

**FROM SCIENTIFIC ANALYSIS TO AGRI-ENVIRONMENTAL  
MEASURES**

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**-- Parallel Session --**

**Group 2-B. Analytical Tools for Measuring Trends in Biodiversity**

**Monday 5 November 2001**

**Paper presented to the:**

**OECD Expert Meeting on Agri-Biodiversity Indicators  
5-8 November 2001  
Zürich, Switzerland**

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### **Abstract**

The methodology explained is the one developed (actually in progress) to carry out the research project “Definition of a common European analytical framework for the development of local agri-environmental programmes for biodiversity and landscape conservation” funded by the EU, under the fifth framework research programme, and by the Nando Peretti Foundation, which has started on the 1<sup>st</sup> of March 2001 and is co-ordinated by IUCN.

In order to develop scientifically sound agri-environmental programmes for biodiversity and landscape conservation, the approach concentrates, at local level of analysis, on identification and measurement of state indicators of natural (semi-natural) ecosystems and agro-ecosystems in performing environmental functions, on definition of indicators of pressures exerted by agricultural activities over provision of environmental goods and services, and finally on the assessment of the sustainability of the resulting impacts on environmental functions performance.

Agro-environmental policy targets and measures are then built up on the results of this analysis, taking into account what are the most relevant socio-economic aspects and using the most appropriate implementation tools (e.g. market and/or command and control approach) for the local situation studied.

### **Background**

To address effectively and comprehensively the topic of biodiversity conservation through the agricultural use of land, there is the need for an interdisciplinary and very comprehensive approach capable to embrace the complexity of the analysis of relevant ecological information and to facilitate the integration of its results in the development and implementation of agri-environmental programmes.

In article 2 the Convention on Biological Diversity provides the following definition of biodiversity: "Biological diversity (or biodiversity) means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the complexes of which they are part: this includes diversity within species, between species and ecosystems".

Given this broad definition it is not surprising that amongst the international scientific community there is no agreement on how to analyse and measure biodiversity in all its aspects, and in particular on how to develop strategies for its conservation.

In order to narrow the object of analysis the approach, proposed herewith following, intends to link the analysis and measurement of biodiversity in agricultural systems to specific environmental aspects or objectives by using the concept of environmental functions. In fact both ecological and agricultural systems, within their intrinsic complexity including interactions amongst their components and with external factors, need a certain amount of biodiversity to maintain the performance of environmental functions.

When considering the sustainability of agriculture it is also strategic to realise that multifunctionality is a common feature characterising both the ecological and the agricultural systems.

In fact it is quite straightforward to demonstrate that natural and semi-natural ecosystems perform ecological functions (e.g. life support cycles), economic functions (e.g. as a medium or substrate for economic activities such as agriculture, tourism, etc.) and social functions (e.g. serving aesthetic, spiritual, scientific, educational and other needs).

Similarly, agricultural systems provide goods and services which are ecological (e.g. soil erosion control, landscape conservation), economic (e.g. food production, support of rural/green tourism), social (e.g. human occupation of countryside, basis of employment in rural areas) and cultural (e.g. cultural identity, traditional knowledge).

Failing to focus on the holistic character of multifunctionality will lead, inevitably, back to a reductionist approach unsuitable to achieve sustainability in the ecological, economic, and social dimensions of agricultural systems, as the recent past and current experiences world wide have shown.

Keeping these considerations in mind while developing agri-environment programmes offers the chance to define, as clearly as the present scientific information allows, the interdependencies existing between conservation of biodiversity and agricultural use.

Moreover, pointing out the linkages between the performance of environmental functions and the provision of environmental goods and services (both private and public), which have an utilitarian value, is useful when the involvement of policy makers, natural resources managers and farmers in developing and implementing agri-environment programmes has to be taken into account.

From the above it follows that a conservation strategy which will start from the identification of the critical amount of biodiversity (baseline) necessary to maintain the performance of environmental functions, and will build upon that critical value the identification, development and monitoring of agri-environmental programmes and the appropriate implementation tools (e.g. market and/or command and control approaches), will offer the advantage to be very practical for biodiversity and landscape conservation showing explicitly what are the anthropocentric utilitarian values attached to it. This will facilitate political, economic and social understanding and acceptability of the agro-environmental programmes developed.

To develop such a strategy it is necessary to define what are environmental functions, what is the most suitable scale for their analysis, and also to identify what are the indicators describing their most important aspects.

### **Identification of environmental functions and description of the most important attributes and characteristics (critical aspects) for their performance**

According to De Groot, environmental functions can be defined as "the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly" (De Groot, Functions of Nature, 1992).

Many different types of environmental functions performed by natural and semi-natural and agricultural ecosystems can be identified. Stig Wandén and Peter Schaber (1998) identify functions which have information values (aesthetic, educative, scientific, orientational, signal), functions which have ethical values (e.g. existence rights for all living creatures), functions which have production values (e.g. production of food, fibre, fruits) and functions which have life support values (e.g. carbon fixation by green plants, protection of the soil against erosion, the maintenance of soil structure and fertility by a healthy soil flora and fauna, biological control of crops and fruits by insects). It is easy to recognise that the

values linked to environmental functions are of ecological, social and economical characters. Table 1 below gives some examples of environmental functions.

**Table 1. Environmental Functions**

<b>Functions (examples)</b>	<b>Most important attributes and characteristics (critical aspects) for their performance (i.e. Ecosystem Processes and components)</b>	<b>Performance (i.e. Goods and services) (examples)</b>
Biodiversity related functions (Habitat Functions: Providing habitat (suitable living space) for wild plants and animal species; Regulation Functions: Maintenance of essential ecological processes and life support systems)		
Refugium functions	Suitability to provide food, shelter & reproduction habitat	Maintenance of biological & genetic diversity Nursery functions for wild species
Pollination	Role of biota in movement of floral gametes	Maintenance of wild plant species & populations Pollination of crops
Biological control	Population control through trophic-dynamic relations	Control of pests and diseases Reduction of herbivory (crop damage)
2) Landscape related functions (Information functions: Providing opportunities for cognitive development)		
Aesthetic information	Attractive landscape features	Enjoyment of scenery (scenic roads, housing, etc.)
Recreation	Variety in landscapes with (potential) recreational uses	Travel to natural ecosystems for eco-tourism, outdoor sports, etc.
Cultural & artistic information	Variety in natural features with cultural and artistic value	Use of nature as motive in books, film, painting, folklore, national symbols, architect., advertising, etc
Spiritual and historic information	Variety in natural features with spiritual and historic value	Use of nature for religious or historic purposes (i.e. heritage value of natural ecosystems and features)
Science & Education	Variety in nature with scientific and educational value	School excursions, etc. Scientific field laboratories, etc.
3) Soil erosion control Regulation Functions: Maintenance of essential ecological processes and life support systems)	Role of vegetation root matrix and soil biota in soil retention	Maintenance of arable land Prevention of damage from erosion/siltation
4) Water supply Regulation Functions: Maintenance of essential ecological processes and life support systems)	Filtering, retention and storage of fresh water (eg in aquifers)	Provision of water for consumptive use (e.g. drinking, irrigation and industrial use)
5) Others		

Source: adapted from De Groot, R.S., J. van der Perk, A.Chiesura, S. Marguliew, 2000.

The scale of analysis to be addressed in order to identify environmental functions and capable of reflecting both the ecological and agricultural systems multifunctionality is the local level, and in particular the (semi-)natural ecosystem for natural systems and the landscape for the agricultural systems.

This is due to the fact that evaluation of conservation of biodiversity and landscape tends to be site specific, covering complex systems of biotic, abiotic and aesthetic components within the ecological dimension, which rarely can be found in similar conditions and relationships elsewhere. This view is supported also by A. Moxey, M. Whitby and P. Lowe (1998) cited in the EU DGVI Commission Working Document VI/7655/98 (p. 33). Adding considerations of social and economic characters to the picture only enhances the specificity of each evaluation.

Following this logic, the approach adopts, at local level of analysis, the general DPSIR (Drivers-Pressures-State-Impact-Responses) framework to promote the development of agri-environmental programmes. This framework proposed by international organisations such as OECD and European Environmental Agency (EEA) to integrate the complex information concerning the environment into the decision making process, will be used to measure the state of natural (semi-natural) ecosystems and agro-ecosystems in performing environmental functions, to identify the pressures exerted by agricultural activities over provision of environmental goods and services, and finally to assess the sustainability of the resulting impacts on environmental functions performance at the level of local scale. Societal responses, in terms of agri-environmental programmes will then be built upon results of this analysis.

The tool used for description of critical aspects of an environmental function is a set of indicators. A set of indicators and a set of assumed relations among them constitute a “model” of the original system (Gallopín, 1997).

Given the final goal of developing agri-environmental measures, indicators have to be selected also considering the development and implementation of agri-environmental programmes and following the criteria below adapted from Robert Prescott-Allen, 1998:

“Characteristics of a high quality indicator are that it is:

- Relevant. It relates to a specific objective
- Representative; It covers the most important aspects of the issue concerned
- Accurate; It correctly reflects how far the objective is met and the state of the issue
- Measurable;
- Feasible; It depends on data that are readily available or obtainable at reasonable costs
- Analytically sound; It is well founded and uses standardised measurement whenever possible to permit comparison
- Sensitive. It shows trends over time.
- Responsive. It reflects changes in condition and differences between places”

The above considerations are taking into account to develop an input-output matrix (table 2) based on a set of indicators measuring processes and components of environmental functions in semi-natural and agricultural ecosystems (state indicators on vertical axe), on characteristics of agricultural systems (pressures indicators on horizontal axe) and on analysis of their vertical relationships (impacts of the latter on the first).



A number of indicators presented simultaneously to give a picture of environmental conditions (but not aggregated) is defined as an “Environmental quality profile”. An environmental quality profile is a vector indicator (including non-numerical indicators). On the contrary a single number generated by aggregation from two or more values is a scalar indicator.

Choosing vectors as indicators means to “*prefer data in their most complete form possible (environmental profile) but ... to accept the resulting complexity, while the other viewpoint (scalars indicators) prefers data in as simple a form as possible..., but is willing to accept distortion introduced in the simplification process*” (Ott, 1978)

In assessing the level of the performance of environmental functions, it is possible to use indices (i.e. aggregating the values of indicators listed in the environmental profiles) or leave indicators separated as environmental profiles.

Once the performance or the potentiality for performance of chosen environmental functions have been identified in the (semi)-natural or agricultural ecosystems concerned, through the selection and interpretation of state indicators (also composite where these have been used) and the relationships existing amongst them, the next step is to analyse what are the "Safe Minimum Standards" (SMS) (or baseline) values that allow the ecosystems to perform the environmental functions indicated. These SMS will be measured by state indicators selected in the environmental profiles which are of biotic, a-biotic and aesthetic characters. For example to allow for the formation of top-soil and the maintenance of soil fertility, among others, some levels of soil quality and of hydrological and soil stability are necessary. The appropriate scale of analysis for these state indicators will be the ecosystem/landscape level.

Safe Minimum Standard values of indicators representing critical attributes for the performance environmental functions, are those values (or range of values, or qualitative aspects) that constitute a benchmark, as said above, a baseline below which the environmental function is becoming in danger to be performed.

The object of reference in determining the value of SMS has to be the presence/absence of the performance of the environmental function. The crucial question that has to be asked is: what are the values of the indicators measuring the most critical aspects of the environmental function in the study area, which if not matched, the performance of the environmental function could be seriously put at risk in the study area.

The Best Professional Judgement (BPJ i.e. based on scientific evidence available) will be the factor determining the local value of SMS.

An example can be what is believed to be the minimum extension of an habitat to perform the refugium function, or what is the minimum level of BOD in surface water to have maintenance of biological and genetic diversity in water bodies (using a particular specie as bio-indicator for instance), or what is believed to be the minimum requirement for vegetation cover on hill slopes to have soil erosion control, or what is believed to be the minimum requirement of diversity of the scenery to have aesthetic information, etc.

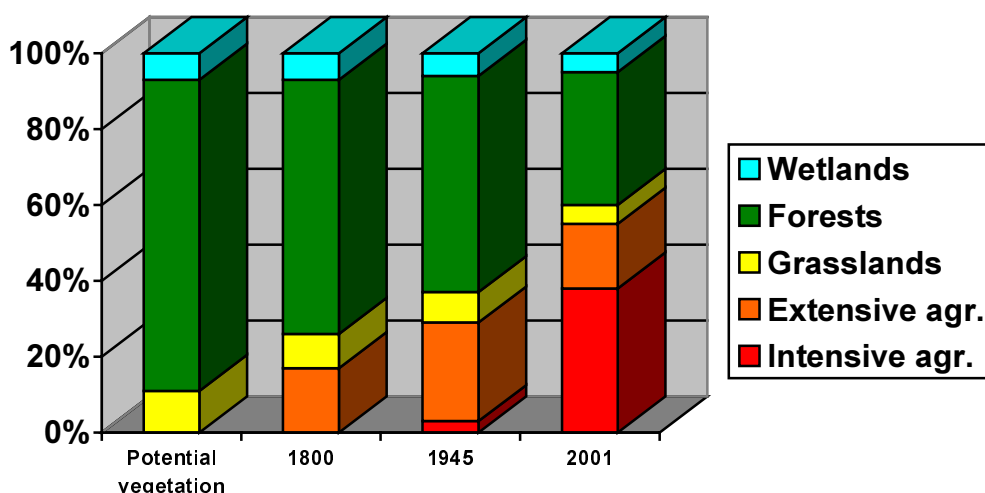
Agricultural practices, on their turn, affect the values of some of these indicators, so producing negative or positive impacts over the environmental functions performed by ecosystems. These pressures exerted over the environment will be identified by pressure indicators such as pesticide use, water use, biodiversity use, etc. The appropriate scale of analysis for pressure indicators is the farm/field level. Results from this analysis will then be aggregated to identify the overall pressures existing at the local agro-ecosystem scale.

From the above the following methodology is recommended to identify indicators and to define their SMS values.

### Agricultural ecosystem: Habitats quantity

In order to define the most appropriate mix of ecosystems diversity and their extensions, which on Best Professional Judgement (i.e. based on most appropriate existing scientific evidence), is believed to be the best situation for the performance of the environmental function studied (e.g. Biodiversity related functions, Landscape related functions, soil erosion control, maintenance of water quality and water recharge processes, etc. see table 1 above), it is useful to identify different habitats (natural/semi-natural, agricultural/man-made) which are relevant for the study area and to assess their extensions (i.e. land cover, land use) at different time references (e.g. potential natural vegetation, before industrial revolution (1750), before World War I (1900), just after World War II, present time, others).

Figure 1. Land cover extension (%) at different time



Source: adapted from OECD, 2001 and B. Ten Brick, 2000.

The above task will serve to assess the first Safe Minimum Standards at the level of study area for the state indicators *Typology of ecosystems* and *extension of ecosystems* concerning quantity of ecosystems and specific habitat types in relation to the performance of the environmental function analysed.

In fact to look at what are the value of selected state indicators in natural ecosystems performing the function of interest, when this is feasible, could be useful in developing the BPJ for certain indicators, as well as looking at past or particular agro-ecosystems (e.g. in 1920's or organic agriculture respectively) whereas the performance of the environmental function analysed was/is performed successfully.

## Agricultural ecosystem: Habitats quality

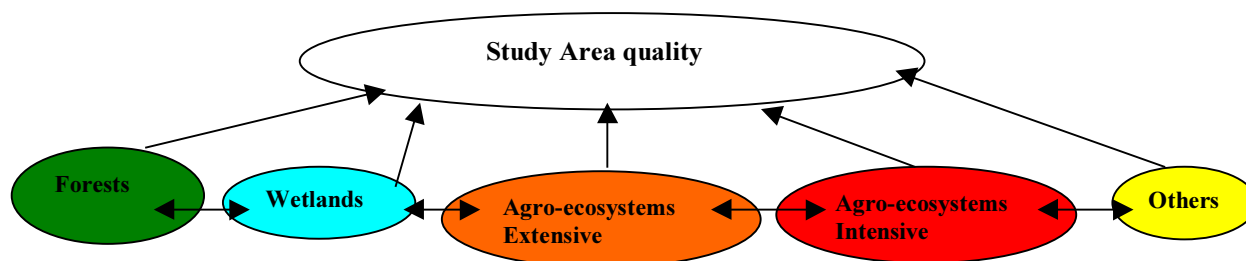
Once the extension per each ecosystem has been defined, it is important to concentrate the analysis on the quality of each habitat selected. For instance, in case we want to assess the quality of a wetland for the performance of refugium function (see tab. 1 above), we could analyse the *presence/absence of a key specie*, (e.g. which is known to be present only if the general condition of the wetland water quality, presence of other species, etc. are optimal), the *species abundance*, *the species richness*, etc.. The same holds true for the analysis of certain types of agro-ecosystems (e.g. presence of birds in the fields, insects, earthworms, etc.).

Proceeding in this way will facilitate the selection of indicators which are site specific relevant, and the consequent assessment of the relative SMS. So following the example, in the wetland or in the agro-ecosystem, the presence of a minimum number of key species, or a certain level of species abundance or richness could be considered the SMS to have the performance of refugium function.

The results will be the selection of one or more quality indicators for each habitat and the following assessment of SMS for each indicator.

The SMS for each indicator will have to be assessed considering the overall quality result at the level of study area. This can be achieved finding out SMS values of quality indicators for each ecosystem present in the area in such a way that the overall result of quality for the whole area will be that of performing Biodiversity related functions, landscape related functions, etc. (for instance as it is supposed should be in the ecosystem mix selected). In other words interrelationships between ecosystems, such as off-farm impacts, shall be taken into account as much as possible as illustrated herewith following:

Figure 2. Study area quality

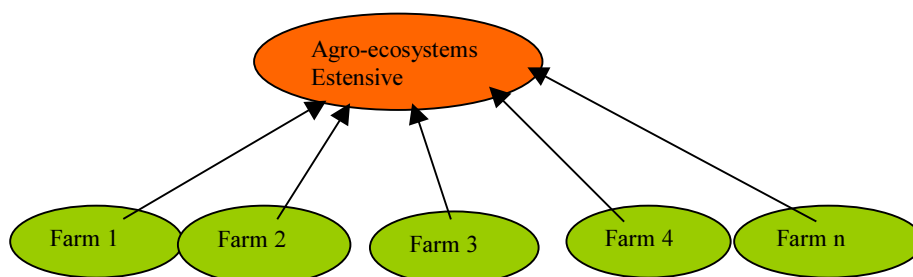


## Intensively and extensively managed land

Following this hierarchical approach we can analyse at the farm/field level the indicators which will be used in the developing of agro-environmental targets and measures. So looking at the results for agro-ecosystems, it would be possible to define the type of indicators and their SMS, useful to assess the most significant and crucial aspects for the performance of selected environmental functions at this scale of analysis. For instance it may come out from the analysis that to have a certain quality of agro-ecosystems which contributes to achieve biodiversity conservation at the level of the study area (e.g. habitat function for insects and birds), hedgerows will have to be present at field margins. The relative SMS can be calculated as length and width of hedgerows to eliminate/mitigate on-farm negative impacts on agrobiodiversity (or when referring to off-farm impacts such as conserving biodiversity in nearby natural ecosystems with creation of vegetation corridors of certain width). Another example can be that of

maintaining a certain rate of soil erosion (SMS) in the fields so that sedimentation of river in the valley below (off-farm impacts) will be sustainable for the maintenance of the quality of that ecosystem. The methodology proposed should consequently facilitate the identification of pressures indicators by the identification of causality relationships to be addressed by associating the values of state indicators to certain pressures of the local agricultural systems, such as the one which links the species richness to the use of pesticide.

*Figure 3. Agro-ecosystem quality as results of aggregate pressures form farm-field levels*



The comparison between the safe minimum standards values of chosen indicators and their resulting values after agricultural impacts have been identified will allow to define if the agricultural uses are within the "ecological sustainability" of an area (i.e. that defined by SMS) and whether they maintain or enhance its environmental functions or, on the contrary do impair them.

A Sustainability Clearing House Mechanism will point out the positive or negative gaps between the values of ecological sustainability indicators relative to the locally defined SMS and their actual values after the impacts of agricultural pressures have been measured. Regarding this point it is noteworthy the fact that, for example, an increase in food production, could correspond to a decrease in the recreational function offered by the same ecosystem or a diminution in the conservation of biodiversity (e.g. intensive agriculture). It is, therefore, necessary to consider the sustainability of agriculture in relation to the most relevant environmental functions taken all together simultaneously (i.e. multifunctional analysis).

Once the impacts of agriculture on the environmental functions considered have been analysed from qualitative and quantitative (physical, chemical, biological), temporal and spatial perspectives, whether they are positive or negative, where they should not be consistent with the sustainability framework (SMS) set out previously, this methodology would pick out the presence of positive or negative impacts/externalities, respectively.

### ***Development of agri-environmental measures***

Starting from the results of the first phase, the second phase concentrates on a common methodology for the development of agri-environmental measures in Europe and in particular on defining the most appropriate kind of societal responses to achieve sustainability in agriculture.

To study and develop such analytical framework various topics will have to be taken into account. First of all the ecological differences existing in European agri-ecosystems will force the research to focus not on designing common agri-environmental standards to be applied indiscriminately all around Europe. On the

contrary different degrees of agricultural sustainability in different agri-ecosystems will also need different agri-environmental standards on the basis of local ecological situations. This procedure reflects the fact that what is sustainable in a particular agri-ecosystem is not straightforwardly transferable to a different one. However, the method to establish them can be comparable for different regions.

Having fixed locally the values of safe minimum standards for different environmental functions in phase 1, the main task for phase 2 will be to define a mechanism capable of attaching different degrees of sustainability to the positive or negative impacts measured with reference to the safe minimum standards. This can be a tool quite similar to that proposed in the Buckwell report (1997b) of associating different tiers to different sustainability levels:

Tier +2 = high enhancement of positive environmental functions  
Tier +1 = presence of positive impacts/externalities  
Tier 0 = respect of SMS = *agriculture ecological sustainability*.

In order to reflect also the presence of negative externalities, also negative Tiers should be assessed:

Tier -1 = presence of negative impacts/externalities  
Tier -2 = high impairment of environmental functions

The former tiers should allow the practical development of rewards for environmental friendly farming. The latter tiers should so allow to finally put in practice the polluter pays principle when translated in agri-environmental measures.

On the basis of this common analytical framework, case studies will define the relationships between different degrees of ecological sustainability (or unsustainability) related to the performance of the environmental functions studied and the impacts of agricultural practices at the ecosystem/local scale of analysis. The different tiers of sustainability defined in an ecological dimensions will serve as a starting point of analysis for the definition of policy targets for agri-environmental measures when also the local economic and social dimensions of agriculture will be considered as part of the picture.

Once the agri-environmental policy targets have been defined, then it will be possible to develop the agri-environmental measures to achieve them (e.g. economic incentives or disincentives could be linked to the matching of agricultural performances with different tiers). This procedure for the definition of agri-environmental measures, while providing a common analytical framework throughout the whole European territory, allows for local conditions to be taken into account for the definition of policy targets. As an example it could be considered an important result achieving Tier 0 when the ecological starting point is Tier -2. In other words, this framework should have a dynamic effect in promoting the scaling up of sustainability within the ecological, economic and social diversity of the European agriculture.

### ***Objectives and expected achievements***

The overall objective of the project described is the definition of a common European analytical framework for the development of local agri-environmental programmes.

The European agriculture is very diverse from an ecological, social, economic and institutional point of view. From this it follows that for a common analytical framework for agri-environmental measures to be effective it should be designed to take account of this diversity and to allow room for it to be managed. In order to represent this diversity the project is carried out in 7 different countries.

The principal aim of the framework proposed is, therefore, not to find common solutions to sustainability in agriculture throughout the whole European territory, but to suggest a common instrument for the identification, development and evaluation of locally more appropriate agri-environmental measures.

The complexity of the Pan-European project proposed will be addressed in three interdependent phases:

The first phase described above, will be used to identify the performances of different agricultural systems in relation to the conservation of biodiversity and landscape in different countries. This involves identification and assessment of agricultural impacts on the environmental multifunctionality of agri-ecosystems, using “state indicators” at the agri-ecosystem level (related to e.g. species diversity and composition, landscape features, soil fertility, water quality), and "pressure indicators" at the farm level (related to pesticide and fertilisers use, soil use, energy use, etc.). Accordingly the presence of positive or negative impacts emerging from different agricultural practices (i.e. enhancing or impairing the environmental functions of agri-ecosystems) will be assessed.

The second phase will be a co-ordinated analytical study to develop a method for the identification of agri-environmental policy targets. These targets will be objective to be reached by the development of agri-environmental measures such as regulatory and/or economic tools that can be used as incentives for the supply of environmental goods and services by farmers and for abandonment of unsustainable agricultural practices. An assessment will be made of the feasibility of market oriented and/or command and control instruments to internalise positive or negative externalities in the economics of the agricultural sector. This phase will be built on the outcomes of the first and will point out the social-institutional and economic realities in the areas studied. It will concern the “translation” of the values in physical terms resulting from the environmental multifunctional analysis, into economic orders of magnitude.

The third phase will build on the first two and will consist of testing, assessing and monitoring the understanding and management feasibility by farmers and administrators of the analytical framework and tools proposed for a Pan-European agri-environmental policy with differences at the regional/local level. In addition an analysis of the administrative and transaction costs to be faced by administrations and environmental accounting procedures to be adopted also by farmers at the local level will be carried out in this phase together with an assessment of the overall economic and financial aspects of the implementation of the agri-environmental measures. This will be achieved through the implementation of on-farm pilot-projects to be conducted in the selected areas in the seven countries participating in the project. This third phase has to be developed with close involvement of different stakeholders concerned (e.g. local farmers and administrators).

In conclusion the recommendations which can be drawn out looking at the approached proposed for the future work of OECD on agro-biodiversity are the following:

- To integrate the analysis of indicators more explicitly with the multifunctionality character of agriculture. This will allow a better understanding by decision makers and the general public of what are the ecological, economic and social benefits of conserving biodiversity, and consequently it will create, a more favourable political environment for the adoption agri-environmental programmes
- To adopt a hierarchical approach linking specific indicators to the scale of analysis. This will facilitate the scientific analysis of what are the most suitable indicators to address problems at their relevant scale, beside pointing out the interdependencies between different levels particularly when analysing the driving forces leading to pressures (i.e. global-international-national/regional-local)
- The availability of information related to detailed environmental objectives as terms of reference such as the values of Safe Minimum Standards scientifically determined will facilitate the identification of

agri-environmental policy targets and measures to be adopted. This will permit also a better effectiveness in monitoring environmental impacts compared for instance to what is often the current practice of measuring the impacts of agri-chemicals by the quantity used (tons/ha) or sold.

- To operate a clear distinction between what are the baseline values for indicators from an ecological point of view and what are the policy targets that are realistically achievable in the short term given the socio-economics and institutional situations (i.e. agri-environmental policy targets) at the local level. This will permit the development of dynamic programmes for the transition phase towards sustainability, promote technological innovation and environmental awareness amongst EU citizens, to define more precisely what are the risks and uncertainties of unsustainable agricultural practices, and to make a trade off between different objectives with more precise information.

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