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Land use and agriculture sustainability: does landscape matter?

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Sylvie FERRARI
CEMAGREF, Research Unit ADER-Bordeaux
CERESUR, Université de La Réunion
Address: Cemagref, 50 Avenue de Verdun, 33612 Cestas cedex. FRANCE
Email : sylvie.ferrari@cemagref.fr

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Abstract

In this paper, we focus on the role played by landscape in the sustainability of agricultural activities and determine the conditions which are required to consider landscape as a sustainable output in this way. Nowadays, agricultural policies in Europe attach a growing importance to the direct management of the countryside by agricultural producers. This actual trend emphasizes the role of non-commodity outputs in the production process, with respect to the multifunctional nature of agriculture. If the traditional function of agriculture activities is to provide food, new functions of agriculture are taken into account and reveal the different attributes of land (use and non use values): agriculture may also produce rural amenities (hunting…), landscape, ecological services, habitat for wildlife and biodiversity. Here, a special emphasis is put on landscape. If several definitions exist (a non-market output, a public good, a positive externality of production, a joint production), all are concerned with the fact that

landscape and other agricultural outputs are complements: they are often jointly produced.

Our analysis relies on an extension of the Georgescu-Roegen's approach on funds and flows. Here, the dynamic property of landscape implies to consider it as a flow. An analytical representation of the agricultural production process lies upon two types of production factors: the funds -human labour, land and manufactured capital- and the flows -energy, natural resources, materials, pollution, waste and products (goods, landscape, amenities…)-. Funds and flows have the property to be complement in the process.

In order to lay emphasis on the physical links between the agricultural production process and the natural environment, we follow a bioeconomic approach where the value of landscape can be appreciated through its physical foundations. According to the second law of thermodynamics, the sustainability of a production process depends upon the quality of all its flow components (inflows and outflows) during a period of time. Thus, the sustainability of any agricultural activity can be measured through the qualitative variation of the production process, *i.e.* through two major outflows: the waste production and the landscape production. A relation between the level of sustainability of any agricultural production process and the landscape change in time may be established and may provide some useful guidelines for policy makers.

1. Towards a bioeconomic perspective of agriculture

Nowadays, agricultural policies in Europe attach a growing importance to the direct management of the countryside by agricultural producers. This actual trend emphasizes the role of non-commodity outputs in the production process, with respect to the multifunctional nature of agriculture (Randall, 2002).

1.1. Multifunctionality: when agriculture is matching sustainability

According to the principles defined in the Agenda 21, the major objective of a sustainable agriculture and rural development is "to increase food production in a sustainable way and enhance food security". In general, sustainability refers to three inter-related dimensions: the economic, environmental and social one. Applied to the agricultural sector, sustainability gives a key place to the satisfaction of food and industrial needs while taking into account economic (efficiency) and environmental (environment protection) constraints. A few years ago, in France, the lawmaker proposed to assign sustainable development objectives to the agricultural policy: the first "loi d'orientation agricole" of the 9^{th} july of 1999 stipulates new functions to agriculture which lies on its multifunctionality nature.

In this connection, for example, (Bromley, 2000) considers three public functions provided by agriculture: amenities, habitat and ecological services. According to (OCDE, 1999), rural amenities refer to "a wide range of natural and man-made features of rural areas, inclunding wilderness, cultivated landscapes, historical monuments, and even cultural traditions".

More generally, if the traditional function of the agricultural production process is to provide food, new functions of agriculture arise and emphasize the different attributes of land (use and non use values): agriculture may thus produce rural amenities (hunting…), landscape, ecological services and habitat for wildlife, biodiversity.

However, besides this normative aspect of multifunctionality (demand side), another one concerns a particular feature of the agricultural production process which is a joint process (supply side) (Vermersch, 2001). It is important in this respect to analyse the physical linkages between non commodity and commodity outputs, and to define the degree of jointness within the agricultural production process. Several recent studies have addressed this issue (Gatto and Merlo, 1999), (Bonnieux and Rainelli, 2000), (Abler, 2001), (Blandford and Boisvert, 2002).

In this paper, we will define the conditions for a sustainable agriculture through this multifunctionality prism. To this aim, a bioeconomic approach of the agricultural production process is chosen with a special emphasis put on landscape.

1.2. Bioeconomics, nature and agriculture

Bioeconomics can be defined as an environmental approach which emphazises the links between the economic system and the natural environment. It relies on the biophysical foundations of the economic system which is open to nature. All economic activities, and agricultural activities particularly, harvest natural resources and generate pollutants and waste into the natural environment. For instance, in many OECD countries, agriculture production processes induce water pollution through excess nutrients (mainly nitrogen and phosphorus): the use of the commodity output requires indeed artificial energy like chemical fertilizers or pesticides. Thereby, the quality of environmental resources is threatened by the agricultural production process (Union Européenne, 1999).

In those circumstances, it would be interesting to deal with the change in landscape production when waste is produced by agricultural activities. If several definitions of landscape exist (a non-market output, a public good, a positive externality of production, a joint production), all are concerned with the fact that landscape and other agricultural outputs are complements in the following way: they are jointly produced. (Blandford and Boisvert, 2002) consider for example two main reasons that give rise to linkages between outputs: the presence of technical interdependencies in the production process or the case of outputs compete for an allocable and fixed input (land for example).

Whatever the case of jointness considered, it is possible to study the production of the joint agricultural process with the help of thermodynamics. Such a methodological direction can be helpful to explain how the agricultural production process performs and how to assess the sustainability of such a process.

2. An entropic analysis of the agricultural production process

2.1. The basic framework

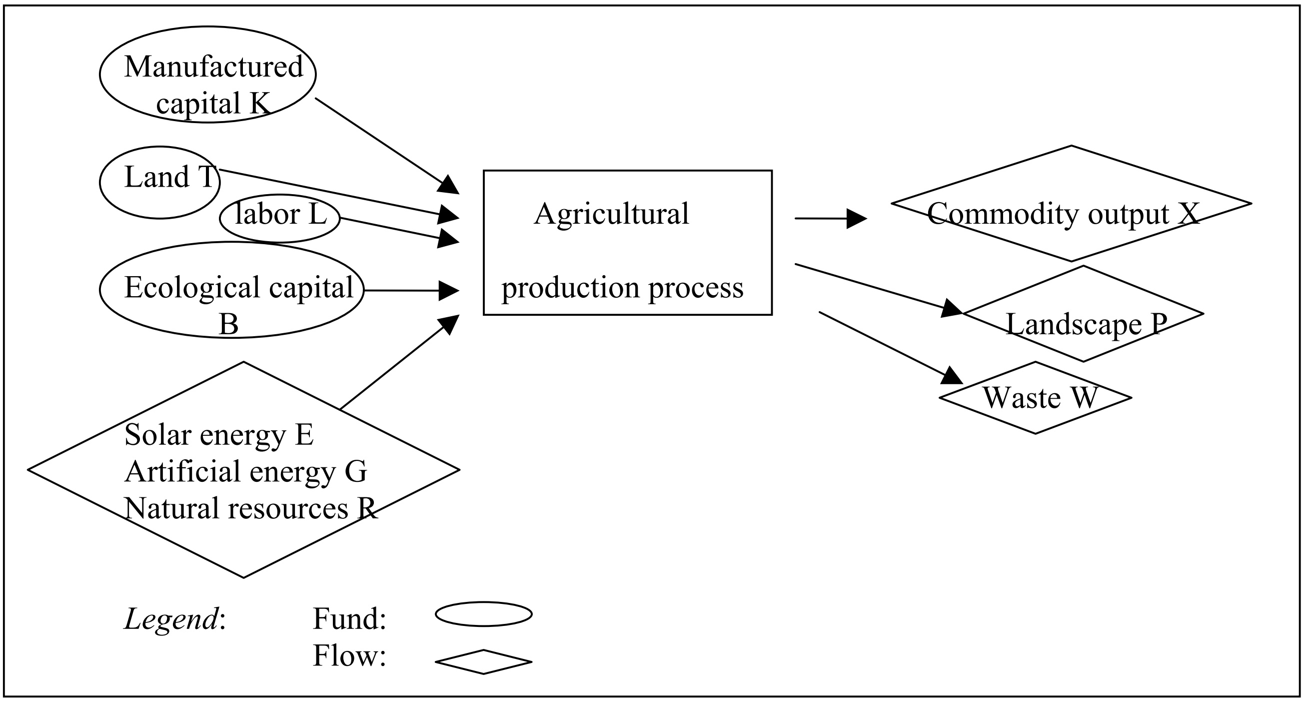
Our analysis relies on an extension of the Georgescu-Roegen's approach on funds and flows (Georgescu-Roegen, 1971) applied to an agricultural production process with landscape. In this context, the dynamic property of landscape is defined in terms of a flow. The analytical representation of the joint production process brings about two types of production factors: the funds and the flows. The funds provide services and are the agents of the transformation of the flows. These are human labour, land, manufactured capital and ecological capital. Ecological capital is made up of non produced organisms like ecosystems which deliver ecological services. Funds are the constant elements (in quality and in quantity) of the production process. Their efficiency does not change with the time duration of the process. They are expressed in physical units appropriate to substances.

The flows are the objects of the agents' actions as well as the 'end products. These are solar energy, artificial energy, natural resources, commodity output, landscape and waste. Artificial energy groups pesticides and chemical fertilizers. Here, natural resources are the material stocks which yield raw materials and receive waste products such as the rainfall, the "natural" chemicals in the air and the soil. Here, flows are not changes in stocks: a flow is a stock spread out over a time interval. Flows can be " inputs " or " outputs " but never both at the same time.

Funds and flows have the property to be complement in the production process. Furthermore, this complementarity hypothesis involves some interesting results about natural capital and the production theory (England, 2000), (Kraev, 2002).

In this context, the agricultural production process (see Fig.1) generates desired goods (commodity and non commodity outputs) and undesired goods which can pollute the natural environment (waste). An entropic analysis of the flows that are involved in the production process may provide a original support to characterize what happens during the process and can explain the distinction between the outflows.

Figure 1
A representation of the agricultural production process



Thus, like any production process, we have both flows and funds. For some given amounts of land, manufactured capital, human labour and ecological capital, a set of input flows is required for production, the technical nature of which determines the flow rate of waste (Georgescu-Roegen, 1984). Because of the jointness property and for a given time interval t (which represents its duration), an analytical representation of the agricultural production process can be given as:

$$X = F^1(G, E, R, W, P; t) \qquad (1)$$

And

$$P = F^2(G, E, R, W, X; t) \qquad (2)$$

Each variable is time dependent. If we assume that the flows are homogeneous linear functions of t, those two equations may be written in term of the rate of flows as follows:

$$x = f^1(g, e, r, w, p) \qquad (1')$$

And

$$p = f^2(g, e, r, w, x) \qquad (2')$$

With: $G(t) = g.t$; $E(t) = e.t$; $R(t) = r.t$; $W(t) = w.t$; $P(t) = p.t$

Furthermore, we assume that technical interdependencies in the production process exist. In other words, there is a link between the level of a negative externality (W) and the level of the agricultural products (e.g. X and P). Thereby, we can note that considering landscape as an outflow reinforces the complement property built on the joint production hypothesis. Here, we consider the case of a technical jointness between the outflows: the level of X both depends on the allocated factors and on the level of P and W.

Following the major works of Georgescu-Roegen mentioned above, we can apply an entropic analysis to the agricultural production process. Substantially, the entropy law states that "In an isolated system, entropy increases over time (irreversible system) or remains constant (reversible system)" according to the Clausius formulation. In this context, entropy is considered as an index of the quantity of the unavailable energy (or dissipated) into heat and waste in a thermodynamic process.

An entropic reading of an agricultural production process is the following: it transforms natural resources, solar and artificial energies, into commodity (agricultural product) and non commodity outputs (landscape and waste). Thereby, it changes some amount of energy into heat and waste: energy is continuously degraded or dissipated.

In other words, the transformation of the flows by the funds is at the bottom of a change of the qualitative state of the production process which creates desired and non desired goods. If all the inflows have an economic value, it is not necessary the case for all the outflows. Furthermore, the economic distinction between goods having value (agricultural product and landscape) and waste without value has suggested the thermodynamic distinction of low and high entropy. The production process produces the next three outflows: the commodity good which has a price and a low entropy, the non-commodity good which has no price but a low entropy too, and, finally, the waste which has no price and a high entropy content.

2.2. Economic value, commodity and non-commodity goods

The question of economic value can be directly connected with the entropic approach of the production process. The major connection between thermodynamics and economics through energy dissipation implies that the original quality of any good lies in its low entropy which is *in fine* the root of economic scarcity.

First, the necessary condition for a good to have economic value lies in some particular physical and chemical properties. The primary quality of any resource refers to its availability to produce work (e.g. available matter and energy). From a thermodynamic viewpoint, the intrinsic quality of any object is the low entropy it contains. In a way, we can say that usefulness is supported by those “ *extra*-economic ” properties. Thereby, thermodynamics teaches us why an object which is useful has also an economic value.

Following Georgescu-Roegen, the link between low entropy and economic value is like the one between economic value and price:

“An object can have a price only if it has economic value, and it can have economic value only if its entropy is low. But the converse is not true”. (Georgescu-Roegen, 1976), p.60. Low entropy is a necessary condition for a thing to have value. But this condition is not sufficient: things may have a low entropy and yet no economic value.

Second, price and economic value cannot be confused: every object used by the production process has an economic value because of its low entropy but does not have necessary a price. It is the case the ecological capital and the services delivered by the ecosystems.

What about the agricultural production process ? All the inflows of the process have an economic value but have not necessary a price. Considering the elements that nature offers without any cost, the sufficient condition for them is to have a low entropy content. All the inputs crossing the production process have necessarily an economic value. Those inflows are market or non-market goods. In the first category, we have artificial energy. In the second one, we include natural resources and the solar energy. Whatever the category the inflow belongs to, it has a content of low entropy (e.g. energy and matter availability).

From a symmetrical standpoint, any outflow with a high entropy content has no economic value. It is the case of waste. But, sometimes, they do not go out of the economic process because they are recycled. In all but this case, a flow of waste has to be taken into account.

3. Sustainability and qualitative change of the production process

3.1. Waste and irreversibility

Because of the entropy law, any production process which does work irreversibly creates entropy. Waste production can be seen as an implication of the irreversibility of the production process. Dissipation takes place any time waste is produced. In this context, waste is a joint product and a necessary consequence of thermodynamics (Baumgärtner, Dyckhoff et al. 2001).

In a previous work, we related the join product notion to the concept of essential (Ferrari, 2001). In the economic literature, some authors have considered that a resource could be essential under some conditions. (Dasgupta and Heal, 1979) who analysed the substitution possibilities between renewable and exhaustible resources to characterize the production factors applied the concept of essential resource. In the absence of such a resource, the level of the output is necessarily nil.

Here, we define waste W as an essential outflow, so that for any positive production, the following condition is observed :

$$\begin{aligned} &\text{If } W(t)=0, \text{then } X = F^{1}(G,E,R,W,P;t)=0 \\ &\text{and } P(t) = F^{2}(G,E,R,W,X;t)=0 \quad \forall t>0 \end{aligned} \tag{3}$$

For any strictly positive production, a positive amount of waste is produced, for all t > 0. Waste is an undesired good which is irreversibly produced when the production process operates. We could say that the absence of waste in the standard production function correspond to a particular case where only the first law of thermodynamics applies: the production process is reversible. However, as from a thermodynamics standpoint waste is a joint product, we have to take it into account.

In those circumstances, when the entropy law is working, e.g. waste is an essential outflow, the agricultural production process is driven by irreversibility. The presence of waste is synonymous with polluting the natural environment, which is coming with a loss in the production value.

3.2. Landscape *versus* waste

If we consider that the level of the waste flow is closely connected with the quality of inflows and their arrangement within the production process, quality change in time can be measured with the entropy variable. In a physical perspective, the qualitative change of the agricultural production process can be assessed by the waste flow. Until the production process is open, the entropy change through time is presented in the form of the following items:

$$dS(t) = d_i S(t) + d_e S(t) \tag{4}$$

with $d_i S(t)) > 0$ because of the waste production which is irreversibly produced by the production process. The second item $d_e S(t)$ represents the exchange of entropy between the process and its environment.

It is possible to appreciate the sustainability of the production process from this relation. For instance, if a growing outflow of pollution if computed, the entropy flow produced by the process is bigger than the entropy coming from the outside of the process. The production process is no longer sustainable from a physical viewpoint. However, the scale of observation of the temporal change is a key variable in order to take into account the role of natural processes. For example, the solar inflow (E) may contribute to reduce the entropy of the production process through the changes that operate within the ecosystems and the biogeochemical cycles (Kaberger and Mansson, 2001). In this connection, biological organisms living within ecosystems (B) may reduce the high entropy produced by the agricultural production process (natural recycling of waste).

The value of the change in entropy is based on the waste production which depends on the production process efficiency. Any increase of waste implies a decrease of the efficiency and conversely. For some given funds, the efficiency of the production process for the outflow X may be given as:

$$\eta(W\,;\,t) = \frac{X}{Z} = \frac{\text{outflow with economic value}}{\text{inflows from nature}} \qquad (5)$$

The efficiency factor is related to the transformation processes. All the quantities are measured in physical units.

According to the entropy law, we have $0 \leq \eta \leq \psi < 1$ where ψ stands for Carnot efficiency. The second law of thermodynamics implies an upper limit for the efficiency (or productivity from the economic standpoint) of a technology: the so-called Carnot efficiency teaches us that the efficiency of any transformation is always less than one.

From a physical viewpoint, the case where $\eta = 1$ is not possible. Furthermore, this case would imply that ”X” reaches its maximum level and waste is zero, which is impossible if W is an essential output. If $\eta = 0$, then the level of outflow is equal to zero and no waste is produced. The production process does not work and the time duration is zero.

Finally, we consider the case where $0 < \eta < 1$. It follows:

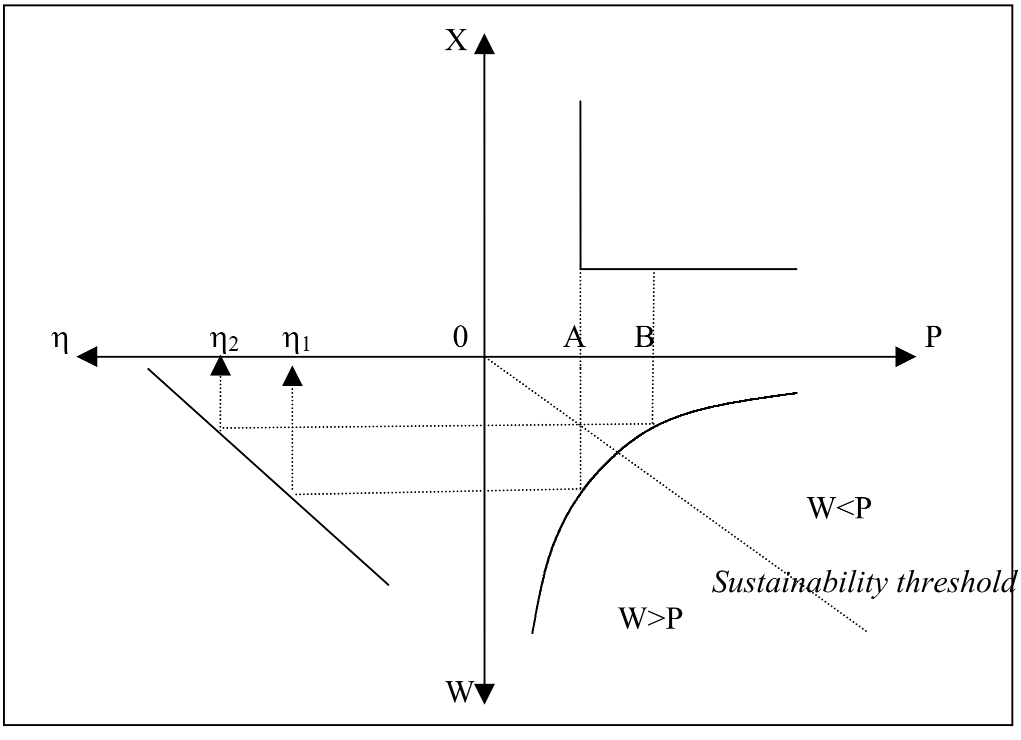
$$X < X_{max} \; ; \; W > 0 \; ; \; \forall t > 0 \qquad (6)$$

This is the general case when the entropy law is applying. When energy is dissipated, the economic process creates a flow of waste without any value because it is a flow of high entropy. According to (Georgescu-Roegen, 1971), waste is a qualitative residual that reflects the qualitative change of the production process in time.

A way to reduce this flow is to increase the Carnot efficiency of the production process. The higher is the efficiency of the production process, the smaller is the waste outflow, for some unchanged amounts of inflows and for a given scale of the process.

If we apply this statement to a joint production process, it follows that a smaller waste output can bring to more landscape production (see Fig.2). We can reach an upper level of the landscape flow (A to B) without reducing the commodity production with the help of a higher efficiency (η_2) coming from a decrease in waste production.

Figure 2
An hypothetical representation of
waste, landscape and the production process efficiency



By reducing the waste outflow and for unchanged funds, some landscape may be substituted to waste and raise the value of the agricultural production. However, the substitution hypothesis is sustainable insofar as the qualitative implications of the entropy law involve to balance the waste flow with an increase of the process efficiency.

4. Conclusion: Landscape as a sustainable outflow

Following the second law of thermodynamics, the sustainability of a production process depends upon the quality of all the elements which flow through it during a period of time.

In the first place, the sustainability of an agricultural activity could be assessed through the qualitative variation of the production process, e.g. through two major outflows: the waste and the landscape productions. On the one hand, every time waste is produced, the irreversibility of the activity is growing. On the other hand, a growing production of landscape traduces its ability to stop the irreversibility of the production process.

However, the landscape production is the only one to be used in order to assess the sustainability of the agricultural production process. Let us recall that landscape has a low entropy content and it may be substituted for waste in accordance with the entropy law. In other words, it is a complement to an outflow with an economic value (like the commodity good) and a substitute for an outflow without any value (such as waste).

Furthermore, landscape has an economic value because of its low entropy. This point implies that it contains both use and non-use values. In this way, the landscape production is in accordance with the environmental dimension of sustainability. When the landscape flow is rising with the fall of waste flow, the production process becomes more sustainable. The roots of sustainability rely on the additional value brought by landscape production: some value is substituted to the “non value” content of waste with the increase of the efficiency of the production process. Consequently, the value of the agricultural production is growing.

In this context, landscape is a sustainable outflow if it is able to raise the economic value of the commodity outflow. This statement is right if there exists technical interdependencies in the production process (e.g. a physical link between externalities and goods produced).

Finally, our approach based upon qualitative items (funds/flows) and offering throughout a qualitative analysis of the production process allows to take into account the time variable. Sustainability of the production process depends on the landscape change in time which is governed by the agricultural activities. Thus, the landscape value has to be related with the preservation of some attributes like biodiversity or habitats. Furthermore, biofuels production or change in the style of farming can lead to a change in landscape because of the decreasing of the waste production.

5. References

Abler, D. (2001). A synthesis of country reports on jointness between commodity and non-commodity outputs in OECD agriculture. Workshop on multifunctionality, Paris, OCDE.

Baumgärtner, S., H. Dyckhoff, et al. (2001). "The concept of joint production and ecological economics." Ecological Economics **36**(3): 365-372.

Blandford, D. and R. N. Boisvert, Eds. (2002). Non-trade concerns and domestic/international policy choice, Working Paper 02-1,

International Agricultural Trade Research Consortium.

Bonnieux, F. and P. Rainelli (2000). "Aménités agricoles et tourisme rural." Revue d'Economie Régionale et Urbaine **5**: 803-820.

Bromley, D. W. (2000). "Can agriculture become an environmental asset ?" World Economics **1**(3): 127-139.

Dasgupta, P. and G. M. Heal (1979). Economic theory and exhaustible resources. Cambridge, Cambridge university press.

England, R. W. (2000). "Natural capital and the theory of economic growth." Ecological Economics **34**(3): 425-431.

Ferrari, S. (2001). Economic value and entropy: Nicholas Georgescu-Roegen's approach with non-market goods. Strasbourg, Université Louis Pasteur, IXth Conference of the Charles Gide Association, Beta-Thème.

Gatto, P. and M. Merlo (1999). The economic nature of stewardship: complementarity and trade-offs with food and fibre production. Countryside stewardship: farmers, policies and markets. G. Van Huylenbroeck and M. Whitby, Pergamon press: 21-46.

Georgescu-Roegen, N. (1971). The entropy law and the economic process. Cambridge (Mass.), Cambridge university press.

Georgescu-Roegen, N. (1976). "Economic growth and its representation by models." Atlantic Economic Journal **4**: 1-8.

Georgescu-Roegen, N. (1984). "Feasible recipes versus viable technologies." Atlantic Economic Journal **12**(1): 21-31.

Kaberger, T. and B. Mansson (2001). "Entropy and economic processes - physics perspectives." Ecological Economics **36**(1): 165-179.

Kraev, E. (2002). "Stocks, flows and complementarity: formalizing a basic insight of ecological economics." Ecological Economics **43**(2-3): 277-286.

OCDE (1999). Cultivating rural amenities. Paris.

Randall, A. (2002). "Valuing the outputs of multifunctional agriculture." European Review of Agricultural Economics **29**(3): 289-307.

Union Européenne (1999). Pistes pour une agriculture durable. Bruxelles, Communication de la Commission au Conseil, au Parlement Européen, au Comité économique et social et au Comité des régions.

Vermersch, D. (2001). La multifonctionnalité : mise en oeuvre du cadre analytique de l'OCDE, Une revue de la littérature en France. Rapport, Direction de l'Alimentation, de l'Agriculture et des Pêcheries, OCDE.