Sustainability, crossdisciplinarity and higher education
—From an agronomic point of view

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Abstract: Nowadays, there is a growing conviction (at least in rhetoric) that sustainability is an idea whose time has come with education being a critical component in the transition towards a sustainable future. In the field of higher agricultural education, systemic approaches have, among others, triggered a lively dialogue. Topics include the challenge of sustainable agricultural development, the understanding of agriculture as the interface between people and their environment, integrated curricula (i.e. multi- inter- and trans-disciplinary approaches), etc. Such powerful debates have (sometimes radical) consequences for the whole curriculum design, i.e. the nature of goals, content (knowledge), and processes (learning methodologies). However, the still dominant scientific paradigm of reductionism, the strong traditions of disciplines and the prevailing approach to agricultural development impede changes towards a new educational paradigm in higher education. Nonetheless, such a new paradigm should be supported if universities are to keep pace in a changing world.

Key words: higher agronomic studies; crossdisciplinarity; systemic approaches; education for sustainability

1. Introduction

Following the Brundtland Report (WCED, 1987) and the "Earth Summit" in Rio (UNCED, 1992) the concept of sustainable development (SD) is by now widely cited in national and international policy documents and agreements as well as publications and articles. However, there is still much confusion about its meaning and practical applications. The term is highly dynamic, largely indefinite and highly contested, and has been adopted by different interests each defending their own discourse of sustainability (e.g., Carley & Cristie, 1992; Pretty, 1995; Reid, 1995; Sachs, 1997; Daly, 1997; Mog, 2004; Faber, Jorna & van Engelen, 2005). Therefore, its characterisation is taken by Stables (1996), as a "paradoxical compound policy slogan".

That education is critical for promoting sustainable development was endorsed by Agenda 21 (UNCED, 1992, ch. 36). Nowadays, education is widely accepted as a key instrument for bringing about a transition to sustainable development. Education is essential in providing a critical reflection of the world, promoting greater consciousness and awareness, and inventing new techniques and tools thus enabling people to make informed and ethical choices. Especially higher education has a profound, pivotal role to play in turning society toward sustainability: it concerns both research and the training of specialists and leaders in all fields (UNESCO, 1997).

Yet, education is part of the un-sustainability problem (Wals & Corcoran, 2006) and the challenge is that education has itself to be transformed in the process. Consequently, education will simultaneously be a change

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agent and a subject of change, or, that currently education is both part of the problem and the solution. Within such a problematique, there has been a recent terminological shift from “environmental education” (EE) to “education for sustainability” (EFS) that has been adopted in international educational documents such as Agenda 21, the United Nations Educational, Scientific and Cultural Organization (UNESCO), the Organization for Economic Co-operation and Development (OECD), and the European Union (EU) (Bosselmann, 2001).

In general, EFS can be said to be rooted in EE’s principles set up in the 1977 Intergovernmental Conference at Tbilisi (UNESCO, 1997): the values of nature and ecological balance; the emergent vision of the world as a complex system; and the development of knowledge through interdisciplinary methods. However, EFS (at least in its “strong” form (Huckle, 1996)) is actually calling for a shift in EE: it has to transcend the romanticised nature conservation messages of EE which end up to technocratic solutions and focus on issues of social justice and participatory politics along with ecological sustainability. Overall, EFS calls for a shift in the objectives, content and methodologies of education in order to facilitate the formation of polyvalent and flexible professionals qualified to design and implement projects toward sustainability.

Following, section 2 of this paper outlines, focusing on agriculture, the evolution of thinking towards the integration of the “social” and the “natural”, systemic thinking and, in the final analysis, sustainability. This is the basis for defining general principles for dealing with sustainable agriculture at the university level. The complexity of the issues involved calls for new ways of research and education; it is argued that dealing with sustainability requires crossing borders not only between different disciplines but also between science and practice. There, in section 3 relevant changes in university curricula are discussed. Then, in section 4 the difficulties of such an endeavour are briefly presented. Finally, conclusions stress the need for innovative ways in dealing with sustainability at the university level.

2. Sustainable (agricultural) development

Climate change, pollution of the environment, food contamination and health challenges, reduction of biodiversity, soil erosion, BSE, and social inequities are among the unwanted and undesirable biophysical and sociocultural impacts of modern, intensive-productivist agriculture. Such phenomena are, in turn, as clear as manifestations underlying the claim that agriculture, in its present form is not sustainable (Bawden, 2005). This is related to the so-called “agricultural treadmill” (Cochrane, 1958), i.e. on the assumptions of economics with respect to human rationality or to the exclusive focus of conventional agricultural development on techno-science and economic productivity at the expense of ethical and cultural considerations (Roling, 2003; Bawden, 2005).

Agrarian sciences have until recently been dominated by instrumental rationalist knowledge over others ways of knowing (Habermas, 1984). Such a (dominant) paradigm of experimental science, also called reductionist science (Packham & Sriskandarajah, 2005), is based on the reduction of complex wholes to their basic, more manageable fragments before an effort is made to predict a logical solution (Nerbonne & Lentz, 2003). It is by focusing on the individual parts and the relations between isolated variables that science has long aspired to understand the functioning of the complex whole. This, in turn, has resulted in a “culture of technical control” (Bawden, 2005) implying reliance upon scientific experimentation to create a “fix” for agricultural problems (Nerbonne & Lentz, 2003).

Despite the fact that the achievements of positivism have been dazzling, alternative proposals have, since the 1970s, flourished based on the realization of the inadequacy of linear and mechanistic thinking in understanding the source and the solutions of problems (Hjorth & Bagheri, 2006). Since Dahlberg's (1979) contention that most intellectual maps of agriculture fail to perceive it as "the basic interface between people and their environment", a growing body of literature has identified the social, cultural and political perspectives involved with sustainable resources management (Pound, et al., 2002). That is, biophysical problems are not isolated but are likely to be associated with problems of social change and stress which, in turn, means that social and ecological systems have to be treated as a single coupled and dynamically complex system (Griffin, 1979; Allison & Hobbs, 2004)

The introduction of farming systems research (FSR) as a set of methodologies to better understand and apply technical interventions was a leap in this respect. Its basic principle is that the process of technology generation and adaptation should be responsive to the characteristics of the targeted farming systems, farmers' objectives, and the conditions under which specific populations practice agriculture. FSR theoretical roots lie in ecology and general systems theory (Schiere, et al., 1999) has been an important evolution concerning agricultural development, on both theoretical and practical terms (Byerlee, et al., 1982; Simmonds, 1986). Through FSR/E vast experience has been accumulated in terms of understanding farmers, eliciting participation, developing tools and methods, and building agricultural and social networks. FSR, a forerunner of formal modelling approaches, contributed substantially to the recognition that different actors in development have conflicting rather than common goals, even though there can be common goals at certain points in space and time (Olson, 1971). This, in turn, helped to create awareness about the need for new ways to conduct research and extension, taking into account context and relations (Collinson, 2000).

In the same vein, Conway (1985) proposed several criteria for agro-ecosystem analysis. Furthermore, agroecology prescribes agricultural and ecosystem management strategies based on a convergence between the agricultural and ecological sciences. Three are the chief characteristics of agroecology:

(1) A systems framework of analysis;

(2) A focus on both biophysical and socio-economic constraints on production;

(3) Use of agroecosystem or region as a unit of analysis (Altieri, 1989).

The understanding that usefulness of a particular technology or intervention depends on its place, the beholder and several different criteria is a turning point in the evolution of agrarian sciences.

Given the contemporary understanding that sustainable development requires a shift in the way development is approached, today's conceptions of agriculture focus increasingly on integrated agricultural systems. A systems approach looks at a potential system as a whole (holistically) and focuses on the relationships (important causal inter-linkages or couplings) among a system's parts and on system dynamics, rather than the parts themselves. It "further, addresses the human and organizational issues that tend to be ignored in the traditional approaches" (Bennetts, et al., 2000). Systems thinking is a way of seeing and understanding complexity and, thus, for understanding reality. Hence the call for a complex-systemic approach to both science and practice (Gallopin, et al., 2001).

Nowadays, the literature on natural resources management (NRM) uses systems thinking and soft systems methodology (Checkland & Scholes, 1990) to analyze how rural actors create multi-stakeholder relationships (Röling & Jiggins, 1998; Woodhill & Röling, 1998). Social learning lies at the heart of multi-stakeholder processes. It refers to the collective action and reflection that occur among stakeholders as they work towards mutually acceptable solution to a problem pertaining to the management of human and environmental interrelationships (Keen, et al., 2005).

In sum, normal (reductionist) science, either as applied science or mission-oriented research, has been successful where the relative uncertainties are low, and the stakes or outcomes associated with decisions to be made are modest. In contrast, sustainability is not merely complicated but involves subsystems at a variety of scale levels, and there is no single privileged point of view for their analysis. When dealing with issues about sustainability there may be little useable science, high levels of inherent uncertainty, and severe potential consequences from decisions that have to be made. This makes sustainability a moving target which is continuously getting enhanced as our understanding of the system improves (Kay, et al., 1999). Therefore, sustainability is to be conceived as a process rather than a set of well-specified goals: a continuing process of questioning, discussion, participation, planning and engagement into appropriate action in order to modify processes in nature, the economy and society (Röling & Wagemakers, 1998).

Such considerations about sustainable development have led to the requirement to move across the boundaries of different scientific branches as well as between scientists and stakeholders. Relating to the sustainable management of natural resources (and agriculture), a wide variety of approaches has been developed with the intention to integrate the "social" and the "natural" based on collaborative—participatory efforts. Examples include the work on adaptive management (Holling, 1978; Gunderson 1999; Jiggins & Röling 2000), social learning (e.g. Webler, et al., 1995) and learning (Meppem & Gill, 1998) for sustainability, sustainable agriculture and agroecology (King 2000; Röling & Wagemakers 1998); ecosystems' approach to sustainability (Kay, et al., 1999), social ecology (Woodhill & Röling, 1998), public ecology (Robertson & Hull, 2003) as well as "local knowledge" and "indigenous science" (e.g. Agrawal, 1995) and citizen science (Irwin, 2001). Important to mention is the turn of CGIAR from a focus on agricultural development to an integrated NRM approach (Campbell & Sayer 2003; Harwood & Kassam 2003) underlying an effort to bridge the gap between research disciplines, different social groups and different sets of ethical values.

It thus becomes apparent that new concepts, theories, and metaphors are flourishing to help understand and predict the links between the social, ecological, and economic systems, meet the real world challenges and address sustainability. Following, one such, widely discussed, approach, called "mode 2", is outlined.

"Mode 2" is built on the recognition of the changing patterns of interaction between society and science; processes of knowledge production are becoming more dispersed, context-dependent, and problem-oriented and thus entail a larger degree of social interaction across institutional boundaries (Gibbons, et al., 1994; Jasanoff, 2003). This form of science is concerned with problems that are characterised by irreducible uncertainties, high complexity and the need to transcend traditional boundaries of science and society; science thus becomes increasingly more accountable to society.

The characteristics of this new Mode include the following:

(1) Knowledge is increasingly produced in contexts of application;

(2) Science is increasingly transdisciplinary—implying the mobilization of a range of theoretical perspectives and practical methodologies to solve problems;

(3) There is a much greater diversity in the variety of sites at which knowledge is produced, and in the types of knowledge producted;

(4) Knowledge is highly reflexive; participants in science are more aware of the social implications of their work and concurrently publics have become more conscious of the ways in which science and technology affect their interests and values. Research has become a dialogic process, an intense (and perhaps endless) "conversation" between research actors and research subjects (Nowotny, et al., 2003; Jasanoff, 2003).

The concept addresses the need for increases in democratic legitimacy (increased participation and transparency) of more open and integrative forms of knowledge production (interactive knowledge-making towards a more socially embedded and more closely tied to contexts of application science)[1].

In a more recent work, Nowotny, et al (2001) further elaborate, or rather open a discussion, on the conflict between "mode 1" and "mode 2" science and their interactions with society (to give substance to the twin notions of "science speaking to society" and "society speaking back to science"). They propose the concept of "socially robust knowledge", i.e. forms of knowledge that would gain robustness from their very embeddedness in society, as the solution to problems of conflict and uncertainty, with contextualization being the key to producing science for public ends.

Given the mounting demands for greater public involvement in assessing the costs and benefits, as well as the risks and uncertainties, of new technologies, the authors introduce the concept of "agora" representing the problem-generating and problem-solving environment in which the contextualization of knowledge production takes place. Their focus on the dynamics of public spaces and on the opening of new "spaces" in complex environments lead them to the idea of "trading zones"; these may give rise to coordination mechanisms such as "contact languages" and "transaction spaces" which, on the one hand, will facilitate the "co-evolution" of knowledge producers and society, on the other hand, may tackle the problem of the institutionalisation of polycentric, interactive, and multipartite processes of knowledge-making as well as trends towards centralization, territory, and control (Winberg, 2006).

3. Higher education and sustainable (agricultural) development

The need, on the one hand, for understanding the interconnections and interdependences between natural processes and human ways of living and, on the other hand, to make decisions and take action that considers the long term future of the environment, the economy and the society points towards a paradigm shift in the worldview of agriculture, as well as how research, extension and education activities are carried out. According to Sterling (2002), it implies the need to re-orient our own thinking toward a systemic-ecological-holistic approach.

Therefore, higher learning institutions are facing the challenge to initiate changes towards participatory and systemic learning for sustainable development (Packham & Sriskandarajah, 2005). This, in turn, calls for the abolishment of the artificial divisions between, on the one hand, the environment and, on the other hand, economy and society in favour of the co-operation (in whatever form) of several disciplines. Within such a framework, education and research cross traditional disciplinary boundaries, i.e. they become "cross-disciplinary". Typically, collaboration that spans disciplines is classified across the continuum: multidisciplinarity, interdidciplinarity, and transdisciplinarity.

Multidisciplinarity entails the bringing together of independent disciplines to bear on a common problem. Each discipline works in a self-contained manner. Interdisciplinarity means moving to joint problem formulation and hypothesis development, analysis and interpretation of data, and application. It provides for a "mixing" of disciplines, looks for systemic outcomes and can lead to new questions and methodologies. Finally, transdisciplinarity denotes the development of an overarching paradigm that encompasses a number of disciplines and (latterly) stakeholder groups; it implies different roles of stakeholders and brings together divergent worldviews (including the transgression of disciplinary boundaries) thus creating new boundaries for exploration

[1] Funtowicz and Ravetz (1993) also proposed a new perspective on science, especially relevant for situations of emergent complexity and based on interactive dialogue, which they call "post normal" science.

and understanding (Jeffrey, 2003; Moore, 2005; Lawrence & Després, 2004).

Nowadays, the need to solve increasingly complex problems with a view to sustainability reinforces "cross-disciplinary" forms of learning and problem solving integrating disciplinary perspectives and insights; the cooperation by diverse academic experts (and practitioners) is called for because real-world problems do not come in disciplinary-shaped boxes. Such "integrated" forms of learning and research then, take into account the complexity of an issue and challenge the fragmentation of knowledge; they accept local contexts and uncertainties; they address both science's and society's diverse perceptions of an issue through communicative action; and, they work in order to produce practically relevant knowledge. In this respect, it is also important to note that UNESCO (2004) supports such an approach (focusing on transdisciplinarity) in the UN Decade of Education for Sustainable Development.

The multiplicity of forms of such variations of "cross-disciplinarity" and their organization into a coherent framework has become the focus of important theoretical contributions (Jantsch, 1972; Kockelmans, 1979; Klein, 1996; Lattuca, 2001; Aram, 2004; Nikitina, 2006). It has to be noted though that despite insightful analyses, the fact that all forms of "cross-disciplinarity" overflow disciplinary boundaries along with the varying terminology employed by scholars may lead to confusion.

3.1 Curricular issues

The abovementioned developments imply that the paradigm of education has to be transformed as well, from business-as-usual (i.e. assumptions and expectations underpinned by traditional notions of education) to "sustainable education" (Capra, 1997). In order to be able to foster students to appreciate, understand and think critically about complex environmental, social and economic problems higher learning institutions have to change. Indeed, nowadays there is a need for the elaboration of new curricula, that is, of their interdependent components: goals (intended outcomes of the learning process), process (the dynamic nature of selected learning activities) and content (subject of the learning process) of higher education.

This, to begin with, requires a change from transmissive learning to transformative learning. The essential difference here is that transmissive learning is "instructive" (where the "teacher" is the authority who runs the show aiming at the transmission of predetermined facts, skills, and values to students whose job is to "get it"), whereas transformative education is constructive and participative (i.e., knowledge and understanding are co-constructed within a social context) (Stables, 2004). The latter, a learning-centred approach, inspired by the socio-cultural theory of Vygotsky (1978), involves active learners and more expert partners (educators) who engage together in learning; learning is a process of transformation of participation in which both sides contribute; the context as well as the way in which something is learned are part of learning.

Then, the learner is an active actor in a community of learners and the educator operates as a supportive tool (provides leadership and assistance) for learners as they construct knowledge (scaffolding) i.e., s/he becomes a manager of learning resources in order to establish the learning task, and to activate the learning system by which the learner can master the learning task (Banathy, 1999). Furthermore, contextual teaching and learning help students to construct knowledge that is personally meaningful by tying learning to actual experience. It enables students to become critically aware of how they perceive the world with a view to fostering citizen engagement with social and environmental issues and participation in decision-making processes (Jickling & Wals, 2008; Cabezas & Cara, 2005; Powel, et al., 2005).

Therefore, it can be useful to integrate the more traditional ways of teaching ("one-way" lecturing) with direct, holistic experiences, entailing discovery rather than reproductive learning, exploring reality further to reading books, productive action and gaining experiences. This implies the examination of complex, controversial issues, the use of complex teaching methods (simulations, group discussions, debates) and the involvement of different levels of personal development (Colucci-Gray, et al., 2006).

In general, there appears to be a convergence of opinion that providing students with significant opportunities to learn through interaction is a promising option. In agriculture (and rural development) both finding out about issues/problems and taking action to improve them in some way are important. Furthermore, this needs to take place in the actual (complex) context thus allowing for participatory and systemic ideas to come forward. Thus the need for "transaction spaces" which will facilitate the "co-evolution" of knowledge producers and society arises (Nowotny, et al., 2001).

Among others, field trips, work-related projects, practical experience (practicum) etc., enable, in the first place, both students and academic staff to move beyond higher education and its contexts.

Project (McDonald, 2008), inquiry (Werner, 2007), enquiry (Allan & Powell, 2007) based learning and case-studies (MIO-ECSDE, 1996), especially when addressing ill-defined, complex and contextualized problems, are gaining in importance. Such methods refer to the investigation (analysis, synthesis and evaluation) of a real-life problem or situation by small groups of students with the teacher acting as facilitator and fellow learning partner. Therefore, students learn independently; they learn themselves how to construct knowledge and solve complicated problems. Advantages of such methods (for students), besides deeper subject matter knowledge, include increased self-direction, improved problem-solving and critical thinking as well as communication—collaborative/networking skills, and thus contribute towards transformative learning experiences (Mezirow, 1997).

Moreover, participatory research, action research, and critical reflection have proved to be motivating and effective and are thus key teaching methodologies for facilitating learning (Terwel, 1999; Meyers, 2006). For example, action research (AR) is explicitly concerned with the improvement of situations through the taking of informed action and the development of relevant theory, which is then used to guide further action (Kemmis & McTaggart, 2000). It was conceived by Lewin (1948) as a cyclic or spiral procedure with a sequence of planning-acting-observing-reflecting aiming at harnessing of science for the service of the community. The approach has since grown in applications and methods in a wide variety of domains including agricultural development, community development and natural resources management especially in terms of participatory action research (PAR) concerned with collaborative research and learning between experts and people as a way to improve praxis and social change (Chambers, 1994; Campbell, 2001; Reason & Bradbury, 2001; Kemmis & McTaggart, 2003; Reason, 2003).

Likewise, experiential learning (based on the work of Kolb (1984) focuses on praxis (the linking of theory with practice with values in a recursive way) grounded in real contextual issues (complex or messy situations) and in partnership with relevant stakeholders. It thus fosters the development of higher order learning capacities (meta-learning and epistemic learning) (Bateson, 1972; Kitchener, 1983) than in instruction-focused situations. In both the aforementioned cases, the role of the educator becomes much more that of a facilitator of learning, rather than simply an expert disseminator of knowledge. Such "methodologies" enhance competencies that enable the graduates to travel between contexts, such as the academic context and the context of a society in transition.

As seen, sustainability calls for the close examination of the dynamic balance among many factors such as political, technological, economic, ethical, cultural and environmental; understanding based on the appreciation of complexity is essential. Moreover, it concerns a process defined neither by fixed goals nor the specific means of achieving them, but an approach for change (Packham & Sriskandarajah, 2005; Hjorth & Bagheri, 2006). It follows that a contribution to learning and acting towards sustainability within the universities concerns the integration of the soft system with the hard system which, as already mentioned, is nowadays emphasized in NRM literature. In other words, systemic thinking is a useful tool for learning about complex situations and "cross-disciplinarity".

Ways of endorsing such thinking in universities, may thus include external and (or) internal (in terms of curriculum) methodological tools (Wals, et al., 2004). The first refer to the integration of different perspectives and ways of knowing (invitation of farmers, specialists, NGOs, etc. in ongoing courses) and/or moving students into the discovery (utilizing techniques such as: case studies, interview and survey techniques, time-series measurements, activity calendars etc.).

The latter range from the most basic, i.e. the invitation of external lecturers from other disciplines (for a presentation, seminar or discussion) and efforts to embed sustainability issues (glossary, subject-based definitions, examples and resources etc.) in subject matter, to team-teaching and the mixing of students from ongoing disciplinary courses for joint exercises to more integrative forms such as: (1) the development of advanced courses requiring the application of specific skills (e.g. in crop production) to general social issues (e.g. integrated local development); (2) the development of a "general studies" programme requiring students and staff from all faculties to focus on issues of a general nature.

Especially the "general studies programme", aiming at enhancing the dialogue on sustainability through the introduction of themes such as globalization, environment-ecological crisis, (sustainable) development, economic systems, and social justice, is perhaps a very ambitious endeavour—especially in terms of the examination of social ethics that, implicitly or explicitly, guide our relationships with the (biophysical and social) world as well as underlie both our statements of goals (desired outcomes) and the choice of the criteria used for the evaluation of our actions vis-à-vis the management of the complex socio-economic-environmental system. Nevertheless, many educators agree that learning about sustainability should include discussions of the implications of ethics and alternative worldviews (Jickling, 1994), i.e. the need to recognize and acknowledge the roots of our worldview and ways of thinking, and to re-orient them (Colucci-Gray, et al., 2006).

4. Barriers to the introduction of the new paradigm

Developing "cross-disciplinary" capacity (in whatever form) will require changes in universities, which in turn, will facilitate the bringing, on the one hand, of distinct forms of knowledge production into some sort of fruitful integration and, on the other hand, researchers with different training, aptitudes and ways of viewing and interrogating the world together (Marzano, et al., 2006). Relevant initiatives (pathways in the movement towards sustainability education) comprise the development of both enabling structures (such as formal and informal opportunities for interaction, flexible, problem-driven groupings and centres, and relevant rewards and incentives) and skills (such as communication, integration, teamwork and management skills) (Russell, et al., 2008; Horlick-Jones & Sime, 2004).

Especially as far as enabling structures are concerned, Notwotny, et al (2001) have, as aforementioned, suggested that "transaction spaces" facilitate collaboration between knowledge producers and the contexts of application. In general, "boundary-" (Klein, 1996) or "border-work" (Horlick-Jones & Sime, 2004) provides a framework and insights for understanding and operationalising "cross-disciplinarity" as a boundary-crossing project. Likewise, for Wals & Corcoran (2006) "(E)ducation for sustainability means, above all, the creation of space for transformative social learning…space for alternative paths of development; space for new ways of thinking, valuing and doing; …space for pluralism, diversity and minority perspectives; …space for autonomous and deviant thinking; space for self-determination, and; finally, space for contextual differences".

Nevertheless, integration is a difficult and complex task. This is often attributed to the fact that universities are traditionally structured according to disciplines (or, in Becher's terms (1989) "tribes" of people inhabiting intellectual territories) which usually have strong cultures and traditions. This implies that academics identify with powerful loyalties, epistemological commitments and discourses, distinctive interests, research practices and communities of practice as well as communication media (journals, conferences). These, in turn, have considerable effects on professional and even personal identity (Aram, 2004; McLean & Abbas, 2002; Dewulf, et al., 2007). For example, given the pressure to publish in internationally recognized journals, academics (especially the early stage ones) working in "cross-disciplinary" projects find it difficult to publish their works since the system of referees and experts is largely organized in a disciplinary manner (Tappeiner, et al., 2007; Shailer, 2005). Therefore, disciplines, based on their autonomy, definitiveness, and stability represent the distinguishing structure of today's university and are integral to the complexities of institutional change.

This situation seems to have roots in the prevailing paradigm of science-based techno-economic development and the fact that the very achievements of disciplinary science often blind academics and researchers to what lies outside of this approach—what is ignored (Packham & Sriskandarajah, 2005). The prevailing paradigm of agricultural development is unable to recognize its own inadequacies. It has been found guilty of fundamentally misconceiving the world (Orr, 1992). In this manner, it is not only failing to adequately deal with the issues, it is actually exacerbating them; this state of affairs is tantamount to what some see as an actual "betrayal of development" (Norgaard, 1994).

This is not to dismiss scientific disciplines. Especially as far as students are concerned, they need a solid grounding in the disciplines associated to their studies along with an understanding of disciplinarity and its relevance (and application) to extra-academic contexts (Winberg, 2006). The overall aim is to promote thinking about why we think as we do and how we might see things afresh (Gough, 2002). This implies a critique of traditional disciplinary research (and teaching) that is not well suited to handle cross-disciplinary problems and extra-academic contexts. The consequences of reduction must be included in the answers that reductive science provides; the cognitive context (societal, intentional, observational) should be exposed and communicated[2].

There are also physical and organizational barriers. The former relate to the fact that scientists from the different disciplines are often based in different institutes or departments, even physical locations. The latter relate to the fact that the engagement in "cross-disciplinary" work means, besides the search for a viewpoint that lies between, or beyond, disciplines which (due to different frames, i.e. boundaries, concepts and problem definitions) is epistemologically challenging, that a workable relationship has to be found between the different frames and the people using these different frames of reference (Dewulf, et al., 2007). This, for example, means, for the more reductionist scientists, fewer opportunities for controlled experiments as they move to higher systemic levels as well as experiments of greater duration and more time spent communicating with scientists from other disciplines (Dalgaard, et al., 2003). Overcrowded curricula and personal time overcommitment along with "small feuds" and the lack of proper communication as well as of institutional drive and commitment should also be mentioned here

[2] See also Nikitina (2006) on "contextualizing", "conceptualizing", and "problem-solving" as three basic approaches to interdisciplinary work.

(Lozano, et al., 2006; Martin, et al., 2006).

Moreover, a cultural change in universities is also deemed necessary. This implies the abandonment of individuality, elitism, the accumulation of advantage and academic territorialism relating to disciplinary purity and specializations (or, "epistemic sovereignty") (Healy, 2003). However, such a hostile to cross-disciplinarity culture is nowadays reinforced by the climate of competitiveness which predominates. This means that universities are increasingly oriented towards market needs, the commercial exploitation of knowledge and research, the struggle for (private) funds and profile. These developments (commercialization/commodification/marketisation) have inspired animated debates; often they are found not only to compromise academic norms (autonomy, mission) and undermine public trust (re: disinterested inquiry and impartial expertise) but as extremely hostile to the "learning university", a collective, cross-disciplinary pursuit of sustainability, as well (Bosselmann, 2001; Moore, 2005; Dalgaard, et al., 2003; Russell, et al., 2008).

It follows that despite the fact that individual disciplines may be able to identify individual aspects of the systemic complexity, the university currently seems badly designed and ill-equipped to cope with the complexity of sustainability; the university has no ethos or collective conscience for sustainability (Bosselmann, 2001). The transition to more "cross-disciplinary" modes of research and education is hindered itself from a lack of systemic implementation taken in order to re-design structures through a thoroughgoing reform (Wals & Corcoran, 2006). Neither old paradigms are replaced by simply advocating new ones, nor the practice of renaming existing structures suffice as they result in initiatives which are inherently incapable of achieving the goals they seek to accomplish (McNeill, 1999).

5. Conclusion

At the beginning of the 21st century, tertiary institutions are faced with a whole host of challenges. This is more acute in the case of agricultural universities since the meaning and practice of agricultural (and rural) development is changing; it is seen as a dynamic system determined by the relationships between the capacity for change in the human systems and the resilience of ecological systems across spatial and temporal scales. Therefore, the need for interdisciplinarity involving scientists from agro-ecological and socio-economic disciplines and transdisciplinarity (involving, in addition, stakeholders in farming and/or rural development) emerges.

In this paper, it is argued that the need to meet the challenges facing (agricultural) science in complex research areas that involve human actors and social and ecological systems, and sustainability in general, can only be communicated across disciplinary boundaries. The hard systems approach needs contextualization, in an effort to understand how environmental problems are constructed by humans in particular ways, depending on particular contexts, practices, and literacies, and on the ways in which these interact with biophysical surroundings over time. Entering the exploration of an issue from a "soft" perspective allows the agronomist first to create a "critical heuristic" concerning agro-ecosystems which integrates consultants/scientists with participants/clients into a human inquiry or action researching system. This, in turn seems to lead to transformations in the way s/he goes about making new sense of the world (Gough, 2002; Winberg, 2006; Alrøe & Kristensen, 2002). Furthermore, while systems' managers (such as agronomists) must have a reasonable understanding of the structure and dynamics of systems, at the same time they must acknowledge that a full understanding will always be beyond us (Funtowicz & Ravetz, 1994).

The university has the task to provide for both the promotion of specialist expertise and the overcoming of specialists' limitations. In particular, universities have a major role to play "in developing students' qualities to cope with uncertainty, poorly defined situations, diverging norms, values, interests and reality constructions" (Wals & Corcoran, 2006). Stember (in Schmelzkorf, 2002) lays out three arguments for interdisciplinarity: the intellectual argument—that ideas in any field are enriched by theories, concepts and methods from other fields; the practical argument—that world issues are not organized according to academic disciplines; and the pedagogical argument—that learning is advanced by integration within the curriculum.

However, there are still many risks (both cognitive and social) associated with engaging in some sort of "cross-disciplinary" research and teaching for both students and the academics/researchers that supervise them. Hence, there is little empirical evidence of any fundamental change encompassing the university science system. Despite a long list of warnings universities continue to be discipline-centered; the goal of reorientation of education systems towards sustainable development generally remains a serious challenge.

Nonetheless, "cross-disciplinarity" should be supported as an essential development if universities are to keep pace in a changing world. While there are significant obstacles to its development in universities, a focus on relevant capacity could assist universities in addressing complex environmental and social problems and in building public trust and confidence. Given the diverging interests, values, perspectives, and constructions of reality the promotion of sustainability in higher education requires a collaborative re-framing process involving stakeholders (i.e. social learning). To this end the role of individual "champions" (visionaries), whether within a bottom-up or a top-down process, seems indispensable (Wals, et al., 2005; Ferrer-Balas, 2006; Lozano, et al., 2006).

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