Agricultural Systems 154 (2017) 25–33

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

Diversity of high-latitude agricultural landscapes and crop rotations: Increased, decreased or back and forth?

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ARTICLE INFO

Article history:
Received 23 July 2016
Received in revised form 16 January 2017
Accepted 26 February 2017
Available online xxxx

Keywords:
Cereal monoculture
Crop sequencing
Diversification
Environmental fallow
Grassland
Break-crop
Land use change

ABSTRACT

Land use change is a continuously on-going process that has many impacts on the environmental footprint of agriculture and especially on the biodiversity of agricultural landscapes. This study used field scale data from 1995 to 2011 (165,760 field parcels) on a study region that represents the prime crop production area of Finland, to assess how agricultural land use has changed since the launching of the EU Common Agricultural Policy. Six five-year crop rotation types were identified: cereal species monoculture, cereal monoculture, rotation with a break-crop, diverse crop rotation, perennial, non-permanent grassland rotation and environmental fallow rotation. Shifts in the frequencies of different crop rotation types and composition of their crop species were monitored. Furthermore, the contribution of different field characteristics, on a farmer's land allocation to different rotation types, was assessed. The ultimate goal was to understand whether land use changes, in general, have contributed to any increase in heterogeneity of landscapes and whether they have impacted diversity of crop rotation types. We found that different crop rotation types were applied on a farm, but that farmers have quite consistent drivers for land allocation to different rotation types; although, economic incentives influence the introduction, expansion and/or withdrawal of crops from rotations. The farmers' readiness to implement land use changes was dependent on farm size. There has been a shift towards lower shares of cereal species monocultures, grassland rotations and diverse crop rotations, while environmental fallow rotations have increased. According to the five-year rotation plans shared by 16 interviewed farmers, there was a noted desire for more diverse rotation types originating from adverse experiences with cereal monocultures and soil degradation; however, they were keen on reducing the number of environmental fallows and concentrating on food production. It is important to carry out follow-up studies to understand the impacts of the demonstrated and anticipated land use changes on biodiversity. Future policy development should benefit from a gained understanding of the drivers of farmers' decisions for facilitating unimpeded implementation.

1. Introduction

Several environmental challenges result from anthropogenic activities, including those reinforced by intensive agriculture (Duru et al., 2015). Hence, agriculture has many challenges to cope with and solve, while simultaneously increasing food production capacities, in many regions (Schulte et al., 2014). Changes in land use, agricultural production systems, management practices, crop choices and genetic diversity have resulted in a loss of biodiversity in agricultural landscapes (Stoate et al., 2001). The rural landscapes of the prime crop production regions represented in this case study, are, however, naturally heterogeneous, consisting of a mosaic of forests, fields, lakes, rivers, and main ditches, with high frequencies of "waste or untouched land" or edges between them and around the field parcels. Furthermore, agriculture is mostly semi-intensive in Finland, driven by the Agri-Environmental Program (AEP) as well as market and price conditions (Peltonen-Sainio et al., 2015b). Despite this, agriculture in Finland is not considered to be high nature value farming as this is defined as having a high proportion of semi-natural vegetation and/or a mosaic of low intensity production with natural and structural elements (Keenleyside et al., 2014). Furthermore, grasslands in Finland are virtually non-permanent as they are ploughed within four years.

As with other countries in Europe (Scheper et al., 2013), the AEP has been launched in Finland following its EU membership, and is aimed at decreasing the environmental footprint of agriculture. In addition, it contains elements for responding to the concerns of biodiversity loss, in agricultural systems. In the UK, the low-intensity management of agricultural land and creation of habitats have been core actions to restore species diversity (Burns et al., 2016). In Finland, the AEP has been successful, e.g., in reducing the nutrient balance of crop production, as well as in the introduction of environmental fallows, i.e., fields that are temporarily taken out of food production to enhance landscape diversity. Introduction of environmental fallows is also aimed at reducing

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http://dx.doi.org/10.1016/j.agsy.2017.02.011
0308-521X/

erosion and nutrient leaching and restoring soil carbon. Environmental fallows include nature managed fields, green fallows and short term break-fallows for arable crops as opposed to productive grasslands that provide feed, biomass or seed. Follow-up studies have been carried out to anticipate and monitor the impact of changes in land use and management on species richness, in different agroecosystems (Kuussaari et al., 2007; Clough et al., 2014; Toivonen et al., 2015, 2016). However, future development within the AEP should consider how different land use plans and implemented actions enhance biodiversity conservation and delivery of ecosystems services (Scheper et al., 2013). Further development of the AEP is also needed, as recent studies showed that the AEP has resulted in stagnated yields of major spring cereals (Peltonen-Sainio et al., 2015b), and minor crops (Peltonen-Sainio et al., 2016) along with some alarming signs of strengthened domination of cereals at the expense of diversifying minor crops. These all call for up to date information on field and farm scale changes in crop choices and rotations, as well as a better understanding of the primary drivers for farmer decisions on land use changes, in order to facilitate development of coherent future policy instruments.

This study aimed to characterize how agricultural land use has changed during Finland's EU membership period, i.e. right after the launching of the Common Agricultural Policy (CAP) and AEP, both known to have many changes in farm economy and intensiveness of agriculture compared to the period prior to EU membership (Peltonen-Sainio et al., 2015b, 2016). Especially, what impact this has had on the frequencies of the different crop rotation types and on crop diversity in each rotation type. Our additional aims were: 1) to understand which farm and field characteristics are primary drivers for farmers' land allocation of the six identified crop rotation types ranging from the ultimate cereal species monocultures to short- and long-term environmental fallow rotations and 2) whether recorded changes in land use and crop choices have increased or decreased heterogeneity of landscapes and/or diversity of crop rotations, in general.

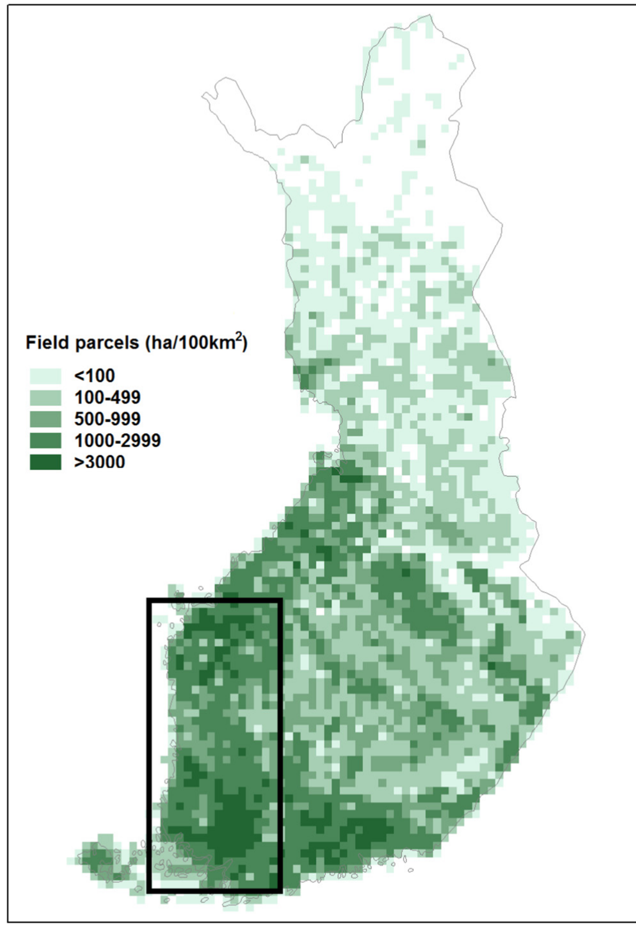

Fig. 1. The total area of field parcels, as hectares per 100 km^2, in Finland and the study region (framed with black), which represents the prime crop production region of Finland.

2. Materials and methods

Data from the Agency of Rural Affairs (Mavi) on crops grown in Finnish field parcels was used to assess the typical compositions of Finnish crop rotation types in 1995–1999 and 2007–2011. These time periods represented early and late EU membership periods of Finland with CAP. The data was comprised of 165,760 fields representing crop production farms in the prime south-western coastal agricultural region of Finland (Fig. 1) (N: 60° 02′ – 63° 14′; E: 20° 38′ – 24° 07′), which corresponded to a total land area of approximately 389,700 ha.

Identification of crop rotation types was based on data clustering where a semi-quantitative expert-based procedure was exploited to identify the most relevant crop rotation types. In addition to cereal and grass crop dominated rotation types the most common diverse crop rotation types were searched with the aim to have a good coverage with reasonable number of rotations. Six flexible, non-cyclical crop rotation types (Castellazzi et al., 2008) were identified for the fixed early and late five-year periods. Additional tests revealed that shifting the period by one year to either direction had no significant effect on frequencies of different rotations or outcomes of the statistical analyses. The identified crop rotation types were: 1) cereal species monoculture, in which the same cereal species was grown in a field for four or five years, and another cereal species appeared in rotation only once during the period, if ever; 2) cereal monoculture, in which two or more cereal species (spring or winter types) were included in the rotation and the conditions set for the cereal species monoculture was not met; 3) crop rotation with a break-crop, in which cereals dominated, but some other crop species appeared as a break-crop once; 4) diverse crop rotation, in which spring cereals appeared for one or two years, winter cereals once or twice and at least two other crops were included in the five-year rotation; 5) perennial grassland rotation, in which nonpermanent production grassland appeared for at least three years and 6) environmental fallow rotation, where green fallow or nature managed fields were grown for at least three years.

The frequency of different crop rotation types as a dependent of farm size was studied by dividing the farms according to their size: medium sized farms were approximately 37 ha, large farms, approximately 75 ha and very large farms, approximately 117 ha as an average. Furthermore, the proportion of certain crop rotation types in each farm was calculated, and the distribution of the proportions was described as a median, 75th and 90th percentiles. The analyses were carried out for early and late CAP periods.

An additional study was carried out to assess farmers' plans to diversify crop rotations, in the near future. For this, 16 farmers provided us with their first, obligatory, AEP five-year crop rotation plans. This data covered a total of 757 field parcels ranging from 25 to 157 parcels per farm, depending on farm. The data consisted of information on the planned five-year crop rotation in each of the field parcels, which was then compared with the allocation of the same fields for different crops, in the recent years. Comparisons were made by identifying six previously defined crop rotation types and by calculating the number of different crops, during the five-year period. When calculating the number of crops, some of Mavi's crop classes were combined: peas for different purposes, barley for malting and forage, starch potatoes and potatoes for human consumptions, spring rape and oilseed rape, different grasslands and fallow types. Proportions of the six rotation types and the number of different crops, in the five-year rotation, were calculated for the same fields for both the early (1999–2003) and late (2007–2011) CAP periods. In this way, we were able to assess whether farmers were aiming for more diverse cropping systems, in the future.