Introduction: Features of environmental sustainability in agriculture: some conceptual and operational issues

Tommy Dalgaard

Department of Agroecology
Danish Institute of Agricultural Sciences
P.O. Box 50, DK-8830 Tjele, Denmark
E-mail: Tommy.Dalgaard@agrsci.dk

Sylvie Ferrari*

University Montesquieu-Bordeaux IV
Grape UMR CNRS 5113
Avenue Léon Duguit, 33608 Pessac cedex, France
E-mail: sylvie.ferrari@u-bordeaux4.fr
*Corresponding author

Mbolatiana Rambonilaza

Cemagref – Agricultural and Environmental Engineering Research
50 Avenue de Verdun, 33612 Cestas cedex, France
E-mail: mbolatiana.rambonilaza@cemagref.fr

Abstract: This introductive paper aims to address the features of environmental sustainability in agriculture. Recent developments of the concept, which are discussed here, emphasise its multi-faceted nature and lead to various definitions as well as to different implications for policy measures in society. On the basis of all the papers presented in this Special Issue, we draw some perspectives for future research on the topic.

Keywords: environmental sustainability in agriculture; sustainability assessment; agroecology; multifunctionnality.

Reference to this paper should be made as follows: Dalgaard, T., Ferrari, S. and Rambonilaza, M. (2006) 'Introduction: Features of environmental sustainability in agriculture: some conceptual and operational issues', *Int. J. Agricultural Resources, Governance and Ecology*, Vol. 5, Nos. 2/3, pp.107–115.

Biographical notes: Dr. Tommy Dalgaard is Head of the Research Unit. He has a PhD in Agroecology. His works focus on interdisciplinary research in agricultural systems, and methods to upscale farm level information for landscape and regional level analyses of rural development issues.

Dr. Sylvie Ferrari is an Assistant Professor. She has a PhD in Economics. Her research is in the following areas: energy, groundwater resource and sustainable development, economics and thermodynamics, agricultural production process and sustainability indicators. During the preparation of this special issue, she was a Visiting Researcher at Cemagref – Agricultural and Environmental Engineering Research in Bordeaux.

Dr. Mbolatiana Rambonilaza is Permanent Researcher at Cemagref. She has a PhD in Economics. Her current research activities address the economic valuation of rural amenities and cultural landscapes within demand approach, and land-use management.

1 Agriculture and environment: why does sustainability matter?

In the late 1980s, the international community wedded to define the concept of 'sustainable development', which became popular with the so-called Brundtland Report (World Commission on Environment and Development, 1987). During that period, the various definitions of the concept of 'sustainable agriculture' emphasised different aspects of agriculture corresponding to three interrelated dimensions: economic, social and environmental (Yunlung and Smit, 1994). Sustainability has thus an intrinsic multi-faceted nature, which is at the core of its various meanings and definitions.

According to Agenda 21, the United Nations' (1992) plan of action to implement sustainable development, the major objective of sustainable agriculture and rural development is:

> "To increase food production in a sustainable way and enhance food security. This will involve education initiatives, utilization of economic incentives and the development of appropriate and new technologies, thus ensuring stable supplies of nutritionally adequate food, access to those supplies by vulnerable groups, and production for markets; employment and income generation to alleviate poverty; and natural resource management and environmental protection."

In addition, sustainability in agriculture is also defined as "the process by which the demands for its outputs-food, fibre and other outputs- are met from farming practices that are economically efficient, respect the environment, and are socially acceptable" (OECD, 2001). Because agriculture has a major impact on the environment, especially on land use, soil, water and biodiversity, there is a general recognition via many agricultural policies in OECD countries of the need to enhance the beneficial and reduce the environmental impacts of agriculture, and to ensure the sustainability of resource use. The environmental impacts can refer to soil quality, water quality, air quality, climate effects, biodiversity and landscape. The degradation of natural capital has various consequences such as loss of topsoil, waste and pollution of water, nutrient loss, and extinction of species.

Here, we especially aim to question the features of environmental sustainability in agriculture, and the recent developments in the conceptualisation and operationalisation of the issue, as debated in this special issue.

2 Definitions of environmental sustainability in agriculture

In a general review of studies related to agriculture and sustainability, Yunlung and Smit (1994) confirm the general division into environmental, social and economic aspects. Following this definition, Pannell and Schilizzi (1997) define sustainability within three categories of elements: ecology (environmental values), ethics (intergenerational equity) and economics (efficiency concern). Thus, sustainability can be identified with the help of three issues: protection of ecological systems and their *per se* values, equity and fairness over generations, and efficiency of resource use.

Miranowski and Carlson (1993) propose to define sustainable agriculture as "a production system that can be maintained over the long run while ensuring profitability, productivity and environmental quality". They added:

> "Such a system may involve the substitution of more farm-source inputs for purchased chemicals and the substitution of crops that enhance nutrients and contribute to pest control for more conventional crops, as well as the substitution of technology and information for conventional practices." (p.6)

Thereby, the economic, social and environmental issues that sustainable agriculture addresses encompass the viability of the system over time.

At a global level, Goodland (1995) proposes to define environmental sustainability as the 'maintenance of natural capital'. He adds that "environmental sustainability seeks to improve human welfare by protecting the sources of raw materials used for human needs and ensuring that the sinks for human wastes are not exceeded, in order to prevent harm to humans" (p.3). Environmental sustainability is thus a goal for society. The author identifies environmental sustainability as a "set of constraints on the four major activities regulating the scale of the human economic subsystem: the use of renewable and non-renewable resources on the source side, and pollution and waste assimilation on the sink side" (p.10).

At the farming system level, Sands and Podmore (2000) provide an operative and axiomatic definition of environmental sustainability. In this case, the main purpose is not only to satisfy human needs but to specify a set of conditions that make the farming system environmentally sustainable. Environmental sustainability move from a qualitative state to a quantitative state in order to support decisions by policymakers, farmers or consumers *etc.* According to the first axiom, an environmentally sustainable agricultural system is "one in which the inherent capacity of the soil and water resources that support agricultural production are maintained or improved over time". This axiom refers to the global criterion for sustainability suggested by Goodland (1995). The second axiom states that "an environmentally sustainable agricultural system is one where no leaching, lateral flow, and/or runoff of degradative constituents occurs (*i.e.*, nutrients, agricultural chemicals, and sediments)". It follows that sustainability at the farming system level is rather a goal than a state. It is almost impossible to prevent any leaching or runoff from farming practices, but at the watershed level, leaching or runoffs might be caught before entering vulnerable water environment recipients, thereby achieving the sustainability goal at a larger scale than the farm. Finally, they specify that "an agricultural system is considered to be environmentally sustainable if certain inherent qualities of soil and water resources are maintained and no drift of nutrients, chemicals or sediment occurs from the system". The sustainability context implies that the inherent capacity to support production has to do with intrinsic characteristics that make soil productive (organic matter, favourable structure *etc.*) and has to be maintained or improved. Within this perspective, environmental sustainability needs time for change, whatever the level – farm, system or global – we consider. The larger the scale, the longer time span is generally needed to reach this steady state of sustainability (Van Gardingen *et al.*, 1997).

3 Critical limits and competing objectives for sustainability

Following Tait and Morris (2000), one may suggest two distinct meanings of sustainability that lead to two conceptual issues in agriculture: 'critical limits' and 'competing objectives' views. In the first case, there is an ecological issue built on critical limits arising from concerns about the earth's carrying capacity and on scientific hypothesis about the functioning of ecosystems. In this respect, farming systems have to be limited by the primacy of the single objective of environmental sustainability; which is for instance the ideal for organic farming systems (IFOAM, 2002). Moreover, sustainable farming makes the best use of nature's goods and services whilst not damaging the environment (Altieri, 1999; Pretty, 1999). Within an ecological view of agricultural production systems, crop outputs are regarded as a part of a diverse agro-ecological system. This is done by integrating natural processes such as nutrient cycling, nitrogen fixation, soil regeneration and natural enemies of pests into food production processes. Moreover, environmental problems associated with conventional or high input agriculture are linked with an increase of the production costs (Pimentel, 1999). To maintain the long-term sustainability of the whole system, agricultural practices must minimise the use of environmental damaging, non-renewable inputs such as fossil fuels, pesticides and fertilisers. One possibility to achieve this goal is to rely more on organic techniques, and make better use of the knowledge and skills of farmers (Gliessman, 1998). Within this context, integrated farming systems are encouraged and viewed as an alternative to intensive farming systems and a way to develop a more sustainable agriculture (Morris and Winter, 1999). At the same time, an ecological approach is necessary for sustainable production and a better understanding of the interdependencies between crops, natural resources and the environment.

In the second case, the 'competing objectives' perspective involves balancing long term agricultural sustainability with ecological, social and economic goals. Sustainability in agriculture thus implies production of food and fibres, which has to be economically viable (efficiency objective), socially acceptable (equity concern) and at the same time avoiding environmental resources degradation and depletion. It is obvious that economic, social and ecological goals may conflict, and because sustainability is defined by a set of various concepts, it is not possible to implement a unique definition of this concept (Pannell and Schilizzi, 1997).

The OECD and Agenda 21 interpretations, mentioned above, both refer to the 'competing objectives' view of agricultural sustainability. The question is how, in practice, to combine long-term agricultural land use with economic viability of farming systems, and with the social, ethical and cultural concerns in the rural areas. Certainly, it is a challenge to reconcile the need for sufficient and safe food with environmental quality.

4 Environmental sustainability and the new model of European agriculture

The Agenda 2000 reform of the Common European Agricultural Policy (CAP) involves major changes in the EU member states (Pacini *et al.*, 2004), where a variety of policy measures to address environmental concerns are pursued (OECD, 2004). The major objective of the CAP-reform was to promote sustainable agriculture by changing the production practices of the farmers. In addition, the 'Model of European Agriculture' (MEA) was introduced into the CAP-terminology (CEC, 1998). The MEA is based on the idea that European farming provides non-market outputs to society. Consequently, the contribution of agriculture to a range of public goods such as food security, food safety, animal welfare, cultural landscape, biodiversity and rural development is leading to a multi-functional agricultural production system (Glebe, 2003). Various, unique functions may thereby be supplied by agriculture in an efficient way, and these non-commodities should be included in the evaluation of the sustainability of agriculture, to which they eventually contribute (Pretty, 1999; Casini *et al.*, 2004; Rizov, 2004).

In the MEA-terminology, agriculture provide a range of ecosystem services – including carbon sequestration and stabilisation of the climate, habitat for endangered species and other wildlife, purification of air and water *etc.* (Heal and Small, 2001). With a 'critical limits' viewpoint, where sustainability is defined as an objective, sustainability thereby becomes a guide to decision for policy makers, who require suitable sustainability indicators for the ecological functions provided by agricultural systems. The environmental sustainability in agriculture is thus linked with distinct ecological functions fulfilled by different farming systems, supposing that environmental sustainability is not inherent in any particular type of farming system (Tait and Morris, 2000).

Finally, sustainability in agriculture cannot be considered without normative settings, which are changing upon time (Giampietro, 2004). Therefore, sustainability is characterised by its adaptability to respond to human needs and its ability to protect the ecological, social and, economic resources. To achieve this goal of sustainability, an efficient use of technology is required. Since all the objectives can be achieved in a number of different ways, a sustainable and multi-functional agriculture is not linked to any particular technological practice or to the exclusive domain of organic farming. In this context, sustainability assessment in agriculture is based on goal-oriented concepts whose dimensions are necessarily normative, spatial and temporal (Von Wiren-Lehr, 2001).

5 Perspectives for future research and the studies of this special issue

During the last couple of decades, agroecology has emerged as an integrative discipline, covering the scientific issues related to the development of sustainable agriculture (Dalgaard *et al.*, 2003). Rooted in the schools of population and process ecology, this new discipline emphasises the key role of biodiversity in agro-ecosystems for bringing sustainability to production, and the necessity to move to a new paradigm in agriculture, which integrates all dimensions of sustainability (Altieri, 1999).

Two of the major challenges for agroecology, and the studies of sustainable development in agriculture, are:

1 How to integrate research results from different disciplines

2 How to communicate these results to decision-makers, who require information on other abstraction levels and spatio-temporal scales than those where research are carried out (Dalgaard *et al.*, 2003).

The first challenge can be approached via the development of models, integrating results and experiences from different research disciplines. Examples on such model development are found in several of the papers in this special issue. In such cases, the development of participatory approaches is important, implicating that the models are developed in close cooperation with the end-users requiring the results of the models. This leads to the second challenge. In order to efficiently communicate research results to decision-makers, researchers need to understand the problems of the decision-makers, and the decision-makers need to understand the limitations of research. Procedures for such bilateral communication must be developed, thereby ensuring the right focus for research. In addition, this communication will serve as a learning process, towards better insight in how to facilitate a sustainable development.

Within this special issue, the requirements for environmental sustainability in agriculture are thus necessarily driven by a pluri-disciplinary perspective. Some topics of the papers include analytical tools for modelling environmental sustainability and strategies for improving the environmental sustainability of the production process, while others put a special emphasis on the multifunctional dimension of agriculture or on the assessment of environmental sustainability with the help of indicators. The various studies presented here show that there is a need to bring together economics, ecology, physics, and other disciplinary fields for raising awareness of the environmental dimensions of agriculture as well as the agriculture-environment interactions.

An original integration of all dimensions of agriculture is exemplified in this special issue where Gomiero *et al.* provide a powerful analysis of the links between sustainability, complexity, and diversity in agricultural systems with the use of a new modelling tool within a Multi-Objective Integrated Representation (MOIR). Furthermore, the analysis of the sustainability of agricultural landscapes, in connection with pollutions, takes a major place in numerous papers. Two important questions are considered:

1 First, how to assess environmental impacts of new practices more respectful for environment, whence the need of simulation models.

2 Second, how to deliver the results to political decision-makers in a comprehensive and operational way; this point involves the building of indicators.

Lacroix *et al.* study, for instance, the problem of the choice of the method for the evaluation of public policies, when these address environmental objectives in the field of agriculture. The analysis of environmental impacts of agriculture leads to four difficulties: the oversimplification of the process; the choice of the spatial dimension suitable for analysing the change (farm, administrative, national, local or watershed scale); the temporal dimension and the necessity to distinguish between the mid-term and long term impacts; the integration of the spatial dimension with the temporal one. Those difficulties are also underlined in the paper of Payraudeau *et al.*, which displays a model suitable for assessing emissions of nitrogen compounds for a group of farms. The model is very innovative because it contains an approach in terms of a system instead of a sole farm. The paper of Turpin *et al.* goes ahead by developing bio-economic models. In the context of assessing good practices for the reduction of diffuse pollution, they combine a hydrologic model with an economic model integrating a cost-effectiveness approach as a criterion for public decision. Their case study concerns a watershed, which allows us to analyse the impact of incitative mechanisms on the set of farms of the area considered. However, the environmental impacts of agricultural practices are not uni-dimensional. Consequently, it seems important to assess the links between the various components by considering a demand-oriented approach and, for instance, by taking into account the set of non-commodity outputs produced by agriculture. Sattler *et al.* suggest an interesting approach based on trade-off functions, which permits to appreciate *ex ante* the disadvantages and the advantages of alternative public policies. Another way to consider this multi-functionality of agriculture is to follow Bernetti *et al.* by analysing the dynamic change in the use of space. In addition, some authors are focusing on the assessment of the ecological sustainability by building standard indicators like Chowdhury *et al.*, or by using energy indicators leading to the recognition of both national and local scales like what Ferreyra's paper did.

The main difficulty met by the agri-environmental measures in the European Union is due to their weak social acceptability. For instance, the adoption rate by the farmers of the agri-environmental contracts remains very low for the major part of the European countries. The analysis of the environmental impacts of the agricultural practices cannot be realised aside the analysis of the economic profitability and above all the social acceptability of the contracts. The article of Amon *et al.* shows the role of socioeconomic aspects, which moderate the voluntary adoption of more respectful agricultural practices, hence the necessity to promote more interdisciplinary approaches. Several ways are then suggested for *ex ante* assessment methods of public policies. Legrusse *et al.* suggest to develop a participatory modelling, a method which associates local decision-makers for setting the evaluation tool (scenario conception and results analysis).

Finally, it is our hope, that the papers of this special issue will inspire future research, facilitating the sustainable development of agricultural systems throughout the World.

Acknowledgements

The guest editors of this special issue of the *International Journal of Agricultural Resources, Governance and Ecology* would like to gratefully acknowledge the following persons for their scientific support during the editorial process:

- D. Bailly, University of Brest, France
- B.K. Bala, Bangladesh Agricultural University, Bangladesh
- M. Bengtsson, Institute of Industrial Science, University of Tokyo, Japan
- D. Blandford, Pennsylvania State University, USA
- J-M. Boisson, University of Montpellier 1, France
- F. Brouwer, Agricultural Economics Research Institute, The Hague, The Netherlands
- F. Carlevaro, University of Geneva, Switzerland
- D. Collentine, University of Gävle, Sweden

- T. Dalgaard, Danish Institute of Agricultural Sciences, Denmark
- M. d'Arcimoles, CSO-Cnrs, France
- C. Dutilly, Cirad, France
- S. Farolfi, Cirad and University of Pretoria, RSA
- G. Flichman, CIHEAM-IAMM, Montpellier, France
- C. Giupponi, University of Milan, Italy
- P. Grundmann, Leibniz Institute of Agricultural Engineering Bornim, Germany
- K. Knickel, Institute for Rural Development Research
- J.W. Goethe-University of Frankfurt/Main, Germany
- I.S. Kristensen, Danish Institute of Agricultural Sciences, Denmark
- P. Lecomte, Cirad-Réunion, France
- D. Marinova, Institute for Sustainability and Technology Policy, Murdoch University, Australia
- A. Mollard, Inra-Grenoble, France
- P. Nijkamp, Free University Amsterdam, The Netherlands
- E. Ortega, Unicamp, Brasil
- L. Piet, Ministry of Agriculture and Fisheries, France
- P. Point, University of Bordeaux IV, France
- J.J. Schröder, Agrosystems Research Department, Plant Research International, Netherlands
- S. Ulgiati, University of Siena, Italy
- G. Van Huylenbroeck, Ghent University, Belgium
- A. Wossink, North Carolina State University, USA

References

Altieri, M.A. (1999) 'The ecological role of biodiversity in agroecosystems', *Agriculture, Ecosystems and Environment*, Vol. 74, pp.19–31.

Casini, L., Lombardi, G., Ferrari, S., Rambonilaza, M., Sattler, C. and Waarts, Y. (2004) 'The analytic multifunctionality framework', *Research Report, MEA-Scope Project*, Electronic address http://www.zalf.de/home_meascope/website/publications/mea-scope_vol1_analytic_multifunctionality_framework.pdf.

CEC (1998) *Proposals for Council Regulations Concerning the Reform of the Common Agricultural Policy*, COM (1998) 158 final, Commission of the European Communities, Brussels.

Dalgaard, T., Hutchings, N.J. and Porter, J.R. (2003) 'Agroecology, scaling and interdisciplinarity', *Agriculture, Ecosystems and Environment*, Vol. 100, pp.39–51.

Giampietro, M. (Ed.) (2004) *Multi-Scale Integrated Analysis of Agroecosystems*, CRC Press.

Glebe, T. (2003) 'Multifunctionality: how "green" is the "European model of agriculture?"', *Discussion Paper 01–2003, Environmental Economics*, Resource Economics and Agricultural Policy Research Group.

Gliessman, S.R. (1998) *Agroecology. Ecological Processes in Sustainable Agriculture*, Chelsea, MI, USA: Ann Arbor Press.

Goodland, R. (1995) 'The concept of environmental sustainability', *Annual Review of Ecology and Systematics*, Vol. 26, pp.1–24.

Heal, G.M. and Small, A.A. (2001) 'Agriculture and ecosystem services', *Handbook of Agricultural Economics*, Elsevier, Vol. 2A, pp.1341–1369.

IFOAM (2002) *IFOAM Norms International Federation of Organic Agriculture Movements*.

Miranowski, J.A. and Carlson, G.A. (1993) 'Agricultural resource economics: an overview', in G.A. Carlson, D. Zilberman and J.A. Miranowski (Eds.) *Agricultural and Environmental Resource Economics*, New York: Oxford University Press, pp.3–27.

Morris, C. and Winter, M. (1999) 'Integrated farming systems: the third way for European agriculture?', *Land Use Policy*, Vol. 16, pp.193–205.

OECD (2001) *Improving the Environmental Performance of Agriculture: Policy Options and Market Approaches*.

OECD (2004) *Agriculture and the Environment: Lessons Learned from a Decade of OECD Work*.

Pacini, C., Giesen, G., Wossink, A., Omodei-Zorini, L. and Huirne, R. (2004) 'The EU's agenda 2000 reform and the sustainability of organic farming in Tuscany: ecological-economic modelling at field and farm level', *Agricultural Systems*, Vol. 80, No. 2, pp.171–197.

Pannell, D.J. and Schilizzi, S. (1997) 'Sustainable agriculture: a question of ecology, equity, economic efficiency or expedience?', *SEA Working Paper 97/01, Agricultural and Resource Economics*, University of Western Australia.

Pimentel, D. (1999) 'Environmental and economic benefits of sustainable agriculture', in J. Köhn, J. Gowdy, F. Hinterberger and J. van der Straaten (Eds.) *Sustainability in Question*, Edward Elgar.

Pretty, J. (1999) 'Can sustainable agriculture feed Africa? New evidence on progress, processes and impacts', *Environment, Development and Sustainability*, Vol. 1, pp.253–274.

Rizov, M. (2004) 'Rural development and welfare implications of CAP reform', *Journal of Policy Modelling*, Vol. 26, pp.209–222.

Sands, G.R. and Podmore, T.H. (2000) 'A generalized environmental sustainability index for agricultural systems', *Agriculture, Ecosystems and Environment*, Vol. 79, pp.29–41.

Tait, J. and Morris, D. (2000) 'Sustainable development of agricultural systems: competing objectives and critical limits', *Futures*, Vol. 32, pp.247–260.

United Nations (1992) 'Agenda 21', *United Nations Conference on Environment and Development Rio de Janerio*, Brazil, 3–14 June, http://www.sidsnet.org/docshare/other/Agenda21_UNCED.pdf.

Van Gardingen, P.R., Foody, G.M. and Curran, P.J. (1997) 'Scaling-up from cell to landscape', *Soc. for Experimental Biology Seminar Series No. 63*, Cambridge University Press.

Von Wiren-Lehr, S. (2001) 'Sustainability in agriculture – an evaluation of principal goal-oriented concepts to close the gap between theory and practice', *Agriculture, Ecosystems and Environment*, Vol. 84, pp.115–129.

World Commission on Environment and Development (1987) *Our Common Future*, Oxford, UK: Oxford University Press.

Yunlung, C. and Smit, B. (1994) 'Sustainability in agriculture: a general review', *Agriculture, Ecosystems and the Environment*, Vol. 49, pp.299–307.