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Does the recoupling of dairy and crop production via cooperation between farms generate environmental benefits? A case-study approach in Europe

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ABSTRACT

The intensification of agriculture in Europe has contributed significantly to the decline of mixed crop-livestock farms in favour of specialised farms. Specialisation, when accompanied by intensive farming practices, leaves farms poorly equipped to sustainably manage by-products of production, capture beneficial ecological interactions, and adapt in a volatile economic climate. An often proposed solution to overcome these environmental and economic constraints is to recouple crop and livestock production via cooperation between specialised farms. If well-managed, synergies between crop and livestock production beyond farm level have the potential to improve feed and fertiliser autonomy, and pest regulation. However, strategies currently used by farmers to recouple dairy livestock and crop production are poorly documented; there is a need to better assess these strategies using empirical farm data. In this paper, we employed farm surveys to describe, analyse and assess the following strategies: (1) Local exchange of materials among dairy and arable farms; (2) Land renting between dairy and arable farms; (3) Animal exchanges between lowland and mountainous areas; and (4) Industrially mediated transfers of dehydrated fodder. For each strategy, cooperating farm groups were compared to non-cooperating farm groups using indicators of metabolic performance (input autonomy, nutrient cycling and use efficiency), and ecosystem services provision. The results indicate that recoupling of crop and dairy production through farm cooperation gives farmers access to otherwise inaccessible or underutilised local resources such as land, labour, livestock feed or organic nutrients. This in turn leads to additional outlets for by-products (e.g. animal manure). Farmers' decisions about how to allocate the additional resources accessed via cooperation essentially determine if the farm diversifies, intensifies or expands operations. The key finding is that in three of the four crop-livestock integration strategies assessed, these newly accessed resources facilitated more intensive farming practices (e.g. higher stocking rate or number of milking cows per hectare) on cooperating dairy farms relative to non-cooperating, specialised dairy farms. As a consequence, cooperation was accompanied by limited environmental benefits but helped to improve resource use efficiency per unit of agricultural product produced. This article provides a critical step toward understanding real-world results of crop-livestock cooperation beyond the farm level relative to within-farm crop-livestock integration. As such, it brings practical knowledge of vital importance for policy making to promote sustainable farming.

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1. Introduction

Contemporary agriculture through its direct impacts on land use and ecosystems, and on regional and global cycles of carbon, nutrients and water is one of the main drivers of environmental change (Foley et al., 2011). Many negative agricultural impacts are related to intensification and specialisation of farming systems in industrialised countries (Maréchal et al., 2008; O'sullivan et al., 2015). In Europe, mixed crop-livestock farms have been declining since 1970 (Ryschawy et al., 2013) and by 2010 only 14% of farm holdings were mixed with both crops and livestock, while 52% were specialised in cropping, and 34% were specialised in livestock keeping (Eurostat, 2013). These specialised farms are often dissociated from land and its natural cycles (Naylor et al., 2005; Peyraud et al., 2014), and as a result generally exhibit low diversity, high-input use, and low resilience in the face of sudden economic or environmental shocks (Oomen et al., 1998).

Given that farmers now have to operate in a context characterised by unprecedented change and high uncertainty, such as ever-more limited and costly production resources, stricter environmental regulations, volatility in agricultural product prices and increasing frequency of extreme climatic events (Lebacq et al., 2015), continuing along a trajectory of specialisation in dairy and arable farming potentially threatens the long-term sustainability of these food production systems. Specialised farms are more vulnerable to increases in the cost of inputs to production than are mixed farms that can source inputs to production from exchanges between the crop and livestock enterprises on the farm (i.e. manure for animal feed). Similarly, a decrease in price received for crop or livestock products is more threatening to a specialised farm producing only one output than it is to a mixed farm with a diversity of outputs (Lebacq et al., 2015). Furthermore, the lower crop diversity and system flexibility generally observed on specialised farms relative to mixed farms leaves the former less well-equipped to adapt their systems in the face of climate shocks. Diversified systems, such as crop-livestock systems (where local integration of crops and livestock systems occurs), therefore appear to be an interesting alternative and path forward for agricultural development (Lemaire et al., 2014). Recoupling crop and livestock production is often advocated as an approach to improve properties of agricultural systems such as productivity (Herrero et al., 2010; Peyraud et al., 2014; Soussana and Lemaire, 2014), resource use efficiency (de Moraes et al., 2014; Schiere et al., 2002; Sulc and Tracy, 2007; Veysset et al., 2014; Villano et al., 2010), autonomy (Ryschawy et al., 2013) and resilience (Havet et al., 2014; Peyraud et al., 2014; Salton et al., 2014) and to provide ecosystem services, such as improved soil fertility, pest regulation and carbon sequestration (Bonaudo et al., 2014; Lemaire et al., 2014; Peyraud et al., 2014; Sanderson et al., 2013; Soussana and Lemaire, 2014; Sulc and Franzluebbers, 2014).

Achieving this recoupling at farm-level on specialised dairy and arable farms will be challenging for farmers: resource and infrastructural constraints on individual specialised farms will make it difficult for farmers to evolve their production system to one where recoupling of crops and livestock can easily occur. As an alternative, several authors (Bell and Moore, 2012; Bell et al., 2014; Franzluebbers et al., 2014; Russelle et al., 2007) have proposed that recoupling can be achieved at larger scales than the farm through cooperation, partnerships and contracts between specialised crop and livestock farms. This is an attractive solution in the current high input cost and resource limited climate as it allows some of the synergies normally provided by within-farm integration to be obtained, but with much smaller increases in farm workload, complexity of rotations, skills and infrastructure on individual farms involved. Integrating crops and livestock via cooperation among specialised farms also has the advantage that a greater quantity and diversity of production resources are accessible compared to those available when integration takes place internally at the farm scale.

Yet, research in this domain remains, except for a few exceptions, largely at a theoretical and conceptual level (Ryschawy et al., 2014; Veysset et al., 2014; Villano et al., 2010), and therefore practical messages for policy makers and farmers are lacking (Moraine et al., 2014; Peyraud et al., 2014; Russelle et al., 2007; Sulc and Franzluebbers, 2014). For example, little is known about the appropriate scale at which to promote integration between crops and livestock or about the difficulties that farmers encounter when cooperating with another farmer to integrate their productions. As a consequence, there are insufficient empirical research studies to assess the performance of integrated crop-livestock systems at scales beyond the farm (Bonaudo et al., 2014; Tanaka et al., 2008). In particular, questions remain as to whether collaboration among specialist farms might achieve the same range of metabolic (improved input autonomy, nutrient use efficiency) and ecological (improved pest biocontrol, higher soil carbon sequestration) synergies as within-farm integration (Peyraud et al., 2014; Russelle et al., 2007).

The objective of this study was to assess the benefits and drawbacks of integrating crops and livestock via cooperation between farms compared to integrating them at the farm scale or keeping them separated on individual specialised crop and livestock farms. Four crop-dairy livestock integration strategies were assessed using empirical farm data from case studies in different biogeographical regions of Europe. The strategies assessed were: (1) Local exchange of straw for manure among dairy and arable farms; (2) Temporary land renting between dairy and arable farms; (3) Animal exchanges between lowland and mountainous areas; and (4) Industrially mediated transfers of dehydrated fodder. By comparing non-cooperating baseline farms (specialised and mixed) with cooperating, specialised farms in each case study area, it was possible to identify the benefits and drawbacks, at both farm and beyond farm levels, of the different integration strategies, in particular relating to system metabolism (nutrient use efficiency and autonomy) and ecosystem services provision (such as soil fertility, pest regulation and carbon sequestration). It was hypothesised that cooperation between specialised arable and livestock farms will improve farm level environmental performances due to better management of natural resources and enhanced provision of ecosystem services. More precisely, we first hypothesised that cooperation between farms specialised in crop or dairy livestock production can help close nutrient cycles and mitigate external inputs of fertiliser and feed beyond the farm level. Second, we hypothesised that the production of ecosystem services will be greater on cooperating farms relative to non-cooperating, specialised farms since it is expected that recoupling crop and livestock production will capture positive ecological interactions such as manure recycling on arable soils and legume fodder insertion in arable crop rotations.

One may want to distinguish between cooperation and integration among specialised farms. In the former, flows of products are generally organised through a marketplace in a pure economic logic where transport of products depends only on costs, with little consideration for the benefits linked to integration, whereas in the latter, there is a collective organisation of the landscape structure such that crop and livestock activities in a collection of farms are considered simultaneously to optimally manage resources and promote ecosystem services (Moraine et al., 2014). However, the difference between these terms can at times be disputed. For example, all the case-studies considered in this paper involved some market mediated cooperation among specialised farms but such cooperation generally took place through two way material exchanges and was designed to improve environmental benefits (such as increased nitrogen fixation by legumes, increased carbon