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Landscape agronomy: a new field for addressing agricultural landscape dynamics*

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Abstract

5 Landscape dynamics increasingly challenge agronomists to explain how and why agricultural landscapes are designed and managed by farmers. Nevertheless, agronomy is rarely included in the wide range of disciplines involved in landscape research.

10 In this paper, we describe how landscape agronomy can help explain the relationship between farming systems and agricultural landscape dynamics. For this, we propose a conceptual model of agricultural landscape dynamics (ALaDyn) that illustrates the specific contribution of agronomy to landscape research. This model describes the relationship between three elements: farming practices, landscape patterns and natural resources. It can stimulate agronomists to deal with research issues in agricultural landscape dynamics and enhance the interdisciplinary integration of farming systems in wider landscape research.

15 On these premises, we discuss the main research issues that will benefit from an active involvement of agronomy, to understand, but also to assess landscape dynamics and to design relevant decision support systems.

Keywords

20 *Conceptual model, Natural resources, Farming practices, Landscape patterns, Landscape design*

1. Introduction

This manuscript is a collaborative work that arose from a debate on the role of agronomic concepts and approaches in landscape research. Two challenges underpin this debate. First, landscape research is called on to provide decision-makers with relevant knowledge on agricultural landscape dynamics, in order to foster a more integrative support for multifunctional landscape design (Council of Europe 2000; Nassauer and Opdam 2008; Conrad et al. 2011). Second, agronomists increasingly have to deal with the positive and negative impacts of the farming systems on these landscape dynamics (Thenail and Baudry 2005; Groot et al. 2010; Pelosi et al. 2010; Wästfelt et al. 2012). It follows that agronomy needs to join forces with landscape research.

In this perspective paper we discuss how a part of agronomy is widening its focus addressing the landscape dynamics and how this new field contributes to deal with research issues on agricultural landscapes. We consider the landscape as the system where farmers interact with both natural and social resources through the management of their fields and of the associated features such as field margins and semi-natural habitat patches. Landscape research, especially from a landscape ecology perspective, appears to be focused on the characterization and understanding of landscape patterns and related ecological processes (e.g., Farina 2006). In the following paragraphs, we argue why and how agronomy can contribute to landscape research with a conceptual model suggesting a new perspective on farming practices as a crucial driver in the pattern-process relationships.

2. *Why* should agronomy contribute to landscape research?

Farming accounts for the majority of human land use: pastures and crops took up 25.8% and 11.8%, respectively, of the earth's land in 2009 (FAOSTAT 2009). It results that more than one third of the land on the planet is managed as farmland. Agronomy is the main discipline committed to the study of farming. Accordingly, this discipline is challenged to widen its conventional focus on farming practices so as to facilitate agriculture, not only for increasing production, but also to meet new social demands on farmland management (e.g., the protection of the environment and the upholding of cultural features).

Farming practices are performed on and interact with natural resources – mainly soil, water, and biodiversity – either at the field level (van Ittersum and Rabbinge 1997) or at wider scales (Veldkamp et al 2001; Dalgaard et al. 2003). Great advances in production techniques and the increasing availability of external inputs have replaced the main services that the local agroecosystems used to provide (e.g., soil fertility, water availability and pest control). However, these advances, fostered by a strong emphasis of agronomy on field performances, have resulted in a loss of interest in and knowledge on the interactions between farming practices and the surrounding natural system. In addition, some authors have highlighted that the mainstream agronomic literature have scarcely considered the role of the spatial configuration of the fields in farming (Cavazza 1996; Veldkamp et al. 2001; Hatfield 2007; Osty et al. 2008). Accordingly, agronomy has been urged for a greater consideration of a spatially explicit approach (White et al. 2002), especially so as to shift analysis from the field/farm scale toward wider levels (Leenhardt et al. 2010; Nesme et al. 2010). In brief, modern cropping system design has largely excluded

the local context, eventually triggering severe environmental problems. This prompted society to request the following from agriculture and agronomy: first for a reduction of the impact on natural resources (e.g., Sheail 1995; Henle et al. 2008), and second for agro-environmental services to be provided (e.g., Viglizzo et al. 2004; Bastian et al. 2007; Brown and Schulte 2011). Recent agronomic approaches, while still seeking to improve crop and forage productions, are redesigning farming practices and trying to foster indeed the sustainable management of natural resources (Martin et al. 2006; Acevedo 2011). Nevertheless, to date, few agronomic studies have acknowledged the agricultural landscape as a complex socio-environmental context that may influence field management (Deffontaines et al. 1995; van Mansvelt 1997; Groot et al. 2010; Pelosi et al. 2010; Valbuena et al. 2010).

Broadly speaking, agronomy is a discipline aimed at delivering operative knowledge to the ultimate landscape managers: the farmers and their organizations (Deffontaines et al. 1995; Cavazza 1996; Benoît et al. 2007). Therefore, to enhance landscape research concerning the design and management of sustainable agricultural landscapes, we argue the need for an effective interdisciplinary approach that includes agronomic knowledge and tools. Operatively, this discipline will play a key role in integrating farming practices in the characterization of past landscape dynamics, in the assessment of contemporary landscape patterns, and in the design of future agricultural landscape scenarios. If agronomy fails to contribute its knowledge to agricultural landscape research, there is a real risk of misunderstanding and underestimating the role of farming in these landscape dynamics, which could lead to ineffective management decisions regarding these landscapes.

The field of agronomy that can make innovative contributions to the analysis of agricultural landscape dynamics is referred to as “landscape agronomy”. Landscape agronomy is the emerging perspective of agronomy focusing on the relations among farming practices, natural resources and landscape patterns, which are involved in the dynamics of agricultural landscapes. This new interest of agronomy for landscape issues and the new synergies that can emerge by collaboration with other disciplines involved in landscape research are the only way to develop sustainable agricultural landscapes for the future.

3. What is our conceptual model?

To explain the heart of landscape agronomy, we propose a conceptual model of the Agricultural Landscape Dynamics: ALaDyn (Fig. 1). This model will support us in discussing, in the next paragraph, how landscape agronomy deals with the characterization, assessment, and modeling of the relationships between farming systems and agricultural landscape dynamics.

We have elaborated this model from certain applications of landscape agronomy in research and education that have been discussed in earlier works (Benoît et al. 2007; Rapey et al. 2008; Rizzo 2009; Lazrak et al. 2010; Moonen et al. 2010; Marraccini et al. 2012). From these exploratory landscape agronomy experiences, we have found that there are three key elements that cannot be disentangled in the analysis of agricultural landscape dynamics: farming practices, natural resources, and landscape patterns.

These core items constitute the poles of the model. The relationships between the three poles are the major novelty of this model and show at the same time the importance of the development of landscape agronomy. The relationships we point-

out are of two main types: (i) the farmers' perception of natural resources and/or landscape patterns, which they use to inform and attune their decision on practices; (ii) the response of landscape to the farming practices, observed either as direct impacts on it or as disturb to the dynamics of natural resources, as well as incidental or fostered effects of the management. Hence, in the model we insist on the feedback loops between people and land for understanding landscape dynamics, in agreement with the call made by Verburg (2006).

The majority of landscape research mainly focuses on one or two of the poles, namely natural resources and landscape patterns. The model indicates instead that a full explanation of agricultural landscape dynamics must consider *all* three poles and therefore that farming practices need to be included if we want explain landscape dynamics appropriately. For example, we stress the need to consider the state of the natural resources and processes together with the spatial pattern in which they are distributed to understand or to improve the way farmers decide upon their farming practices (e.g., Acevedo 2011). Similarly, we consider that the analysis of the state of natural resources needs to account for how they are affected by the farming practices according to the local landscape patterns (e.g., Moonen and Bàrberi 2008). Finally, to be able to explain or to design agricultural landscape patterns, we need to know how they were affected by the interactions between farming practices and natural resources (e.g., Groot et al. 2010).

Therefore, ALaDyn introduces farming practices as the main levers with which to steer landscape dynamics. Farming practices are so pointed out as crucial activities in the management of spatial patterns and environmental processes occurring in agricultural landscapes, although they are rarely analyzed by the other disciplines involved in landscape research, particularly landscape ecology.

Figure 1 approximately here

On the one hand farming practices are the activities chosen and performed by
5 farmers, mainly to improve the suitability of land for crops and livestock production.
On the other hand farming practices are the elementary operations that affect the
greatest part of the agricultural landscape dynamics through the choice and the
allocation of the cropping systems. Sebillotte (1974) identified three choices of
farmers that define the cropping systems over seasons and years: (i) the land cover,
10 namely, the type of annual and multiannual crops or the type of grasslands; (ii) the
temporal sequence of the different land covers and their allocation on the ensemble
of farm land units (i.e., the fields, sometimes managed as a cluster), ordinarily over a
given time-span; (iii) the crop management defined by the array of technical
operations for each land cover, such as the type and timing of tillage, the quantity
15 and type of fertilization, the time and density of sowing and so forth.

Although farming practices are chiefly performed in fields, they affect landscape
dynamics through several trade-offs. Firstly, changes in farming practices shape
various spatial and environmental characteristics of the landscape. It follows that
farming practices can be oriented to design [*sensu* Nassauer and Opdam 2008; see
20 also Gobster et al. 2007] new agricultural landscapes and intentionally-created
landscape patterns. Moreover, natural resources can be actively managed through
farming and are not only passively affected (Pelosi et al. 2010). Secondly, farming
practices are responsible for the upholding of characteristic landscape features like
hedges, terraces, channels, and roads (e.g., Thenail and Baudry 2004; Daugstad et
25 al. 2006; Rizzo et al. 2007; Primdahl and Kristensen, 2011) as well as of the overall

landscape care (Wästfelt et al. 2012). Therefore, ALaDyn lies at the crossroads between farming management and landscape design (Fig. 1).

From this brief presentation of ALaDyn becomes clear the two main contributions of landscape agronomy to research on agricultural landscape dynamics. On the one hand, this model clarifies that landscape agronomy explains landscape patterns in agricultural landscape as a configuration of fields designed by farming practices interacting with natural resources. On the other hand, it points out that landscape agronomy also considers the landscape patterns and the natural resources as drivers for farming practices. This cross-regard on landscape patterns makes a difference between landscape ecology and landscape agronomy. Landscape ecology mainly characterizes landscape patterns as observed research object to explain associated ecological processes and functions (Forman 1995; Farina 2006), while landscape agronomy characterizes and explains landscape patterns as a result of specific farming practices, as illustrated by pioneering landscape agronomic research (e.g., INRA-ENSSAA 1977; Sereni 1997) and recently highlighted by Wästfelt et al. (2012).

4. How can landscape agronomy contribute to agricultural landscape research?

In this section, we apply ALaDyn to analyze the specific contribution of landscape agronomy to crucial issues in agricultural landscape research. The first issue is to enhance the *characterization* of the relationship between current landscapes patterns and farming practices (4.1); the second issue is to clarify the role of farming practices in *assessing* landscape patterns (4.2); and the third issue is to improve the *design* of future agricultural landscapes (4.3).

4.1 Characterizing landscape patterns as a result of farming practices

The structure of an agricultural landscape and its ecosystem services is largely defined by the agricultural practices that have been performed and that are constantly renewed by farmers. Farming practices can be viewed as determinants of the landscape patterns, and their potential impact on natural resources and cultural features has been evaluated (Egoz et al. 2001; Mignolet 2008; Rizzo 2009; Galli et al. 2010; Jacopin 2011). Farming practices have also been identified as the crucial pivot between the local landscape identity and global agro-industrial trajectories (e.g., Jarosz and Qazi 2000; Jackson 2008). These two examples highlight the different ways in which patterns and resources in agricultural landscapes are affected by past and current farming practices. Accordingly, we deem that the systematic inclusion of the study of farming practices into landscape research would help to increase our knowledge of the relationships between landscape patterns and agro-ecosystem services, such as the preservation of functional biodiversity (Moonen and Barberi 2008) or the improvement of spatial heterogeneity (Brandt et al. 2012), and would allow us to steer these services in future landscapes. Recent research on farming practices has highlighted the need to collect a large amount of data in order to characterize the real practices and choices of farmers over long time-spans (to overcome seasonal variability) and wide regions (to skip local specificities) (e.g., Mignolet 2008; Leenhardt et al. 2010). Landscape agronomy, by considering the relationships between landscape patterns, farming practices, and natural resources (see the ALaDyn model in Fig. 1), can help to enhance the relevance of these time-consuming surveys for interdisciplinary landscape research.

4.2 Understanding farming practices to assess current landscape patterns

Landscape dynamics occurring in today's agricultural landscapes are mainly managed at the field level. Classic agronomy has focused on the field as the space where farming practices are performed, thus identifying it as an interface with ecology and other disciplines (Deffontaines 1991; Le Ber and Benoît 1998; Thenail et al. 2009; Pelosi et al. 2010). Indeed, the field defined by agronomists seems to give an operational translation to the "landscape unit," which Moss (2000) identified as the critical element with which socioeconomic and cultural factors interact across heterogeneous agricultural landscapes.

To improve on the classic agronomic approach, landscape agronomy moves the focus from the field to the spatial configuration of fields as the crucial concept for assessing and managing the three poles of agricultural landscape dynamics (Fig. 1) and thereby meeting new societal demands (Benoît et al. 2007). The spatial configuration includes both the topological characteristics of an "ensemble" [*sensu* Antrop 1997] of fields (e.g., their shape, size, and location) and their spatial and functional relationship with other landscape features (e.g., irrigation and drainage channels, hedgerows, and field margins). These configurations are further influenced by natural resources and local topographical conditions. For instance, water accessibility or proximity to the farmstead could constrain or enhance farming practices, thus shaping field configurations accordingly (Morlon and Benoît 1990; Thenail and Baudry 2004; Thenail et al. 2009).

The issue at stake is to select the criteria to aggregate fields into landscape patterns when fostering a salient assessment and an improved management of landscape dynamics. A first criterion could be to focus on the environmental

resources, such as water, thus characterizing the spatial configuration of farmed fields at the watershed level (Vogt et al. 2002; Mignolet et al. 2004). Another criterion could be the field aggregation designed by a legal framework, such as in the case of regulations for traditional or quality food with a Protected Geographical Status (Vollet et al. 2008). Another criterion could be plot aggregation as a function of recurring crop rotations (Thenail et al. 2009; Lazrak et al. 2010). The relevance of crop rotations is still poorly considered (Leenhardt et al. 2010), even though highly consistent with the assessment of farming practices over wide regions. In general, the main advantage of these criteria should be to overcome the vagueness in the definition of single field limits, which change according to seasonally evolving practices (Morlon 2005) and may differ according to the approach used for their definition (Nesme et al. 2010). In addition the aggregation of fields according to different criteria would tackle the call for an interdisciplinary and multi-scalar approach in agronomy made so far by some authors (Moss 2000; Dalgaard et al. 2003, Acevedo 2011).

By introducing farming practices as a crucial element for understanding the spatial configuration of landscapes, landscape agronomy complements the knowledge of landscape patterns provided by landscape ecology. In particular, landscape agronomy can help explain patterns as “regularities” shaped by farming practices (e.g., Lazrak 2012). In other words, it is the farmers’ decision making when choosing their farming practices that determines the spatial configuration of fields [perceived and measured as landscape patterns]. Shaller et al. (2012) have demonstrated that today’s landscape spatial organization can be explained by coupling decision-making process modeling (“rules”) and stochastic modeling (“regularities”). In this way, they have shown how the emerging landscape agronomy approach can make original

contributions to the interpretation and explanation of agricultural landscape dynamics relating farming practices and landscape patterns.

4.3 Improving tools to design future agricultural landscapes

The main contribution of landscape agronomy to improve the design of future landscapes is to integrate appropriate descriptors of the farming practices and their evolutions in the assessment and scenarios of landscape dynamics, so as to meet the increasing societal demands for multifunctional landscapes (Beuret 2002; Gobster et al. 2007; Gaucherel et al. 2009; Pinto-Correia and Breman 2009; Groot et al. 2010; Domon 2011; Brandt et al. 2012).

More generally, landscape agronomy will contribute to landscape research also by integrating the goals of agricultural production into the multiple objectives of the landscape design and management. Such a goal has been identified as a priority for the agricultural policy agenda itself (Beddington et al. 2012; Wästfelt et al. 2012). For this, landscape agronomy may for instance assess and operationalize future landscape designs on the knowledge about farmers' entrepreneurial goals, in a way they could more easily master and discuss the proposed scenarios with the other local actors.

Recent advances in agronomy have largely taken advantage of the availability of spatial data and improved measurements of crops performances to address spatially attuned practices (such as the *precision agriculture* approach) at the field/farm level (e.g., Schellberg et al. 2008; Oliver et al. 2010; Lamanda et al. 2012). By mean of ALaDyn (fig. 1) we spur research on agriculture (uppermost the studies focusing on farming practices) to develop tools to stress and integrate the diversity of place-based and contextual challenges/opportunities over larger scales. For example, landscape agronomic methods should address the (re)design of farming systems

assessing crop rotations and crop management for the impacts on natural resources given the specific landscape patterns into which they will be proposed. In this regard, few researchers (e.g., Grilli 2008, Groot et al. 2010, Lovell et al 2010) have tested an iterative “sketch design” process of agricultural landscape management from the field or feature level to wider field configurations and regional level that means closer to scales at which landscape patterns are-designed.

Future agricultural landscape dynamics will likely be driven by conflicts in land use (e.g., energy versus food production) and constrained by the availability of resources (e.g., water shortage due to climate change) (see Acevedo 2011). Accordingly, the relationships between farming practices, natural resources and landscape patterns will be further stressed and even exacerbated on a place-based perspective.

Therefore, the role of agronomists could become crucial to properly elicit and assess the spatial diversity and impacts of farming practices on the overall management of agricultural landscapes.

5. Conclusions and perspectives

The relationships between farming practices and landscape dynamics are still poorly explored despite the conflicting expectations on land use stressed by land change science (Rindfuss et al. 2004; Turner et al. 2007; Rounsevell et al. 2012) and concerns over the loss of agricultural land (Dramstad and Fjellstad 2011). In this context, the underpinning idea of landscape agronomy is that research on agricultural landscape should integrate both the influence of the landscape on farming practices, only partly explored by some authors (e.g., Primdahl 1999; Busck 2002; Claessens et al. 2009), *and* the role of the farmer as actor shaping patterns and processes observed from a landscape ecology perspective (e.g., Baudry et al. 2003; Burel and

Baudry 2005). From this viewpoint, we see landscape agronomy as fertile ground for the interaction between agronomy and landscape ecology seeking an agreement on shared concepts (Fig. 1), as well as with the wide range of disciplines classically involved in landscape research such as geography, ecology, planning, and
5 architecture. Landscape agronomy is intended to include issues raised, for instance, in policies, by extensionists and so forth, about the roles of farmers in the management of the landscape. This management concerns the natural resources and the services expected by societies at the landscape level, such as attractiveness for leisure, preservation of cultural features, tourism, etc.

10 Our knowledge and experience as agronomists allowed us to define a conceptual model of agricultural landscape dynamics (Fig. 1) whose main novelty is the integration of farming practices as a core item with which to understand and consequently steer landscape dynamics. We acknowledge to ALaDyn three roles. First, it is meant as a *conceptual basis* to orient research on agricultural landscape
15 dynamics defining a relative positioning according to the integrative perspective of landscape agronomy. Second, it could work as *template to develop research tools and scenarios* that include the crucial components and relations (poles and arrows in Fig. 1) of landscape dynamics in farmed lands. Third, it could be used as *reference grid* to highlight gaps in the development of agronomic research, especially
20 concerning the spatial patterns of farming practices.

In conclusion, landscape agronomy is for us closely related to the research on agricultural landscape dynamics because its principal aim is to deal with the reciprocal influence between the landscape dynamics and the farmers. In addressing this influence we draw attention to some critical questions. How do farmers affect the
25 landscape through their practices? What are the levers of action to support or

reorient these practices? Are the policies appropriate? How are farmer practices influenced by landscape features? Are the proposals for new multifunctional landscapes sustainable to combine practices for landscape management and practices for production management? Hence, who is working on this?

- 5 We hope to initiate a constructive dialogue between agronomists and other landscape scientists in order to strengthen the agronomic contribution to landscape research and to formulate a shared understanding of the role of agronomy in research on landscape dynamics.

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Captions

Fig. 1. Our conceptual model of agricultural landscape dynamics (ALaDyn), structuring the relationships between natural resources, landscape patterns, and farming practices.

5

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- within the text:

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15