with low growth mixed with young forests after fires etc.). Those describing biodiversity should cover some acceptable measures for the common types of diversities.

The process of finding and aggregating the data needed to describe the bioquality is analogue to the LCA procedure. Finding data for the parameters describing bioproductivity and biodiversity, respectively, is similar to the inventory process. They may then be classified into parameters describing bioproductivity and biodiversity respectively.

Aggregating the parameters further under their respective heading, would be an analogue to characterization. Whether it is possible to perform such an aggregation based on natural science only was not investigated in the project, but a possible way is suggested in Appendix No 1.

Aggregating data to one measure describing bioquality will include a weighting procedure involving values held by humans in the social system. Comparisons of areas with different kinds of bioquality will introduce still more weighting.

The parameter values should mirror the relative importance of the indicator to the total level of bioquality. Thus also the relative importance of biodiversity compared to bioproductivity is determined in this bottom-up procedure.

The parameters mentioned above thus belong to different phases of an LCA The procedure can be depicted as follows.

Inventory Parameters	Classification	Characterization	Weighting
aaa	aaa		
bbb	ccc	Bioproductivity	
ccc	eee		
ddd	hhh		Bioquality
eee			
fff	bbb		
ggg	ddd	Biodiversity	
hhh	fff		
	ggg		

It is possible to find existing measures at different levels of aggregation referring to the procedure described above. For example, there exists indices for bioproductivity both for forestry and farming, at least for Swedish conditions. Under the forestry section another way of finding a bioquality measure is demonstrated. Using such ways, a top-down procedure can be arrived at, giving inroads to the use of the equations presented in the section seven.

It should be kept in mind that the bioquality value is - in terms of willingness to pay - what we are willing to pay to avoid that an area goes from its natural bioquality to a sealed area state. Thus it is not only a question of biodiversity. This fact paves the way for the use of equ.3, although W is something else than the economical value of the biomass etc. within that area.

The ratio p is placing the actual bioquality of an area on a linear scale between W and zero. Thus $p = W_{actual} / W$. The way to estimate p is to use the same parameters as used for the estimation of W, but using them for the actual situation.

Estimation of q.

The estimation of q should be based on criteria for what is important to reach a high bioquality. Criteria per se are not workable in an LCA, however. We need indicators which can be expressed in numbers, and which are indicative for the criteria concerned. As is the case for the bioquality parameters mentioned above, the parameter figures must be weighted according to the potential effect they may have on the future bioquality. Here the set of parameters are different, however. The value of p is the result of the land use management during a number of preceding years. If the management measures have been constant during these years, p might be equal or close to q, but **p is always a measure of the actual state of the bioquality, and q is an estimation of how the actual management measures will probably influence on the bioquality in the long run.**

The estimation of the value or weight of each parameter can be made via safeguard subjects or other effect categories, see App. No 1, a "bottom-up" procedure.

A "top-down" way is to estimate the total possible impact compared with other groups of effects in the LCA, and based on that create the impact range. In this project the latter way is recommended and used by setting the estimation of the bioquality W in the first place.

In modern forestry the desired indicator box for the LCA application is to a high degree to be found in the certification processes, which are now being implemented. For the agricultural sector the corresponding possibilities are at present not at hand.

7.6 A transition example

So far the discussion has been on a general level. However, when an example is demonstrated an impact assessment and weighting system must be chosen. In this report the EPS system has been used, but any other system having the required category indicators defined could have been used as well.

Two hectares of forest area are transferred to agricultural land and used for corn cultivation. Assumptions: The forest area was of a good quality mixed wood type, having good bioproductivity, but the biodiversity less than average. The W value was estimated to 12 ELU/ha*yr. The way of managing the silviculture had rendered the area a p as well as a q number of 0,6. This mark was also significant for the neighboring forest landscape. After the transition the area got part of an agricultural landscape that was more like an island in the forest landscape. The farm is of the multiple use type with cattle. The potential bioquality is as before, the biodiversity low, yet far from the minimum level. Close to the farm is unused wetlands and a shallow lake with reed and a rich bird fauna. Say that $p = 0,2$ and $q = 0,3$.

The actual level of bioquality on area A before the transition :

$$A*W*p = 2*12*0,6 = 14,4 \text{ ELU/yr}$$

After the transition the bioquality is:

$$A*W*p = 2*12*0,2 = 4,8 \text{ ELU/yr}$$

Thus the transition difference in bioquality is $(14,4 - 4,8)/2 = 4,8 \text{ ELU/ ha*yr}$, which is a deterioration that is in the order of 40% of the potential bioquality.

The corresponding effects are:

$$E_b = A*W*(1-p)*(1-q) = 2*12*(1-0,6)*(1-0,6) = 3,8 \text{ ELU/yr, and}$$

$$E_a = A*W*(1-p)*(1-q) = 2*12*(1-0,2)*(1-0,3) = 13,4 \text{ ELU/yr}$$

As there is a deterioration of 9,6 ELU = 4,8 ELU/ha *yr because of the transition, this burden must be allocated on the products taken from this area, in this case $4,8/3 = 1,6 \text{ ELU/t seed}$.

In principle there will be a loss of 4,8 ELU each year to follow compared with the forestry alternative, which should be allocated on the annual crop. Keeping the rule against inherited burdens, this burden should be levelled off in ten years or so.

7.7 Summary

The project group has accepted that man has the right to occupy land for his living, but not to misuse it. Thus the way of land use management and the environmental impacts caused by this will form the basis for the life cycle assessment.

Another basis is the setting of bioquality in a central position. The estimation of the bioquality for each area also dictates the range of the environmental impact of land use management. Bioquality is based on two components, bioproductivity and biodiversity. Both components are built up by parameters defining the essential properties.

The parameters to be used for the bioquality estimation have not been defined within this project, only their nature have been touched upon.

Using a top-down way of reasoning, after having estimated the potential bioquality of the untouched area as well as the actual bioquality in relation to the natural, the effect of different kinds of land use management can be calculated as a result of the quality of the management.

Thus, although a hemorobic scale is used for the estimation of the bioquality, it is not the distance to the natural, undisturbed bioquality, but the quality of the land use management that will decide the environmental impact reported. This is of course a "political" decision. The way of estimating the final effect (E), confines this effect to be a fraction of the bioquality value, and depending on the quality of the management - the better, the lower the impact.

7.8 Recommendations for future work

This paper describes a possible methodology for the evaluation of land use. In order to arrive at a full-fledged tool, another few steps have to be taken:

- Indicators defining the bioquality components have to be found and evaluated.
- Indicators for the evaluation of management suiting different land uses must be defined
- The feasibility of the method has to be tested on real cases.
- As the discussion has circled around Swedish conditions, an international examination is warranted.

8. Land use evaluation in Forestry

By Göran Swan, Stora Corporate Research, and Börje Pettersson, Stora Forestry and Timber.

8.1 Introduction and certification procedures

The forests on the Earth have in consequence of their extension a dominant influence on the process in the biosphere, especially the photosynthesis and the biological growth, the formation of soil and the energy transfer processes.

From human points of view we can consider the forests as our supporters and protectors. They maintain the ecological diversity, they protect the runoff areas of our rivers, they protect against erosions and they furnish us with fuel, wood and products thereof.

The Bruntland Commission in 1987 defined the sustainability principles, that during the Rio Meeting in 1992 resulted in Agenda 21. During a Ministerial Conference in Helsinki 1993 and a follow-up meeting in Geneva in 1994, criteria were drawn up for the European forestry:

Maintaining;

- and developing forest resources and their participation in the global cycle.
- the health and vitality of the forest ecosystem.
- and developing the ability of the forests to produce timber and other products and services.
- preserving and developing the biological diversity of the forests.
- and developing the role of the forests in water supply and protection against erosion.
- other socioeconomic roles and functions of the forests.

These criteria and similar ones have formed the basis for criteria, standards and indicators intended for **forest certifications** in many countries. They have been published by Forest Stewardship Council (FSC) and other organizations

These criteria seem to be of good use also when the corresponding elements are to be formed for the LCA assessment.

Sturm and Westphal [1995] see untouched natural forest as the goal for the management, making it very difficult to extract wood without withdrawing too much from the goal.

The Nordic view on these matters is different. Biodiversity is more seen like a specific and defined resource at the gene and species levels. In order to preserve biodiversity a number of forest landscape parameters at different levels need to be considered. In a boreal forest landscape stand structures (e.g. old trees, dead trees, hardwood trees), landscape elements (e.g. proportion of different forest types and successions, old forests, key biotopes, fragmentation levels/connectivity) and processes (e.g. forest fires, flooded areas, predator pressures, herbivore levels) are important features to take into account within a sustainable management of the forest. Since the biological diversity in such a system is dependent on disturbance, dynamics and successions, a full comprehension of the biodiversity goal can only be obtained at the landscape level (see above). This also means that even more intensive management in minor parts of a landscape is possible without putting the possibilities to maintain biodiversity at high risk. Implementation of adequate management rules is thus

important to reach biodiversity goals and the degree of implementation of such rules might be the best way of evaluating the biodiversity component of the bioquality index (see below).

An assessment system can be built up along one of two lines.

One direct one is that the parameters are based on measurements in the forests, and have to be repeated after a period of time in order to be able to detect any difference based on the changes in the management.

The other more indirect one, is that the indicators are based on how the management rules are formed and implemented. The idea is that the rules, when fulfilled, are supposed to give the desired effects on the ecosystems. If the management system is built up with effective rules for the preservation or improvement of the sustainability parameters, and the system includes controls as well as follow-up stipulations, as in a certification system, the resulting mark will be a pretty good parallel to the outcome of an LCA based on a similar battery of parameters.

8.2 The LCA procedure

In trying to implement such principles into LCAs, both ways above can be followed.

The first alternative would certainly give more exact indications of the effects of the forest management, but only after a considerable period of time, and after very cost- and time-consuming expeditions. The scientific knowledge to collect the right set of indicators is also, for most systems, too sparse.

The second alternative is more of easier desk-top work, and the evaluation can follow directly at the end of the data collection work. The certification principles used in e.g. Sweden are built up along the second way of reasoning. That means that much of the data collection work needed for an LCA is already at hand for areas that are certified if the LCA indicators are built up like the certification principles.

The normal LCA way to arrive at suitable indices describing the end effects, is to suggest principles and criteria that will cover the goals set for the evaluation, and then to name indicators that will make it possible to do the necessary calculation using figures. In principle then, the indicator parameters should be classified and characterized in the assessment step so as to be included in the ordinary effect or impact categories. If this line is followed, both the weighting and the grading function will be fulfilled. Such an approach made by B. Steen is indicated in App. No.1. This way is appropriate to follow when the weighting system holds safeguard subjects (e.g. EPS and Eco-indicator 97).

Another practical way to follow, would be to use the indicators already accepted for certification works along with the total valuation based on those values. An FSC certification may result in a mark on a percentage scale from zero to 100 %, where e.g. 80 % might be the minimum for a certificate. Most certification systems cover the whole LCA range of parameters needed, but also other parameters of the socio-economic type, which can be excluded. That would in many cases mean that the data collection work was already done at the certification, making the LCA part simple.

The forestry line is to suggest using the certification result as a whole or after breaking it down to its components wherever applicable, which then also would mean that the evaluation would be based on the management principles that guide the practical measures and their implementation.

Thus, if the indirect alternative mentioned above is followed, and the criteria and indicator sets from a certification procedure were utilized, the task for an expert group to do, would be to come up with the relations and figures needed in Fig.2 and section seven in the general part to make it possible to carry through a study.

8.3 The intensity of forest management

If the silviculture measures are intensified, e.g. by growing monocultures and increasing the amount of mineral fertilizers, the result is a plantation. In the life-cycle assessment such a transformation will result in an increase of the bioproductivity far over the potential bioproductivity combined with a serious decrease in biodiversity. The outcome of such a comparison will be positive on the productivity parameter, but negative for the biodiversity, unless special arrangements are made to increase the biodiversity in the surrounding landscape. Stephen Bass [1997] stressed the possibilities to enable us to extract our wood requirements from very small areas of land by using technological improvements, thereby potentially liberating natural forests for biodiversity conservation. "Plantations should be integrated into the forest landscape" [l.c.]. New knowledge about forest ecosystems indicate that relations between productivity and biodiversity exist and that they are more complex than their separate handling in this model is suggesting [Brussaard et al. 1997, Wardle et al. 1997]. This does not invalidate the bioquality concept but more the way of calculating such a value in the future.

8.4 Criteria

Through principles, criteria, guidelines and indicators the requirements for a forest management without environmental effects can be settled. In App. No 2 such sets of parameters are described. The main points are:

- to preserve the biodiversity,
- to maintain the ecosystem health and vitality
- to preserve unique and fragile ecosystems and landscapes
- to maintain ecological functions and integrity of forests
- to maintain the forest resources and their function as a sink for carbon

In order to ensure the fulfillment of such plans, there is also a need for:

- a management plan
- monitoring the environmental impact and
- conserve valuable areas

8.5 Calculation of forest management effects

In the general section paragraph 7.4 the formula for the calculation of the effect E per ha*yr was described;

$$E = W*(1-p)*(1-q). \quad (3)$$

In forestry the landscape should be the base for the estimation of biodiversity. When that is done, and the task is to calculate E according to equ.(3), the area A should be the area (ha) which has the annual yield suiting the purpose defined by the functional unit.

The bioquality W, consists of the two components bioproductivity and biodiversity. The full and detailed description of this bioquality must be left to later research to find out. However, based on the EPS weighting system, G Swan has suggested a connection between the LCA assessment as a whole and the forest management part, see App. No 3.

The solution was to find the willingness of the Swedish forestry to pay for a improvement from obsolete Swedish forestry management to a modern one resulting in a certification mark.

According to App. No.3, the total loss of bioquality, corresponding to a sealed area, would have the price 10 ELU/m³sub. If the annual growth of an area is 4 m³sub, it's bioquality value would then be 40 ELU/ha. In an average Swedish forest harvested in a certifiable way, the environmental effect is 2 ELU/m³sub. Considering that the average yield per ha in Northern Sweden is around 2 m³sub and about 8 m³sub in southernmost Sweden, the bioquality value for average forest areas would be 20 ELU/ha in northern Sweden and 80 ELU/ha in southern Sweden.

8.6 Example: Calculation of effect of forestry management according to EPS.

Assumptions:

Two forest areas, both having an annual yield of 4 m³sub are used. A potential bioquality value of W = 4*10 ELU = 40 ELU is calculated. One area will exemplify the obsolete Swedish forestry, having p=q=0,6. The other has better bioquality and management; p=q=0,8.

Two kinds of pulp are to be produced; mechanical pulp requiring 2,5 m³sub/ton, and bleached kraft pulp, requiring 5 m³sub. Thus the areas required are 2,5/4 = 0,625 ha, and 5/4 = 1,25 ha respectively.

Using equ. (3) on obsolete forestry and mechanical pulp the calculation is:

$$E = 0,625*40*(1-0,6)^2 = 4$$

Doing the same kind of calculations for all four cases the result in ELUs is:

Obsolete		Modern	
Mechanical	Chemical	Mechanical	Chemical
4	8	1	2

The following conclusions can be drawn from this result:

- The improvement to a modern certifiable forestry radically diminishes the impact
- When the wood utilization is halved, the effect also goes down 50%

Beside these effects connected to the land use part, those connected to the extraction of the wood should be added as part of the impacts from wood extraction in the final LCA.

8.7 Geographical boundaries.

In principle the minimum landscape area to be evaluated must offer possibilities to extract a desired amount of wood each year during a life-cycle of a forest, that is 80 to 150 years in Scandinavia. The possibilities to house different kinds of biotopes will increase further if the minimum land area is increased. Thus the forest landscape we are discussing holds preferably at least a few thousand hectares.

For smaller forest areas the bioproductivity can be estimated, whilst the biodiversity must be estimated based on the small area and its relation to the situation in the surrounding forest landscape.

A similar kind of reasoning can be applied for intensive forestry within plantations. The high loss in biodiversity might be partly compensated if the landscape holds areas with a high biodiversity. As the plantation bioproductivity usually is very high, the resulting bioquality might reach quite acceptable levels. When comparing traditional forestry with intense plantations, the comparison should usually be made per unit volume of output. Then the conventional alternative needs more forest area for the same volume of production. Thus a bigger area has to be considered.

8.8 A concrete view of a forest landscape of high and low value and after transitions.

To help create the right feeling for how the bioquality levels indicated in Fig.2 might look like, the following table 1 is presented. As with Fig.2, it is made with the traditional view on bioquality (the hemorobic scale) and should not be cited because of its figures. BAT = Best Available Technique.

Table 1. Bioquality levels based on a 0 - 100 p scale of W for a forest area

Scale No	Forest use	Infras level See [Infras]	Transition to Agricultural use	Transition to Urbanization
100	Natural forest			
90] Good modern] certified] forestry	A		
80		B		
70	Good old Swedish forestry	C		
60				
50	Obsolete Swedish forestry	D	BAT agriculture	
40	BAT plantation		Org-agriculture	
30	Normal plantation		Conventional agriculture	Green urbanization
20	Cloned plantation		Intense and specialized agriculture	Normal urbanization
10	No trees Erosion			
0	Sealed area		Sealed area	Sealed area

Above it has been suggested that bioquality is the product of bioproductivity and the biodiversity. If instead the two components of bioquality are dealt with separately, other outcomes can be discussed. Say that p has the components p_p for productivity and p_d for biodiversity. Then p can be formed in at least two different ways: $p = 0,5(p_p + p_d)$, average or $p = p_p * p_d$, product. The result can be as follows. The potential bioquality W is supposed to be 40 ELU/ha. E is calculated as $E = A * W * (1-p) * (1-q)$, where $A = 1,0$ and $q = 0,8$.

Table 2. Bioquality and final effect based on possible but not representative figures.

Type of land use	p_p	p_d	$0,5 * (p_p + p_d)$	$p_p * p_d$	$W(1-p) +$	$W(1-p) *$	E+	E*
Natural forest	0,8	1,2	1,0	0,96	0	1,6	0	0,3
Sust. Forestry	1,0	0,8	0,9	0,8	4	8,0	0,8	1,6
Productivity F	1,1	0,6	0,85	0,66	6	13,6	1,2	2,7
Norm. Plantation	1,5	0,1	0,8	0,15	8	34	1,6	6,8
Norm. Agriculture	1,2	0,2	0,7	0,24	12	30,4	2,4	6,1
Settlement	0,1	0,1	0,1	0,01	36,0	39,6	7,2	7,9

In Table 2 the resulting bioquality is very much depending on how p is built up. Two alternatives are presented in the table. The first alternative is to use the sum of the p figures, the second is to use the product. All figures here are guesstimates, yet the result indicates that Wp^* (product) is closer to our picture of the truth than $Wp+$ (average) as has been indicated earlier. Thus, for the future research, the approach made in Table 2, using the product, might be better.

9. Land use evaluation in Agriculture

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The description is mainly extracted from a paper made by part of the CPM project group [Mattsson et al 1998].

9.1 General and global issues

Agriculture requires soil covered land. Only 25% of the surface of the earth is land area, which corresponds to about 13 billion ha. Soil covers most of it in a layer, ranging in thickness from a few centimeters to several meters. Where rain and organic matter are plentiful, it may take only 50 years to build up a thin layer of soil, while in dry or cold areas it can take thousands of years. However, the process of degradation, through misuse or erosion, can be very fast [Myers 1990].

Soils vary greatly in their fertility and ability to hold water and nutrients in the right amounts for successful agriculture. Only 11% of the total land area has soils which, without improvement, are suitable for agriculture (1 500 million ha) [Myers, l.c.].

Agricultural land area is definitely a limited resource which is already a problem, and this will be an even more serious problem in the future. The management of agricultural land is also important, since it decides whether the land area will be a sink or a source of emissions.

Folke *et al.* (1996) have made calculations of the acreage needed for food and fiber supply but also land area required for reception of nitrogen and phosphate emissions and carbon dioxide from combustion of fossil fuels. Production areas (forest and farm land) are naturally used for this purpose, but the calculations showed that extra land area is needed. Under Swedish conditions there is a calculated need for 7 km² per 1000 people for forest and agricultural production, while neutralization of emissions produced by the same number of people requires between 27 and 68 km².

Most animal feed originate from plants that are not used for human consumption. It is not very efficient to use grains for animal production. It takes 10 calories of grain-feed to produce 1 calorie of meat. About 40% of the grain-production world-wide are used in animal husbandry. In USA it is even more: up till 90%, and in Sweden 75%.

The number of husbandry animals in the world is significant. There are twice as many husbandry animals as humans on earth; more than 10 billion. For example there are 3 billion cows, sheep, goats, buffaloes, camels and lamas. There are about 750 million pigs and more than 6 billion hens.

Land use in agriculture has a major impact on the environment and it is one of the most crucial issues concerning the losses of nitrogen resulting in eutrophication and acidification. Parameters like density of husbandry animals on the farmland and choice of crops influence the size of the losses directly. Cultivating crops for fiber and energy could lead to a less intense land use in agricultural districts. Jørgensen and Mortensen [1997] calculated that substitution of annual agricultural crops with perennial crops such as *Miscanthus* can decrease leaching by 60 kg N/ha under Danish conditions. Another way to reduce the negative environmental

impact of agriculture is an extensification of land use by promoting low input farming which will decrease the total losses of nutrients and pesticides from agriculture.

Agricultural use of land area contributes to global warming through N₂O and CO₂ emissions. The rate of N₂O emissions is dependent on the nitrogen content in the soil (Fleischer & Pantzar, 1997). The increase in atmospheric carbon dioxide is attributed to two anthropogenic sources: fossil fuel combustion and land cover conversion. Although the current net flux of carbon is dominated by the fossil fuel source, biogenic net sources contribute approximately 25%-30% of the total. However, over the last two hundred years the contribution from land cover conversion has been approximately equal to that of fossil fuel combustion. (Skole, 1996)

9.2 Fresh water

The availability of fresh water is likely to be the major factor limiting the world's capacity to provide food for all. Agriculture accounts for 65% of water use, but the demands of industry and urban centers are increasing. In Sweden, there are 100 people per million cubic meters of water, while in Saudi Arabia and Israel the corresponding number is 4000 people. More than 230 million people live in 20 countries, mainly in Africa and Near East, where less than 1000 cubic metres of water are available per person each year - the limit for water scarcity. [Chapter 9.2 - 9.6 refer to Myers, l.c.]

9.3 Biological diversity regarding cultivation and husbandry

The living world provides the raw stock for food production. Some 1 300 million farmers, day by day, practice on-farm conservation, selecting and refining the varieties of crops. Despite the wealth of biodiversity and more than 12 000 years of organized farming, comparatively few plants and animals have ever been widely used agriculture. So far around 270 000 plant species are known, 30 000 are edible, but only about 120 of them are widely cultivated today for food and just three - wheat, maize and rice - provide more than half of the dietary energy of the world's population. A similarly narrow base for food production exists among domesticated land animals, with just five species providing the vast majority of animal protein.

The world has already lost 10% of its domesticated animal breeds, with nearly a further 15% now at risk. As much as 85% of the genetic diversity of crops may already have been lost at a time when concern is also growing over the capacity of gene banks to preserve and maintain both in situ and ex situ collections.

9.4 Productivity

Despite this narrow base, both productivity and production have increased, with a world-wide gain of 10% in cereal production in the past decade (1985 to 1995). Over the same period, the number of domesticated animals bred for food has also risen, cattle by 3%, sheep and goats by 6%, pigs by 13% and chickens by 50%.

9.5 Threats to the world's soils

By far the greatest threat to the world's soils comes from erosion, which every year strips 25 000 million tons of topsoil away. This happens mainly as a result of deforestation, overgrazing, or poor management of arable land. Moderate to severe erosion now affects 2 000 million ha of arable and grazing land, an area larger than the United States and Mexico combined. FAO estimates that 5 to 7 million ha of productive land are lost annually because of erosion and other forms of degradation including nutrient "mining". Additionally, poor irrigation

management lead to a loss of 2 million ha annually due to salinization and 1 million ha as a result of overgrazing in dry areas. Great areas are also built at, approximately 6 million ha annually.

9.6 The future

With current population growth the arable area per person will diminish. Every person has 0.26 ha today. If we cannot slow down the population growth and land degradation we will have 0.17 ha per person in 2025 and 0.13 ha per person in the year of 2100. Remember that the productive land then also must be used to produce energy and different kinds of industrial products.

The production of animal protein demands 3 000 million ha of grazing land, which is twice as much as the arable land requirement. This can be a serious problem in a near future.

9.7 Swedish agriculture, historical development

Our open and diversified rural landscape with forests, arable and pasture land has been formed by farmers for centuries. This landscape plays an important role for recreation of modern people. The cultivated landscape also offers habitat for a large number of plants and animals adapted to this biotope. Dynamic processes keep on changing the agricultural landscape, and they will always do so (SCB & LRF, 1997).

Until the beginning of the 19th century the area under cultivation was approximately 1.5 million hectares in Sweden. In 1920, the acreage had increased to 3.7 million hectares. For a growing population more food was required. The arable land expansion reached a maximum in the 1930s, with a total of approximately 4.8 million hectares (3.7 million ha of arable land and the rest meadows and grazing pastures) (Hansson, 1992).

The major reduction of farm land took place at the end of the 1950s and the beginning of the 1960s when more than 400.000 hectares of pasture and arable land was taken out of production. Since the 1950s there has been a total reduction of 700.000 ha (20%) of farm land. The agricultural production has become highly specialised and animal husbandry has been concentrated to certain geographical areas. Mineral fertilisers has made it possible to separate plant husbandry and animal husbandry geographically (SCB, 1996).

One effect of this dramatic change, when the area for agricultural production more than doubled, was that areas with wetlands were turned into agricultural land. This transformation has created negative effects on the biodiversity in the agricultural landscape and the ability of the landscape to eliminate nutrient losses. Another profound effect of the drastic changes of the agricultural landscape was the almost total removal of the productive, broad leaved, nemoral forest ecosystems formerly found in meadows, coppice woods and pastures. These habitats were transferred mainly to cultivated grounds with and the remaining parts to forest management. Very few areas have retained traditional management of so high importance for biodiversity conservation.

After the second world war, the degree of mechanization was intensified, resulting in a decreased rural population, but also in covered drains, less meandering streams, less wet or flooded areas, less shrubbery, but larger use of pesticides. This change has regarded as

necessary for the economical survival of the Swedish agriculture, but it has also resulted in an agricultural landscape with decreased biodiversity and aesthetic experiences.

A serious threat to the farm land is the transfer into urban areas, since the loss of farm land is permanent. Especially during the late 1960s many cities and municipalities expanded at the expense of arable land. In 1977 a bill was passed that arable land should be saved if there was less valuable land available. Between 1965 and 1975 approximately 35 000 ha of arable land was transferred to urban areas. An additional 15 000 ha of arable land was turned into urban areas after 1975 (SCB, 1992).

In 1995 the arable land acreage was approximately 2.8 million hectares in Sweden (SCB, 1996). This accounts for approximately 7% of the total land area, while 54% was forest land, 9% water, 3% urban areas, 16% mountains and 11% wetlands. The distribution between different types of land varies from one region to another. In some districts arable land is dominating the landscape.

In 1997 the set-aside acreage in Sweden was approximately 5% of the arable land used for cereal and rape seed production, in order to limit the total production. This indicates that arable land is not a limited resource when current production methods are being used. In 1996 the share of organic farming was 5%. Since the average crop yields are lower for organic production, more arable land is required to maintain the same production level. As long as the amount of set-aside land in the country is substantial, lack of farm land does not appear to be a serious problem.

Cultural policy is also of importance for the environment. The Swedish Parliament stated in 1975 that "*bevarandet av den historiska kontinuiteten i den fysiska kulturmiljön måste tillmätas grundläggande betydelse för den enskildes känsla av trygghet och förankring i tillvaron*". This means that it is important to preserve the cultural environment for the well-being of people, since they experience a sense of security and anchorage in life in a familiar environment.

9.8 Environmental goals for land use in agriculture

The suggested two main environmental goals for arable land use are:

1. To preserve and if possible improve the soil properties to assure future biological production and soil fertility.
2. To assure a diversified rural landscape of high aesthetic value which also has a high ability to maintain resilience of the ecosystem.

In the first productivity goal, the soil quality is of paramount importance, since the soil is much more effected than in forestry. Important direct factors are for example content of organic matter, soil structure including degree of compacting, and accumulation of heavy metals [Audsley *et al.*, 1996]. Indirectly, low variety cultivated crops (monocultures), will be more susceptible to attacks of insects and fungi lowering the productivity, than if they had been cultivated with a larger variety of crops.

The second goal is more difficult to describe and evaluate - especially the issue concerning "high aesthetic values" - since this is very subjective. The discussions on this second goal are

based on the environmental program for Swedish agriculture which is decided according to the European Union Agriculture Policy in order to promote a more environmentally friendly production. Every member country in the EU has the freedom to suggest a national program, which means that the environmental programs are adjusted to the different national environmental goals. Therefore the suggested approach concerning goal no. 2 may only be applicable to Swedish conditions.

Anyhow, these two goals are very consistent to the bioproductivity and biodiversity components of bioquality mentioned in the general section.

9.9 Suggestions for criteria and indicators for soil fertility

a) Biological properties

Criteria: "to maintain a good level of organic matter in the soil"
"to maintain a diversified soil fauna"
"using cultivation methods which do not lead to increased weed pressure"

Example of indicator: The content of organic matter of the soil.

b) Physical properties

Criteria: "to avoid soil erosion"
"to promote good soil structure"
"to promote efficient water drainage"

Example of indicator: Soil loss caused by erosion, see Loomis & Connor (1992) and Grass & Kiefer (1993).

c) Chemical properties

Criteria: "to assure favorable soil chemistry properties"
"to avoid accumulation of heavy metals".

Example of indicators: pH, P-AI (plant available phosphorus), CEC (cation exchange capacity). These parameters are easy to measure, and it is done frequently in soil analysis of agricultural soils.

d) Crop variety in the agricultural landscape

Criteria: "some degree of diversification in the agricultural landscape due to the choice of crops"

Example of indicator: Percentage of the produced crop in relation to the total acreage.

9.10 Discussion on aesthetic values and resilience of the ecosystem

The second environmental goal is based on political policies and people's ideas of a "perfect" rural landscape; where preservation of the beauty of scenery, open landscapes, and cultural heritage are important issues. In order to promote biodiversity it is also important to assure preservation of sustainable populations of species typical for key biotopes. Functional elements are crucial for prevention of negative environmental impact like soil erosion, plant nutrient leakage etc.

a) Open landscapes

Relinquishment of arable land is considered as a problem in the whole of Norrland, the north and inland of Svealand, the inland of Götaland, the north of the West coast and parts of the islands Öland and Gotland.

b) Cultural heritage

Financial support is given to preserve arable areas with remnants of older land use in agriculture and this should be done by tending and maintenance of valuable "landscape elements".

Examples of landscape elements (only a few mentioned):

- Irregular field shapes	<i>fält med flikiga naturgivna former</i>
- Lanes (fenced with stones or wood)	<i>fägator (stenmur/trägårdsomgärdade</i>
- Stonewalls	<i>gårdsgårdar (sten/trä)</i>
- Avenues, tree and bush rows	<i>alléer, träd-och buskrader, pilevallar</i>
- Tree islets	<i>åkerholmar</i>
- Ponds formed from marl-pits	<i>märgelgravar</i>
- Summer barns	<i>sommarladugårdar</i>

c) Biodiversity

To preserve the biodiversity two areas are especially emphasised *i)* grazing pastures and *ii)* old days haymaking meadows (*slätterängar*).

i) Grazing pastures (*betesmarker*) are arranged in different classes, for example "alvarbete" (Öland) and "skogsbete, fäbodbete" (Norrland). General claims for this areas are no permitting of chemicals, fertilisers, liming or irrigation. For this type of land a financial support of 800-1600 SEK/ha yearly can be granted.

ii) Old days haymaking meadows (*slätterängar*) are very few left in Sweden and must be tended in a special way to keep these areas rich in biodiversity. (EU support of 1300-1800 SEK/ha yearly with additional support if the meadow is cut using a scythe, "lieslätter")

d) Functional elements

The aim with this part of the program is to reduce leaching of nutrients and soil erosion from arable land. Support can be granted for non-cropped areas along waters and rivers, extensive cultivated leys, catch crops and wetlands. It is a way of using elements in the environment to reduce and eliminate emissions from an intense agricultural production.

Table 2. An overview of criteria concerning land use

Open landscapes	To preserve an "open" rural country side and prevent relinquishment or forestation of arable land.
Cultural heritage	Certain landscape elements are regarded as high valued concerning cultural heritage and the "general opinion" about what the countryside should look like. Examples: meadows, stone fences, fields with irregular forms, old trees and bushes, tree islets etc. These criteria should also include preservation of old species of domestic animals, for example mountain cattle and blue ducks.
Biodiversity	Level 1 - variation of ecosystems - e.g. ponds or group of trees. Level 2 - variation of species - e.g. meadow flora Level 3 - genetic variation - e.g. varieties of frogs (e.g. <i>lövgrödan</i>)
Functional elements	Waters like wetlands, ponds and creeks Catch crops Buffer zones, for example a protection zone near rivers
Suggestion for indicators are left to future research	

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11. Land use for factories in life cycle assessment

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- General issues** To use an area of land for a factory is more or less a destructive use. The area is reshaped to be fit for the houses, constructions and process equipment. Vegetation is removed, ground water level is often lowered, rocks are flattened out, shallow waters are filled out and areas are covered with buildings, constructions, asphalt, concrete or gravel. These activities can also affect ambient biotopes outside the factory area. Lower ground water can make larger areas than the site of the factory to dry out. The increased burden from roads and storage areas on the ground can make the ground of the area of the factory to sink and the ground in the nearby sea or lake to be raised, changing the environment for water living organisms. These effects should also be accounted for. This reshaping is normally a process over several years when the area acquired for a factory is more and more being taken into use. The area used for factories globally is a minor part of the earth but is locally of great importance as the restoration back to the original natural state of conditions is impossible.
- Land use phases** We can identify three phases in land use for factories:
- Acquisition** Under this phase we acquire the land for the factory and build it. The ecosystem in the area of factories will be destroyed, the landscape altered and the surrounding biotopes changed due to changes in ground water flows. This is normally a process over a time period.
- Production** during production more and more of the acquired area is reshaped. The vegetation is removed and more buildings and other constructions are built. The gradual change and destruction of the local ecosystem can be monitored or assessed.
- Abundance** Finally factory areas are left and should be restored to a state that can be used by the nature. Restoration to the original ecosystems is impossible. But it is reasonable that all buildings and other installation shall be removed. Contaminated soil shall be cleaned. Under ground constructions shall at least be removed to an extent that makes it possible to recultivate the area.

Elements for safeguarding

The land use for factories affect the biodiversity, bioproduction, soil fertility, geology and aesthetic values in the actual area and it's near by environment. The land use as such can effect some people's health by being more or less willingly driven from their homes. This is normally a minor factor. So the major safeguarding elements are the following:

- Biodiversity This is normally drastically reduced. But the reshaping of the landscape can give resorts for other species. As factory areas including effected surroundings are limited, it is possible time to time to make inventories over the biotope in the areas.
- Bioproductivity This is normally drastically reduced. Bioproduction at the residual areas with a functioning biotope can be assessed.
- Soil fertility This is normally drastically reduced and can be assessed for the residual areas with a functioning biotope by suitable soil analyses.
- Geology The reshaping of the area has often large consequences for the ground water flows. The impact on the surroundings must be assessed.
- Aesthetic values Aesthetic and recreational values are normally lost when using land for industry. Also, this impact is to be accounted for in the assessment.

Impact evaluation

In all land use phases we can determine the effects from different activities. The amount and consequences of chemicals that we are letting out to the land, water and air are normally measured and assessed. So can amount and effects of waste water, cooling water and chemicals to water and air be measured and assessed. This is normally done in a LCA-study.

The mere fact that we use land for production of products effects the nature, even if we could do it without any pollution of the ground or ground water. We are in one or another way reshaping the nature for our purposes. This action should also be accounted for in the LCA. By time to time making inventories of the ecosystem, analyses of the soil conditions and making assessments of the environmental consequences of the reshaping of the area for factories, we can get a good picture about the impact on the local environment and in a reasonable way monitor the effects on the element to be safeguarded.

When starting the assessment we have to decide the total area to be assessed. That is the area for the factory and surrounding area which has been or will be effected. The extent of the inventories, analyses, assessments of environmental consequences and chosen bioindicators shall be stated. We also have to decide which development phases that shall be accounted for.

Acquisition

If we intend to break new land for any use, we naturally must calculate for the change we intend to do.

Production

we have to decide to what extent we shall consider, what we already have done during the acquisition phase. If for example we are to compare expansion in an old production unit with building a new plant at virgin land, we need to assess also the impact of acquisition for the old plant to get a comparison on equal terms. In other cases we can account for the reshaping made each year and write off the old effects in for example ten years.

Restoration

all assessments that include closing down a factory should contain activities for restoration to a functioning ecosystem

These inventories and assessments can give us a good base for actions to limit the consequences of the use of land for factories.

Impact evaluation

The problem is how to evaluate biodiversity, bioproduction and soil condition in a way that we can compare it with impacts from effluents of different kinds.

A coarse method is to ask people about their willingness to pay for preserving the nature or for the products that the ground can produce. An alternative is to see what governments are accounting for protecting the environment in the national budgets. These both values are used in the EPS - method. Perhaps it is the only practical way to handle the problem to day. Even if it focuses too much on the need of man.

As economists to day are searching ways to make environmental accounts and at least in Sweden you have to make assessments of the environmental consequences to get permits to build factories, roads etc, there is a growing source of economic values on the environment. (3)

Bioproduction

The impact on bioproductivity can be evaluated by the economic value of farm products, wood, cattle, marine product and game lost pro year in the actual area as a consequence of the use of the land for a factory.

Biodiversity

The impact on biodiversity can be evaluated by willingness to pay for preservation of different habitats. For example Söderqvist (1) states values for preserving seashore, pastures land and wetland and to avoid planting of spruce on arable and pasture land. He has also given

	“environmental values” for arable land, grazing land, natural grazing land, energy forest and for wetland.
Soil condition	The impact on soil condition can be evaluated by changes in bio production and bio diversity. Another value is the cost for restoration to conditions making the ground suitable for an acceptable ecosystem. The cost for restoration can be estimated to the same cost as the construction and building of the main structure of the factories plus cost for sowing and planting etc. The restoration cost shall be independent of the complexity of the processes in the factory.
Aesthetic value's	Aesthetic values and recreational uses can be evaluated by estimations of peoples willingness to pay. There are values given for recreation in forests and at sea(1,2), willingness to pay for avoiding view over industries and getting view over small houses and arable land. (1)

Expressing these costs for the impact to the safeguarding elements in ECU gives us ELU -value in the EPS-system. Then we have to decide how to allocate these environmental burdens on the production of goods. One way is to account for everything on each year's production, so some what overestimating the environmental burdens. Another way is to allocate as much as possible to each production year and allocate the restoration cost by estimating the total lifetime of the factory and divide the cost over that time.

How this has been handled shall be stated in the assessment.

To make these calculations for a production site we have to have some “natural” state of order to compare with. We can describe the area before we erected the factory. For example it could be the condition on the farm, forest or whatever was there before the transition to a factory started. The production to day on equal land could than be a base. Another way to find a state of reference is to estimate the alternative “natural” use of equal land in that area; arable or pasture lands, forest etc.

Even if the environmental burden from land use per amount of produced goods normally is small compared to environmental effects from effluents of different kind, there is a good need for land use assessment in many investment situations. All constructions ought to be done in a way so the environmental effects on the site for the factory and the surrounding land are minimized.

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Land use - Hydropower

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The harnessing of rivers for hydroelectric purposes influences both land and water resources. The size of the area used as well as the degree of utilisation, differs between different projects.

Within a catchment, hydroelectric facilities of different kinds are developed. E.g., in the uppermost parts of a river, it is common to build dams for the storage of water on a long-term basis (up to a several year's worth of run-off). Reservoirs often inundate vast areas. On downstream reaches, run-of-river plants are common. This type of power plants doesn't require the storage of large amounts of water bodies, at most a day's to a week's worth of run-off, and is therefore less land consuming.

Beside Impoundments, hydroelectric power plants require land area for power stations, switch-yards, access roads, transmission rights-of-way, quarries, dumps, control buildings and other technical structures. Furthermore, downstream of the dams, the former river reach is frequently run dry since the water is led through a tailrace tunnel to a point downstream. This is done in order to aggregate the height of delivery and hence the power output per unit.

The possible depletion of biodiversity caused by this land use has lately become an important environmental issue. Up to now, the impact on biodiversity has only been treated in a qualitative way, making it impossible to fit it into the traditional life-cycle-assessments (LCA).

One approach to make quantitative surveys of the effects on biodiversity from certain human activities, is to carry out comprehensive on-site monitoring studies and registering actual changes in biodiversity. These studies are, however, both time-consuming and expensive. Furthermore, these types of monitoring programs often lack the comparational capacities required by LCAs.

Another approach, simplified but cost-effective, is to use a set of indicators that together reflects the overall impacts on biodiversity.

In a co-operative project between Vattenfall and Scientific Certification Systems (SCS), an LCSEA-methodology (Life-Cycle Stressor Effects Assessment) is being developed, primarily for use in type III-labeling. This methodology is based on a few, easily measurable indicators that represent the impact, i.e. the deviation of the ecosystem from an established baseline, caused by e.g. hydroelectric power projects.

The indicators, as being suggested by SCS, are:

- net terrestrial habitat loss and net terrestrial habitat gain
- net aquatic habitat loss and net aquatic habitat gain
- net soil loss

The indicators are treated separately throughout the entire process, and will remain unaggregated. If found necessary, they can naturally be further divided into sub-indicators, which would also remain unaggregated.

The habitats are being classified into two categories; general and critical. Habitats are classified as general when they occur in abundance or have an extended distribution, assuming they don't support rare or endangered species. Habitats are considered critical if they are rare or if they harbour rare or endangered species.

According to this method, land use can either cause either habitat loss, or both loss of certain habitat types and gain of others. E.g., a switch yard causes loss of general or trivial terrestrial habitat types but gains none. An impoundment on the other hand causes loss of both aquatic and terrestrial habitats, general and/or trivial, but also gains in terms of aquatic habitats that were terrestrial land before flooding.

The methodology can be described as a two-step-process, characterised by the following parts:

1. Definition of the initial baseline. Mapping of the area in concern, and categorisation of the area into different habitats including splitting into critical and general habitats.
2. Definition of the current baseline. Calculation of the losses and gains of habitats and soil.

Testing the LCSEA-method

A case study based on this methodology was carried out in 1997 at Harsprånget power station, on the Lule River, northern Sweden.

The baseline was established with the use of interpretation of aerial photographs and assessment of available scientific pre-impoundment surveys. Together, these two approaches gave us a good overview of what habitats, and which species and assemblages of species, that were present prior to the project. Based on the scientific surveys, we were also able to sort the registered species into the different habitat categories, which in turn allowed us to split the habitats into general and critical habitats.

Thereafter, we mapped and calculated the area used for different purposes in this particular project and splitting the areas into lost, critical and general habitats. The net soil loss, defined as the area within the draw-down zone, was also calculated.

The results of the study can either be presented as an eco-profile (or a fingerprint) of the hydroelectric project, or as figures of losses and gains of habitats and soil per unit of electricity produced. The indicators, as reflectors of the overall impact on biodiversity, are quantitative, and since no aggregation has been made, the final outcome is transparent and allow comparisons with other power plants.

However, it is not unlikely that every hydropower project, depending on the biogeographical setting, to some extent affects a unique set of habitat categories. It is therefore necessary to describe and quantify these habitats for every new project that is to be evaluated. In the future, one can hope for the development of the methodology even further in order to make full-cost-chain comparisons between all important impacts of different methods for power generation.

Impact assessment of land use in the EPS system and in ISO terms.

By Bengt Steen, CPM

ISO has described the impact assessment procedure to include the following steps:

1. choice of impact categories
2. choice of impact indicators within the categories
3. identifying relations between inventory parameters and impact categories
4. modelling relations between impact parameters and impact indicators, usually in the form of characterisation factors
5. weighting different impact indicators to one or several common numbers

The EPS system has chosen impact categories and indicators from five safeguard subjects. The indicators are chosen considering both the possibility of finding characterisation factors and weighting factors. Other aspects considered is to minimise overlapping and to cover most environmental impacts caused by human activities.

As for ground use several parameters has to be chosen. Initially inventory parameters have to be identified. Normally an industrial plant can be characterised with respect to its impacts from flows to and from the plant. For ground use this is not directly applicable. Other inventory parameters have to be considered. For example managing measures.

In a similar way as for impact assessment of flows, impact categories should be chosen. For the EPS system these are shown in table 1. Today however there are no models connecting inventory parameters to impact indicators. Such characterisation factors ought to be possible to derive from multiple regression analysis where managing measures and impact indicators are measured.

Further research in this area is recommended.

Safe guard subject	Impact category	Impact indicator
Biodiversity	Annual decrease of global biodiversity	Portion of globally endangered species
Ecosystem production capacity	Crop growth rate	Decrease in kg
--	Wood growth rate.	Decrease in kg dry substance
--	Fish and meat production rate.	Decrease in kg
Natural stock resources	Depletion of ore resources.	Decrease in kg metal
--	Depletion of fossil mineral resources	Decrease in kg oil, coal or gas
Human health	Excess mortality	One case of excess death or 50% reduction of life expectancy at birth
--	Severe morbidity and suffering	Person-years
--	Morbidity	Person-years
--	Severe nuisance	Person-years
--	Moderate nuisance	Person-years
Aesthetic values		

Table 1 Impact indicators in the EPS system

EXAMPLES OF STRUCTURE FOR ENVIRONMENTAL IMPACT PRINCIPLES ETC. FOR SUSTAINABLE FORESTRY

(Italic letters corresponds to criteria and indicators used in the political processes for nations in Helsinki, while fat letters corresponds to contents originating from the Montreal-process. Contents written with common letters area derived from different certification documents.)

PRINCIPLES

Preserve biodiversity

- Protect rare, threatened and endangered species
- Protect representative samples of different ecosystems in natural state
- Avoid use of chemicals
- Document use of biological control agents
- Control and monitor use of exotic species

STANDARDS/GUIDELINES

- Specified types and proportion of productive forest lands of valuable habitats shall be preserved or managed for biodiversity
- Specification of valuable habitats in need for specific management and demand of such management
- Demand of conservation evaluation of areas planned for cuttings
- Rules for hardwood proportions after thinning operations
- Rules for management in stands bordering to open cultural areas
- Rules for the protection of small valuable habitats
- Rules for green tree retention
- Rules for dead wood maintenance and restoration
- Rules for use of native tree species and provenances
- Rules for use of natural regeneration
- Rules for afforestation of

INDICATORS at different levels (Indirect indicators)

- Use of exotic species and genetically engineered organisms.
- Involvement of ecological expertise in planning and management
- Extent and use of data concerning biodiversity, habitat conditions and species' requirements
- Degree of retention of desirable habitat features
- Status of working relationships with eg county and community authorities
- Extent and condition of nature conservation special management areas.
- Frequency and effectiveness of chemical use
- Avoidance of methods causing need of chemical use
- Use of targeted versus broadcast aerial chemical application
- Policies and procedures for proper use and disposal of hazardous

abandoned farmlands and its edge zones

- Rules for the use of exotic tree species
- Demands on environmental management system and continuous improvement
- Demands regarding handling of chemicals
- Demands about use of environmental impact assessments in connection to use of new methods
- Rules about future age distribution among forest stands
- Rules about level of hardwood dominated stands
- Demands about use of ecological landscape planning procedures
- Rules about actions to counteract high levels of herbivory from game species
- Rules about restrictions in connection to localities for red-listed species and places of importance for the cultural heritage.

materials

- Structural components of ecosystems
- Diversity in comparison with natural ecosystems
- Coherence of the forest landscape
- Degree of fragmentation
- Provision of wildlife corridors
- Changes of habitats
- Landscape diversity per unit area
- Ecosystem diversity per unit area
- Species diversity per unit area and forest type
- Genetic diversity per unit area and forest type
- Regenerative ability of the ecosystem
- Legal framework to enhance biodiversity in forest ecosystems
- Institutional framework to maintain and conserve biodiversity and threatened species
- Financial instruments to support maintenance of biodiversity and threatened species
- Informational means to implement the policy framework
- Area of stands managed for conservation

2

- Area of stands with exotic species
- Tree species composition
- Development classes of stands
- Proportion of natural regeneration
- Number and volume of dead standing trees per unit of area
- Number and volume of lying decaying trees per unit area
- Trees to be left uncut in production forests
- Number of aspen, goat willow larger than 10 cm and valuable deciduous trees of all sizes per hectare
- Primeval pines, numgber and proportion.
- Protection of valuable biotopes
- Area and changes in area of prescribed burning
- Area of burned forest
- Old-growth forest area
- Area and changes in area of undrained spruce swamps and pine bogs
- Changes in numbers of specific forest bird species
- Coverage of ecosystem management plans
- Coverage of landscape-ecology forest planning
- Changes in the number and

3

Preserve soils and their productivity or *Maintenance of forest ecosystem health and vitality.*

-Write guidelines for protection against erosion, against forest damage and of water resources

-Specification of rules for forestry in connection to aquatic systems
-Specification of rules for fertilisation, use of energy components, soil scarification and prescribed burning

proportion of threatened species

- Length of managed rotations relative to ecological rotations
- Efforts to maintain nutrient capital
- Extent of soil damage during harvest operations
- Extent of whole tree harvesting
- Exposure of soils to harsh micro-climatic stress
- Design and execution of watercourse buffer policies
- Extent and effectiveness of stream restoration projects
- Effectiveness and maintenance of stream crossings
- Frequency of stream crossings within harvest areas
- Locations of roadways near watercourses
- Road bank vegetative mgmt near watercourses
- Extent of roadway rainfall runoff into watercourses
- Area of specific forest types
- Total ecosystem biomass
- Biomass of specific ecosystem components
- Population monitoring of selected species
- Biomass removal/destruction
- Growth rates of selected organisms

- Nature and abundance of regeneration in monitored plots
- Fecundity of organisms
- Rates of ecosystem disturbance
- Soil nutrient status
- Level of specific air pollutants in relation to critical loads/levels
- Incidence of rapid mass movements
- Incidence of other natural hazards
- Incidence of slow mass movements
- Soil erosion
- Soil microflora and microfauna
- Soil quality
- Water quantity
- Chemical water quality
- Biological water quality
- Legal framework that enforces the control of deposition of air pollutants and soil and water quality
- Institutional framework to arrange monitoring of forest health, soil and water quality
- Financial instruments to support improvement of forest health and protection of water and soils
- Informational means to carry out and apply research on forest health, soil and water quality

- Amount and changes over the past 5 years in deposition of air pollutants
- Changes in serious defoliation of forests
- Areas with serious damage caused by: insects, diseases, fire, storm, snow, cold, frost, game species
- Changes in nutrient balance and acidity
- Degree of pollution in forest soils due to a moss survey
- Amount of organic matter in the humus layer
- Number and area of forest lands sensitive to erosion
- Number and area of shelter zones in regeneration, soil preparation, fertilisation, use of pesticides and prescribed burning areas
- Number and area of first sime drainage
- Drained peatlands fertilised with phosphor

Preserve unique and fragile ecosystems and landscapes

- Protect representative samples of different ecosystems in natural state

Maintain ecological functions and integrity of forests

- Maintain or restore ecological functions and values e.g. forest regeneration, succession, diversity and natural cycles

- Site type and seral stage distribution within forest landscapes

- Age, size and species diversity of

Write an management plan

- Description of what a plan must include
- Demands of revision
- Demands on training
- Demands on transparency

- trees in stands
- Occurrence and diversity of natural shrub, field and bottom layers of vegetation
- Extent of green retention after harvest operations
- Vertical diversity
- Use of exotic species and genetically engineered organisms.
- Breadth, depth and currency of the forest plan
- Inclusion of ecological planning in the system
- Occurrence of written guidelines to avoid or minimize environmental impact
- Extent of use of forest plan by field foresters
- Extent to which aggregate harvesting activities are recociled to the forest plan
- Extent and accuracy of field data
- Monitoring procedures
- Adequacy of planning response to natural catastrophies

Monitor the environmental impact

- Complete assessment of environmental impact
- Demands on monitoring methods
- Chain of custody demands fulfilled
- Demands on monitoring transparency
- Protect representative samples of

Conserve valuable areas

- Extent to which areas of

different ecosystems in natural state

-Planting may not alter natural ecosystems

ecological significance are afforded protection

- Permanence of retained set-aside areas
- Observations of alterations due to logging in protected areas
- Legal framework to protect forests
- Institutional framework to protect forests
- Financial instruments to protect forests
- Informational means to implement policy frameworks
- Number and area of forests included in protected areas
- Representativeness of protected forests
- Areas of strictly protected forests
- Forest conservation programmes and plans and their implementation
- Changes in area of forests protected by special mgmt regime
- Legal framework to maintain forest resources, secure mgmt of the growing stock and secure clarity of rights related forests
- Institutional framework to maintain forest resources and integrate management and land-use planning

Maintenance and appropriate enhancement of forest resources and their contribution to global carbon cycles, **contribution to global ecological cycles**

-Financial instruments to influence forest conditions

- Informational means to implement policy framework
- Area of forest and other wooded land
- Changes in: volume of growing stock, mean volume of the growth stock, age structure and stand development distribution
- Carbon balance
- Use of wood and wood-originating energy resources.
- Specific impact studies of forest on air quality, water quality
- Radiatively active gas emissions from forests
- A total carbon budget
- Disturbance of sensitive ecosystems (e.g. peatlands) by forest practices
- Hydrological cycle
- Interactions among species

Appendix No 3.

Land use index for forest management - effect on biodiversity/sustainability.

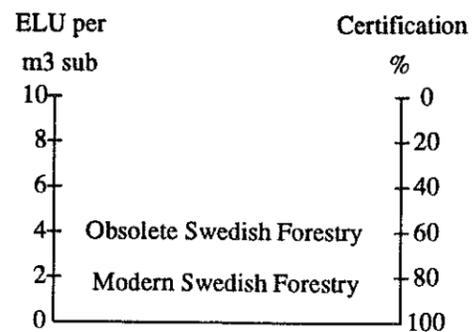
G Swan, Stora Corporate Research, Säffle. Second version 97-11-25

Within the EPS valuation method, a calculation of land use forestry was earlier made based on the willingness to pay for the Swedish forestry part of the loss of global biodiversity. The outcome for Sweden was about 0.9 ELU per m³sub (cubic meter of solid wood under bark). Originally the index was calculated per sq. meter, but as the area needed to harvest a volume unit of wood varies a lot, it is more convenient to use the unit ELU/ m³sub. The effect of the forest management was thus allocated on the most important product of forestry, and the product which is causing the major part of the loss in bioquality as well.

Swedish foresters nowadays can make a calculation based on an estimation of the real loss of income if such measures were taken as to ensure certification for the Swedish forests.

What they say is, that if 10 % of the present cut is preserved, as reservations or as savings in exotic biotopes, in corridors and as living or dead wood in clear-cuttings, certification would be reached. The cost or lost income for those cubic meter wood not being cut, would then be 10 % of the value of the wood, which in Sweden can be estimated to 200 kr/m³sub. Thus the cost for arriving at the certification level from the now obsolete Swedish forestry is 20 kr/m³, which is just above 2 ECU, or as many ELU (Environmental Load Units).

If the obsolete forestry corresponds to 60% on the FSC scale, there is a step of about 2 ELU/m³sub to reach the 80% level. Based on these two points mentioned, an ELU scale can be fit in as shown below.



Because of the connection to the certification, this revised ELU scale includes not only the biodiversity, but rather the total aspect of environmental safeguarding in land use.

Following this, the value of 4 ELU/m³sub is suggested for common use of softwood for a forestry of the now obsolete Swedish type, corresponding to 0,010 ELU/kg softwood (density 415 kg/m³ oven dry), and 0,009 ELU/m³fub for birch (450).

For modern Swedish forestry passing the 80 per cent bar for certification, the value will be 2 ELU/m³sub based on the same way of reasoning.