SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY

Intermediary report - January 2003

FRAMEWORK FOR ASSESSING SUSTAINABILITY LEVELS IN BELGIAN AGRICULTURAL SYSTEMS - SAFE
CP-28

UCL - KUL

SPSD II

PART 1
SUSTAINABLE PRODUCTION AND CONSUMPTION PATTERNS

- GENERAL ISSUES
- AGRO-FOOD
- ENERGY
- TRANSPORT

This research project is realised within the framework of the Scientific support plan for a sustainable development policy (SPSD II)

Part I "Sustainable production and consumption patterns"

The appendixes to this report are available at :
http://www.belspo.be (FEDRA)

Published in 2003 by the
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OSTC PROJECT CP 04

FRAMEWORK FOR ASSESSING SUSTAINABILITY LEVELS IN BELGIAN AGRICULTURAL SYSTEMS - SAFE

ANNUAL REPORT 2002

SCIENTIFIC REPORT

CONTENT

4-12-2002

I INTRODUCTION

I.1 Context and summary

The project is a collaboration between Prof. Hermy and Prof. Muys (Laboratory of Forest, Nature and Landscape Research, KULeuven), Prof. Vanclooster and Prof. Bielders (Department of Environmental Sciences and Land Use Planning, UCL), Prof. Mathijs (Agricultural and Environmental Economics Unit, KULeuven) and Prof. Peeters (Laboratory of grassland Ecology, UCL).

The sustainability of farming systems is currently under debate. There is indeed a strong concern that the intensification of agriculture has long term consequences for soil and water quality, for global climate and for biodiversity. As a consequence, sustainability should thus be regarded in the future as an emergent property of agricultural systems.

At international level, several organisations are analysing and testing sets of agri-environmental indicators: Elisa project (EU, Wascher, 2000), OECD Environmental Indicators for Agriculture (OECD, 2000), …

This project suggests a holistic approach to deal with sustainability in agriculture by definition of an analytical framework which integrates all factors influencing and influenced by agriculture. The proposed analytical framework is not intended to find a common solution for sustainability in Belgian agriculture, but to suggest a management tool for the identification, development and evaluation of locally more appropriate agricultural techniques. At a first stage, a literature review of existing methods (criteria and indicators) will be made and a first set of indicators tested on the field. Existing methods will be compared to identify effectiveness, deficiencies and similarities, from which to build forward.

I.2 Objectives

The analysis of sustainability will be mainly based on the multiple functions performed by agriculture within the ecosystem/landscape where it is practiced, such as food production, soil, water, landscape and biodiversity conservation functions. Existing and new indicators will be used for the analysis. They will be measured, calculated and/or extrapolated at three scales: field, farm and ecosystem/landscape. This will help understanding the interactions between the different scales of indicators, as well as their geographic distribution. The field scale gives the opportunity to compare different management techniques. We are interested in conventional and alternative/innovative techniques, such as mechanical weed treatment, minimum labour and reduction of pesticide applications in the field margins. The farm level is the critical unit for practical implementation of different management techniques. Finally, the ecosystem/landscape is the dimension able to reflect both agricultural and ecological multifunctionality. Considerations on biodiversity and landscape conservation will be of special importance at this level given that the other two scales are too small to adequately reflect them.

Four test sites, defined at the ecosystem/landscape level, will be monitored during the project. Several parcels will be comprised in a single test site, including conventional and alternative situations. The sustainability evaluation will be of comparative character, either (a) spatial (simultaneous analysis of several parcels within a test site, a reference will be chosen for each site) or (b) temporal (analysis of the same system over time).

The most important step for the final definition of the analytical framework will be the choice of a technique to combine all the measured indicators in order to obtain a global sustainable performance of the different agricultural practices studied. Three different techniques will be researched during the project: qualitative, quantitative and graphic.

I.3 Expected outcomes

The resulting analytical framework will provide a scientifically sound tool for decision making in agriculture, incorporating sustainability concerns. Therefore, it will enable the enhancement of environmental quality in the long term, ensuring at the same time the continuity of agriculture not only as a productive activity but also as a provider of environmental goods and services. This coherent resulting analytic framework will accomplish the preconditions for the development of policy objectives and measures to support sustainable agriculture at local/regional level.

II DETAILED DESCRIPTION OF THE SCIENTIFIC METHODOLOGY

II.1 Hierarchical framework for SAFE

The first year was important for the development of the general framework.

II.1.1 Sustainable agriculture

Sustainable agriculture can be defined as agriculture that conserves the resources of the earth, water, plants and animals, does not degrade the environment, is economically viable and socially acceptable (Hinrichsen, 1997).

Where the emphasis used to be on yield increasing technologies, the idea of ecological and social sustainability next to economics gradually appeared in agricultural practices.

In the 'sustainable agriculture idea', an agricultural system is considered as an ecosystem. The Conference on Biological Diversity (1992) defined this as a "dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit". Within this agro-ecosystem, biological diversity should be maintained or enhanced. This includes diversity within species, between species and ecosystems (CBD, 1992).

The objective of the hierarchical framework is evaluating sustainability in agriculture by selection of principles, criteria and indicators. The indicators will be selected to measure the sustainability level of a particular system.

II.1.2 Hierarchical framework structure

In Figure II-1, definitions and examples of each component of the hierarchical framework are provided.

II.1.3 Selection of principles

The multifunctional character of the agro-ecosystems concerns three pillars: economic, environmental and social pillars. Diverse functions performed by the agro-ecosystem are associated (Table II-1). The following list is not hierarchical, the three pillars are equally important.

Principles are associated to these functions (Table II-2).

To emphasise long-term ecological sustainability, the system must (Altieri, 1995):

- Reduce energy and other resource use
- Employ production methods that restore homeostatic mechanisms conducive to community stability, optimise the rate of turnover and recycling of matter and nutrients, maximise the multiple-use capacity of the landscape, and ensure an efficient energy flow
- Encourage local production of food items adapted to the natural and socio-economic setting
- Reduce costs and increase the efficiency and economic viability of small and medium-sized farms, thereby promoting a diverse, potentially resilient agricultural system

A principle must be formulated as a wish to strive for.

II.1.4 Selection of criteria

A criterion is the resulting state or aspect of the agro-ecosystem when the principle related to it, is respected. Criteria are specific objectives, more concrete than principles, and therefore easier to assess and to link indicators to.

The selection of criteria is based on the knowledge of the system of study. They will not be defined on a case study basis but taking into account the broader conditions of the area where the framework is to be applied (Table II-2).

The formulation of a criterion must allow a verdict (Yes/No) on the compliance with the criterion in an actual situation.

II.1.5 Selection of indicators

There are several conditions an indicator should fulfil (Doran & Parkin, 1994; Archard & Martin, 2002; Dumanski & Pieri, 2000):

- They should be measurable in time and space
- They should reflect changes over a recognisable time period
- They should reflect spatial changes
- They should be analytically sound
- They should be understandable by both policy makers and farmers
- They should be feasible to obtain or to develop
- They should be a function of independent variables
- They should be applicable to different scale levels

An extensive list of indicators is presented in Annex IV : List of proposed principles, criteria and indicators for measurement.

II.1.6 Spatial and temporal scale

II.1.6.1 SPATIAL SCALE

The SAFE project concentrates on the parcel/farm/landscape levels:

(a) Field. This scale gives the opportunity to compare different management techniques;

(b) Farm. It is the critical level for practical implementation of different management techniques;

(c) Ecosystem/landscape. It is the dimension that best reflects both agricultural and ecological multifunctionality. Considerations on biodiversity and landscape conservation will be of special importance at this level.

TEMPORAL SCALE

Although we are aware that some principles will be ideally formulated differently in short and long term, the SAFE project analyses the present situation.

II.1.6.2 SCALE DEPENDENCY

Goal and Principles are to be formulated so that they become scale independent. The same kind of formulation is desirable for Criteria.

Scale dependency appears only at the Indicator level.

II.1.7 Applications of the hierarchical framework

After a first evaluation of the agricultural systems (parcel, farm and landscape) in 2002 by the indicators set, we will improve the system.

The goal is to obtain a maximum of valid information with a minimum data collection. This information must give recommendations of actions in order to reach a higher level of sustainability, compromise between the different functions performed by the agro-ecosystems and the unique state of the farm (pedology, climatology, sociology and economics).

The analysis must enlighten decision makers and attract farmers. It must provide information for investments and must allow to find a compromise between profitability and environmental constraints.

II.2 Experiment

II.2.1 Selection and monitoring of test sites (all teams)

Four farms and their surroundings are selected as test sites. The selection is based on the following criteria.

- Geographic position (different regions in Belgium)
- Social aspect ; co-operation and enthusiasm for the project of the farmer.
- Use of alternative or innovative practices.
- Representativeness of the farm within the region

It should be taken into account that criteria: alternative practices or co-operativeness of the farmer lead into an error for representativeness.

II.2.2 Description of agricultural production systems

The basic components of an agroecosystem which will enhance sustainability include (Altieri, 1995):

- Vegetative cover as an effective soil and water-conserving measure, met through the use of no-tillage practices, mulch farming, and use of cover crops.
- Regular supply of organic matter (manure, compost) and promotion of soil biotic activity
- Nutrient recycling mechanisms through the use of crop rotations, crop/livestock mixed systems, intercropping systems based on legumes, etc
- Pest regulation ensured through enhanced activity of biological control agents achieved through biodiversity manipulations and by introducing and /or conserving enemies.
- Enhanced biological pest control through crop diversification
- Increased multiple use capacity of the landscape
- Sustained crop production without use of environmentally degrading chemical inputs.

The objective of the description is to have a global view of the farming system, which indicates:

- Yield per ha and Production /LU (meat, milk…)
- State of equilibrium between crop production and animal breeding activities
- Use of input (fertiliser, pesticide, drug, energy, capital, land)
- Use of technique for increasing the efficiency of input use: crop rotation, tillage features…
- Marketing system .

Agriculture production features are needed for calculating and deriving indicators related to productive function of agro-ecosystems.

For data collection, farmers received a logbook. In this logbook they are asked to fill in information about crop and land management. This winter a logbook for animal activities will be given to the farmers to obtain additional data. For the economic and social aspects they will get a questionnaire. Once during the project period, there will be a survey on the impact of agriculture on the neighbourhood.

For the landscape level, we will use data from INS (National Statistical Institute), and CEA (Centre for Agricultural Economics).

II.3 Development and evaluation of indicators

II.3.1 Farming system

A literature review has been carried out for selecting suitable indicators: Diagnostic SOLAGRO (Pointereau *et al*., 1999), ECOBILAN (Rossier, 1999), Multi-objectif parameter (Vereijken, 1997), PAEXA, ECOFARM (Van Bol, 2000), PROP'EAU-SABLE (Lambert *et al.,* 2002), EdeN (Couvreur, en cours), European CAPER Project (1999), SAFE 1 (Van Bol *et al*., 1998), OECD (2001), ELISA (EU concerted Action Project on Environmental Indicators for Sustainable Agriculture) and the Washer's technical report (2000)...

For some subjects, the literature review is running its course.

II.3.2 Water and soil quality

Simply said, sustainable agriculture means that agricultural production systems should be managed in such a way that future generations will still be able to feed the world population with nutritious and healthy food. Where the emphasis used to be on fertiliser research in order to reach this goal, it shifted gradually towards the sustainable agriculture idea. This means that agricultural production should be maintained but also that the soil quality should be maintained. Closely related to soil quality there is groundwater quality.

Soil quality was defined by the Soil Science Society of America (USDA http://soils.usda.gov/sqi/sqiinfo.html) as the capacity of a specific soil to function within natural or managed ecosystem boundaries to sustain plant and animal production, maintain or enhance water quality and support human health and habitation.

There are several methods mentioned in literature to evaluate soil quality. The first is to define a soil quality index as proposed by Doran and Parking (1994) and Parr et al. (1992). The soil quality index of Parr et al.(1992) is a function of several soil properties, potential productivity, environmental factors, health, erodibility, biological diversity, food quality and management inputs. The soil quality index of Doran and Parking (1994) is a function of food and fibre production, erosivity, ground water quality, surface water quality, air quality and food quality.

These soil quality indexes demand an enormous amount of data, which is not always available. Therefore minimum data sets were proposed, which contain the most important data to determine soil Quality, that should be measured always. The minimum data set of Doran and Parking (1994) and Archard and Martin (2002) are given in Table II-3.

There is still no consensus about the minimum data set, what can also be seen in this table. The question is if it is possible to establish such a minimum data set, because soil conditions are highly variable within and between regions. This implies that a minimum data set can give perfect results for one region, but bad results for an other region, where other factors are more important, for instance salinity or erosion.

Looking at these minimum data sets, it can be noticed that the indicators mentioned give only an indication of the soil quality at a certain time. Most indicators do not take temporal variation into account, which is important when studying sustainability: The indicators evaluating sustainability should give an impression about the future, reflect changes so that a good evaluation of sustainability can be made. The indicators as mentioned in table 3 will be referred to as time invariant indicators. The indicator types mentioned below will be referred to as time variant indicators. These indicators can be:

- Risk assessments: These indicators give a risk of a non-sustainable property that can occur in a specific kind of management or landscape, for instance leaching risk or erosion risk.

- Trends: These indicators can be based on time invariant indicators but they should reflect changes in time. They will give information on the magnitude of change and the velocity of change. Also a stability index should be incorporated, to define optimal situations.

- Balances: These indicators do not only show the in- and outputs, but also the efficiency, for instance water balance, nutrient balance.

In this project, different types of indicators will be evaluated.

II.3.3 Biodiversity

Several indicators have been proposed to measure or evaluate biodiversity. However, a consensus on one or more indicators is probably utopian, because biodiversity as a whole is far too vast and complex to summarise easily. Nevertheless, several general conditions that biodiversity indicators should meet are proposed by different authors. Niëmela (2001) gives a compilation of most occurring conditions (Table II-4.)

In some cases, one specific indicator, often an indicator species (e.g. Chase et al. 2000), is used to evaluate the condition of the environment or an aspect of that. However, when it comes to evaluation of general biodiversity on ecosystem level, researchers tend to promote the use of sets of indicators (e.g. multi-taxa indicator sets, Van Dijck ET al., 1999).

II.3.3.1 Indicator subset

A large amount of biodiversity indicators was identified using literature, scientific databases and internet. Those and new indicators were included in an extensive indicator list. From this list an indicator subset was selected for further development within the project. They are presented in the framework; biodiversity indicators are covered by principles 8 to 10. Because indicators will be tested, evaluated and compared during the project, the subset contains several analogous indicators for the same topic. Further selection will refine and compact the framework into a final indicator set.

II.3.4 Socio-economics

II.3.4.1 Indicator subset

The ALME team monitors indicators for different principles: (1) Economic well-being of local communities function of the ecosystem shall be maintained, (2) Production of Food and Raw materials function of the ecosystem shall be maintained, (3) Social well-being of local communities function of the ecosystem shall be maintained, (4) Welfare of livestock shall be maintained, (5) Aesthetic information function of the ecosystem shall be maintained, and (6) Recreation function of the ecosystem shall be maintained. A literature review has been carried out to identify and select suitable indicators that best reflect these principles. The indicators are presented in the framework.

II.3.4.2 Monitoring indicators

The economic indicators values will be obtained by analysing the bookkeeping data. Bookkeepings of the last 3 years were collected and compared with average Belgian values (from the Centre of Agricultural Economics) to get an idea of the financial situation of each farm. An interview with the farmers will give additional information about economic indicators. This questionnaire will also give information about the social pillars: the quality of life of the farmer and his family, the welfare of livestock. An enquiry in the local village will give more information about the image of agriculture.

To combine financial returns and environmental impacts, Hill (2001) developed a sustainability indicator at farm level, based on macro-economic sustainability indicators. The farm level indicator of sustainability is summarised as:

$$ENVA = NVA - Dep.\ K_N - Deg.\ K_N - X + Y$$

where ENVA is environmentally adjusted net value added, NVA the net value added, Dep. K_N and Deg. K_N are depreciation allowances for the depletion and degradation of on-farm natural capital, X represents the sum of all negative environmental externalities, including the depletion and degradation of off-farm natural capital, and Y represents the sum of all positive environmental externalities including non-market ecosystems service flows. For the internalisation of externalities, the results of the 3 other teams will be used. To assign economic values to the externalities, measured by the other teams, different methods can be applied, for example:

1. Pretty *et al.* (2000) estimated the costs of erosion as the off-site costs that arise when soil carried off farms by water or wind blocks ditches and roads, damages property and induces traffic accidents.
2. Bailey *et al*. (1999) estimated the economic value of earthworms as the difference in cost between ploughing and minimal tillage practices, assuming that the difference equates to the value of the soil structuring service provided by earthworms. In order to calculate the economic value of nitrate lost from the agricultural system, it was assumed that all the residue in the soil is leached from the system. The environmental damage cost incurred as a result of this leaching was taken to be equal to the costs of treating the pollution. In the case of ground water this equates to the cost of removal of nitrates from the water when it is abstracted for drinking water.
3. Pesticides can affect workers engaged in their manufacture, transport and disposal, operators who apply them in the field, and the general public. Both acute and chronic effects of pesticides warrant concern. The acute toxicity of most pesticides is well documented but information on chronic human illnesses resulting from pesticide exposure, including cancer, is weak and therefore it is almost impossible to calculate the costs of chronic effects of pesticide use (Pimentel and Acquay, 1992, Pretty *et al*., 2000). So the costs of pesticide use can be calculated as the costs for the farmer (doctor and medical costs) and the general health system (Pretty *et al*., 2000).

4. Agricultural landscapes are the visible outcomes from the interaction between agriculture, natural resources and the environment, and encompass amenity, cultural and other societal values. Considering agricultural landscape as a public good, its economic value should be analysed as such. A possible approach is based on surrogate markets, allowing to estimate the use value. One of the most important use values of the agricultural landscape is the recreational value. This can be defined as the value people attach to the use of agricultural landscape for recreational activities, such as enjoying the silence and beauty by staying, walking, cycling and driving through the countryside. An appropriate method to estimate the value of recreational sites is the travel cost method because most of the rural tourists have to travel to enjoy the landscape (Vanslembrouck, 2002).

A logbook, kept by the farmers and the bookkeeping data will give the information to calculate the energetic indicator values. Other information is collected in literature. For this energetic analysis all inputs and outputs of each system (parcel, farm) are defined.

II.4 Monitoring ecosystems

The first monitoring will take place before the first field campaign to characterize the starting situation. Maps are created for spatial presentation of the situation, but we must wait till April or June 2003 (for economic indicators) to have the result for the campain 2002.

II.5 Monitoring energy

Energy analysis provides a good supplement to economic valuation in order to identify externalities because energy use may also be considered as an environmental issue (Bailey et al., 1999). Energy performance of the different practices will be monitored in order to calculate the efficiency in the use of resources. The energy analysis will follow a life cycle assessment (LCA) approach. Life cycle assessment is a method to compile a total inventory, to evaluate and to assess all relevant environmental impacts (Haas *et al.*, 2001). For the energy analysis an input/output balance model of the system will be made and the results will be expressed per ha of land, per ton dry matter of foodstuff produced and per monetary value (Euro). This model analyses the energy transfers between the different agroecosystem components. The methodology can be applied to the farm, considered as hierarchically organised in the following way: individual fields; individual crops, animal breeding and whole farm (Tellarini and Caporali, 2000).

To analyse *ecosystems* Odum (1996) introduced the term “emergy”. Emergy is defined as the energy of one type, i.e., solar energy, required to produce a certain good or flow. The emergy-accounting unit is solar emjoules, this unit results from the fact that every joule on earth could be carried back to the sun. The factor between the usual energy unit joules and solar emjoules is the *transformity* value (Lagerberg, 2000). The environmental resource fraction that is used in agriculture without being priced or accounted for commercial purposes is in an emergy analysis called ‘emternality’ and its dimension is defined by the measurement of nonmarket environmental inputs into economic processes. Emternalities are evaluated in emergy and monetary terms, the former being a quantitative tool for valuing natural ecosystems interacting with economic systems. Emergy accounting allows evaluation of all work done or needed to produce agricultural outputs. All incoming flows (nonmarket inputs such as sun, wind, land as well as market inputs like seeds, pesticides and fuels) that contribute to agricultural products, including the final products (e.g.

crops or livestock), can therefore be evaluated in emjoules. The emergy analysis can be compared with and forms a valuable addition to an economic cost benefit analysis (Maradan *et al*., 2000).

The energetic analyses will be carried out at parcel and farm level. A report containing a literature review has been produced.

II.6 Monitoring economics

For the internalisation of external costs, a cost benefit analysis (CBA) will be used. Developments in modern agriculture include heavy reliance on chemical fertilisers, pesticides and herbicides, the destruction of wildlife habitats, environmental pollution and risks to human health (Rigby *et al*., 2001). The costs of using the environment in this way are called externalities, because they are side effects of the economic activity and their costs are not part of the prices paid by producers or consumers. CBA applies monetary values to all costs and benefits resulting from an action to be undertaken (Bailey *et al*., 1999; Park *et al*., 1999). Measurements of agricultural productivity as yield and direct economic profit for the farmer will be performed. The output from agriculture is conventionally measured in financial terms. Farm income, or profit, on arable farms for example, is a function of yield, crop price, area payments, and the costs directly influenced by management variables such as input choices and levels of fertiliser and pesticide use and cultivation practices. Conventional farm accounts are, therefore, the main criteria for measuring the financial viability of agricultural systems (Bailey *et al*., 1999).

The economic analyses will be carried out at parcel and farm level. A report containing a literature review has been produced (see annex III).

II.7 Data management

The database management is supervised by GERU. In the first project year a project-website has been created (http://www.geru.ucl.ac.be/recherche/projets/Safe/publications/index.htm) as well as a project folder for distribution. On this website a general description of the project is given, information about the project partners and information about the members of the users committee. In the future it will be possible to give more background information about the work of the teams.

An FTP-server is linked to the web-page and makes it possible for the project partners to transfer and store data. All general data, as maps, information about the farms, and field information is stored on the FTP-server and can be accessed by all project partners.

For the GERU part, the data will be geo-referenced, using GPS (global positioning system). They can be linked to the maps available in ArcView 3.2.

II.8 Dissemination of results

Two Users'committee meetings took place in the first year. The first, on 21st May 2002, aimed at the presentation of the project. Before the second one, on 17th October 2002, a document had been distributed, which facilitated discussion during the meeting.

III INTERMEDIARY RESULTS

III.1 Experiment

The selection does not aim to be representative of the Belgian agriculture. The farms selected are more innovative and efficient than the average.

Three farms are mixed, they associate milk and crop production (Table III-1), the last one is specialised in crop production: wheat, sugar beet, chicory, meadow grass for seed production, flax, set-aside. (annex II: aerial view of cultivated parcel..)

The alternative practices, are the following:

- Organic farming has a positive impact on the environment, except for the risk of winter nitrate. There could be difficulties for marketing, there could be an increased annual variability of income and this system may restrict animal welfare (forbid drugs).
- Agri-environmental measures. They consist in agreement with society for enhancing the impact of farming practices on the environment.
- Mechanical weeding has a positive impact on wild flora diversity, water and soil quality.
- No tillage. When successfully applied, this system may reduce energy consumption, control erosion, and respect life cycle of soil invertebrates. However, it often increases pesticide use. A good crop rotation is essential.

Clear agreements are signed by the farmers and the scientists to carry out the project on selected sites. Economic compensations are given to farmers for time allowed to the research, sampling namely.

III.1.1.1 Parcel selection

The measurements and monitoring of most indicators take place on all farm parcels of the four sites. But because of the time and energy consumed for some indicators, a selection of parcels was made for each farm. Selection was made in co-operation (GERU and ILWB team). The measurements and monitoring program took place on 33 selected fields of the 4 selected farms. Cf. annex III: selected parcel.

First of all the fields were selected on the basis of soil types (soil map). The fields with an acceptable homogeneity of soil type were selected to make fieldwork activities easier.

The second criterion was the crop type. Maize and grassland were chosen as the most important crop types on the four farms. Although these crops were not available on the arable farm; for this farm, selection was made on land use history.

III.2 Farming system

A first selection of indicators is presented below. If necessary, indicators from the literature are adapted to Belgian pedo-climatic and socio-economic conditions.

Table III-2: Farming system indicators

References	Indicators	Unit
	III.2.1.1 Farming system	
PAEXA	• Average parcel size	ha
SAFE	• Price Index Achieved price / average price	%
ECOFARM	• Quality Production Index QPI = Quality Index * Production Index (Vereijken et al. ,1995) Quality Index (QI) = achieved price / top quality price Production Index (PI) = marketed yield / on-field yield	%
SAFE	• Transformation Index (Secondary Products : cheese, butter, yoghurt) Quantity transformed / quantity product for primary product	%
SAFE	• Quality Indicator Index QII = Quantity sold under quality label / Quantity sold	%
	• Protein production per ha (for crop)	kg /ha
	• Energy production per ha (for crop)	mJ/ha
SOLAGRO	• Direct energy consumption	mJ/ha
SAFE	• Power $\sum$ Power (tractors + motorised tools) per AA	W /h.ha
SAFE	• Mechanical working time $\sum_{tractors}$ Working time * power	W /ha
PAEXA	• Soil link rate for manure application Organic nitrogen produced / $\sum_{\text{land on the farm}}$ maximum spreading	%
SAFE	• Soil link rate of animal feeding Intraconsumption / total consumption (for energy and protein)	%
ECOFARM	• Milk from roughage Average annual milk production per cow minus the quantity of milk produced by concentrates (based on ± 2 litres of milk / kg of concentrate)	l/cow
	III.2.1.2 Biodiversity	
EU	• Area under nature protection	% AA
ECOFARM	• Ecological infrastructure index Percentage of the farm area devoted to the ecological infrastructure	%
PAEXA	• Hedge network (agri-environmental measures)	km/ha
PAEXA	• Late mowing dates in marginal meadows	Datum
SAFE	• Proportion of legumes and Brassicaceae (pollinators)	ha/ ha AA
SAFE	• Ratio between cultivated/ naturally occurring species	%
SAFE	• Agricultural area managed for wild flora (orchard, fallow land, late cut meadows…)	ha/ ha AA
SAFE	• Non agricultural area managed for wild flora (grove, pond, farmyard…)	ha/ ha AA
SAFE	• Non agricultural linear elements managed for wild flora (hedge, low wall, field margin)	km/ha AA
PAEXA	• Number of cultivated species and varieties	-
PAEXA	• Number of threatened crop varieties	-
SAFE	• Existence of special devices in farm building for wild fauna	Binary
PAEXA	• Number of threatened livestock breeds	-
SAFE	• Number of livestock breeds	-
	• Number of cultivated and raised species	-
	Pesticide use	
OECD	• Pesticide consumption $\sum$ quantity of diverse active substances (per AA and per output) Total and per class (herbicide, fungicide, insecticide, coating seed, other..)	kg MA/ha
SAFE	• % AA free of pesticide use	% AA
	• Pollution risk for pesticides Using results of the European CAPER Project (Reus, 1999).	-

The methodology uses a risk ratio approach, i.e. the ratio between exposure (the concentration in an environmental compartment: surface water, groundwater, air or soil) and toxicity for relevant organisms. Concentrations are determined by calculations, which take into account differences in environmental conditions and applications factors.

For groundwater and surface water: SyPEP, System for predicting the Environmental Impact of Pesticides : L. Pussemier, CERVA Belgium

For air : IPEST, Pesticide environmental impact indicator: van der Werf & Bockstaller, INRA France

For soil: SYNOPS_2, Gutsche & Rossberg, BBA, Germany

III.2.1.3 Fertilisation

Source	Indicator	Unit
EU	• Organic and inorganic fertiliser consumption Nitrogen, phosphorus and potassium consumption (per ha and per kg output)	U/ha and U/kg
ECOFARM	• Nitrogen annual balance (input-output)	kg N/Year
ECOFARM	• Phosphorus annual balance (input-output)	kg P/Year
ECOFARM	• Potassium annual balance (input-output)	kg K/Year

III.2.1.4 Crop management

Source	Indicator	Unit
SAFE	• Crop varieties adapted for local condition	Binary
SAFE	• Sowing density Sowed quantity / average advise quantity (function of datum)	%
SAFE	• Adequate input use in relation with yield target	Binary
	Realistic yield target (achievable every second year)	Binary
PAEXA	• Good fertilisation practices Results of a list of questions, response binary, % for relevant point and surface	%
PAEXA	• Good crop protection practices Results of a list of questions, response binary, % for relevant point and surface	%
Safe	• Crop rotation index Crop rotations influence plant production by affecting soil fertility and survival plant pathogens, physical properties of soils, soil erosion, soil microbiology, and prevalence of nematodes, insects, weeds, earthworms and phytotoxins (Sumner, 1982) Inspired by Viaux (1999), the rotation index takes into account the preceding crop, the time interval between two croppings of a plant on the same parcel. It quantifies the risks and advantages concerning : - Crop protection - Nitrogen management - Weed control - Alternation of crops with different root systems	-
SAFE	• Legumes cover	%
	• Minimum tillage techniques	Binary

III.2.1.5 Breeding management

Source	Indicator	Unit
	• Consumption index	-
PAEXA	• LU/ fodder area	LU /ha
	• Disease index Σ disease / animal . year (caesarean = 1 disease)	%
OECD	• Use of anti helminthic products for cattle	Binary

Soil and water

Source	Indicator	Unit
	• Water consumption for milk production Quantity water consumption (breeding + washing)/ Quantity milk production	l Water / l Milk
SAFE	• Soil potentially exported at harvest (indirect measurements)	kg /ha
SAFE	• Anti-erosion practices index Takes into account of tillage orientation, tillage techniques, crop index for erosion risk, parcel size, ..	-
PAEXA	• River length protected	%
SAFE	• Existence of a device for avoiding river pollution by animals	Binary
SAFE	• Existence of anti-erosion techniquess	Binary
PAEXA	• Storage capacity (Slurry)	Month

PAEXA	• Storage capacity (FYM)	Month
PAEXA	• Soil cover index	%
ECOFARM	• Potentially leacheable nitrogen Nitrate content in the soil profile (0-150 cm) in autumn	kg N-NO_3 /ha
	Visual and odour effect of farming practices	
SAFE	• Number of isolated trees in the landscape	/ha
	• Vertical element	Binary
EdeN	• Landscape assessment	
SAFE	• Farm building visual effect	-
	• Presence of unaesthetic elements	Binary
	• Odour effect	Binary

The spatial relevance (parcel, farm, landscape) of each indicator is mentioned in V.3. annex III

For 2002, the data collecting is running its course. However, half-year break in the project due to the departure of Mrs Garcia caused a delay.

It may be difficult to estimate indicators: first, for the data collecting and secondly for subjectivity with interpretation of the data.

For subjectivity problem, we must have threshold for harmonise interpretation.

Now indicators must be tested for different level of spatial scale and only convenient held.

III.3 Water and soil quality

III.3.1.1 Indicator subset

From the initial set of defined indicators the following sub selection (Table III-4) was made for further development within the project. Some indicators will be developed with cooperation of other teams.

III.3.1.2 Monitoring of indicators

Table III-4 mentions indicators that will be obtained by measuring programs and modelling. Monitoring of the soil moisture content will be performed with a soil moisture probe and access tubes. After installation of the access tubes the monitoring program started. This means that soil moisture is measured at several depths every 2 weeks. During these measurements it is also possible to monitor the soil cover and texture (visual) and occurrence of surface sealing. This will be added to the monitoring program. On fields with high water tables piezometers will be installed to monitor groundwater level.

The moisture content measurements will be used to validate the leaching model and to develop an indicator for the moisture balance and storage capacity. The structural data will be used to develop a structural index and to see the effect of management on structure.

Hydraulic properties will also be determined from undisturbed samples, but only once. They will be used as model input. The leaching risk will be obtained using a leaching model. This will also give information about the water flux at the bottom of the root zone.

Erosion risk will also be developed as an indicator, using an erosion model and when necessary additional field measurements. Another important erosion type can be tillage erosion and harvest erosion. Tillage erosion can be modelled in some models, and when possible it will also be taken into account. Harvest erosion, that can be enormous with root crops and moist conditions during harvest, can also be taken into account but using data from the farmers.

Together with ECOP the nutrient balance will be established and nutrient concentrations in the soils will be measured. A complete nitrate profile will be measured as validation/calibration for the leaching model. Other soil characteristics as texture, structure, CEC, organic matter content will be measured and subsequently indicators for these characteristics will be developed. Management information will be obtained with a farmer's log.

For a more detailed monitoring scheme we refer to the administrative report.

III.3.1.3 Preliminary results

Soil samples are being processed for determination of hydraulic properties. These hydraulic properties will be used as model input. The measurements are not complete and therefore can not be represented in this report. Although, the measurements give also other information, for example porosity. Porosity is also mentioned as an indicator and the percentage of larger pores gives information about the possibility of rapid water movement through the soil. The porosity and the percentage of pores larger than 50µm for some fields in Ternat, are presented in Figure III-1.

In Figure III-1 soil 6 and soil 9 are dry loamy soils and the other 2 fields are humid loamy soils. The land use on field 6 and 40 are permanent grassland. Field 9 is in use as temporary grassland and field 22 is a piece of fallow/nature land. A, B and C are the defined horizons.

The monitoring of the soil moisture content gives information on the soil moisture profiles. Some soil moisture profiles of the farm in Ternat, are presented in Figure III-2. Figure III-2 gives for 2 soil types and 3 management types the measured soil moisture profile on 3 different days. It must be noted that the probe is not calibrated for the presented soil types, but that will be done in the near future. These graps give only an indication of the profile at the moment.

The results presented here are preliminary results, because measurements are still in progress. However they give an indication about the presented soil properties.

III.4 Biodiversity

III.4.1.1 Monitoring of the indicators

The indicator values mentioned in the framework will be obtained by measuring programs, a minor part by modelling.

The biodiversity indicators can roughly be divided into four main categories: vascular flora, butterflies, earthworms and landscape elements. For all categories, data collection will be different.

Most of the indicators dealing with flora are calculated from vegetation surveys. Therefore in the four sites detailed surveys of occurring plant species and their respective coverage were made. This was done both on the parcels and on the parcel margins. Most of the farm parcels, and some reference parcels outside the farm area, were visited during the period June-July 2002. In August 2002, some additional surveys were done, other parcels were surveyed a second time. A total of 91 parcels and 570 margins were investigated. Details per site are given in Table III-5.

An inventory of butterflies was made using a census transect method. Per site a transect was divided into sections. Butterfly species and numbers were counted per section. We encountered methodological problems because of the low number of butterflies. To obtain interpretable results, numbers should be higher, or replications (transect visits) should be increased to a practically infeasible number.

Earthworm surveys were done in October-November 2002 because earthworm activity is highest in this period. The method consists of a formaldehyde treatment of 6 quadrats per parcel, followed by handsorting of a soil sample per quadrat. Species were determined in the laboratory and biomass per species was calculated. The data set consist of a total of 145 subsamples (formaldehyde and soil samples).

Indicators concerning landscape elements are calculated indirectly from geographic data. Therefore digital ‘landscape structure maps’ were made, based on all available (digital) maps (e.g. topographic maps, orthofoto maps, land use maps, …) containing useful information. The landscape structure maps can be used to derive indicators concerning point, line and/or polygon elements and measures like isolation and connectivity.

Preliminary results

All fieldwork data are imported in a MS Access database for further analysis. Geographic data, like the landscape structure maps, are stored in a geographical database (ArcView). A connection between the two databases was established, to be able to perform spatial analysis on relational data (Figure III-3).

Because measurements only finished very recently, only few results of the analysis can be shown at this time. Based on the floristic surveys, species lists were built per parcel and per margin. Descriptive statistic measures were calculated, like ‘mean floristic diversity’ per parcel and per border. Results are shown graphically in Figure III-4. All other data are still being processed. Results are expected in the coming months.

As stated before, butterfly numbers were too low to be interpretable. Figure III-5 shows mean butterfly numbers per section counted on 5 transect visits in the period May-June 2002.

IV PERSPECTIVES

IV.1 Farming system

The data collection and the testing of indicators will be continued in 2003. For 2 regions, additional farms will be studied in order to get more information on regional reference values in conventional agriculture.

Activities of the second year of research:

- Indicators:
  - When feasible, norms will be defined (threshold value that allow the ecosystem to perform the different functions). The values can locally vary.
  - Information about the reaction time of indicators will be collected.
  - For each selected indicator information will be collected on difficulty, precision, replicability, time and cost.
  - Landscape level, collecting data
- Response evaluation:
  - The difference between the norm and the value of each indicator will be estimated and interpreted within a future multifunctional analysis.
  - First exploration for interpretation approaches defined in the project: qualitative, quantitative and graphic techniques.

IV.2 Water and soil quality

The farms were selected on alternative management practices. With the set-up of our experiments we expect to find good indicators that reflect not only the effect of soil properties but also the effect of management. A good indicator should reflect both natural conditions and management influence.

On the first farm (FAUV) it should be possible to see changes occur. Although, the most important crop is grassland, it should be possible to see some changes during the project because the shift to organic farming is rather recent. Pesticides and chemical fertilisers are not used, which will first of all lead to less leaching of pesticides and nutrients. Organic fertilisers are used, which can still result in leaching of nutrients, but the leaching risk will probably be much lower than under conventional tillage. The use of only organic fertilisers will also increase soil properties as CEC, structure aggregates and result in better infiltration, diminishing surface water runoff. Although ploughing of temporary grassland and arable land will speed up the SOM turnover, high levels of SOM are expected on this farm.

On the second farm (SART), we expect to find also high SOM contents with more favourable soil conditions due to 15 years of using cover crops in winter and minimal tillage. The effect of different crops and their subsequent pesticide use should be reflected in different soil properties.

Due to the high SOM content and the improved structure, erosion risk should be less than at comparative soils without minimum tillage and cover crops.

The farm with mechanical weeding (TERN) will show the effect of breaking the topsoil several times. It is expected that this will influence the structure of the topsoil. Turnover of SOM is expected to be higher in the top layer due to tearing the surface layer. This technique will have effect on the leaching risk, due to less pesticide use.

The last farm (PEER) can, to some extent, be used as a reference farm. The problem here is that it is situated on an other soil type than the other farms. But it also gives the effect of soil type on sustainability. Leaching will be a large problem on this sandy soil, with high groundwater levels.

IV.3 Biodiversity

Within the setup of our research we expect to find biodiversity indicators that reflect not only the effect of abiotic conditions but also agricultural practices.

Earthworms are expected to be not only indicators for (soil) biodiversity, but also soil properties and agricultural practices, like tillage, pesticide use … and this on a small (parcel) scale level.

Floristic indicators will reflect abiotic conditions like soil and hydrologic properties, but also agricultural characteristics like land use, herbicide use, intensity, rotation, … Scale level for flora diversity varies from parcel to ecosystem level.

Landscape indicators will reflect landscape structure, which is together with the habitat patch characteristics one of the main driving forces for ecosystem biodiversity. Configuration of the parcels, barriers, corridors, … determine colonisation possibilities for most plant and animal species. Habitat patch characteristics – the 'quality' of the parcels – measured with the other indicators determine the survival and/or extinction chance for plant and animal species. The interaction between extinction and colonisation will determine the sustainability of the ecosystem biodiversity.

We will have to re-evaluate the feasibility of butterfly indicators. Because of methodological problems (numbers too low), it might be considered to select another taxon for next year's monitoring programme.

IV.4 Socio-economics

An interview, that will give additional information about the economic and energetic indicators and the necessary information for the social indicators will be held at each farm in January/February 2003 because the farmers have more time during the winter. This interview will be repeated at the beginning of 2004. The bookkeepings of 2002 will be available at the beginning of 2003. These bookkeeping data, the information from the questionnaire, the logbook and the results from the other teams will be used to obtain the socio-economic and energetic indicators values for 2002. Results of the energetic/emergy analysis will be compared with the economic cost/benefit analysis.

V ANNEXES

V.1 References

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