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Abstract

Sustainability rests on the principle that we must meet the needs of the present without compromising the ability of future generations to meet their own needs. Starving people in poor nations, obesity in rich nations, increasing food prices, on-going climate changes, increasing fuel and transportation costs, flaws of the global market, worldwide pesticide pollution, pest adaptation and resistance, loss of soil fertility and organic carbon, soil erosion, decreasing biodiversity, desertification, and so on. Despite unprecedented advances in sciences allowing to visit planets and disclose subatomic particles, serious terrestrial issues about food show clearly that conventional agriculture is not suited any longer to feed humans and to preserve ecosystems. Sustainable agriculture is an alternative for solving fundamental and applied issues related to food production in an ecological way (Lal, 2008). While conventional agriculture is driven almost solely by productivity and profit, sustainable agriculture integrates biological, chemical, physical, ecological, economic and social sciences in a comprehensive way to develop new farming practices that are safe and do not degrade our environment. To address current agronomical issues and to promote worldwide discussions and cooperation we implemented sharp changes at the journal Agronomy for Sustainable Development from 2003 to 2006. Here we report 1) the results of the renovation of the journal and 2) a short overview of current concepts of agronomical research for sustainable agriculture. Considered for a long time as a soft, side science, Agronomy is rising fast as a central science because actual issues are about food, and humans eat food. This report is the introductory article of the book Sustainable Agriculture, volume 1, published by EDP Sciences and Springer (Lichtfouse et al. 2009)

Keywords: sustainable agriculture; climate change; biodiversity; agronomy for sustainable development; organic farming; pest control; food; water; soil; pesticide; farming system

Foreword

This article is dedicated to Ms. Josiane Ménassieu. Josiane was the Editorial Secretary of the journal Agronomy for Sustainable Development (ASD) from 2003 and retired in April 2008. The success of the renovation of the journal from 2003 to 2006 is mainly due to her intensive work. Her kindness was greatly appreciated by authors, peer-reviewers, and Field Editors. Figure 1 shows a picture of the present that was offered to her by colleagues for her retirement.

Figure 1. *Coquelicots* painting by artist Agathe Rémy, living near Aix-en-Provence, France. *Coquelicots* is the French word for poppies.

1. The journal Agronomy for Sustainable Development

Agronomy for Sustainable Development (ASD, agronomy-journal.org) is one of the seven journals of the French Institute of Agronomical Research (INRA, international.inra.fr). The journal is managed by a collaboration of two INRA departments, the Department of Environment and Agronomy (www.inra.fr/ea), and the Department of Sciences for Action and Development (www.inra.fr/sad). Journal issues are produced by EDP Sciences (edpsciences.org). Our Editorial board collaborates with 3 Associate Editors and 32 Fields Editors for manuscript peer-review. ASD publishes research and review articles. Submitted articles are first evaluated by a Pre-Selection Committee that declines about 50% of incoming manuscripts. Selected submissions are then sent to Field Editors for in-depth evaluation. The global rejection rate was 77% in 2006. The actual impact factor (2007) is 1.000, ranking the journal 25/49 in the category Agronomy (Figure 2).
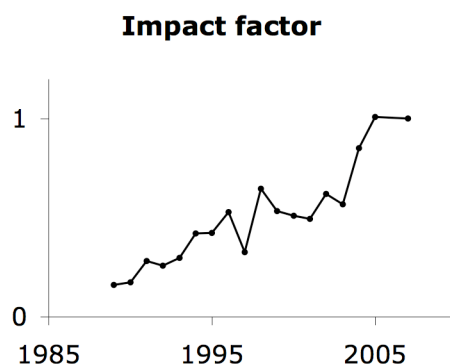

Figure 2. Impact factor of the journal Agronomy for Sustainable Development (ASD). Note the increase of the impact factor from 0.566 in 2003 to 1.000 in 2007 (+77%). In 2006 the journal had two impact factors due to title change in 2005 : 0.863 for the old title, Agronomie, and 0.306 for the new title, ASD. Those factors are not shown in the graph above because their calculation is different from that of normal impact factors. Specifically, the value for the old title is higher because it takes into account only older articles (2004) that have thus higher chances to get cited (see scientific.thomsonreuters.com/isi for details).

ASD Journal was deeply reformed from 2003 to 2006. We changed topics from classical, production-oriented agronomy to sustainable and ecological agriculture (Lichtfouse et al., 2004, Alberola et al., 2008). We integrated social and economic sciences by setting a collaboration between the INRA Department of Environment and Agronomy and the INRA Department of Sciences for Action and Development. Major journal topics currently include:

- Agriculture and global changes;
- Agricultural production of renewable energies;
- Ecological pest control and biopesticides;

- Organic farming;
- Genetically modified organisms in cropping systems;
- Environmental impact on soil, water, air and biodiversity;
- Risk assessment for food, ecotoxicology;
- Decision support systems and companion modelling;
- Social and economical issues of agricultural changes;
- Innovation in farming systems;
- Pollutants in agrosystems.

Major journal changes implemented during the journal renovation are shown in Table 1. They include: the set-up of a pre-selection committee at submission stage; an increase of the number of Field Editors from 14 to 32; novel topics focussing on sustainable agriculture (Lichtfouse et al. 2004); novel format instructions for more concise articles; a novel title (formerly *Agronomie)*; a switch from hardcopy to fully electronic managing; 100% of articles in English and a novel journal cover; and 7 review reports produced per manuscript: 3 reports from Associate Editors at the pre-selection step, 1 report from the Field Editor, 2 reports from peer-reviewers and 1 report from the Editor-in-Chief; active commissioning of review articles by the Editor-in-Chief. As a consequence, we observe several positive trends during the last years (Table 1). The impact factor increased by from 0.566 in 2003 to 1.000 in 2007 (+ 77%, Figure 2). The rejection rate increased from 44% in 2003 to 77% in 2006. The number of submissions increased from 108 in 2003 to 211 in 2007 (+ 95%). The number of pdf article downloads at ASD website increased from 89,158 in 2004 to 231,504 in 2007 (+ 160%). The number of subscribers to the free e-mail alert increased from to 417 in 2004 to 1307 in 2007 (+213%). The number of published review articles increased from 3 in 2005 to 13 in 2008 (+333%).

From 2005, review articles are published both in ASD and in the book series Sustainable Agriculture (Lichtfouse et al., 2009). The first volume is scheduled to be issued early 2009. A call for review articles for the next volumes is posted on ASD website (agronomy-journal.org). To conclude, the trends observed are very promising to encourage scientists to publish their best results in ASD. In the next section we discuss views on sustainable agriculture.

Table 1. Major changes of the journal Agronomy for Sustainable Development (ASD) from 2003 to 2006.

	BEFORE RENOVATION	ACTUAL
Title	Agronomie	Agronomy for Sustainable Development
Field Editors	14	32
Pre-selection Committee	None	3 Associate Editors
Topics	Conventional agronomy	Sustainable agronomy
Research article format	No size limit	Short articles
Language	93 % English	100 % English
Submissions per year	108	211
Pre-selection rejection (%)	0	50
Global rejection (%)	44	77
Research articles per year	79	44
Review articles per year	3	18
Impact factor	0.566	1.000
Acceptance delay	10.3 months	3.8 months
Article management	Hardcopy, post	100% electronic, pdfs
Article pdf downloads (/yr)	89,158	231,504
E-mail alert subscribers	417	1307

2. Sustainable development and sustainable agriculture

The term "sustainable development" was first defined in 1987 by the Brundtland Commission, formally the World Commission on Environment and Development, solicited by the United Nations:

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

This concept was then enhanced by the United Nations Conference on Environment and Development at the Earth Summit, Rio de Janeiro, in 1992. From that time, sustainable development became a key issue in political and scientific bodies, e.g. the Intergovernmental Panel on Climate Change (IPCC, ipcc.ch), the Millennium Ecosystem Assessment (millenniumassessment.org) and more recently the *Grenelle de l'Environnement* in France (legrenelle-environnement.fr). The concept of sustainable development is well accepted by a large public because it has defined global stakes, but is very vague about the practical ways to reach those stakes.

Sustainable agriculture does not escape this weakness, as shown by many reports (Hansen, 1996, Hansen and Jones, 1996, Gliessman, 1998, Gold, 1999, Tilman et al., 2002, Boiffin et al., 2004, Dupraz, 2005). Many authors and organisations worldwide give their own definition of sustainable agriculture. Some authors consider sustainable agriculture as a set of management strategies addressing the main societal concerns about food quality or environment protection (Francis et al., 1987). Other authors focus on the ability of agricultural systems to maintain crop productivity over the long term (Ikerd, 1993). Other authors focus on one main factor of sustainability, for instance flexibility, which is the adaptive capacity of agriculture to adapt to future changes (Gafsi et al. 2006). Overall, all authors agree on the occurrence of three approaches of the concept of sustainable agriculture: environmental, economical and social approaches. In other words, agricultural systems are considered to be sustainable if they sustain themselves over a long period of time, that is if they are economically viable, environmentally safe and socially fair. Beyond this ideological definition, the practical issue is to build operational solutions to reach global goals. This is a challenging task because the stakeholders do not agree on the criteria to measure the sustainability of a farming system, and on how to balance those criteria. Many indicators have indeed already been produced to evaluate sustainability.

The link between sustainable agriculture and sustainable development is not obvious (Legrand et al., 2002). Sustainable agriculture could involve two approaches (Boiffin et al., 2004). The first approach is that agriculture should sustain itself over a long period of time by protecting its productive resources, e.g. maintaining soil fertility, protecting groundwater, developing renewable energies, and finding solutions to adapt farming systems to climate change. This first approach is considering the farming system as a closed area. The second approach is to consider that agriculture has also to contribute to the sustainability of large territories and social communities. Accordingly, agriculture should help urban areas to manage wastes, e.g., by recycling urban sewage sludge, developing rural employment, and offering rural landscape for urban people. This second approach has wider goals and do not separate rural and urban areas. To conclude, the vagueness of the concept of sustainable development and sustainable agriculture is a strength because it does not restrict too much the research field, and, in turn give freedom to scientists to explore wide, unknown domains.

2. Future sustainable farming systems

After the Second World War, the development of conventional farming, or "industrial farming", was promoted in order to increase sharply food production worldwide. This social aim led to extensive use of pesticides, fertilizers and water, and to fast crop rotations and monoculture. Positive effects on yield were rapidly counterbalanced by negative environmental impacts such as soil erosion, groundwater pollution, river eutrophication, excessive water use and the development of weeds and diseases resistant to chemical control. Industrial farming and other industrial activities have indeed led to the presence of pesticides and persistent organic pollutants in soils, water, air, and food (Lichtfouse and Eglinton, 1995, Lichtfouse, 1997a, Lichtfouse et al., 1997, 2005a)

Today, to reach economical profitability, environmental safety and social fairness, farming systems should use fewer inputs and resources without drastically reducing yields. As the population is forecasted to increase up to 9 billions in the next 50 years, it is necessary the maintain a high level of food production. Nonetheless farming systems should also meet food quality policies enforced by national and international policies. This issue is particularly relevant given the occurrence of pesticide residues in food products because consumers and environmental associations are concerned about of a possible new sanitary crisis. Pesticide use by farmers is thus widely criticised. On the other hand, decreasing pesticide use may lead to negative effects such as toxin risk in food (Le Bail et al., 2005). To reach more sustainable practices, several strategies are described in the literature. Those strategies involve various changes, from simple adjustment of crop management sequence to deep changes at farming system level. For example, MacRae et al. (1989) proposed the following framework based on three strategies: efficiency - substitution - redesign (ESR).

2.1 Level 1: the substitution strategy

This level refers to the substitution logic, meaning that existing farming systems are only slightly adapted, but not deeply altered (Altieri and Rosset, 1996). For instance, toxic chemicals and mineral fertilizers (NPK) should be replaced by compounds that are less pollutant, less persistent in soil and less energy-consuming. Applying biopesticides and growing genetically modified plants should decrease both pest development and the use of toxic pesticides. Growing symbiotic N legumes instead of applying costly, energy-consuming N fertilizers should also improve sustainability. Here, research is usually done at the plot level, which is the most common level for agronomists. Collaborations with scientists studying elementary processes such as geochemists, pathologists, and biologists, should be fostered. The substitution logic should be effective for a short time period because it allows a substantial reduction of chemical treatments. However it may be not be efficient on the long run due to the appearance of pest resistance following the use of biopesticides, for instance.

2.2 Level 2: the agroecological strategy

The principle of the agroecological strategy is to build innovative technical scenarios relying on biological regulations in an integrated crop production scheme. This strategy involves applying ecological concepts and principles to the design, development and management of sustainable agricultural systems. Promoting biodiversity in agrosystems provides ecological services such as nutrient cycling, soil structuration and disease control. Biodiversity can be enhanced by cultural practices such as intercropping, rotation, agroforestry, composting and green manuring. Recent studies address also new issues in integrated pest management by combining the use of biological, physical, cultural and genetic control measures (Gurr et al., 2004). Increasing biodiversity by crop rotations (combination in time), intercropping (combination in space) and varietal mixtures was pointed out as an alternative to chemicals (Vandermeer et al, 1998). At this level, agronomy should interact with landscape ecology, because spatial variations in the landscape may be used for pest management. The productivity of farming systems should be increased by developing ecological principles and adapting them to farming systems. The agroecological strategy thus requires to enlarge the experimental scale. Experimental scenarios should not be designed at plot level, but at the scale of larger territories. Therefore, investigations need a much better understanding of interactions of living organisms at plot and larger levels. They also require input from other disciplines such as ecology and geography.

2.3 Level 3: the global strategy

The principle of the global strategy is to solve agriculture issues at the global scale, by rethinking its relation with society. Indeed, most failures of intensive agriculture are closely linked to its economical model. There are fundamental contradictions among several aims assigned to agriculture. For instance, producing more and cheaper food products without polluting soils; and producing fruits and vegetables without pesticide residues and without visual pest damages appear to be unrealistic aims. Therefore the global strategy relies on rethinking the role of agriculture in our society, as shown by new trends in agroecology (Gliessman, 2006). This approach considers that sustainability cannot be solely reached by farming systems, but should also involve the food system, i.e. the relations between farms and food consumption, and the marketing networks. For example, authors studying the

relationships between production and marketing highlighted the interest of alternative food networks focussed on local production (Lamine and Bellon, 2008). The global strategy thus requires an interdisciplinary work with scientists from various sciences such as agronomy, ecology, sociology, economics and politics.

3. Agronomical research for sustainable agriculture

Agronomy was first defined as the science of crop production. It was mainly focussed on the study of relationships between climate, soil, cultural practices, and crop yield and quality. Agronomy integrates therefore sciences such as biology, chemistry, soil science, ecology, and genetics. Agronomists then enlarged their studies to the individuals performing the cultural practices, namely farmers. This approach raised new issues on the modelling of farmers practices, and on the consequences of farmers choices on crop production. Agronomists further analysed environmental impacts of farmers practices. More recently they studied also how agriculture could benefit from environment and ecosystems to improve crop production, thus leading to the concept of "ecological services".

To study crop production, agronomists have to integrate highly complex sciences that rule farming systems at very different spatial and temporal scales. Agronomists have also to cope with a high environmental variability. As a consequence, results obtained in an experimental field may not be reproducible in another field due to slight - possibly unknown - variations of soil and climate factors. Therefore a key point of agronomical investigations is to define the validity domain of each finding. Concerning the integration of agricultural practices, a key point is to enlarge the classical scales of crop production studies, "plant and plot", to scales that are meaningful for the farmers, such as combination of plots and farm territory, and even larger scales. In a way, agronomy is a science of complexity aimed at integrating knowledge at various spatial levels from the molecule to the living organism, the farming system and the global scale. Thus agronomy appears more and more as the science relevant for global issues because it integrates knowledge from various sciences at various spatial scales. Considered for a long time as a soft, side science, Agronomy is rising fast as a central science because actual issues are about food, and humans eat food.

The systemic dimension is essential because in the next decades most improvements of farming systems will rely on enhancing positive interactions among various parts of farming systems. To build sustainable farming systems, agronomists will not only have to assess the direct effects of techniques on a crop, but also the indirect effects on the whole ecosystem such as biodiversity changes, water pollution, and soil erosion. The economical and social consequences of the new farming systems should also be evaluated with a pluridisciplinary approach with economists or social scientists. Therefore sustainable agriculture fosters the development of multidisciplinary studies that associate agronomy with ecology, economics, sociology and geography (Lichtfouse et al, 2004). Meynard et al (2006) identified four different ways to design of innovative agricultural systems for sustainable development:

- inventing new farming systems, breaking off with the actual ones;
- identifying and improving farming systems built by the local stakeholders;
- giving tools and methods to stakeholders to improve their own systems or evaluate those proposed by scientists;
- identifying the economical, social, organisations conditions that may help the actors to adopt alternative farming systems.

These approaches raise several new issues for agronomical scientists. For instance, it is not clear whether solutions will be found either by only a slight adaptation of research practices or by a sharp change of experimentation and modelling. Studying new spatial scales that show heterogeneous areas such as field margins will be a challenge. The integration of long-term changes in farming systems, such as soil organic matter turnover (Lichtfouse, 1997b) and sewage sludge pollution (Lichtfouse et al., 2005b), should also be experimented and modelled because concepts of resilience and flexibility are relevant. It should also be noted that some farmers have already an accurate expertise of sustainable practices. Some are even ahead of research and are experimenting new systems for, e.g.,

organic farming. Here the issue for the agronomist is to build effective methods to gather local knowledge, to check findings and eventually to redesign experiments. Innovative agricultural systems will benefit from a close collaboration between scientists and farmers.

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