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Nitrogen, land and water inputs in changing cattle farming systems. A historical comparison for France, 19th–21st centuries

Petros Chatzimpiros *, Sabine Barles

Laboratory Techniques, Territories and Societies (LATTS), 5, rue Eistein, 77420, Marne-la-Vallée, France

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ABSTRACT

This paper provides an original account of the long-term regional metabolism in relation to the cattle rearing in western France starting by the precise formulation of animal diets at three key dates of the 19th, 20th and 21st centuries. We established links between the demand in fodder of the meat and dairy sectors and the necessary inputs of nitrogen, water and land as well as the land cover changes occurring on the affected local and remote cattle acreage. The average agricultural productivity for fodder supply is estimated at about 50 kg N/ha in the mid-19th, 54 kg N/ha in the early 20th and 150 kg N/ha at the turning of the 21st century. Jointly for the dairy and meat productions, the potential efficiency in the conversion of the vegetal into animal protein more than doubled over the studied period, passing from less than 9% in the 19th to 20% in the 21st century. The current cattle sector is sustained for about 25% by land situated beyond the regional frontiers and uses water at intensities that approach or exceed the availability of renewable water. The nitrogen pollution is expressed in terms of the Net Anthropogenic Nitrogen Inputs (NANI) and, by comparison to the N recovered in products, is used to define the N-Environmental Efficiency of the farming. We discuss the historical succession of the factors that contributed to the growth of the meat and milk production and make a comparison of the impacts and policy between the local and distant resources.

1. Introduction

Livestock's most essential role before the green revolution was to supply manure to cereal crops. Crop fertility relied upon the nitrogen (N) biologically fixed in leguminous meadows and vectored by the means of pastured animals into the arable land (Tilman et al., 2002). This pivotal role of the livestock got largely disrupted during the second half of the 20th century due to the development of the chemical fertilizer industry and the international trade in feed. Short after 1960, the N inputs in the biosphere in the form of industrial fertilizer outnumbered at the global scale the N inputs originating from Biological Nitrogen Fixation (BNF) (Cowling and Galloway, 2002) while the international trade in soybean, a primary high-protein feed, grew 16-fold between 1961 and 2003 (FAOSTAT, 2004). France shows for the same period an increasing dependency upon imported protein for livestock production. The French net imports of soybean feeds rose from 0.22 million tons in 1961 to 5.24 million tons in 2003 (FAOSTAT, 2004) at the same time that the cultivation of alfalfa, which constitutes a major source of protein in pastoral systems, regressed by a factor of 5 on the national territory (Thiebeau et al., 2003). The present cattle sector absorbs large amounts of proteins that in some producing regions are largely sourced by traded soybean. Following the trade in feeds, environmental externalities occur in both the exporting and importing regions (Naylor et al., 2005) due to the physical and virtual flows of N, water and land (Galloway et al., 2007; Burke et al., 2009). The feed production often drives land-use changes, impoverishes soil fertility and leaves behind water shortages in the exporting sites while the importing farms receive more nutrients than their local land base can recover into further crop biomass. The growing global demand and international trade in livestock food products along with the high feed input requirements of the livestock that are increasingly sourced by global markets have recently stimulated detailed accounting from a global perspective of the environmental issues related to the farming activity (Cowling and Galloway, 2002; Steinfeld et al., 2006), with particular emphasis given on the fastest-growing industrial sectors: swine and poultry (Galloway et al., 2007; Burke et al., 2009). Nonetheless, despite being less industrialized, the actual cattle sector has emerged from the transformation of the cattle from an integral and vital component of the traditional agrarian system into a distinct food generator, usually confined within single-oriented production units. Biogeochemical approaches adopting a historical perspective

* Corresponding author. Laboratory Techniques, Territories and Societies (LATTS), France. Tel.: +33 164153836; fax: +33 164689687.
E-mail address: chatzimp@enpc.fr (P. Chatzimpiros).

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to contrast changing food producing systems are rare. Long-term biogeochemistry studies with respect to the food production have barely been developed for France (we can nonetheless refer to Billen et al., 2009 where emphasis is given to the grain production) while the historians of the French agriculture have scantily studied the environmental impacts related to the profound agricultural mutations brought upon by the agro-industrial revolutions during the last two centuries (Duby and Wallon, 1976). The feed intake of the cattle and the origins of the feeds, different for beef and dairy animals as well as among regions and centuries are two key determinants of the pressure that the livestock production exerts on the environment. Another key parameter is whether the animal and crop agriculture at a specific location form a single agrarian system with the organic effluents of the first meeting the demand for nutrients of the second. An original methodology is used to put these factors together and draw the long-term agro-environmental evolution of the cattle farming. Particular attention is paid on aspects including the cattle diets, the conversion efficiency of the vegetal into animal protein, the requirements in land, N and water for fodder generation, the potential N pollution from point and diffuse sources and the uneven unfolding of policy measures upon the various components of the cattle production chain.

2. Methods and data

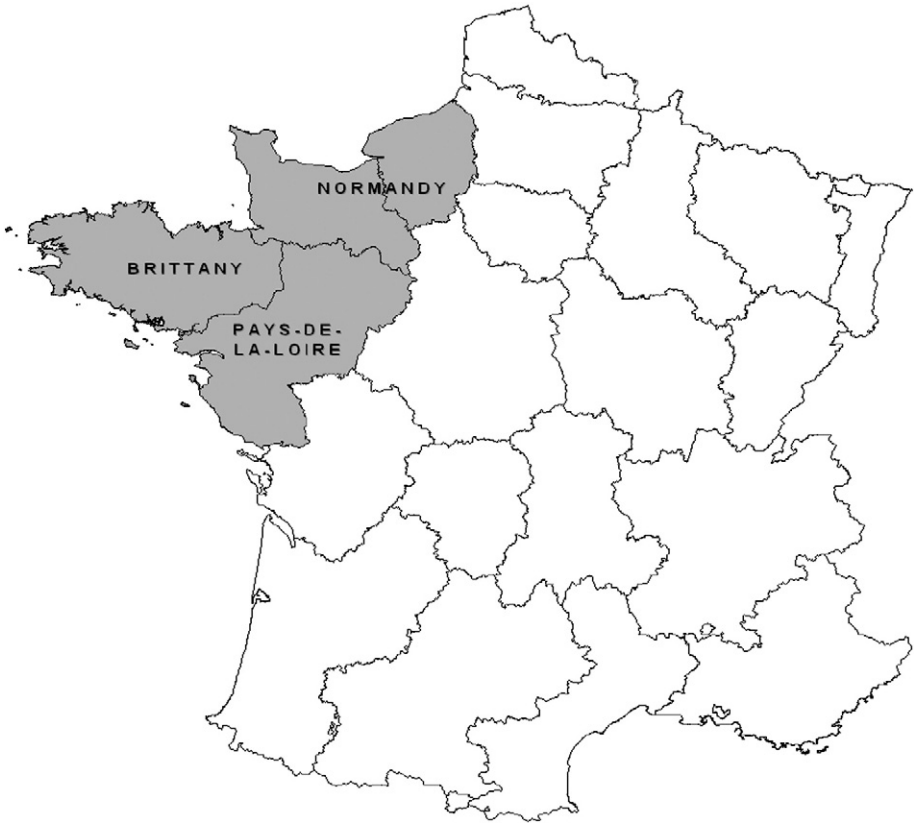
2.1. Study sites and dates

In France, agricultural land spreads all over the national territory. This study focuses on Normandy, Brittany and Pays-de-la-Loire, three regions in western France with important farming activity since the early 19th century (Map1).

Narrowing down from the national to the regional scale allowed taking into account geographic and socioeconomic specificities often disregarded when working on the national scale. On the other hand, the selection of three specific regions let for drawing three long-term agro-environmental trajectories. Three dates (1839, 1906 and 2004) were selected for being representative of three distinct phases of the farming history, as well as because of data availability. 1839 is used for being the first year fitted with statistical records detailed enough for drawing the regional metabolism of the cattle farming. It is representative of the multiple roles that the cattle fulfilled in the French agriculture – manure production, traction and food generation – during the 19th century. The year 1906 is in the middle of a transition period. Starting in the second half of the 19th century and until about the end of the second world war, numerous mutations occurred in relation to the industrialization and demography: changes in fodder inputs, the growth of the dairy industry, the increase in the demand for meat and dairy products as well as the acceleration of urbanization (Duby and Wallon, 1976). Nonetheless, the N supply to cropland was, as in 1839, still mainly depended upon cattle manuring. Finally, the year 2004 is representative of the industrialized and globalized high productive agriculture, largely sustained by chemical fertilizers and international feed markets, but not any global environmental policies. Numerous data about the size of the cattle population, the structure of the agrarian systems, the available fodder for rearing and the agricultural productivity are collected for these three dates in order to couple the regional capacity for milk and meat generation with the resulting environmental change.

2.2. Cattle herd

A first step consisted in dividing the cattle herd per region and date into dairy and non-dairy animals, assuming that they respectively constitute the mechanisms of the milk and meat production. We used



Map 1. Brittany, Normandy and Pays-de-la-Loire in France.