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"The Meadow is the Mother of the Field" Comparing Transformations in Hay Production in Three European Agroecosystems

Tommy Lennartsson
Researcher, PhD., Associate Professor, Swedish Biodiversity Centre, Swedish University of Agricultural Sciences, Sweden
tommy.lennartsson@slu.se

Anna Westin
Researcher, PhD., Associate Professor, Swedish Biodiversity Centre, Swedish University of Agricultural Sciences, Sweden
Anna.Westin@slu.se

Anamaria Iuga
Researcher, PhD., National Museum of the Romanian Peasant, Romania
anaiuga@gmail.com

Elizabeth Jones
Research Associate, PhD., of the Research Laboratories of Archaeology, University of North Carolina at Chapel Hill, USA
elizabeth.anne.jones@unc.edu

Scott Madry
Research Associate Professor, PhD., Research Laboratories of Archaeology, University of North Carolina at Chapel Hill, USA
madrys@email.unc.edu

Seth Murray
Teaching Associate Professor, PhD., North Carolina State University, USA
seth_murray@ncsu.edu

Eva Gustavsson
Senior Lecturer, PhD., Department of Conservation, University of Gothenburg, Sweden
eva.gustavsson@conservation.gu.se

ABSTRACT

This research compares the production of hay in three historical European agro-ecological systems: in northern Romania, central Sweden and eastern central France. We analyse hay production in relation to the entire production system, the local natural conditions, and the variety of ways by which hay production was transformed over time. We found broad commonalities, but also discovered significant differences in each of three historical trajectories. Introduction of fodder crops, crop rotations and mechanization are important drivers of changes in all three areas, although the timing, sequence and causation vary from place to place. There are significant differences in the organization of farm labour, in the role of beef and dairy production, the role of political reforms and the climatic constraints of outdoor grazing which affected the transformation of fodder production. This paper highlights the potential of an integrated, interdisciplinary approach for better understanding the complex interaction of people, their social and economic contexts, and their environment.

KEYWORDS

agroecology, comparative landscape studies, historical ecology, hay production, social-ecological systems (SES)

Introduction

The majority of agricultural production in Europe has historically been based on a combination of animal husbandry and cultivation, where livestock are necessary for manuring the fields. Although manure has now been largely replaced by artificial fertilisers, mixed farming systems remain important, particularly in biodynamic or organic farming and in some areas where shorter growing seasons and geological and topographical conditions constrain intensive grain production (Poux 2013). Few of Europe's livestock species can survive cold and snowy winter periods entirely by foraging in the field. Most of them, such as cattle, sheep, goats and horses require hay that is harvested during the summer. In cold winter regions, hay or other stored fodder has therefore been a non-negotiable

necessity in mixed farming systems since the emergence of animal-based agriculture. However, the systems and practices for producing hay have varied widely between regions of Europe, influenced by ecological conditions, evolving technologies, and by assorted social, political and economic conditions. The process of change from a meadow-based to an arable field-based hay production has now occurred practically everywhere in Europe, along with a general intensification of agriculture. We recognize that this process of change happened in a wide variety of ways — with different causal factors and occurring across different temporal spans.

Historical ecology is an explicitly interdisciplinary research framework based on the premise that landscapes embody the history of the dialectical relationships between humans and their environment (Crumley 1994; 2007; Balée and Erickson 2006). Comparative landscape studies within an historical ecology framework offer both opportunities and challenges to conducting the type of research that can answer questions in a holistic, interdisciplinary manner. The research results presented in this article examine the land-use history of three different locations in Europe: in central Sweden, in the Carpathians Mountains of northern Romania, and in the southwest part of Burgundy, France (Figure 1). In each of these three areas, the local histories and local environmental contexts are critical for understanding how agricultural transitions unfolded. Our comparative, interdisciplinary approach to European landscapes addresses three issues: 1) It enables a historical analysis of the agro-ecological use of hay meadows and pastures in the three different sites, 2) reviews the role of both ecological and socio-economic factors in the changing role of hay and 3) contrasts the different patterns in the transition phases from meadow-based to an arable field-based hay production farming system. Our comparison of the transition in these three locations in Europe allows us to reach a more nuanced understanding of the varying processes of causation and the key differences between them. The questions of interest for this research include: What are the principal conditions and mechanisms explaining the production of hay in different regions of Europe, and how has this production changed over time?

Fig. 1. A map of Europe showing the field sites in Sweden, France, and Romania.

Agriculture as a social-ecological system

A large proportion of the world's food is produced in high-input, industrial systems of production, which are based on the input of nutrients (artificial fertilisers) and energy (fossil fuels) from external sources to the arable land, and thus to livestock. In late nineteenth century Europe, before external sources became available, farming depended on local ecosystem resources, and a nutrient flow from unfertilised meadows and pastures to the livestock and arable fields, and on to the household (Krausmann 2004). In this low-input agricultural system, livestock can be regarded as agents that transform non-edible vegetation into products for humans, either directly, through milk, meat etc., or indirectly through manure fertilising crops (Figure 2). In contemporary Europe, traditional low-input agriculture still occurs in regions where intensification of farming is hampered by environmental and topographical, political, or economic conditions (e.g., Elbersen and Andersen 2008). One such region is the Romanian

Carpathians studied here.

Low-input agriculture can be viewed as a dynamic *social-ecological system* (SES), in which ecological and socio-economic factors interact with each other (Berkes and Folke 1998). The *ecological* domains of this system include the ecosystems and landscapes, the individual plots of land, and the livestock. These ecological components function together as an *agroecosystem* (Guzmán *et al.* 2014), managed by the farmer in order to ensure a sustainable production base for the agrarian livelihood[1]. The *socio-economic* domains include property rights, organization of household labour, markets, taxes, land-use policies and other legislation, technology, and cultural/ local traditions. All these factors influence the demand for products from the agroecosystem, as well as the potential for production (e.g. Erb 2012, Scott 1976; see Figure 2A and 2B).

Hay in agrarian production systems

Agrarian SES has been studied from various perspectives. In this paper, we focus on one part of the SES, namely the functions of the agroecosystem, and compare its change over time in three regions, Uxeau (Burgundy, France), Botiza (Maramureș, Romania) and Folkare (Dalarna, Sweden).

In low-input agriculture, the agroecosystem can be considered to consist of three main parts: manured arable land mainly used for production of human food, livestock, and the non-manured ecosystems used for production of animal feed, fuelwood, timber and other products (Krausmann 2004). Winter fodder, summer feed, livestock and nutrients for crop production need to be in balance within each farm (Tello *et al.* 2012). In many temperate regions, the provision of hay tends to be the bottleneck, because of its key function for maintaining the livestock over winter (Lennartsson *et al.* 2015). Thus, there is a strong correlation between the amount of hay and the number of livestock, which, in turn determines the nutrient status and productivity of arable fields. In the Swedish tradition, this relationship is expressed by the saying "the meadow is the mother of the field" (Rosenhane 1663; see also Figure 2A and 2B).

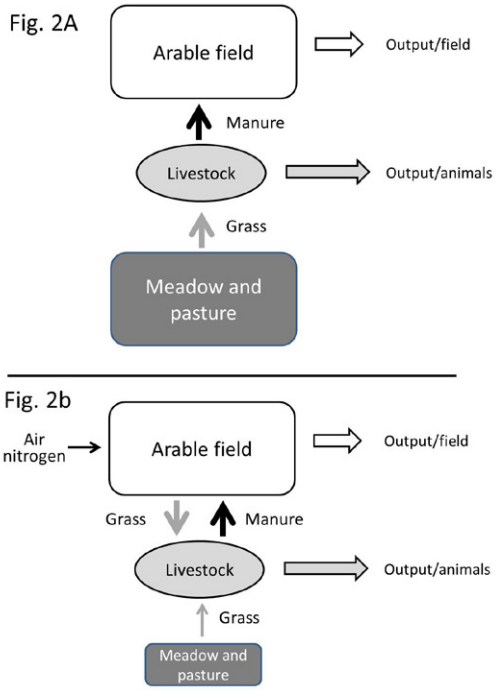

Fig. 2. Schematic presentation of the role of hay and pasture (grass) in agricultural production systems. A) shows a system entirely based on un-manured meadow and pasture, thus based on a flow of nutrients from such grasslands to the fields and to the harvested products. In that system, "the meadow is the mother of the field", see text. B) illustrates a system in which a majority of the hay and pasture is produced on manured fields, in crop rotation including nitrogen-fixing legumes.

Methodological approach

Since hay is a central component of agriculture in most cold winter regions, hay is suitable as a starting point for agroecosystem analysis in order to understand the regional drivers of agriculture and agricultural change. In the comparison of regions and time periods, disparate sources of information are problematic. One study region may be well documented in some respects, while other regions lack comparable historical information. Interdisciplinary comparative studies provide a powerful tool for revealing mechanisms and drivers, but also require

1) In this paper, the term *agroecosystem* thus denotes the "machinery" by which the land is used for production. We use the term *livelihood* to include also other means of income than natural resources (Ellis 1998).

methods for handling different types of information that enable valid comparisons.

This paper presents an example of a broadly interdisciplinary and multi-data approach to historical ecology research. Each of the three geographical case studies presented here utilize, in differing degrees, a combination of methodological approaches. Our research group involved scholars with expertise in a variety of methods drawn from a number of disciplines, including ecology, history, historical cartography, GIS, ethnography, and anthropology. One of the basic assumptions of historical ecology is that at the intersection of the physical sciences, social sciences, and the humanities one can discern a more complete understanding of the complex interactions between people and their environments over time.

Sources of information

In order to understand the agro-ecological system in which hay production is embedded, it is necessary to consult a wide range of source materials that reflect the complex interaction of environmental, sociocultural, economic and political factors involved. For these three case studies, the types of data collected fall into the broad categories of biological, cartographic/ GIS, documentary, and ethnographic. In Botiza we compared information concerning the communist period, ca. 1948-1989, with the post-communist period 1990 to present. In Uxeau and Folkare we focused on the period ca. 1830-1910, during which rotational cropping and other new techniques were gradually introduced.

The analysis for each site utilizes the most relevant of the available sources of information considered appropriate for the time period under study. In Folkare research is based on historical documents which are interpreted ecologically, as presented below. Our Uxeau research combines multiple historical sources, including historical documents, oral history, cartographic and GIS data, with ethnographic methods for researching present farming practices. The Botiza research is mainly based on the contemporary period using ethnographic and ecological methods, but also incorporating a few historical documents, including the use of vegetation as a historical source.

Biological data collected include surveys of plant species found in contemporary hay meadows in Sweden, Romania and France. Different plant species are favoured or disfavoured by various sets of environmental conditions in combination with management regimes. Some species can persist for a long time in unfavourable conditions. This creates a record of past land-use such as hay production practices, including periods of ley (sown or naturally established grass sward) and the timing of hay harvests.

Historical cartographic data include representations of the topography of a landscape, the distribution of available resources and distances between homesteads and resources. These can also provide information about land use, ownership, settlement patterns, transportation networks and productivity. Detailed nineteenth-century cadastral maps at the parish level, in addition to other maps, were collected for all three regions[2]. When integrated with other types of historical records these can provide information about past farming practices and how land use changed over time. When the cartographic data is integrated into a GIS, in-depth analyses may be conducted relating the land use with topographic features such as the slope of a field, which affects drainage and the ability to plough or use mechanical equipment. Aspect, or the compass direction of slope, affects the amount of sunlight a field receives and elevation affects the susceptibility to frosts and the number of growing days.

Documentary data encompass a diverse range of records. Governmental records such as population records, tax records,

2) Digital versions available for Botiza at www.mapire.eu and for Folkare at www.lantmateriet.se.

and agricultural reports can provide much detail on the labour pool, land ownership, and agricultural production at the local level[3]. In our Swedish case, personal records from the owners of individual farms were available that included diaries and the farm's financial accounts. Information was provided on management practices in different types of fields and meadows and animal husbandry.

Ethnographic data include both oral history accounts of farm practices within the living memory of the informants and the information handed down from previous generations as traditional knowledge. This type of information provides a level of detail about farming practices that is unavailable from other types of sources. These details can include factors such as how individual farmers make their decisions in response to different factors, and the variation between farms and individual farmers. In Botiza, we used semi-structured interviews in 10 households (15 people interviewed, ages 15-86), combined with direct observations, including photo documentation of the field sites, land-use practices and ecosystems. These photographs supported the analysis of the variety of landscape interventions, the spatial distribution of land-use, timing of certain practices and changes over time.

Agroecosystem analysis

We use a nutrient flow approach in order to identify the essential components of the agroecosystems of each study area: the manured crop-producing arable land, the grass-producing land (either un-manured meadows, pastures and forest, or manured arable land), and the livestock that transform grass to manure (Figures 2A and 2B). Agroecosystems are contextualized in their ecological and social aspects by adding information about basic biophysical and socioeconomic properties of each region.

Results – Agroecosystem analysis of the three study regions

In Uxeau and Folkare, our study covers a period in which two-field cropping in a meadow-based system (Figure 2A) was replaced by rotational cropping (Figure 2B). In two-field cropping, each year one half of the land was cultivated and the other half fallowed using harrowing, which works the soil and the weeds. The next year the fallow and cultivated fields are switched. In Botiza, high input agriculture using artificial fertilisers during the communist period was abandoned following regime collapse in 1990, as farmers returned to a low-input system of rotational cropping.

The common processes for low-input agriculture outlined in Figures 2A and 2B are used as the template for the following descriptions of our three study area agroecosystems.

Folkare hundred, Sweden

The study region is a historical hundred, which consisted of one urban and four rural parishes, with an area of ca. 600 square kilometres of land and 60 of water.

Environmental context

Around 1850, the land surveyor made a detailed description of one of the parishes, named 'By parish', that we use in the following description.[4] By parish consisted of 6% arable land (including gardens), 14% hay meadows, and 80% forest and peat bogs, that were more or less used for pasture.[5] The land use was, and still is, strongly determined by the geologic and topographic conditions, forming a mosaic of three types of land: (1) fine-particle soils suitable for cultivation; (2) till and wetlands useful only as hay-meadow or pasture; (3)

3) For Uxeau, Burgundy most of these local reports and maps were housed in either the local Uxeau Mairie (Town Hall) or at the Archives Départementales de Saône-et-Loire in Mâcon.

4) By parish map with description: Lantmäteristyrelsens arkiv. By Sockenkarta med beskrivning 1853-1858. (U6-1:6).

5) Gardens = 60 ha, arable = 1680 ha, hay meadow = 4320 ha, pasture = 630 ha, forest = 21680 ha (including bogs 1930 ha). Total = 31 646 ha of land. By parish map with description 1853-1858.

Fig. 3. Landscape around the River Dalälven, with remnants of former alluvial meadows. Photo by Bergslagsbild, copyright Upplandsstiftelsen and the Uppsala County Administrative Board.

stone-rich soils which could only be used for grazing and forest products. The forests were dominated by coniferous trees. One important prerequisite for the agricultural changes c. 1850-1950 was the continuous transformation of wet meadows to arable fields by artificial drainage.

Some villages were strongly influenced by the river Dalälven which, on the one hand, provided fertile alluvial meadows but, on the other hand, threatened agricultural output by its unpredictable flooding (Figure 3).

The landscape is rich in water. In addition to the river, there are also lakes, small streams and mires of various types. The streams provided hydropower for mills, sawmills, and ironworks. All villages, often also single farms, had their own mill and sawmill. The lakes and open mires provided good conditions for transportation in winter, on snow and ice.

Socio-economic context

In the 1850s, 4% of the households in By parish were landless rural households and 10% landless millers, smiths and blast furnace workers. The remaining 86% were farmers that owned their own land. Landlords did not occur in the region, and crofters were very few. Farmers having little land, landless persons and the sons and daughters of farmers provided a source of labour, employed temporarily according to need, or on a one-year basis, as maids and farmhands. Both categories were usually paid both in cash and in-kind.[6] In 1850, the total population in Folkare was 10,739.[7]

The household economy was characterized by access to large forest resources, and by the proximity to Sweden's most important iron district, *Bergslagen*. Grains, dairy products (mainly butter) and sometimes live animals and meat could be sold in towns nearby or directly to the ironworks, but sometimes trading trips by horse were made to larger towns as far away as Stockholm, a trip of 300 kilometres there and back. Charcoal production for the iron industry, transported from the farms on winter roads on mires and lakes, was an important income for the farmers. In summer, goods were transported to the harbour of Gävle at the Baltic coast, and salted herring taken back. Horses were a prerequisite for most of this income.[8]

Main products from the agroecosystem

The most important crops were potatoes, oats and rye. Rye and oats were the main cash crops for those who had a surplus to sell. Oats were used as "fuel" for the 1500-1800 horses in Folkare and transportation capacity using horses was one important output from the agroecosystem. Horses were also used as traction in the fields. Only 110 oxen were reported from Folkare in 1865, and oxen disappearing entirely during the study period.[9]

Dairy products from cattle were produced for the farmers' own consumption, and much of the milk was processed into butter for the market. Sheep and goats were kept for wool, meat and milk; goats were kept mainly by the poor. Some households fattened one or two pigs for their own consumption.

During the study period, the major changes were increased production of oats (Figure 4[10]), milk and pigs, and a decreasing number of sheep (Figure 5[11]).

6) Sources: By Parish map with description 1853-1858. Church records from By, Folkärna and Garpenberg, Peasants diaries from Hyttbäcken in Folkärna parish, Matses in By parish, and Backåkers in Garpenberg parish.

7) Statistics Sweden, BISOS A, Population, 1850-55.

8) Sources: Peasants diaries from Hyttbäcken in Folkärna parish, Matses in By parish, and Backåkers in Garpenberg parish.

9) Statistics Sweden, BISOS N, Agriculture, 1865-1911.

10) *Ibidem*.

11) *Ibidem*.

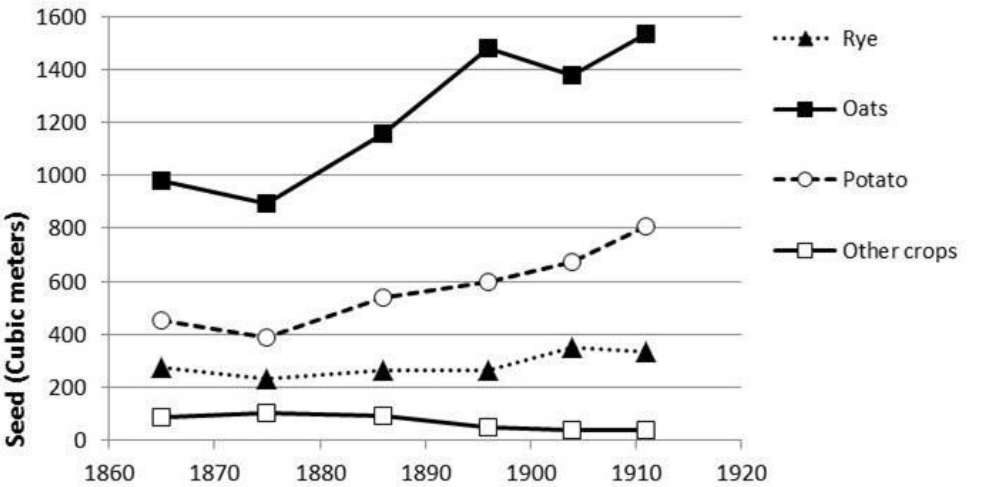

Fig. 4. Annual seed of different crops in Folkare 1865-1911. "Other crops" are wheat, barley, mixed grain, peas, vetche, flax, and timothy/clover (see Statistics Sweden, BISOS N, Agriculture).

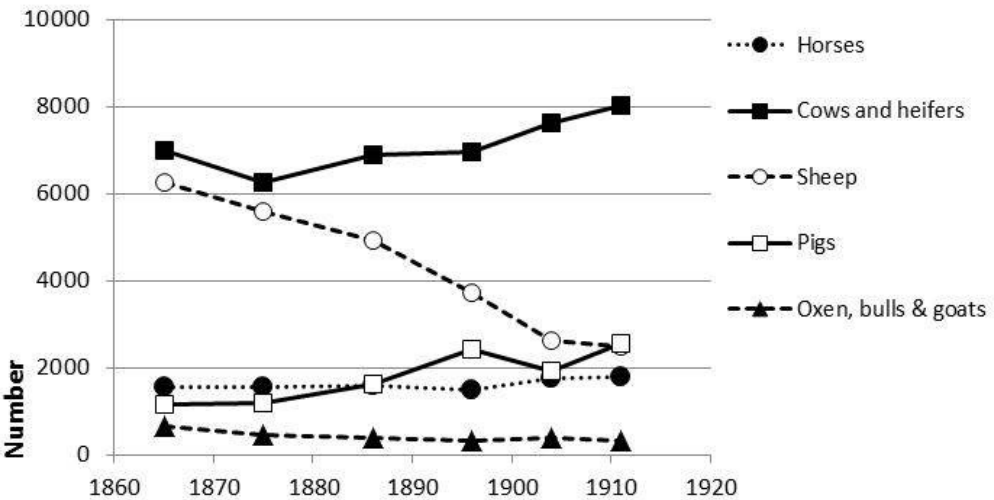

Fig. 5. Number of livestock in Folkare 1865-1911 (see Statistics Sweden, BISOS N, Agriculture).

Arable fields and crop rotation

Cadastral maps from the late seventeenth and eighteenth centuries show that two-field cropping, as described above, was the prevailing system in the fields close to the villages. The arable land was arranged in an open field system with large pairwise blocks, where all farms in the village had their own plots. Large farms had more land in the blocks than small farms. Although all arable land was individually owned, the use of land in the open field system, such as crops sown, timing of planting and harvest, was decided by the village council.

Arable fields separated from the open field blocks were subject to a rather flexible and variable rotational cropping, using long periods of grass ley. Land enclosure reforms, *Laga skifte*, 1829-1861, ended the old open field system and enabled the introduction of rotational cropping, employed by each farm separately (Gadd 2000). A typical rotation, described by the land surveyor for By parish, was:

Year 1, autumn: ploughing of the grass ley. Year 2: oats and autumn ploughing. Year 3: oats. Year 4: spring ploughing, fallowing during summer, and in autumn manuring and sowing of rye together with a fodder crop (timothy or red clover). Sometimes rye was replaced by a spring crop (barley or mixed grains), which was sown in the spring of year 5 in combination with manuring

and a fodder crop. Year 5: Rye. Year 6-9: fodder crop, successively turning into more semi-natural ley. Depending on the supply of manure and the fertility of the soil, the ley periods could be longer than four years.

Winter feed

Winter fodder consisted of hay collected from un-manured semi-natural meadows, fodder crops from leys on manured arable land, straw from grains and leaves. Leaves of birch, rowan, willow and aspen constituted a rescue resource during years of poor growth on meadows and fields, since leaves could be collected late, after the year's hay had been harvested. Straw and hay often complemented each other as the cereal crops and the hay normally did not fail during the same years. Different types of semi-natural meadows are mentioned in the historical sources. The alluvial meadows along the River Dalälven normally benefited from spring inundation, but if the water stayed too long on the meadows the grass sward decayed, which lead to reduced production the following 1-3 years. Another moist meadow type occurred in lower stretches in the landscape, not inundated but with good groundwater supply. A third wet meadow type was the mire meadows, usually rather low-productive and probably not mown every year. Dry meadows on hills within and between the fields, were among the most low-productive types. Leys could produce 4-5 cartloads of hay per acre, wet meadows 2 cartloads, and dry semi-natural meadows and mires 0.5 cartload per acre.[12] In all, the parish map from mid-19th century (Figure 6[13]) shows that the semi-natural meadows (black colour) constituted a large proportion of the open land in the landscape.

12) By Parish map with description 1853-1858.

13) *Ibidem.*

14) Statistics Sweden, BISOS N, Agriculture, 1865-1911.

15) *Ibidem.*

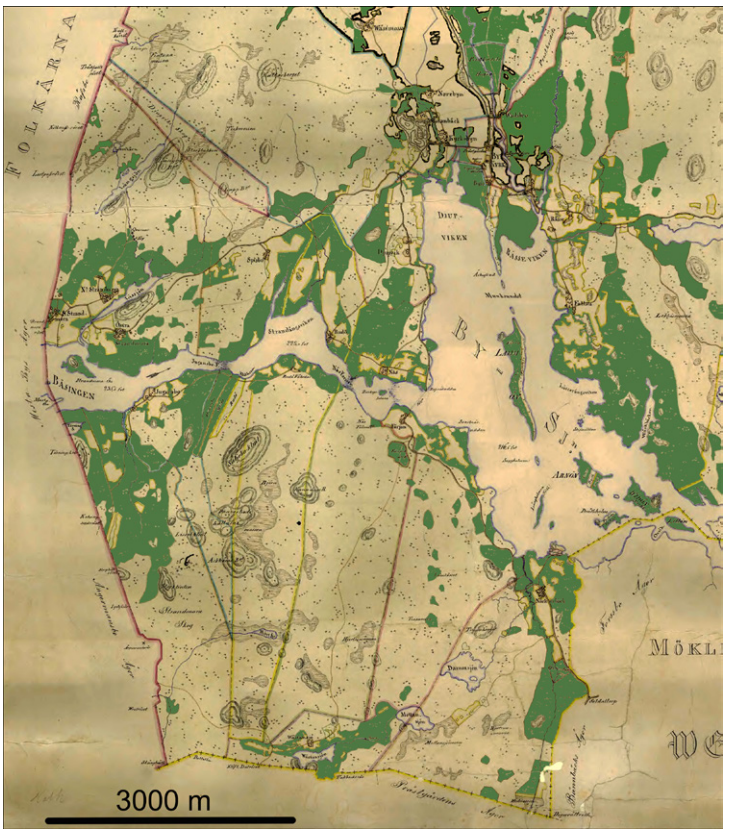

Fig. 6. Section of map over By parish in Folkare in 1858. In the grayscale version, meadows are shown in dark gray. In the colour version the Dalälven river is shown with blue outline, villages with arable land in yellow, hay meadow in green, outland forest and pasture in beige and useless rock and bog in grey. Original scale 1:20 000.

After the land enclosure reforms, an increasing proportion of the hay was produced on arable land, in rotation with crops as described above and in Figure 7[14]. Timothy was frequently sown, and sometimes clover, but the use of nitrogen-fixing legumes does not seem to have been systematic. At the same time, the area of arable land increased due to drainage and the cultivation of meadows (Figure 8[15]).

Summer feed

Some fencing of grassland in the village for pasture occurred, but the dominant type of pasture was in the open forest. The forest pastures were not fenced, but the animals

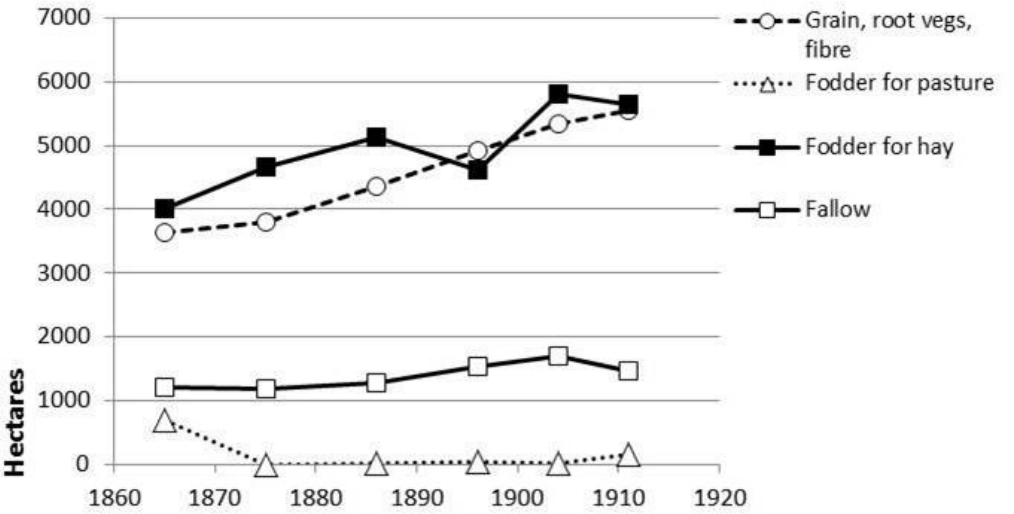

Fig. 7. Crops on arable land in Folkare 1865-1911 (Statistics Sweden, BISOS N, Agriculture).

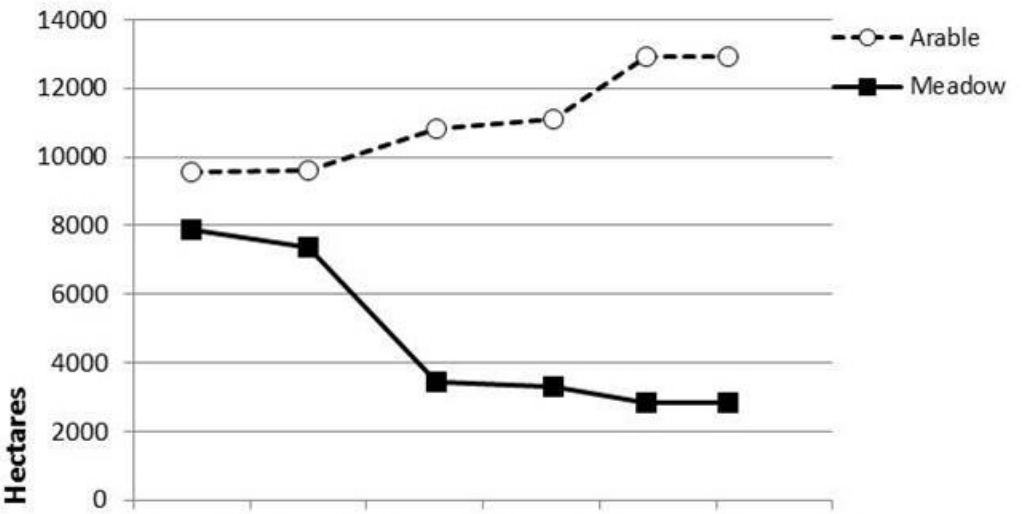

Fig. 8. Area of arable land and semi-natural meadow in Folkare 1865-1911 (Statistics Sweden, BISOS N, Agriculture).

were herded during grazing. Even though the productivity was low in the forests, the area was sufficient. In By Parish, the stocking rate was ca. 0.21 Livestock Units of 250 kg of weight (LU 250). Forage-rich gaps in the forest were created by logging for charcoal burning and timber.

After harvest on the fields and meadows, the livestock were often allowed to graze on the stubble. This source of summer feed may have increased as rotational cropping replaced two-field agriculture, but the forests remained the major pasture throughout the study period. Hardly any arable land was designated for grazing (Figure 7).

Nutrient cycling

Manure was the dominating source of nutrients for the arable fields. Nitrogen fixation by sown legumes was probably of limited importance, although wild legumes could probably be abundant on some leys. Most of the manure was accumulated during winter stabling. In summer, the manure was dropped in forests and pastures during grazing, but some could be collected in the barn where the lactating cattle stayed overnight between the evening and morning milking. In particular, summer manure was collected at the summer farms in the forest, where all the livestock were night stabled for

protection against predators. The manure was transported down from the summer farms on winter roads.

Increased production of hay on manured fields after ca. 1850 implied that a larger proportion of the nutrients was allocated to hay instead of human food (Figure 2B). This was partly compensated by mixing the manure with peat from the forest mires, around one cartload of peat per three loads of manure.[16] It is unknown whether peat was systematically used also earlier, in the two-field cropping. The first crop after the ley period was oats, sown without manuring, and therefore relied on the release of nutrients from decaying roots in the ploughed grass sward.

16) The Matses peasant diary, By Parish, notes from 1867-1871.

17) http://primariabotiza.ro/agricultura

18) http://primariabotiza.ro/agricultura

19) http://www.maramures.insse.ro

20) See also Anghel 2005 referring to a similar community in the Maramureş region.

21) Interviews conducted in 2010 and 2013 on 10 households (15 interlocutors).

22) "Circular migration" (Sandu 2000) refers to the social phenomenon of a temporary migration, a "come-and-go" between Romania and other countries, that has become a life strategy in Maramureş, positively valued both among those who migrate and within the native community.

Botiza, Romania

Environmental context

The village of Botiza in Maramureş County is one of the many mountain villages in the Romanian Carpathians. It has an area of 74,80 square kilometres[17], and is situated in a valley of approximately 500 m above sea level, surrounded by hills (800-1000 m) and mountains (1400 m). Due to the topography, land-use is stratified. The main arable land is situated in the flat valley bottom and on terraces just above the village gardens, which reduces the need for uphill transportation of manure to the fields and makes the fields accessible for daily work. The hay meadows are found higher and further from the farmhouses. From the valley bottoms, the hills and mountains gradually become too steep and rocky for cultivation and mowing and often also for convenient grazing. The steep slopes therefore mainly constitute a zone with deciduous forest. The shapes of old trees of beech and hornbeam show that the forests were historically managed with coppicing and pollarding. Above the steep slopes, a high plateau zone occurs, mainly used for grazing at summer farms. In Botiza 56% of the area constitute pastures and hay meadows and 11% arable land[18].

Apart from the river in the valley, streams are rare, but groundwater reaches the surface as scattered small springs and wet meadows. The climate is continental and south-facing slopes are usually drought constrained in July-August.

Socio-economic context

Botiza had a population of 2957 inhabitants in 1992 and 2717 in 2011[19]. Land use in the region was characterized by the many social and political changes during the past 100 years. Traditionally, small scale subsistence farming prevailed, but after the Second World War, between 1949 and 1962, the communist state collectivised Romanian agriculture. Botiza was not collectivized, mainly because of its poor agricultural production, but people were obliged to offer quotas of most of their products to the state: animal products, crops of potatoes, corn, beans, and cereals, hay and fruits. Forest and forest use was also heavily controlled.[20]

The total area of arable land is rather small, as well as the area per household, with an average of 3 hectares per household. Individual properties are scattered in small plots, from 3 to 11 plots per household.[21]

During the communist period, many people worked in a nearby mine, which made the village less dependent on agriculture. Some people were also working in agriculture in other regions of Romania. They were paid in cash, and also in products, mainly wheat and corn, that was brought home for household use. After the fall of Communism, European and global food markets have become accessible. At the same time, working abroad, referred to as "circular migration" (Sandu 2000), has been common.[22] This strategy was facilitated by the entrance of Romania in the EU in 2007. Considerable amounts of the income earned abroad are transferred back to relatives in the village and used for household consumption (e.g. buying cereals) and

for building new houses. This migration has made older people overrepresented in agriculture, although the circular migration decreased after the European economic crisis in 2009. Other socioeconomic changes are currently causing modifications of land management. These include the agri-environment payment within the EU CAP subsidies system, which has become an increasingly important source of income for farmers. Management regulations, tied to the subsidies, also influence local practices (Dahlström *et al.* 2013).

Fig. 9a. Drying fences and winter stacks on leys in rotational cropping in Botiza, July 2015. Photo credits: Tommy Lennartsson.

Fig. 9b. Fields with fodder crops and beans in the foreground, semi-natural meadows in the middle, some with fruit trees, and a communal pasture in the back. Botiza, July 2015. Photo credits: Tommy Lennartsson.

Main products from the agroecosystem

Products from grazing animals dominate the village production today: mainly milk from cows and cheese from cows and sheep. The cheese is largely produced at summer farms. During communism and before, wool was also an important product, used in local textile production and delivered to the state within the quota system. Wool is now considered obsolete, as other materials and textiles are accessible on the market. The households have a varied livestock, with 4970 poultry, 769 cattle, 270 goats, 1168 sheep, 1322 pigs, 316 horses and 280 bee hives in the village in 2011.[23]

During the communist period, the farmers had to produce both for quota delivery obligations and for their own household use, which forced them to maximise their agricultural production of cereals (mainly wheat and corn) and vegetables. Interviews show that today, few cereals are cultivated, but are instead purchased in the local market for household consumption, including wheat for baking. Vegetables, such as beans, pumpkins and potatoes are the main crops today in the rotation system, together with corn, some rye and oats and triticale (a hybrid of wheat and rye), the latter crop for animal fodder.

The reduced need for cereal production has released arable land for other types of use. Many arable field terraces have been planted with fruit trees, and a characteristic feature of the agroecosystem is that the production of winter fodder and arable crops is often done in orchards of plums, apples, pears and other fruits. These fruits are used in the household, mainly for jam and the distillation of brandy, locally called *horinca*.

23) http://primariabotiza.ro/agricultura

Arable fields and crop rotation

The vegetables and other food crops are currently produced in an irregular rotation with fodder crops and grass ley. Interviews and field observations show that fields are subject to intense rotation, in which two or three years of vegetables are followed by two or three years of alfalfa or clover. In other fields, the fodder crops are allowed to gradually turn into a grass ley, eventually resembling the semi-natural meadows. Rotation is performed also in fields planted with fruit trees, using precise and shallow ploughing.

Fig. 10. Section of land use map of Botiza from around 1870, made by the Austro-Hungarian Empire in scale 1:2 880. Hay-producing meadows and fields are grey (green in colour version), cropland white, and pasture/forest dark grey with thick black borders. The river is indicated by dashed lines. www.mapire.eu.

Earlier rotation systems were more regular, and focussed on high yields of cereals and corn. A typical sequence was corn (for 1-3 years), cereals (wheat, rye, barley etc., for 1-3 years), followed by potatoes and other vegetables (1-3 years). Leys with alfalfa or clover were used when the soil became depleted and needed to rest.

The regularly ploughed arable land today covers considerably less area than during the communist era, and abandoned terraces, now mainly used as hay meadows, are found everywhere in the landscape.

Horses are still used for most of the heavy work. In spring they are used for ploughing and taking the manure to the fields; in summer for transporting the hay from the meadows and timber from the forests; and in autumn and winter for transporting the hay and the crops home to the farm. The steep topography is one reason for the limited mechanization of agriculture, as tractors can be used only in the more accessible fields. The number of motorized single-axis mowing machines continues to increase in the village, but horses are still needed to transport the mowers to the hay meadows.

Winter feed

Compared to the communist era, a larger proportion of hay is now produced on the arable land that is no longer needed for cereal production. Alfalfa and clover constitute the main cultivated fodder crops, which can be harvested twice or more each year, depending on the weather and nutrient status of the field. The fodder crops vanish after a few years, clover sooner than alfalfa and the leys are then ploughed again for vegetables or left to develop more semi-natural grass-herb vegetation.

The semi-natural meadows provide the majority of the winter feed and are the dominating provisioning ecosystem in the landscape, both historically (Figure 10) and today. Several types of semi-natural meadows have been shaped through an interplay between adaptive management practices, and biophysical and socio-economic preconditions for hay production (Dahlström *et al.* 2013). Open dry, annually cut meadows, constitute the most common type. On more organic and moist soils, open or semi-open mesic bluegrass meadow occurs (*Molinia caerulea*, șovar

in Romanian). Such meadows are often managed in a rotational system, consisting of 3-7 years of mowing, followed by at least five years without management. Before a resting meadow can be mown again, it needs restoration by burning and bush clearing. Another type of meadow is the semi-open alder meadow (*Alnus* spp., *arin* in Romanian), in which hay production is combined with production of fuelwood. Hay production is enhanced by the alders' nitrogen fixation. Common on former arable fields is the semi-open orchard meadow, in which hay production is combined with the production of fruits, mainly plums. Further away from the farms "reserve meadows" occur, which are mown during years of hay deficit. In between they are burned regularly to keep them ready for use when needed, and they are also used for grazing by sheep and cattle in the autumn.

Some hay is brought to the farm for storage, but the majority is stored in the fields, in small barns or in haystacks (Figure 9). The stacks are carefully constructed and can keep outdoors for at least 3 years. The meadows are often situated far from the village, and much transport work is needed during winter to bring the hay to the farm.

The production of hay varies considerably between years due to the summer humidity. The variation is largely buffered by keeping haystacks from good years and using them in poor years. The reserve meadows are mowed in the driest years, in Botiza, for example, during the dry years of 2003-2004 and 2012.

Trees improve the production and quality of the hay, both through nitrogen fixation as in the *Alnus* meadows mentioned above, and through drawing up nutrients from deeper soils, as do fruit trees and birch. This is well known by the local population, who appreciate the trees in the hay meadows, but this use of trees is now challenged by subsidies regulations. Previously, leaf fodder was collected from hazels in coppice meadows or from pollarded beech trees in the pastures. This practice is no longer present, but is still remembered by the farmers.

The preponderance of current hay production is found close to the village, on old meadows and former arable fields (see above). In earlier times, extensive meadow areas also occurred further from the village. As former arable land has become available for mowing, the remote meadows have been transformed to pastures or abandoned. Another driver for this change is a decrease in the number of animals, mainly sheep, after the year 2000, which has reduced the need for hay. Recently, an opposite trend of restoring remote meadows has been brought about by subsidy policies that encourage people to restore abandoned meadows in order to obtain the subventions associated with managed grasslands (Stroe 2015).

Summer feed

In early May and again in October-November, the meadows and some of the fields are grazed by sheep. This enhances the release of nutrients from the aftermath (regrowth after cutting) and litter, and also makes the meadows in better shape for mowing by removing old litter. Few fences exist in the village, and the grazing relies on herding.

In the summer, three main types of pastures are used. Some dairy cattle graze common pastures close to the village where they are herded during the day and brought to the farm every evening (Figure 9). Many cattle and sheep are brought to mountainous pastures in the spring and stay there most of the summer. They are milked at permanent summer farms and the dairy products are transported to the village. During the communist era the mountainous pastures were more important than today, as the animals now can be brought to lower pastures on former remote meadows by the early autumn. Such former meadows provide a third type of pasture for herded sheep and goats, which are milked in temporary summer

farms in which the milk is processed into cheese. These summer farms are moved once or twice during the summer in order to utilise the best pastures. All pastures are commons and the farmers using them need to pay a fee to the local administration and to contribute to the yearly cleaning of the pastures of undesirable weeds and bushes.

Nutrient cycling

Traditionally, manuring was the main way to fertilize arable land. Ploughing of grass sward, mainly on old leys, is an old method for releasing nutrients from the decaying grass sward, enough for one or two crops. During the communist period chemical fertilizers were used, even sprayed from planes flying over the fields, according to our interviews. Farmers, however, preferred to use manure and the use of chemical fertilizers was given up immediately after the communist fall in 1989. Today, the available manure is enough for the rather small areas of arable land, and no artificial fertilizers are needed.

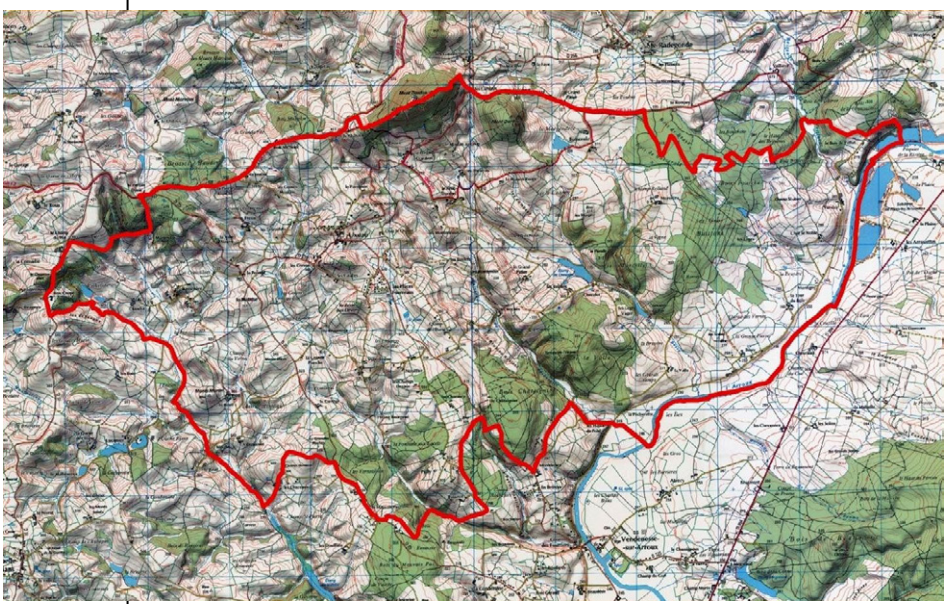

Fig. 11. Outline of Uxeau Commune shown over Institut Geographique National 1:25,000 map (image courtesy IGN, Paris).

Both vegetables/ cereals and fodder crops are manured when sown and farmers with excess manure sometimes also spread it on unploughed old leys.

Fig. 12. Uxeau landscape. Photo credits Elizabeth Jones.

Since the major source of winter fodder is the un-manured semi-natural meadows, the production on arable fields today is largely based on a one-way flow of nutrients from meadows to animals and fields. During spring and autumn grazing in meadows, manure can be concentrated by using mobile fences which serve to protect the animals against predators at night. The manure from the permanent summer farm is not used in the fields today, but traces of earlier cultivation around summer farms indicate that this nutrient source has been more important historically.

Burgundy, France

Environmental context

The Commune of Uxeau (approximately 33 square kilometres) in southern Burgundy lies in the foothills of the Morvan Mountains in Eastern central France (Figure 11). The Commune ranges from the uplands of Mont Dardon – at 492 metres, it is the highest peak in the area – to the lowlands along the Arroux River, and is characterized by acidic, granitic soils. The rugged topography forms a patchwork of woods, cropland, pastures and meadows. Fields are

Fig. 13. Plow team of 8 oxen used in Issy L'Évêque, a commune bordering Uxeau. (http://www.notrefamille.com/produits/publique/cartespostales/version_150/20070828/2922/f1c6j4b7g0u7q1g6d7q4.jpg)

still largely bounded by hedgerows (Figure 12). Abundant springs produce a network of small streams that flow down to join the Arroux River. Permanent grasslands (those not part of the crop rotation) were traditionally located along the well-watered stream beds in narrow valleys and on the upper reaches and steep slopes of the hills.

In 1840, roughly 70% of the land constituted cropland, 15% meadow and 15% forest (Madry *et al.* 2011).

Socio-economic context

The organization of farm labour changed radically during our study period. At the beginning of the nineteenth century, large communal farms (sometimes over 100 persons) sharecropped land owned by the aristocracy and bourgeoisie in the local towns. The sharecropping contracts, where half the crop was to be given to the landlord, required the maximization of grain production and a large labour force.

In the mid-nineteenth century the construction of roads, canals and railroads progressively linked rural areas with distant cities. This enabled the beginning of the shift from self-sufficient farms raising food largely for their own consumption to farms specializing in raising cattle for market. Increased urban demand and rising prices for beef encouraged the transition. By mid-nineteenth century the last of the communal farms had disappeared in Uxeau.[24]

The early nineteenth century agricultural system required a great deal

24) Personal communication Hubert Loreau, Uxeau.

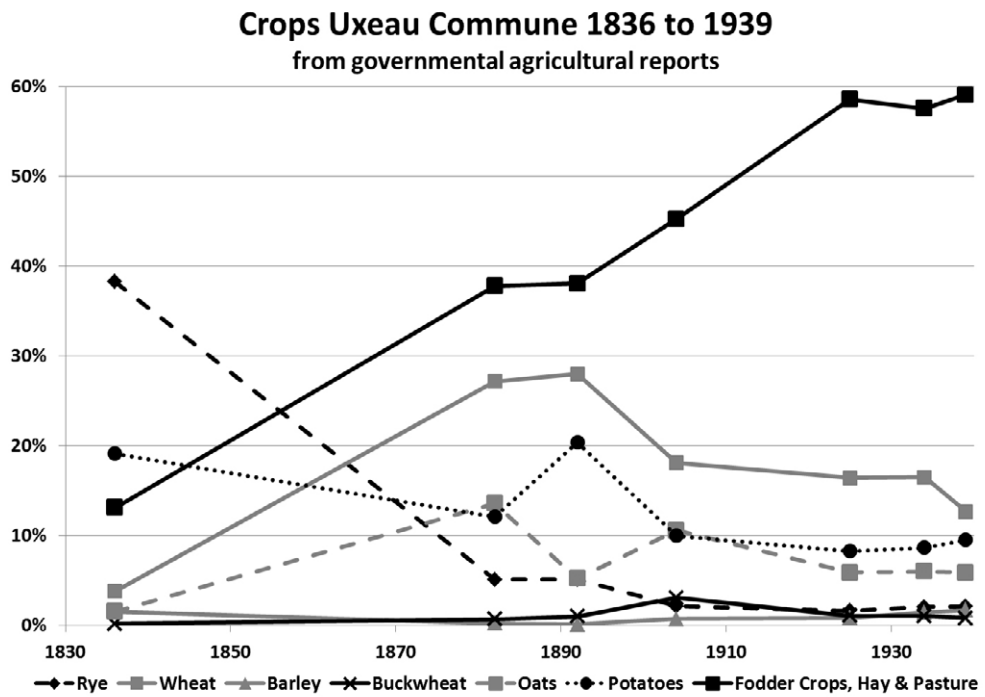

Fig. 14.Percentage of arable land sown in various crops from 1836 to 1939.

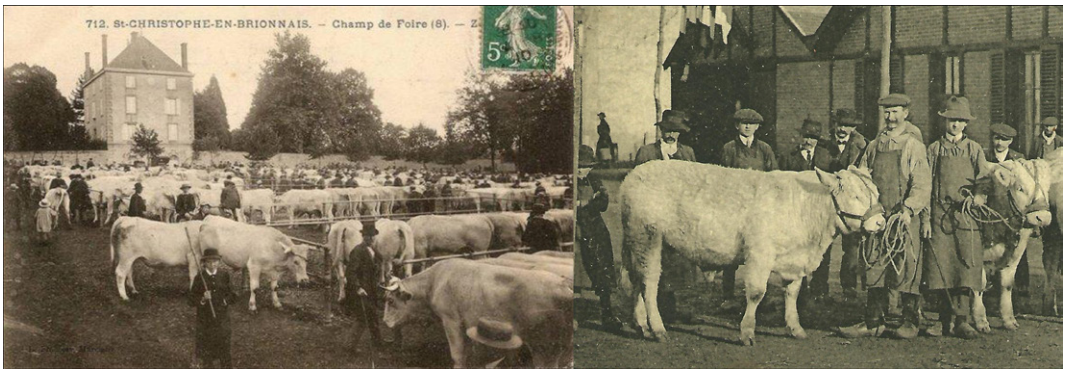

Fig. 15. Historical postcards of the Charollais cattle markets in Burgundy.

of year-round labour, further intensified in the summer when the hay and grain crops were harvested. The switch from two-field systems to crop rotations, as well as the switch from growing grain to raising cattle, greatly reduced the size of the labour force needed. According to agricultural reports in 1852, "a thirty percent reduction in man-days per hectare could be achieved simply by employing clover to replace fallow. When pasture replaced arable land, the number of man-days per hectare dropped by eighty percent!" (Shaffer 1982, 142). Population records for Uxeau show a slow but steady decrease in population from 1119 people in 1851 to 522 in 2008.[25] Beginning in the nineteenth century many of these excess agricultural workers found employment in the steel forges in the neighbouring town of Gueugnon, some ten kilometres away.

25) http://www.archives71.fr/arkotheque/consult_fonds/fonds_seriel_resu_rech.php?ref_fonds=4.

Main products from the agroecosystem

In order to guard against the risk of crop failure which would result in both famine and losing the sharecropping contract to farm the land, the large sharecropping farms employed a very diverse economic strategy that included raising sheep. Sheep manure was essential for fertilizing the grain fields, and side ventures such as selling wool and weaving cloth also raised the cash necessary to pay taxes and church tithes. Plow oxen were required to till the land. The rocky, heavy soils of the area required a plough team of 8 oxen (Figure 13). It is estimated that the large communal farms working 60 hectares of land would need three plough teams consisting of six men and 24 head of cattle. They would also have a few cows for reproduction and for dairy products to sell. Every year farms would sell off the oldest pair in the 8-oxen plough team to *emboucheurs* ("fatteners") who had rich meadows along the Arroux river (Shaffer 1983, 135). The fattened cattle would be sold at nearby regional markets for consumption in local towns.

As the nineteenth century progressed, the market for wool dropped off due to competition from Britain, and at the same time both "green manure" crops and cattle replaced the function of sheep as fertilizer producers. A small number of sheep continued to be raised for meat rather than wool.

Another change during this period was an increase in the production of wheat at the expense of rye (Figure 14).

As discussed above, the agropastoral system switched from a subsistence economy based on grain production to a market-oriented economy based on beef cattle production. Earlier, in the eighteenth century the regional distinctive white Charolais cattle breed was developed, prized for its ability to fatten quickly (Figure 15). Production of beef based on this breed and cattle in general rose steadily and dramatically over the study period, but there were dips in cattle numbers during the depression in 1929 when the markets collapsed, and again 1955 in response to the food shortages resulting from World War II

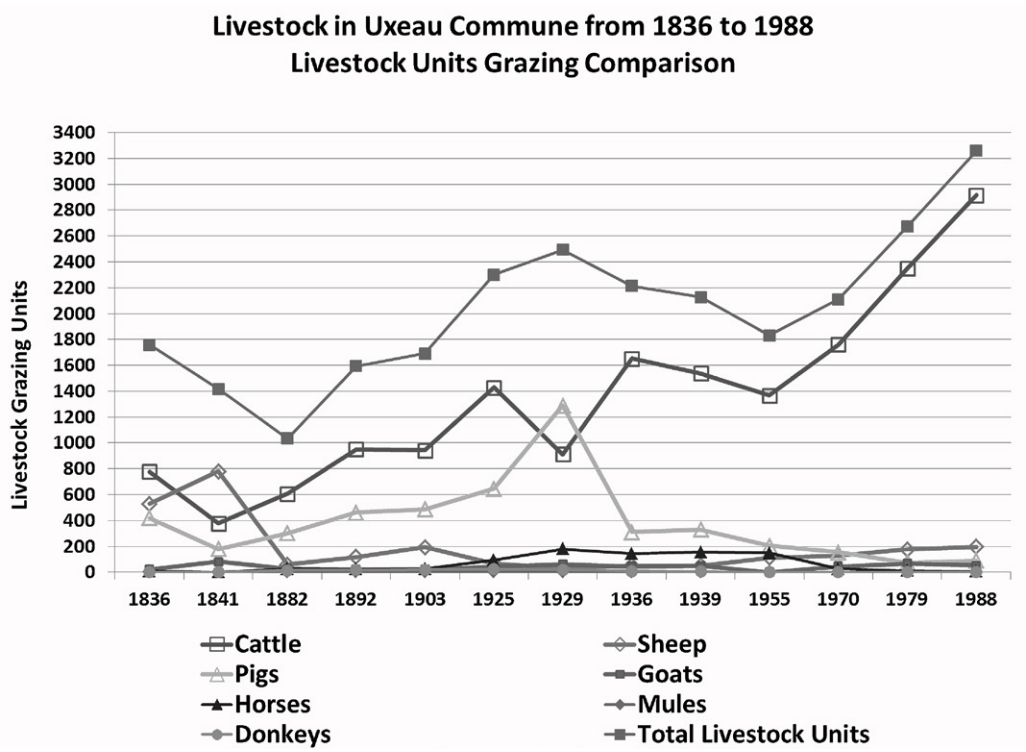

Fig. 16. Livestock in Uxeau Commune 1836 – 1988. The reference unit (=1 LSU) used for the calculation of livestock units is the grazing equivalent of one adult dairy cow of 600 kg producing 3000 kg of milk annually, without additional concentrated foodstuffs.

(Figure 16). As a result of this combination of factors, land formerly used for growing grain could be turned to fodder production enabling the expansion of cattle herds.

Livestock other than cattle included pigs and horses. A pig was the only animal whose meat was traditionally eaten on the farms, and pork is still favoured in the Burgundian cuisine. In 1929 when the market crashed, pig production increased with the temporary return of a subsistence economy. The number of horses in Uxeau was never very large, but there is a slight increase beginning in the late nineteenth century, because they were used instead of oxen to pull the new mechanical farm equipment (Figure 16). A horse-drawn mechanical mower first appeared in Uxeau in 1892, while horse-drawn tedders, for turning the hay to speed up drying and baling machines are first recorded in 1929.

Arable fields and crop rotation

The method of farming prior to the mid-nineteenth century was based on a two-field system with half the land lying fallow.. The fallow land required 3 ploughings in order to incorporate weeds and the manure from grazing animals and to loosen the ground for planting.

This two-field system proceeded as follows (Shaffer 1982:139): Year 1 rye planted in the fall; Year 2 rye harvested in July or August, and field left fallow after summer harvest; Year 3 three ploughings, in March or April, in June, and in early fall, whereafter rye was planted again.

With the introduction in the mid-nineteenth century of "green manure" (crops that fixed air nitrogen) fallows were gradually abandoned. Grass swards including nitrogen-fixing clover and alfalfa inhibited the weeds and reduced the number of ploughings required. A complex system of crop rotation was introduced. An example of an 8-year crop rotation from an 1852 agricultural report for our research area is as follows: Year 1 fallow or green fodder ; Year 2 rape ; Year 3 wheat ; Year 4 clover ; Year 5 wheat; Year 6 root crops; Year 7 wheat; Year 8 fodder crops, e.g. alfalfa, maize.[26]

26) Gueugnon Canton Agricultural Report 1852.

Winter feed

In the two-field system, the livestock would graze on the fallow land and pasture most of the year and often well into the winter. There was thus not a great need for hay meadows to produce winter fodder, so hay meadows were few and found on land unsuitable for grain production. When the hay crop was decimated by drought or long winters, farmers were forced to run their animals in the woodlands to search for whatever scrubs and grasses they could find (Shaffer 1982, 124). The young shoots of pollarded trees (e.g. beech and hornbeam) were also used as fodder in bad years well into the twentieth century.[27]

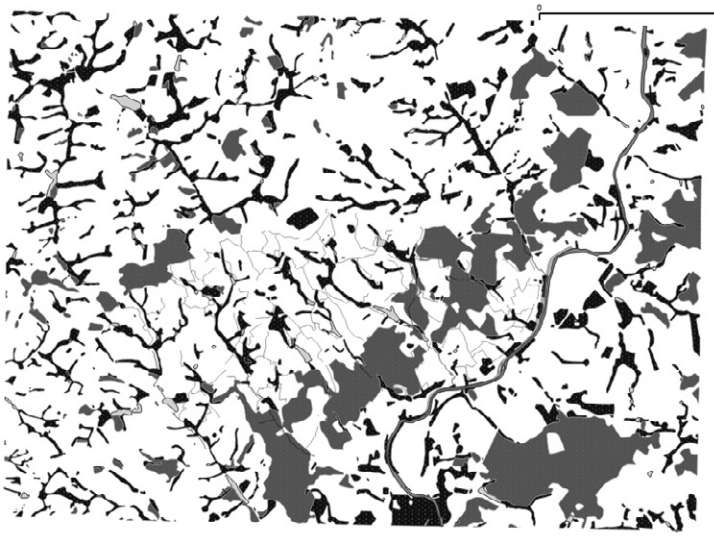

Fig. 17. 1840 Etat Major GIS data, with the meadows shown in black. It is clear that many of these meadows follow along the stream in the area or lie near the rocky ride tops. Forest areas are shown in gray, primarily located along the river and in the uplands. (Madry et al. 2011).

In the early nineteenth century winter fodder came from the semi-natural meadows in the uplands and along the stream beds (Figure 17). The area of un-manured semi-natural hay meadows extant in 1836 did not decrease much as a result of modernization in farming practices, but during the 19th century, an increasing proportion of the hay was produced on arable fields in crop rotation (Figure 18). Additionally, some arable land was turned into permanent meadows, adding to the natural meadows.

By the late nineteenth century, fodder for cattle, sheep and horses came from five different types of fields: 1) permanent upland dry meadows reserved solely for producing hay, 2) permanent stream bed wet meadows/pastures, 3) semi-permanent grasslands (in place for 6 years or more) on arable land, 4) fodder-producing arable fields of clover and alfalfa grown in a complicated 8-year rotation, used for hay production and grazing, and 5) fodder crops such as maize, oats, potatoes and sugar beets.

Summer feed

Uxeau differs from Sweden and Romania in that there were no common grazing areas. All land was privately owned, and even the forest was divided into small privately owned parcels. There were no large tracts of forest that could accommodate grazing on a regular basis.

The preferred Charolais breed required very little maintenance compared to other cattle breeds. Each herd could be left alone in a watered field, with a bull to protect it, for weeks or months at a time if the field was large enough. They were able to remain outdoors for most of the year.

In the two-field system, spring, summer and autumn forage came from the fallow land, permanent pastures, and aftermath on mown meadows. With the switch to beef cattle production after the 1870s, a good deal of former cropland was converted to pasture, thus replacing the grazing on fallows (Figure 18).

Nutrient cycling

The two-field system relied on a nutrient flow from permanent semi-natural meadows and pastures to the fields. The fallow period

27) Unpublished ethnographic data from Carole Crumley 1994.

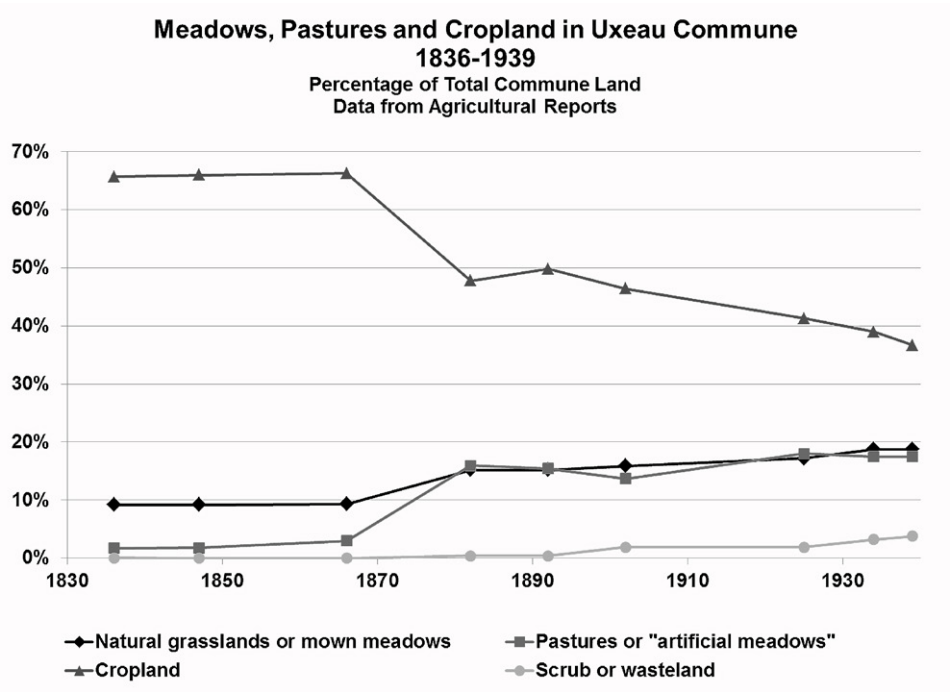

Fig. 18. Meadows, Pastures and Cropland (for grain and vegetable production) in Uxeau Commune 1836-1939.

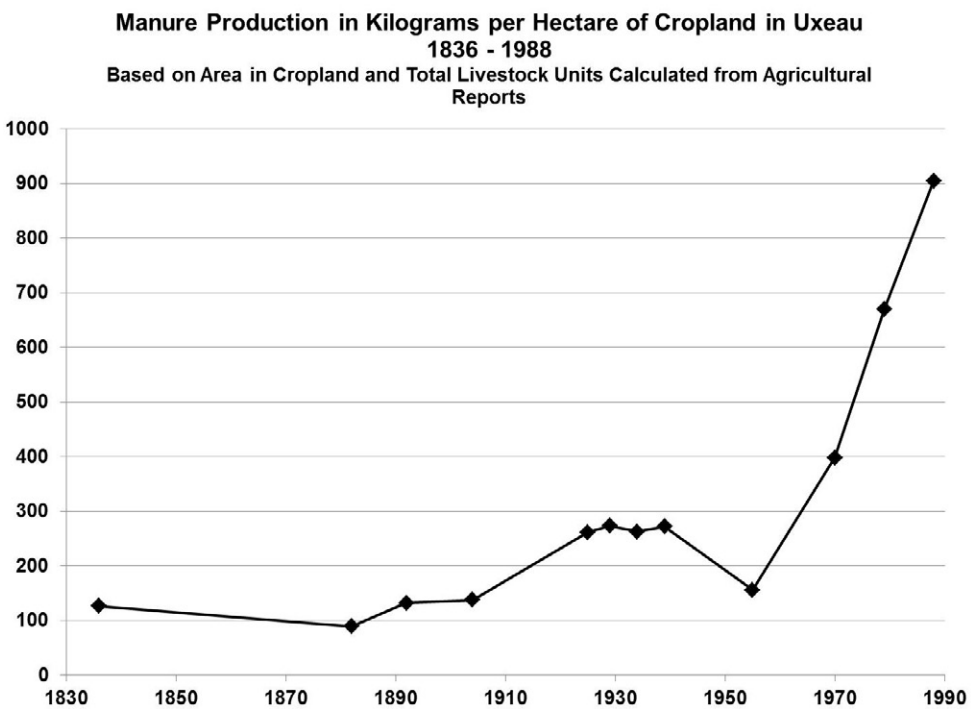

Fig. 19. Manure Production in Uxeau Commune. Manure amounts are calculated as 125 kg for every 500 kg of livestock grazing units (includes, cattle, sheep, goats, horses, donkeys, mules, pigs). Cropland is arable land on which fodder crops may be grown, but excludes the grasslands of permanent and semi-permanent meadows and pastures.

served to mineralise soil nutrients for next year's crop, but in rainy winters, most of the nutrients were instead washed out. The switch to cattle-based agriculture and crop rotation included the use of nitrogen-fixing plants such as clover and alfalfa.

The increased herds eventually increased the amount of manure available which made the shrinking area of grain fields more intensely manured and productive (Figure 19), although some of the nutrients stored in the crops (maize, oats, potatoes and sugar

beets) were transferred back to the animals as supplementary feed for fattening. Gradually, more and more cropland was turned into permanent or semi-permanent meadows and pastures.

Discussion

The three study regions are spread out over a distance of approximately 1500 km east-west, as well as north-south. In spite of their different biogeographic regions, the agroecosystems show considerable similarities. These similarities are due to the fact that most low-input systems in temperate regions share the same fundamental properties related to nutrient circulation (Bieleman 1999). In all three regions the arable fields needed nutrients and traction power to work the land, and these required animals. The livestock needed both summer forage and winter fodder, and in the absence of external sources of nutrients, a certain proportion of un-manured meadows were needed for hay, and un-manured pastures for the summer forage (Figure 2). The regions are also similar in terms of overall composition of the grassland vegetation.

There are, however, also considerable differences between regions regarding how these basic requirements of low-input agriculture are fulfilled. Both differences and similarities are elucidated in this article through studying the agroecosystems in the social-ecological context of the regions, because agriculture and its change over time are influenced by the interactions between the agro-ecology and socio-economic factors.

We analyse the role of hay in agriculture, which demonstrates how local hay production, and agriculture in general, is shaped through a complex and dynamic interplay between socio-economy, traditions, and ecology – thus through a dynamic social-ecological system. Changing socio-economic conditions may alter some of the frames for agriculture, but without the input of external sources of nutrients and energy, the SES still needs to provide a balance between different types of land. Conversely, there are many different ways of achieving such an ecological balance and how it is done locally, is largely determined by institutions, socio-economy and culture (Christensen 1999). Our study regions illustrate how agriculture was tightly coupled to the specific SES of each time period.

The importance of social-ecological interactions is illustrated by choice of crops. In Uxeau, rye was the dominant cereal in the early period. The cold conditions of the Little Ice Age made rye a safer crop than wheat which favours warm, dry weather. As well as providing food, the rye straw was used as thatching of houses and as fodder for livestock (Clout 1983: 21). When the prevailing climate warmed in the mid-nineteenth century, it was possible to replace rye with wheat (Le Roy Ladurie 1972). Wheat still came with a greater chance of crop failure, but unlike rye, it could be sold to urban areas whose populations favoured white bread. In Botiza, wheat is highly appreciated for baking, but the climate and soils are not optimal for intense production of winter wheat (cf. Wolf 1993). During communist time, quota delivery obligations forced the farmers to use the best plots of arable land for production of wheat and other cereals. Farmers were paid for their quotas by the state, but at less than their market value. The ending of the quota system and the access to new markets after the fall of communism, have, in combination with biophysical factors, reduced local wheat production, and cereals are today largely purchased in the market. In Folkare, the production of oats increased during the period. Oats could be combined with the increased fodder production on arable land, since it grew well on ploughed leys (Arrhenius 1904). Oats were also needed for the expanding urban transportation systems, and oats for the London Hansom

cabs were one of Sweden's largest export products around 1870 (Gadd 2000).

Changing hay practices

Hay production on manured arable fields became more common over time in all three study regions, as in Europe in general (Gadd 2000). The analyses of our study regions suggest a number of drivers for this change, which illustrates the social-ecological interactions in agriculture.

One driver is the adaptation to changing socioeconomic conditions. In Maramureș, the change took place around 1990 when the need for cereal production decreased as the quota system ended, and the accessibility of market cereals increased. The less fertile fields were taken out of cultivation first. Since the area of un-manured meadow is still high, supporting large numbers of livestock, the amount of manure is more than needed for food production, and some can be used for hay production.

A new type of adaptation is currently seen in Romania, as hay production on abandoned semi-natural meadows has resumed for EU subsidy reasons. In general, changing policy and markets are important drivers of agricultural change in Romania, but landscape properties, such as the topography, still strongly influence how such socioeconomic drivers influence agriculture in Mountainous regions such as Botiza.

Also in Folkare and Uxeau, socio-economic drives are important for explaining the changes of hay production. Increased demands for dairy products in Folkare and meat in Uxeau, made the animal production an increasingly important source of income in comparison with grain. In Uxeau, the changeover to a reliance on cattle over grain had multiple causes. Importation of wheat from Canada and America in the 1870s caused wheat prices to drop dramatically. Also in the 1870s, compulsory military service was established. While in the military, men were given meat to eat every day, which was not the custom on the farms and that contributed to an increase in the demand for meat among the general population. Also in Folkare, increased demand for dairy products and pork reflect national urbanisation and new food habits. In both Uxeau and Folkare, improvements of transportation modalities were a prerequisite for these markets, and in both regions the railroad had arrived by the 1870s, allowing the shipment of cattle to distant urban markets, and for milled flour to be delivered cheaply to the rural areas.

The increased animal production, however, influenced hay production differently in Uxeau and Folkare, due to differences in the interactions between biogeographic factors and market. The shorter winters in Uxeau in general meant that not as much fodder had to be produced compared with Folkare and Botiza. Pasture was a more important bottleneck than hay meadows in the Burgundian agro-ecological system. In Folkare, the increased number of dairy cattle that must be brought into the barn everyday and fed through the winter, required increased hay production. In Uxeau, animal production instead increased in terms of beef cattle, which were less dependent on hay since they could spend most of their time outdoors.

In Uxeau, we see yet another example of how socioeconomic change influenced the hay practices, namely the increased use of nitrogen-fixating legumes. Shaffer (1983:148) describes how "grasses such as clover and sainfoin were effective only on soils with sufficient lime, an ingredient that the sandy granites of the Morvan lacked entirely. Before clover crops could be introduced, fields had to be marled with deposits brought from outside the region." The import of marl was possible after the 1870s due to the improved transportation system.

Another driver of changing hay practices is probably agroecological necessity. In Folkare and Uxeau, farmers may have been forced to increase the proportion of

hay-producing leys in the system, but for different reasons. During the 19th century in Sweden, the area of un-manured meadows decreased as they were transformed to arable fields (Figure 8), at the same time as the demand for fodder increased (Gadd 2005). This would have led to hay shortages unless some of the fields were used for producing hay instead of human food. In Uxeau, it was the increasingly sizeable herds that made the farmers start to grow hay and other fodder crops on manured cropland in a rotation with grains. Figure 18 shows an exact inverse relationship between cropland and meadows/ pasture. The area of natural meadows was not reduced at the expense of crops in Uxeau, because meadows were located on land that was too wet, rocky, or steep for food production and all land suitable for cultivation had been under production since medieval times. Furthermore, as the diet changed from a reliance on fish for protein to beef consumption, the many large fish/ mill ponds that dotted the area were drained and converted to permanent pasture or meadow (Madry *et al.* 2015).

Also poor nutrient status in arable fields due to manure shortage and poor soils may have forced farmers to reduce the area of arable land by letting the poorest fields rest as leys for a number of years (Cunfer and Krausmann 2009). This was certainly the case in Folkare, where contemporary mid-19th century descriptions explicitly show a correlation with soil fertility and duration of grass leys in the rotation.

A third driver is that fodder production on arable fields provided a number of advantages for agriculture. In many cases, the use of arable fields instead of semi-natural meadow for hay production was a prerequisite for the mechanization of hay production as mowing machines and horse-pulled rakes only worked on flat ground (Gadd 2000). The more mountainous areas of Maramureș didn't experience the same degree and pace of mechanization as in the flatter region of Folkare; this difference can principally be explained by the degree of field access, parcel sizes and topographical constraints.

Another advantage was that fodder crops and semi-natural vegetation were a more efficient method of weed control than the labour and energy intensive practice of the three ploughings required when using fallowing for weed control (Shaffer 1982).

An interesting aspect of the SES in Uxeau is that the switch from subsistence grain agriculture to cattle-based production also greatly reduced the size of the labour force needed and the number of mouths to be fed locally.

Sustainability issues

Although hay production on manured fields increased the production of hay per hectare, it reduced the amount of nutrients available for production of food crops for human consumption. Animal products increased but, in general, animal production is not sustainable in a closed system only containing manured fields. The cycle of animal-manure-crop-animal will lose nutrients due to leakage, and animal growth and metabolism (Russelle 1992), especially if some of the products are traded off the farm. Nitrogen fixation by legumes may compensate this loss (Figure 2), but other minerals than nitrogen may be depleted in the long run.

In present-day Maramureș, the large proportion of "un-manured hay" in the system likely ensures its sustainability, and the current agriculture in the Romanian Carpathians probably constitutes Europe's most extensive area of organic farming.

In both Folkare and Burgundy, the fodder-production in rotational cropping probably extracted considerable amounts of nutrients from the fields. In Burgundy because of short ley periods, in Folkare because manure was added to the last cereal crop in the cycle, the autumn rye, which gave high nutrient levels in the first fodder yields. In Folkare the use of peat for

fertilizing was probably in response to the high nutrient extraction (Fulmer 1917).

In today's society, preservation of biodiversity and cultural heritage are considered essential components of sustainability. A diverse hay production, such as in Botiza, promotes both. Semi-natural meadows are among the most biodiversity-rich ecosystems and highlighted in conservations frameworks all over Europe (Huband and McCracken 2011). Less attention is, however, paid to the cultural values of the use of semi-natural meadows. The patchwork of meadows in Botiza, as well as the variety of haymaking practices, demonstrate a number of interactions between nature and culture and thus represent a rich environmental cultural heritage, local traditional knowledge about ecosystems and species, and source of biocultural diversity (e.g. Knowles 2011; Babai and Molnár 2013; Ivașcu and Rákosy 2015).

Concluding remarks

At the beginning of this study our assumptions were that the agropastoral systems in the 3 areas were fairly similar in the earlier low-input subsistence economy eras and in their transition to a higher input market oriented economy. But as we examined the multiplicity of social-ecological factors and drivers affecting these systems, more and more differences became apparent, revealing different patterns of causation.

There is analytical value in comparing agro-ecological systems that are different in space and time, since this obliges researchers to identify primary drivers of change in the systems. This paper promotes the potential of an integrated and interdisciplinary approach for better understanding the complex interaction of people, their social and economic context and their environment.

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