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Integrated crop and livestock systems in Western Europe and South America: A review

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ABSTRACT

For many years, we have seen an increasing specialization of agricultural systems and territories, with a clear separation between territories with very high animal densities and those devoted to the growing of annual crops. This development is explained by market and sector economic logic and has been reinforced by the availability of low-cost inputs and animal housing systems based on direct grazing not requiring straw. It has, however, also involved negative environmental impacts and, in some cases, the impoverishment of soil fertility, a loss of biodiversity, and excesses of N and P, leading to eutrophication and hot spots of ammonia emission in livestock-breeding territories. Having recapped the mechanisms behind the specialization of systems and territories, we examined the extent to which the development of innovative mixed-farming systems that reconnect livestock and crop production on various territorial scales (farm, district, region) can reduce the negative impacts of agriculture on the environment, produce valuable ecosystem services and achieve acceptable economic efficiency for farming enterprises. Examples from temperate regions will be used to show that mixed-farming systems increase the possibilities of better recycling of nutrients within systems, limiting recourse to the purchase of increasingly expensive inputs and safeguarding the biodiversity of agricultural ecosystems.

1. Introduction

In response to increased market demand and economic pressures, agricultural systems and territories have become increasingly specialized (Clothier et al., 2008). The productivity of the agricultural sector has greatly increased and mixed-farming systems integrating crop and livestock production have strongly declined in many countries or regions. These changes have been greatly favoured by an era of cheap energy, which has encouraged high inputs of fertilizers and pesticides and the development of animal housing systems that do not need cereal straw. During this period, the negative impacts of agriculture on the environment have been largely ignored. In 2007, 52% of European holdings were specialized in cropping (20% annual crops, 22% perennial crops and horticulture, and 12% mixed crops), while 34% of holdings were specialized in livestock breeding (17% ruminants, 5% monogastrics and 12% with mixed types of animals). Only 14% of holdings are now mixed farms with both livestock and crops (Eurostat, 2010a,b). Some territories are highly specialized in animal production (West of France, Netherlands, Denmark, Po Valley), while other are specialized in crop production (South West and Central France, East of England, East Germany). Specialization has also occurred in Argentina. Most livestock farming takes place in the flood prone Pampa sub-region, a scarcely cultivated area having from 240 to 830 thousand head of livestock per county, mostly beef cattle, while the highest cropping intensity is found in the Rolling Pampa subregion, where soybean (*Glycine max* L. Merrill) and maize (*Zea mays* L.) are predominant. Despite the predominance of cropping, the Rolling Pampa can be subdivided in an eastern part, with as few as 2–140 thousand head of livestock per county, and a western part, with 140–440 thousand of head of livestock per county (Ministerio de Agricultura, Ganadería y Pesca, 2012).

Highly intensive and specialized livestock production systems and a landscape dominated by intensive cropping have both contributed to environmental degradation. Specialized livestock systems and territories face problems of waste disposal leading to nutrient accumulation in the soil (P) and emissions of N to water and air. Meanwhile, territories specialized in crop-growing face soil

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impoverishment and have to import mineral fertilizer and pesticides. It would appear that conservation-oriented mixed-farming systems can maintain high levels of productivity while using N more efficiently, and can offer solutions that alleviate environmental damage (Donaghy et al., 1997; Oomen et al., 1998). After recapping the mechanisms behind the specialization of systems and territories, in this paper we shall examine the consequences of specialization and intensification. We shall then analyze the extent to which the development of conservation-oriented mixed-farming systems that reconnect livestock farming and crop production on various territorial scales can achieve acceptable economic efficiency on the part of farming enterprises, while reducing the negative impacts of agriculture on the environment and contributing valuable ecosystem services.

2. Economic and social mechanisms leading to the concentration of farms and specialization of territories

The specialization of territories is primarily related to their agronomic potential, competitive advantages and such structural factors as farm size. At the same time, the workloads involved in animal production and the increased size of farms has led to the disappearance of livestock-farming systems in areas such as the Paris basin, which now specialize in annual crops. On the other hand, the desire to maintain employment in a region can also lead to specialization. This was the initial reason for the development of the livestock-farming sector in Brittany in the early 1960s, where specialization and concentration were subsequently reinforced by economic logic. These mechanisms of territories specialization have been well studied in the case of animal (Larue et al., 2011 for pig sector in Denmark; Roe et al., 2002 for pig sector in US, Gaigné, 2004 for pig sector in France, Ben Arfa et al., 2010 for dairy sector in France).

2.1. Consequences for land use of the specialization of territories and intensification of farming systems

In Europe, the specialization of territories and intensification of farming systems has been accompanied by changes in land use. As a result of the development of cereal crops and the growing of maize silage for ruminants, there has been a sharp decrease in permanent grassland areas and the growing of pure forage legume crops. Between 1967 and 2007, the permanent grassland area in the EU-6 (France, Germany, Italy, Netherlands, Belgium, Luxembourg) decreased by 7.1 million ha (about 30% of the 1967 figure) (Eurostat, 2010a,b). The tendency was similar in France (−4 M ha, i.e. −30%), the Netherlands and Belgium. Where the EU-27 is concerned, the grassland area has decreased by 15 million ha. Even marginal grasslands tend to be abandoned, particularly in mountainous and Mediterranean areas, and many grassland areas (up to 30%) have also been abandoned in new member states (NSI, 2004, 2005). Notable exceptions are Ireland and UK, where the acreage of permanent grassland has been maintained at a high level (respectively 75 and 65% of utilized agricultural area UAA), whereas permanent grassland acreage averages just 31% for the 27 European countries. In France, the acreages of lucerne (*Medicago sativa* L.) and red clover (*Trifolium pratense*) have decreased by 75% over the last 30 years. These forage legumes accounted for 1.0 million ha in 1970 but only 321,000 ha in 2000 (Pflimlin et al., 2003), whereas over the same period the area devoted to maize silage increased from 350,000 ha to 1.4 million ha. At the same time, the acreage of peas (*Pisum sativum* L.) decreased from 700,000 ha to less than 200,000 ha (UNIP, 2011). These changes were encouraged by the CAP reform of 1992, which was favourable to cereals and very unfavourable to legumes and grassland, at least until the mid-term review for grasslands.

At the same time, crop rotations have been greatly simplified. Until the 1960s, a balanced rotation included between six and eight crops, thus ensuring a high degree of diversity. Empirical research indicated that this was the best solution for maintaining soil fertility, restricting the development of pathogens and limiting the use of mineral fertilizers, symbiotic N fixation being the primary source of N for crops and recycling of organic N the second (Jensen et al., 2010). Comparison of the 1994 and 2001 data shows a marked trend towards the simplification of crop rotations. There was a very marked increase in the planting of wheat (*Triticum aestivum* L.) after rapeseed (*Brassica oleracea* L.) (25% vs. 12% of land planted with wheat), and wheat after small-grain cereals (19% vs. 13%), with a parallel reduction in wheat after "other" crops. Small-grain cereals, grain and forage maize, rapeseed and sunflower (*Helianthus annus* L.) accounted for 56% of crops preceding wheat in 1994, but almost 75% in 2001 (Le Roux et al., 2008).

Grassland acreage has also decreased in South America. The temperate portion of South America has its northern boundary at latitude 30° S, which excludes most of the subtropical areas, and covers almost 60 million ha (Cabrera, 1976; Paruelo et al., 2001). This region can be subdivided into different types of ecosystem, with the Pampas Grasslands of Argentina the most important temperate cropland area of South America. Except in the Rolling Pampa and Flooding Pampa sub-regions, where the integration of agriculture and livestock farming is only occasional, because of the respective prevalence of annual crops and cattle-raising, the land surface is used for both cropping and livestock-farming, albeit in different proportions from the other Pampa sub-regions. During the 20th century, about 65% of the Pampas region of Argentina was covered by grasslands and pastures, but this proportion had decreased to 55% by the first decade of the 21st century (Viglizzo et al., 2010). According to the National Agriculture Census (INDEC, 2012), about 8 million ha of pastures were converted to cropping (mainly soybean) between 1988 and 2002. The decrease in grasslands and pastures was common to all the Pampean sub-regions, with the exception of the Semi-arid Pampa. The process of intensification was particularly dramatic in the Rolling Pampa, where the area covered by grassland and pastures decreased from 66% in the 1956–1960 period, to 43% in 1986–1990, and 30% in 2001–2005 (Fig. 1). The grazing of livestock on these pastures has shifted to subtropical areas of Argentina, and calves are now fattened with a higher proportion of grain supplements or in feed lots (Paruelo et al., 2005; Viglizzo et al., 2010). About 1.6 million head of livestock were being fattened in feed lots in March 2010 (Subsecretaría de Ganadería, 2012). The proportion of grasslands and pastures is still as high as 56–61% in the Flooding, Semi-arid Inland and Mesopotamian Pampa sub-regions, where livestock-farming still prevails, despite significant advances in crop-growing over the last decade. The proportion of grasslands and pastures approaches 50% in the Southern (47.4%) and Sub-humid (49.2%) Pampa sub-regions, suggesting integration of crop and livestock production in both areas (Paruelo et al., 2005; Viglizzo et al., 2010).

2.2. The economic logic underlying the dual process of concentration and specialization

The process of concentration and specialization is explained by a number of concurrent factors. The savings made on certain factors of production when an installation expands are greater than those that can be made from reducing purchases of inputs (energy, inorganic fertilizers). Purchases of inputs are lower in multiple cropping/livestock systems that combine plant and animal production. In particular, faster growth in the cost of labour compared with that of energy and chemical N fertilizer has led to the specialization