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Order Address:
Department of Food and Resource Economics, University of Bonn
Meckenheimer Allee 174, D-53115 Bonn, Germany
Phone: ++49-228-733500, Fax: ++49-228-733431
e-mail: uf.ilr@uni-bonn.de
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Towards an Ecologically Intensive Agriculture
From Concept to Implementation by an Agricultural Cooperative

Mohamed Ben El Ghali[1], Karine Daniel [1,2], François Colson [3], and Stéphane Sorin[4]
[1]PRES LUNAM Université d'Angers, GRANEM
[2]PRES LUNAM Université, Ecole supérieure d'Agriculture d'Angers, LARESS
[3]INRA LERECO UR1134 [4]AGROCAMPUS-OUEST [5]TERRENA, coopérative agricole
m.ghali@groupe-esa.com

Abstract
French agriculture is now facing a double challenge, environmental and productive. Following the Grenelle environment forum (organized by French government in 2007), ecologically intensive agriculture (EIA) has emerged as a new concept to reach this dual challenge. The large Agricultural Cooperative TERRENA in western France chose to refer to the EIA as a structural element of its business strategy. The aim of this paper is to present an economic approach of the emerging concept of EIA, and its implementation by the cooperative and its members.

Keywords: *Ecologically intensive agriculture, productivity, productive efficiency, environmental efficiency, agricultural cooperative.*

1 Introduction

The agriculture intensification in the XXth century allowed developed countries to satisfy their self sufficient in food and encouraged farmers to adopt innovative agricultural practices, leading to a simplification of productions systems and homogenization of farming practices (Morgan and Murdoch, (1978)).
This productivist development model has greatly improved production volumes per both area and labour unit and in lesser extent volumes per unit of capital or intermediate input used. This growth has until recently been assessed by only land, capital and intermediate inputs factors. This assessment ignored quantity of natural resources used for agricultural production. This is mainly due to ignorance of the limits of natural resources exploitation when the economic model was developed in the nineteenth and early twentieth century (Fourastié, (1978)).
In this context, agriculture is facing two important challenges that may appear paradoxical, protect the environment and produce more to meet with the population growth and changing consumption patterns.
Thus, as many agronomists expose, it's across all the world that agriculture needs a real change based on new technologies founded on scientific ecology knowledge's and where farmers will be the managers of production and ecosystems. It is this concept of "doubly green revolution" that was reformulated by Griffon to the term of "ecologically intensive agriculture"(EIA) (Griffon, (2007)) as a step towards sustainable development resulting from a new equilibrium in terms of food requirements, land need and economic scarcity.
The EIA term was brought by an association based in Angers on the college of Agriculture (ESA Angers) to organize debates and confrontations on the future of French agriculture. It was then taken over by the Terrena cooperative officers to offer to their members, aware of environmental issues, a development strategy to overcome the tensions arising from the discussion of experimental varieties of GM maize, while expressing the need to maintain production volumes and guarantee of employment for employees of the cooperative group.

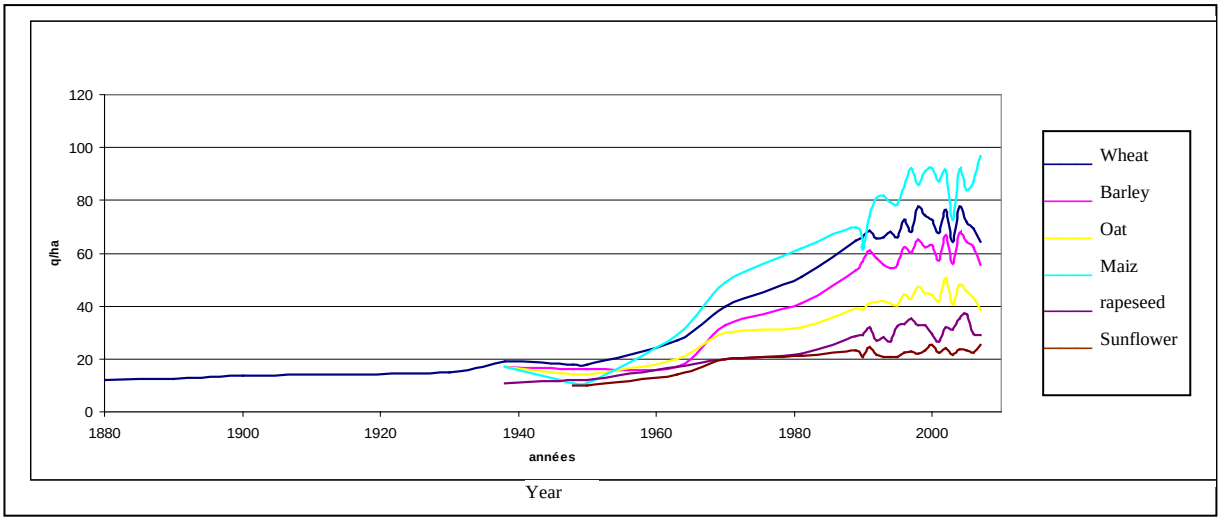
This paper aims to understand the reasons for adopting the concept of EIA by a large cooperative group and consider its relevance to meet the seemingly contradictory objectives and the possibility to implement in practice. In the first part, we shows the evolution of the relationship between agriculture and the environment and the emergence of new production systems, before proposing in a second part an economic analysis of the concept of ecologically intensive agriculture. In the third part, we explain the Terrena strategy and some practices implemented by its members in this new perspective.

2 Evolution of agriculture - environnement Relationship

After the 2nd World War, the intensification has ensured food self-sufficiency in Western Europe. In France, this goal was met in the early 1950s. However the limits of this intensification process appeared to meet the growing expectations of consumers in terms of food quality and environmental requirements.

2.1 The intensification of production factors and environmental degradation

The major changes in agriculture have been characterized by the gradual integration of agriculture in the market sphere and the increasing of productions factors productivities. (Polanyi (2008), Roux (1987)). While improving the efficiency of the organic production of plants and animals has largely benefited from genetic improvement, productivity gains in agriculture have developed through the increasing use of fertilizers and pesticides. Indeed, the selection of resistant varieties and more productive breeds has increased yields (Fig. 1) and decreased production costs especially by the simplification of farming operations and livestock management (artificial insemination). Pesticides have been effective against the development of organisms affecting crops. They improve the consistency of returns and reduce the drudgery, promoting their use by farmers. French pesticide consumption is estimated at 78.600[1] tons in 2008 (over 90% for agriculture).



Source: Agreste, annual agricultural statistics

Figure 1. Evolution of the averages yields of principal cereals

[1] UIPP : Union for protection plants industry

To better understand the increase in overall agriculture productivity, we analyze the partial productivity of production factors (capital, intermediate consumption, labour, land), differentiated depending on the type of production (animal or plant) (Butault, (1999)) (Table

1). Observed over a period of 18 years (1979-1997), these results highlight three characteristic tendencies of French agriculture. In every production, increased labour productivity dominates, far ahead of capital and land. Productivity gains of inputs are still lower on average than other factors, and are sometimes negative for some productions. Consumption of inputs increasing faster than the volume of final production
Finally, the table also point a higher gains productivity for field crops (cereals here, rapeseed, sunflower) and livestock production "above soil" (in this case pork) than for herbivores production (beef and milk) which remains related to the land for most of the feeding need. The same trends observed also in the vegetable and fruit production, but are more difficult to quantify due to the diversity of products and the small sample sizes available on the RICA database.

Table 1.
Annual rates variation (%) of partial and total productivity for field crops and animals between "1980" (average 79, 80-81) and 1996 (average 95-96-97)

	Soft Wheat			Rapeseed			Sunflower			beef			Milk			Pig	
Productivity	80-96	80-90	90-96	80-96	80-90	90-96	80-96	80-90	90-96	80-96	80-90	90-96	80-96	80-90	90-96	80-96	80-90	90-96
Capital	3.6	1.7	7	-0.1	0.3	-0.9	3.7	1.6	7.3	1.2	1.4	0.8	0.4	0.3	0.6	3.7	3.7	3.5
Intermediate Consuption	2	2.1	1.9	3.8	1.6	7.5	-4.4	-7.1	0.3	-1.4	-2.5	0.4	-1.2	-2.5	1	1.1	0.5	2.2
land	2.2	3.2	0.4	2.7	3.2	2	-0.1	0.7	-1.5	-1.2	-1.1	-1.3	2.2	2.4	1.8	9	11.4	5
Labour	7.5	8.7	5.4	5.2	3	8.9	6.7	8.5	3.7	5	5.4	4.2	5	4.9	5.3	9.5	9.8	9
Total	3.6	3.5	3.7	3.3	2.2	5.2	2.5	1.8	3.6	1	0.7	1.6	0.9	0.2	2.1	2.5	2.2	3.2

Source : J-P. Butault, 1999

Labour productivity grew at a rapid pace and has increased production in a context of sharp decline in farm population. In 2005, it represents only 4% of the French labour population, reflecting a strong substitution of labour by capital and by the use of more power mechanistic tools.
In the economic development literature, agricultural productivity has been consistently attributed to the characteristics of supply, such as, the promotion of production technology, economies of scale and technical change (Luh et al (2008)). However, the state of natural resources and their contribution to agricultural production is not considered as a factor of development. Nevertheless for Porter and Van der Linde (1995), environmental protection and natural resources are considered as a constraint giving farmer the opportunity to improve overall productivity through a practices change or a new technologies adoption. This hypothesis is contested by Palmer et al. (1995) (Piot-Lepetit, Le Moing, (2007)).

This clearly shows that during the fifty years of rapid development of agriculture, natural resources were seen as an external support to this activity without incorporating their degradation and their limited potential.

Intensive agriculture led to an overexploitation of natural resources and became an active element in environmental degradation, but also a victim of the disturbance of ecological balance. The use of the "conventional" agricultural practices has many involuntary effects formalized by the environmental economics as externalities and ecological economics as a joint production.

These externalities create limitations in the use of natural resources, which may inhibit or block economic growth. For example, the increasing pollution of streams by nitrogen and pesticides causes conflicts between users (drinking water, irrigation), and increase the abatement costs.

A global level the increase of population leads to greater demand for food and heating increasing pressure on the exploitation of resources, land use, and increases the emission of waste. This has caused deforestation, biodiversity loss, soil mineralization, reduced water resources and contributes to climate change.

Food consumption patterns and the nature of the used technology have caused significant environmental degradation in all countries, developed or developing, namely the emission of greenhouse gases, water pollution, overexploitation of renewable resources (forests, wetlands ...) and non-renewable (oil, coal, gas) (Bontems and Rotillon, (2003)).

Faced with rising concerns about the environment, the need to preserve natural resources and agricultural sustainability become critical issues. Neoclassical economists have reconsidered natural resources and they integrated them in their economic analysis involving allocation of use to ensure their future availability (Faucheux and Noël (1995)).

In this way, there are two different approaches for evaluating environmental externalities and natural resources (Louhichi et al (2007)). First, the traditional approach based on the monetary valuation of environmental damage in order to internalize the externalities in the economic sphere. Under this approach, the internalization of externalities in the production process takes place by the development of the market and to find a market solution to externalities. This assumes that the resources exchanged are well defined, protected, exclusive and freely transferable. Thus, the introduction of tradable property rights between polluters and polluted (Coase theorem) would suffice to solve the problem of the internalization of social costs. However, natural resources and the environment considered as public property and free are not subject to property rights and the solution described by Coase is applicable only in a limited number of cases of pollution (Vallée, (2007)). In addition, the reality is that negative externalities are increasing, thus more we have environmental degradation, more we need to develop markets for clean-up, more are welfare spending, and intergenerational equity will be reduced and the concept of sustainable development impossible.

On the other hand, the second approach offers a physical valuation of the externality and integrates it into logic of economic optimization under environmental constraints. It is expressed in physical quantity (Barde, (1991)). Under this approach, physical assessment takes into account the capacity and rate of reproduction of renewable resources and the risk of depletion of exhaustible resources. It is used to estimate a threshold above which no damage seems to occur. The physical assessment of the externality can set environmental objectives and upper limits must not be exceeded to ensure sustainability of ecosystems (Barde, (1991); Louhichi et al (2007)).

To correct market failures, governments intervenes in two forms, either by direct action in protecting and restoring the environment (sanitation and water purification, waste management) or by affecting the behavior of economic agents through regulatory instruments (compliance with good agricultural and environmental cross-compliance, etc.) and economic instruments (taxes, subsidies). Due to the limited effectiveness of these instruments, the incentive to change production patterns of economic actors is an important element for sustainable development.

2.2 To new modes of production

The challenge to intensive agriculture began in the first half of the twentieth century. Movements originally marginal, such as organic or biodynamic have grown in the 70's with the critics on the quality food (calves with hormones) and health crises (BSE ...). Other concepts of alternative types of agriculture more respectful of the natural balance emerged gradually, with specific production systems that are distinguished by their production process, their socio-economic and environmental impacts. Their origins are diverse, minority associations of farmers but also alternative farming organizations or technical center and research laboratories, and all now claim to a process of sustainable agricultural development. Some are primarily based on theoretical approaches (Agro ecology) others are coded specifications with specific technical rules (organic farming, integrated farming or those imposed by large distribution chains of food). Some may be understood as recommendations for the improvement of agricultural practices, while others looks first to a better market valuation of products derived from these new forms of production.
Before discussing the concept of ecologically intensive agriculture, it became necessary to outline the main terms and concepts of agriculture called alternative (Table 2), without trying to lock them up into categories according to their estimated impact on the environment ... The agro-environmental measures and other types of contracts or territorialized agricultural policy measures were not taken into account in this simplified presentation of alternative production systems. Also listed are the production rules imposed by food companies or large distribution chains.

i) *Types of labelled and / or regulated production :*

In this group there are organic products that are differentiated on the market and certified (organic certification or label “AB”), integrated farming (products labeled "integrated production" in Switzerland), sustainable agriculture and family farming. Following the recent discussions of the Grenelle Environment Forum, Agriculture with high environmental value (HVE) becomes a subject to specific regulations in France. These production methods are associated with traceability rules in formal specifications, technical guides or certification process or agreement. They are based on respect for the living and natural cycles and manages overall production by promoting agricultural system. In these types of agriculture, farmers rely on crop rotation, green manure, compost, biological pest control, use of natural products, and mechanical cultivation to maintain soil productivity and control of diseases and of parasites. In organic farming for example, the use of fertilizers and synthetic pesticides and genetically modified organisms is prohibited.

ii) *Types of non-labelled, non-regulated production:*

This category includes types of agriculture under concepts, some presented by scientists, others by farmers' associations or associations alternate environmentalists but not officially recognized by the regulations. We can especially be mentioned the concepts of conservation agriculture, ecological agriculture, agro-ecology, eco-agriculture or evergreen revolution. The ecologically intensive agriculture is a continuation of these proposals.

All these modes of production are part of a comprehensive approach to farm management and aim to enhance the positive impacts of agricultural practices and reduce the negative aspects without affecting its profitability.

Table 2.
Main mode of agricultural production : origin, actors, recognition and traceability

Approach /concept	Origin	Actors	Market recognition	Traceability	Official recognition
Labeled productions					
Organic Farming	1920 : • Biodynamic mouvement Rudolph Steiner • «Organic agriculture» British Soil Association Organo-biological agriculture Switzerland	• National federation of biological farmers (Fnab) • Nature & Progrès • Ecocert • Organic Cooperatives (Biocoop) International Federation of Organic Agriculture Movements (IFOAM)	European Label … AB	• Special specifications by production • Certification • Allocation of the AB mark	Framework law on agriculture 1980 + EU
Integrated Farming	1976 : Protections of the cultures against the bio-aggressors	• International organization for biological control (OILB) • INRA • Technical Instituts (ITCF)	• Not in France • Label «integrated production» (Switzerland)	• Not in France • Switzerland : Special specifications, technical approvals	• Not in France • European directive 91/414/CEE du 15 July 1991
integrated Farm management (reasoned Agriculture)	2001 : Strengthen the positive impacts of the agricultural practices on the environment and reduce the negative effects.	• Ministry of agriculture and ecology • Forum for reasoned agriculture and respectfuf for environment (FARRE) • Pesticides Industries (UIPP) • Agricultural Unions (FNSEA, CNJA)	Partial recognition (Cf. Tera vitis for wine grower)	• Reference table • Certification • Professional technical Guides	• Executive order n° 2002-631 of 25 April 2002 concerning qualification of farms in conformance with the integrated farm Mang.
Agriculture of high environmental value (HVE)	2008 : due to discussions of the Grenelle Environment Forum	• Ministry of environment (France) • OPA et Chambers of agriculture	No	• Certification (in project)	Executive order n° 2011-1914 of 20/12/11 Concerning the developing mention" stemming from a farm of high environmental value

Source: our synthesis

Approach /concept	Origin	Actors	Market recognition	Traceability	Official recognition
Other non-labeled productions					
Conservation agriculture	In Europe : 1960, for reduction of production costs In America : 1930 for reduction of erosion and increasing soils fertility	• Farmers • CIRAD, FAO • ECAF : european federation for conservation agriculture	No	No	No
Agro ecology / Eco agriculture	1928 : begin of agro ecology with combination of agronomy and ecology by Bensin, 1928 ; 1970-2000 : expansion (Altieri, Gliessman) 2001 : integration of biodiversity defined by Mc Neely et S. Scheer (eco agriculture)	• CIRAD • Agronomists and veterinarians Without Borders (avsf) • UICN (international Union for conservation of the nature) • CGIAR (international Alliance of agronomic research)) • Eco agriculture Partners (international organization for promotion of eco agriculture)	No	No	No
Evergreen revolution	1968 : initiated by MS Swaminathan to correct the green revolution concept 1990 : taked back by CGIAR,then Gordon Conway 1997.	• CGIAR • CIRAD (international center for agricultural research and development) • MS Swaminathan research Foundation	No	No	No
Sustainable Agriculture	1994 : sustainable agriculture network (RAD)	• Farmers group	No	No	No
Peasant Agriculture	1987: Farmers' movement defending a more respectful agriculture for farmers and environment.	• Associative federation for the development of agricultural and rural employment l(FADEAR) • Peasant confederation • European peasant coordination • Via campesina (international peasant movement's) AMAP (association for maintaining peasant agriculture)	No	Charter of peasant agriculture	No

Agronomic and economic literature on these production methods focuses on natural resource conservation and sustainability of agricultural holdings (Wezel et al (2009), Lahmar, (2010), Kafadaroff, (2008), Paccini et al, (2003)). Indeed, several methods and indicators were developed to assess durability. One cites, for example those developed in France to learn the IDEA method (Vilain, (2000)), ADAMA (Häni et al., (2003)), the tree of sustainable agriculture (Pervanchon, (2004a)), the method of the Sustainable Agriculture Network (Feret, (2004)), and the charter of peasant agriculture (Pervanchon, (2004, b)). For each objective (economic, environmental or social) indicator are proposed. For the environmental dimension, these methods provide a list of indicators attributed to agricultural practices in a note prepared by experts. Other approaches developed outside the agricultural sector as the Guide for Sustainable Development (AFNOR, (2003)) were applied to farms (horticultural and gardening).

More recently, researchers at INRA have developed a new method for ex ante evaluation of sustainability throughout the culture system, the MASC method. This is based on a hierarchical decision tree aggregating by rules of qualitative attributes. Attributes are derived (by setting class) from relevant indicators partly proven from different methods (ex. INDIGO indicators for the environmental dimension, IDEA indicators for the Economic). The various dimensions agro environmental, economic and territorial are each the subject of a sub tree independent evaluation (Sadok et al, (2008)).

Although many indicators have been developed, methods of "alternative» production does not cover all aspects of sustainability (Rasul and Thapa, (2004)) which have to be assessed in terms of ecological sustainability, social acceptability and economic viability (Yunlong and Smith (1994), Rasul (2004), Pretty (1995)). For example, organic farming is of obvious interest to the environment on two points: the removal of pesticides and synthetic fertilizers and implementing organic methods contributing to the improvement of soil fertility. However its impact on CO2 emissions (mechanical work) and the effect on soil and biological balance of the repeated use of copper and sulfur are still being evaluated. Moreover, it responds only partially to the economic and social concern. Indeed, yields remain relatively low and could not meet the food needs of a growing population. In addition, the variability of its returns and their prices can not ensure a stable income to farmers. It is also the case for integrated farming where the comparative study of INRA in 1998 (Aubertot et al, (2005)) for 4 types of production: conventional, organic, integrated and under cover crop showed a decrease yield of 10% offset by lower expenses related to energy consumption.

Proponents of "peasant agriculture" reject the principle of sustainable agriculture with large farms based on hired labour. They characterized as a rather agricultural fabric of small and medium-oriented production of quality food, primarily in short circuits, with environmentally friendly practices. "Organic farming" includes environmental, economic and social privilege while small mixed farms (mixed farming) to ensure a high demand for labour. These models do not seem in line with the relatively specialized and agrarian structures of increasing size in developed countries.

Note also that the lower yields caused by production methods mentioned is more or less accepted by farmers engaged in a process of environmental protection. On the scale of business and agricultural cooperatives, yield losses can be detrimental to the overall production and affect the organization of industries and business competitiveness.

To capture the environmental performance of different production systems, it is necessary that the environmental effectiveness is related to the productive efficiency of operations. This means that farmers must manage their different inputs including natural resources to

improve their economic and environmental productivity. The measurement of environmental productivity raises the question of the possibility of integrating the environmental impacts as a joint production attached to the main economic activity. Several researchers have managed to incorporate some of the impacts in the index for calculating Malmquist productivity (1953), however, this integration remains valid for measurable environmental damage such as emissions of greenhouse gases (Ball et al (2002), Fare et al (2004), Manage and Jena, (2008), Kabata, 2011)). This is not the case for all environmental damages.

At this level, we can wonder about the originality and the novelty of the term of EIA. Is it a shape of «green washing» of agricultural practices without big changes, is it a new type of environment-friendlier farming worn by a specific cooperative movement or is it really a new concept with its specificities, that would differentiate it from the others?

3 The ecologically intensive agriculture (EIA)

The concept of the EIA was initiated by Michel Griffon following the debate on the Grenelle Environment forum (2007). It has resulted in the creation of an association for reflection and exchange on new farming practices that respect the environment (see EIA Interviews 2010 and 2011). The current interest for the EIA is due to two main reasons. First, this concept does not oppose the preservation of environmental resources and maintaining or improving yields. The second is that, it does not refer to a list of agricultural techniques or a reference for a type of operation but a process of gradual evolution of practices implemented by farmers engaged in this innovation process to better respect the environment. It knows a real interest in western France and it is adopted by significant players, such as a major French agricultural cooperative, TERRENA, for which the EIA is an element of its development strategy.

3.1 The concept of ecologically intensive agriculture (EIA)

The term EIA is based on the idea of amplifying the natural mechanisms and their integration in agricultural practices. It has a main objective of increasing both agricultural production and preservation for environment resources. It assumes more complex management of agricultural techniques and landscaping than conventional farming. However, the EIA still follow the logic of conventional farming maximizing yields and incomes. It is thus necessary to have plants and animals with an important intrinsically potential of production, and production conditions maximizing the expression of this potential, including adding the necessary quantities of inputs for its growth and development (Griffon (2007, 2006)). The challenge is to reclaim the optimization features of ecosystems, thereby reducing the use of synthetic inputs and non-renewable resources without adversely affecting the production levels and farm viability.

Reflections on the EIA proceed first on considerations of agricultural production and limited natural resources. This is to produce enough to meet the needs of a growing population while limiting the taking of natural resources become scarce, such as energy, water and land. Of consumer's highly-rated, the reflection proceeds of a different logic which tries to put in the state of mind of the consumers that it is necessary to turn to a more responsible consumption (towards more thrifty products in natural resources).

From an ideological point of view the EIA does not try to make of profit with the putting on sale of products EIA. The expected added value lies in the improvement of the global well-being by proposing sufficient food quantities and produced in the environmental protection

and the future generations. However, the economic reality requires a certain valuation of EIA products allowing consumer to move their choices to agricultural products with better properties. This will favor the diffusion and the adoption of the ecologically intensive practices. At the level of farmers, cooperatives and food industry, the added value will correspond to a gain of productivity and competitiveness which improved their competitive advantages.
According to Griffon, (2007) EIA approach is based on two pillars:

• ***New technology:*** Production techniques are strongly inspired by the knowledge of the mechanisms of the life and the functioning of the nature. An ecologically extensive technology bases on four elements to consider simultaneously i) the quantitative effort where every region of the world must increase its cultivated surfaces or its yields without affecting irreversibly the biodiversity by massive clearings. Europe for example has to maintain its returns, reduce its consumption of fertilizer, pesticides and energy by reducing environmental damage (ii) the qualitative effort corresponds to the improvement of the sanitary and gustative quality of food. The sense of change is the phasing out of the standard qualities for the benefit of diversification of products, iii) the production of ecological services: Maintain the natural cycles such as water, carbon by sequestration of the organic matter in soils, etc… and (iv) adaptation to climate change.

• ***A new agricultural policy*** assuming a redistribution of natural capital, significant investments in ecological restoration, more stable prices, markets and provided tariff protection when the market competition can only lead to a scenario of under-nutrition and stagnation of food economics. It is also a political incentive to change their technology to improve the environmental quality of agriculture.
For the EIA, ecological intensification refers to the process of transformation of productive ecosystems taking place within the limits of viability of a given ecosystem, without forcing the ecosystem (increasing yields through inputs), but leads to increase the intake of certain variables within the system to operate at a high speed. "The ecological intensification is to obtain a higher yield per unit of biosphere for a set of sustainability objectives sought" (Griffon, (2007)).
The logic of the EIA that can be defined as "*a production system characterized by a set of techniques and technologies aimed to increase the functions of an ecosystem production and to maximize agricultural production and environmental amenities, reducing negative externalities and to better manage natural resources* ", The ecosystem features and natural resources are in the heart of the functioning of the production system and are considered as a full factor of production. Beyond the usual criteria, the economic performance is estimated by the level of productivity of these factors.

3.2 Conceptual framework for the economic analysis of EIA

The concept of EIA is based on an oxymoron that combines two terms a priori opposed "ecology" and "intensive". However, this term describes an intensive agriculture that must be ecological. It will have more and better mobilize natural mechanisms and resources in the production process. The originality of the concept of EIA compared to other concepts of alternative agriculture formulated is therefore to specify "ecological features and natural resources (NR) as a production factor". Respecting the natural balance is not primarily

promoted as a constraint or a limit to the use of pollutant inputs, but as a necessary condition for sustainability and increased volumes production.

The EIA in its definition points out that agricultural production is a biological process of transformation of minerals in crops, the latter being themselves mobilized for livestock. If the land is essential to support this activity, other factors of production (fixed and circulating capital, labour) involved only to accompany this process, technological innovations (genetics, physiology, nutrition, plant protection,…) helping to increase performance. In economic terms this analysis leads us to assume that the ecological and natural resources are not an external constraint, but are a factor of production specific and autonomous. We must not return to the economic thinking of François Quesnay and the Physiocrats who thought the land was the only source of wealth (Pearce and Turner (1990), Vallée (2002)), but clearly identify the ecosystem features or mechanisms and natural resources in the production function. The increase in wealth generated by agriculture should also be analyzed from a decomposition of the overall increase in productivity, a contribution of partial productivity of production factors, including natural resources.

To analyze this hypothesis we need to clarify the difference between the ecosystem features and the natural resources in order to show whether or not to consider them as production factors.

- ***The ecological features***

The ecosystem features correspond to ecological functions which are defined as biological processes operating and maintaining the ecosystem. They provide the ability of ecosystems to cope with disruptions and to remain in a favorable state of production (MEEDDM, (2010)). The Millennium Ecosystem Assessment (2005) has characterized certain of ecological functions related to the natural environment and ecosystem services and has identified four broad categories of services (production, regulating, cultural and support) (Bonny (2010), MEEDDM, (2010)) After some criticisms of this classification including the blurring of the definitions of regulatory services and support, Lavorel and Sarthoo (2008) have separated this classification into three categories to make it more operational. They proposed (1) inputs services contributing to the provision of resources and maintenance of physical and chemical materials in agricultural production, and ensuring the regulation of biotic interactions, (2) production services contributing to agricultural income where' s essentially acts of crop production, considering the level but also the temporal stability and quality of products, including livestock production and (3) the services of direct out-farm income, which include monitoring water quality, carbon sequestration or landscape values.

Given this definition, the EIA must be based on the intensification of natural processes to maximize the ecological services. Although these processes are directly or indirectly in the agricultural production function, the integration as a production factor is difficult or impossible since we do not know their quantitative contribution in the production function. (For example, how many "function of carbon sequestration" do we use to produce one quintal of wheat? Or, what is the required amount of exchange gas at the plant level to produce an apple). In addition to physical quantification, it is necessary to give this new factor a price to calculate production costs and to consider it in terms of economic rationality. Moreover, ecological process generally requires an interval time greater than an agricultural production process, making its integration into the production function impossible.

At this level, the interest of the EIA appears through the encouragement of agricultural stakeholders in search technologies and techniques that will increase understanding of these

ecological mechanisms, so we can even partially replace some other chemical factors. This will better protect the environment, biodiversity and improve crop yields. Thus the impact of EIA practices will be assessed through indicators that reflect the ecological mechanisms and their states of degradation and conservation, not through integration into the production function.

- ***Natural ressources***

Natural resources are distinguished by their own regeneration capacity and they have meaning only in relation to a given technology and favorable economic conditions (Rotillon, (2005)). We distinguish then (1) exhaustible natural resources that come in the form of stocks over a physical point of view and that their depletion raises the question of the future of the economy and (2) renewable resources that have clean and independent reproduction ability. Their stocks are often referred to as biomass or population growth depends on their capacity (balance between birth and death rates outside human intervention).

According to the EIA, better management of these resources requires a better compliance rate of extraction for finite resources and better use of renewable resources. This can be achieved by integrating these resources or at least those used in agriculture in the agricultural production function, which will seek greater efficiency of use in operation, in other words this is increase their productivity. In economics, the theory of production is based on economic modeling of the producer's behavior. According to the neoclassical approach, the producer is an economic agent that transforms inputs into outputs through a production function where the decision making process depends on:

• The physical relationships between inputs and outputs.
• Prices of inputs and outputs.
• The resource endowments (factors of production).
• And the objective (s) of the producer.

According to the economic, environmental and social contexts, farmer identifies activities that are technically efficient and therefore chooses the optimal combination of these activities that will enable him to have maximum benefit (profit, utility), considering the availability of scarce resources (land, labour, water).

Considering the natural resources as a production factor is just expressing the amount of resource used in the production function. This leads to several problems, in fact the majority of natural resources are considered as free goods or public goods (no value), that escape the economic analysis and their degradation were not an obstacle in the optimization of functions productions, although these degradations are assessed as externalities or a joint production.

In its general mathematical form, a production function is expressed as:

$Q = F (X1, X2,\ldots,Xn)$, where Q is the amount of output and X1, X2 ,..., Xn are the productions factors (capital, labour, land, technology or management). If we limit ourselves to three factors characteristic of farming (capital "K", Land "L" and labour "W") and we add natural resources, we can write the production function as the following:

$$Q = F (K, L, W, RN)$$

The contribution of the natural resources factor in the production process can be appreciated on average or at the margin level with:

Average productivity of RN = Q / RN

Marginal productivity of the RN = $\Delta Q / \Delta RN$

In this perspective of consideration of natural resources productivity, as proposed by the EIA, the analysis of productive efficiency of farms involves identifying what factor in the

boundaries of the production function is more effective. It leads to reflect technological innovations not only as an improvement in respect for the environment but as an increase in overall efficiency, including natural resources.

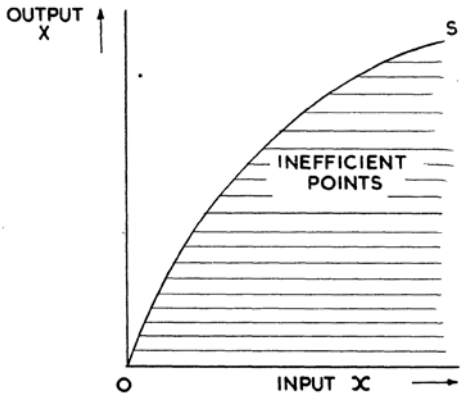
Measuring the effectiveness of a farm is a way to determine if it can increase production without using more inputs, or reduce the use of at least one of these factors while maintaining the same level of production (Atkinson and Cornwell, 1994).

Within this framework of effectiveness research that ecologically intensive agriculture approach is integrated. Their new technologies and practices should enable farmers to improve their technical, economic and environmental efficiencies. This by improving productivity of naturals resources used (eg. fossil fuels) or available at the farm level (soil, water, etc.). This is not only to improve the efficiency of technology and / or agricultural practice adopted but rather to improve the efficiency of the whole system of production, allowing farmers more competitive and better adaptation to changes in economic policies, in particular those concerning the environmental aspects, while ensuring their social role of food production.

To go further in this economic approach of ecologically intensive agriculture we based our analysis on the efficiency concept initiated by Koopmans and Debreu (1951) and developed by Farrell (1957). We assumed that relationship between natural resources and production is known.

3.3 Approach of the technical and economic efficiency of natural resources

Farell (1957) was the first to clearly define the concept of economic efficiency and to distinguish between technical efficiency and allocative efficiency. It assumes that the measure of technical efficiency is related to the use of a production frontier, which indicates the maximum level of production to achieve with a given combination of inputs. Each combination of inputs on the border is technically efficient. The score of technical efficiency in this case is equal to 1. Any point below and to the right of border is technically inefficient (Fig.2).



Source : Farrell, 1957 p.258

Figure 2. Illustration of efficiency measure: case one input/ one output

According to the EIA, farms must increase the efficiency of natural resources used or available. It is assumed that the production frontier for the use of a resource is determined by the deterministic or stochastic approach and corresponds to conventional farming technologies. Let G be the curve that defines the relationship between efficient output Y (yield) and the input X (natural resource) (Fig.3). Farms A and B that are on this curve are technically efficient. Farms “C” and “D” are technically inefficient. The Farm C using the

quantity X2 of resource have an ineffective production process because the efficiency level for the same input can be found in A.
Based on the EIA concept, the analysis of farms effectiveness can have two cases: The first case concerns technically inefficient farms (C and D) that should increase their overall productivity through a better allocation of their production factors or by a change in their production practices. In this case, farms which are below the production frontier can increase their production for the same amount of natural resource factor (C moves A), or to keep the same output with fewer inputs (C to C '). This situation can be observed in many farms where crop yields are not fully expressed.

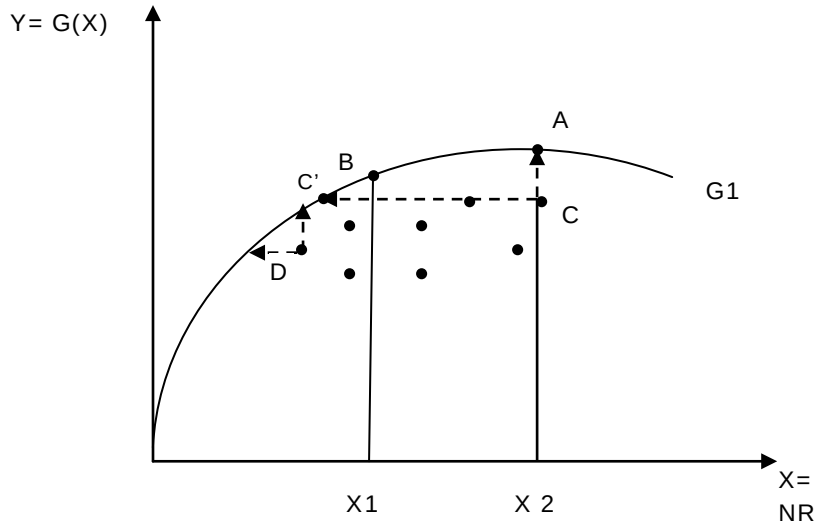


Figure 3. Technical change and natural resources productivity

The second case concerns farms on the production frontier for which the increase in productivity factors can be obtained only with the technological progress that will push the point of reducing returns factor. This is relative to a change in the production frontier corresponding to a different state of technology. So, EIA technology will allow farms to get for the same quantity of input a greater quantity of output (Fig. 4). The graph G2 represents a new production frontier different from G1. Then, farms “A”, “B”, “C” and “D” can increase their total productivity factor. For farms with a maximum potential of production, the increase in productivity can not be secured without technological progress.

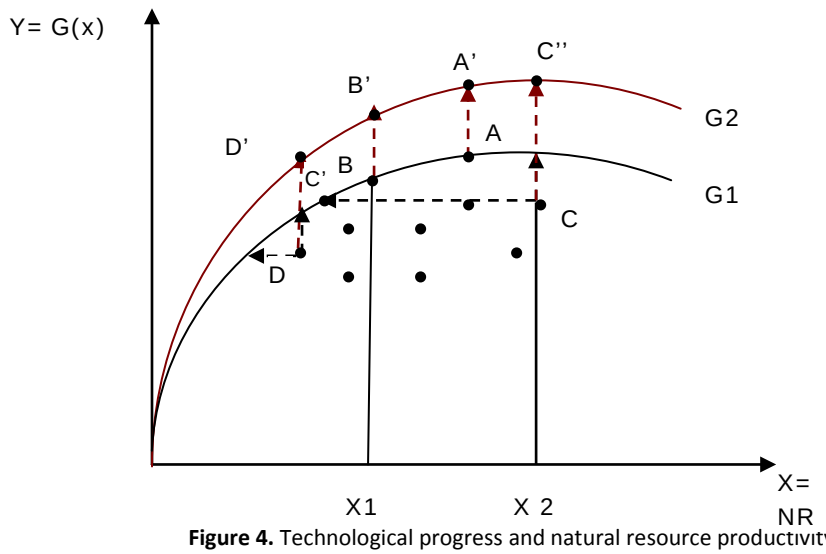


Figure 4. Technological progress and natural resource productivity

It is particularly difficult to assess the economic efficiency of natural resources since this concept uses market prices for inputs and outputs. Indeed, allocative efficiency (AE) measures for a given input and output prices, the distance between farm and the point of maximum profitability. Allocative efficiency shows whether the use of different proportions of production factors ensures the attainment of maximum production with a particular market price. Economic efficiency (EE) is the product of technical and allocative efficiency. It can be interpreted as a potential reduction of production costs or as a potential increase of income.

If some natural resources have a price such as oil, water and land, the estimation of the resource effectiveness such as soil fertility or natural nitrogen is more difficult to quantify. However, the level of income or reducing costs of other factors related to the substitution of an input such as chemical fertilizers and pesticides through increased functionality of the ecosystem may reflect the overall economic efficiency of farm. In this context of researching efficiency, that the EIA is introduced as an important element for an agriculture cooperative strategy. So in the next part we will present the emergency context and the implementation approach of the EIA.

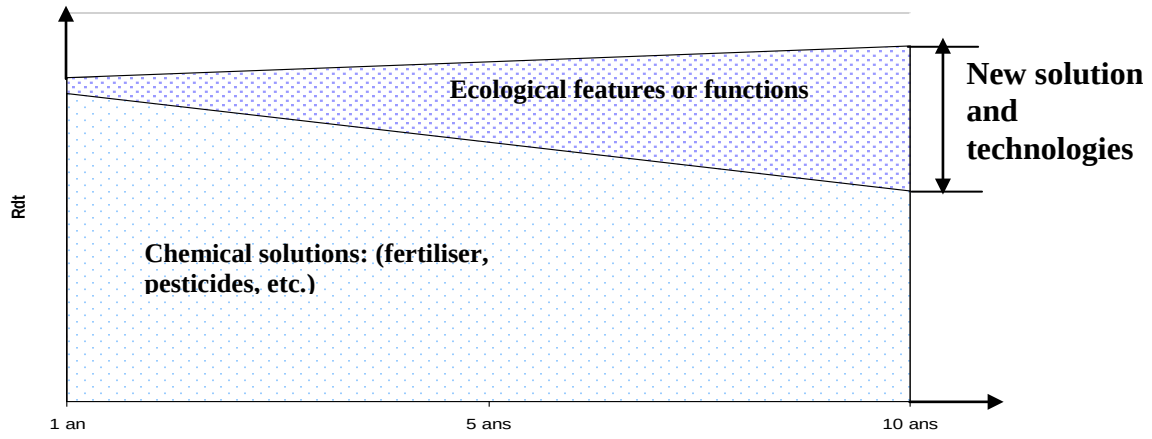
4 The EIA at a cooperative scale

After the Earth Summit (1992), several multinational companies which almost all are frequently accused of environmental degradation are committed to implement measures for the environment (Demazière, (2007)). The action of cooperatives farms such as Terrena in this process has a significant effect due to the specificity of food production and the complex relationships linking agriculture and environment.

4.1 Context of emergence and ownership factors of EIA by Terrena

Agricultural cooperatives in all countries, have accompanied the process of modernization and intensification of their farms member. This feature was particularly important in the context of the so-called multipurpose cooperatives that not provided only a collection and recovery of a more or less extensive production (plant and animal), but also the supply of

inputs (fertilizers, pesticides, feed ...) and materials. This upstream function is generally accompanied by an advisory on the effective methods of production.
TERRENA[2] is the first French cooperative group and it has an important role in the development of regional agriculture and increased agricultural production.
In 2007, the establishment of feasibility test of seed production of GM maize has caused a media crisis disturbing all economic stakes of production branches and processing. In addition, changes in economic regulations and the conclusions of the Grenelle Environment forum where government has advocated a 50% decrease in pesticides use in a decade, led Terrena to a debate with their farmer members to discuss the use of pesticides, chemical fertilizers or the opportunity to grow GMOs. Then a survey was conducted (3116 farmers) to know farmers' expectations from the cooperative and their commitments to the environment. In addition to the great caution in the interest of GMOs, the survey results showed that 90% of participants were aware of the need to significantly reduce pesticides and chemical fertilizers use and required efficient alternatives for meeting the ecosystem, emitting revenue (Terrena, (2010)). The cooperative has decided to meet this challenge by engaging in a process of ecologically intensive agriculture and placing the EIA in the heart of its business strategy[3]. This is in the optical of anticipating the societal, economic and regulatory changes such as rising input costs, growth of food and crops requirements for energy and the absence of chemical solutions following the withdrawal of certain molecules.
This strategic objective is to maintain or increase yields by a process of non-renewable input substitution by technologies based on ecological and biological features (Fig.5). It has a global vision of Terrena territory and it integrates all the cooperative business (division of livestock and crops, division of plant and distribution and food chain division) in this innovative process. This substitution will create an added value for farmer and other stakeholders of the agricultural and food chains and strengthen their competitiveness and economic performance at the European level.



Source : Terrena 2010

Figure 5. Expected evolution of production volumes by substitution of the chemical inputs by ecological features

[2] Situated in Western France, it has a total turnover of 3.9 thousand million Euros, 25000 members and 2 thousand hectares of usable agriculture area.

[3] Annual report 2008 : http://www.terrena.fr/uploads/images/RA_2008_Terrena.pdf

4.2 Implementation of the EIA: a practical approach

Reflection on the implementation of the EIA has gone through a revision of the economic model of the company with an upstream action for agricultural activity seeking to create value and anchor a sustainable agriculture on territory, and a downstream action concerning nutrition and health by integrating consumer expectations. To implement this new model, important financial and human resources have been made to provide a necessary break and go to the EIA. The most important of these elements included the creation of an “EIA team" asked to searching and identification of potentially adaptive innovations in agriculture.

- Implement of a technology watch on all the active research in unconventional farming techniques.
- Establishment of research partnerships in France with companies and public institutes so that they are sure to get technology that could be crucial for competitiveness and future of farms.
- Creation of financial security fund for pioneer farmers particularly in the context of the «earth sentinels." This is consisting on a group of farmers willing to test new technologies or practices on their farms?

Note also that since his involvement in the EIA process, Terrena annually invests nearly 2 million euro in equipment and applied research, nearly 10% of net income.

These tools allow cooperative to participate with research laboratory and tests in micro plots or experimental stations to develop practices and technologies that meet the four conditions of EIA, approved by the cooperative directors and which are:

i. The maintenance and improvement of technical and economic performance.
ii. A significant limitation of non-renewable inputs and chemical alternatives based on natural features.
iii. Limiting the negative impacts of inputs on the environment.
iv. The innovative nature of technology, or by use or in conception.

This work of technology watch and research gets organized around eight themes:

1. Soil conservation: better exploitation of the natural soil potential, including developing techniques to restore and optimize the biological activity

2. Water management: ensuring the availability of water quantity and quality

3. Nutrition and plant protection: integrating prevention, methods, and reliable alternative products, preferably of natural origin, and reason as accurately as possible direct intervention on crops (fertilization treatments...)

4. Tools and machinery: design and integrate new equipment to meet agricultural challenges (alternative farming practices), energy (better use of fuels) and managerial (optimize data flows and tools)

5. Animal Health and Nutrition: Improving the efficiency of feed and thus limit its impact on the environment, while improving the nutritional quality of products for the consumer.

6. Livestock buildings: the techniques of this theme are the development of livestock buildings to make them more economically viable and more efficient from an environmental and energy.

7. Biomass: finding alternatives to fossil resources, valuing co-products or by producing biomass.

8. Biodiversity: biodiversity as developing a pool of real solutions of reduced inputs, and as a collective natural heritage to be preserved.

The second stage of the EIA implementation, is to place the farmer in the heart of the testing process" (Terrena, (2010)) and strengthen links between research, development structures

and farmer. Collaboration with farmer's member is implemented as a farms network. These farmers test new EIA solutions or more complex combinations of solutions (rerouting techniques, system changes). In addition to a reliable experiment on the effectiveness and feasibility, they will allow a better diffusion of innovations.

A number of techniques are well tested and disseminated. For example, the addition of liming, more massive compared to the usual practices, produces beneficial effects on soil structure, biological life and productivity of crops. The combination of two varieties of maize chosen with different types of starch, improves the performance of the food ration. The use of computer disease modeling for wheat is widely deployed in the form of personal advice, it allowed over 2000 farmers to adjust finely their fungicide treatments, (70 000 ha: 50% of the Wheat Terrena surface), resulting in a total decrease of 20% in products used. The cooperative has provided project management for about 50 photovoltaic installations in 2 years (3.2 Mega Wh). Training in eco-driving tractors and energy conservation was launched in 2010.

All these technical solutions have proven equivalent in performance and positive economic results, allowing them more widely. In 2010, a national meeting is organized by Terrena which 90 innovations have been presented to 7,000 farmer members. They correspond to different solutions such as agricultural practices, advices to farmers or even technology products as decision support tools and agricultural machinery.

In some cases experienced techniques have a positive trend in terms of environmental performance; this is the case of simplified techniques for plough the soil. But economic efficiency is complex to understand in context of random prices. While some practices are technically easier to set up and converted into economic results, others are more difficult to assess because of interactions between natural environment and production system. In addition, the evaluation of practices according to the criteria of the EIA requires a long-term analysis to better assess the environmental impacts, especially as it must be part of a systemic approach to take into account interactions that they can generate and reach the economic and environmental sustainability. Indeed, EIA practices only make sense if they are technically and economically feasible, so their evaluations must be established at the farm level in order to assess their impact on the production system and evaluate their effectiveness against the criteria EIA.

5 Conclusion and discussion

This article focused on the presentation of a protective agriculture concept which sets the objective to maintain or improve yields and its adoption as a strategic element for an agricultural cooperative. It raises both conceptual and empirical problems that can not be processed at the same time. For this particular interest, we focused our analysis on the theoretical concept of EIA showing the need for a profound change of the production systems analysis, by placing natural resources the center of the economic functioning of the agricultural sector. It is this strong assumption to consider natural resources as factors of production that distinguishes EIA approach compared to all other concepts of agriculture that they value the environmental objective through a measurement of a large number of sustainability indicators.

Given the complexity of the EIA approach in terms of achievement of its environmental and economic goals, its success depends on three essential elements: the first one concerns the characterization of natural resources and identifying their relationship with yields. That is to identify the "input-output" relation determining the production function. The second one

concerns both assessment of the economic and environmental efficiency of production systems and the contribution of natural resources in the level of overall efficiency. Besides, the issue of technical efficiency measurement for each specific input was raised in the literature by Kumbhaka (1988) and Kalirajan and Obwona (1994). The third element of practices and technologies research is to enhance the functioning of natural resources and improving yields and economic performance.

With regard to the adoption of the EIA in the cooperative strategy, an assessment of the overall cost of the process, including the impact on all activities and evaluation of farmer's ability to adopt EIA practices are required. Indeed, these tests require adapted approaches to the cooperative organization and the role of each center activity (production, processing, and marketing). These steps may correspond to different scales of analysis: a micro level, by analyzing the economic behavior of agents and economic sector analysis in order to take into account links between its different economic actors. In addition, the search for downstream added value, will necessarily guide the company to other strategic options such as eco labeling and marketing of products from EIA (environmental differentiation, strategy of mass, etc.). So the EIA can be a strategic opportunity for the company when it can optimize the use of the results of EIA innovation. The retirement of the innovator who can release Terrena will strengthen its market position by creating assets that is difficult to substitute such as the expertise and brand image. To go further in the EIA approach, it is essential to initiate a thorough analysis of few farms engaged in this process of evolution to identify the farmers' objectives, to understand their operating logic and try to capture their technical, economic and environmental performances by analyzing the natural resources productivity. It is therefore necessary to have a multi-objective and multidisciplinary reason combining economy with particular life sciences (biology, ecology, agronomy, etc.), to capture non-market interdependencies and better appreciate the complexity linked to the environmental phenomena.

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