The situation of current crop rotations in Northern Germany: risks and chances for future farming systems

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Abstract: This study aimed at analysing patterns of crop sequences over time throughout the German federal state of Lower Saxony from 2005 to 2012. Therefore, the IACS (Integrated Administration and Control System) data was analysed for the identification of spatial and temporal pattern of crops grown on farmer's fields. Lower Saxony is a region where maize growing had a steep increase and, therefore, was preferentially incorporated in farmer's decisions on crop sequences and crop rotations. Furthermore winter wheat, oilseed rape, sugar beet and potatoes are the decisive components of crop sequences in this region. We distinguished between crop sequence patterns (any sequence, that could be identified generally) and crop rotation (a recurring pattern representing meaningful agronomical background). Studying crop sequence patterns on farmers' fields during the six years (2005-2011), a total of 24 118 combinations of crops on 772 940 ha were determined. Only a small number of combinations represent a large proportion of the arable area. Continuous maize cropping covers 8.6 % of the whole arable area in Lower Saxony. The combinations of other crops are multiform. Typical crop rotations basing on oilseed rape or sugar beet are underrepresented on only 7% of arable land, respectively. The results suggest that crop rotation is a disregarded agricultural practice.

Keywords: crop sequence pattern, maize, Lower Saxony

Introduction

Crop rotation has been a basic instrument of arable farming. The advantages of a multi-unit crop rotation for the environment like prevention of water contamination and efficient use of rare resources (e.g. fertilizer, pesticides) cannot be denied (Freyer, 2003). Even if a simplified rotation implies a lower professional and technical effort for cultivation and selling, the farmer risks degradation of soil fertility, the occurrence of pests and diseases and evolvement of weed herbicide resistance (Steinmann & Dobers, 2013). Under the goal of reducing the pesticides and synthetic fertilizer requirements appropriate crop rotation is an important instrument for replenishing the soil with organic matter and breaking disease and pest cycles (Könnecke, 1967, Meissle et al., 2010).

The reform of the European Common Agricultural Policy (CAP) 2014 includes a step forward to increase crop diversification, but targets in another direction. The "Greening" of the basic payment means that a farmer with more than 30 ha of arable land has to cultivate at least 3 crops - each crop covering not less than 5% and not more than 75% of arable land (EU 2013). The measure does not include any specification for rotating of the crops at the single field. The cross compliance requirements in Germany imply standards for crop diversification as well since 2009, but not in particular for crop rotation. However 2009 the EU recommended crop rotation as an element of integrated pest management in the course of establishing a more sustainable use of pesticides (Directive 2009/128/EC(III) EU 2009). So crop rotation is - still and again - an important instrument for appropriate land use and integrated production (see also IOBC 1997).

The application of a crop rotation is limited by environmental (soil, climate, water supply, site, etc.) and economical (farming management, market, etc.) conditions (Sedlmayr, 1927, Dubslaff, 1963, Freyer, 2003, Glemnitz et al., 2011). The limiting factors influence a specific spatial pattern in the landscape and a crop sequence pattern in time (Deffontaines et al., 1995, Thenail et al., 2009, Schönhart et al., 2011).

Recently, crop rotations seem to be an instrument of decreasing importance. There is strong evidence that crop rotations tend towards simplification due to the enormous progresses in plant breeding, chemical pest management and technical soil cultivation which allow farmers for abandoning principles of crop sequences and break phases. For Germany, land use data shows the dominance of three major crops on 58% of arable area (Steinmann & Dobers, 2013). Especially maize area had shown a dramatic increase, since cultivation of bioenergy crops became extremely profitable. However, today most researchers and also farmers are aware that a simplified land use bears agronomical risks that might eventually result in economic losses. In public discussions farmers are blamed to maximize profit and to abandon traditional farming practices, such as rotational diversity.

This study aims at establishing an analytical framework to study the recent status of crop rotations and crop sequence patterns in a region of agricultural importance for Germany. With special emphasis, it should be analysed, to what extent maize dominates land use and crop rotations in the study region.

Methods

Study area

The study is based on land use data of the federal state of Lower Saxony (Niedersachsen) in the North-West of Germany. Lower Saxony is characterized by a strong agricultural production mainly based on arable farming and dairy grassland farming. Area of arable land is about 1.8 million hectare and grassland covers c. 700 000 hectare. The north-western part of the state is dominated by dairy and livestock farming with a proportion of maize cropping up to 75% of arable area. The south-eastern part of the region and the coast area is characterized by cultivation of winter wheat, sugar beet and oilseed rape. The land use of the middle part of Lower Saxony is diverse with mainly mixed farming. Lately in all parts of Lower Saxony an expansion of the maize acreage is observable (LSKN, 2012).

Data

The Member States of the EU set up an Integrated Administration and Control System (IACS) to administrate and check the farmers land use and cross compliance obligations (EU, 2003). First of all, these systems enable the local administration to effectively observe and document the implementation of CAP payments. Beside this, IACS contains information on agricultural practice and landscape for about each parcel of agricultural land. Field size and specification of the main crop is accurately specified for each year. We had access on data of the years 2005 to 2012 with about 990 000 records (sensu: fields) per year for the entire state Lower Saxony. In addition to the data set we used a digital field map to project the information in space by connecting the specific field identification number with the digital map. For all spatial analysis the geographic information system ArcGIS 10.x was used. The raw data was stored and handled with MS Access®. The site-specific arable yield potential for soil fertility in Lower Saxony (LBEG, 2004) was used as spatial information. The classification of the soils in seven classes refers to the supply with water and nutrients, rootability and climatic conditions.

All data entries which are not relevant for rotation of arable crops like orchards or permanent grassland were omitted from calculations. The compulsory set-aside ended in 2008 and therefore was excluded from consideration as a rotational element. The year 2012 was disregarded due to the occurrence of strong frost that led to crop damages and – as a consequence – enforced farmers to establish replacement crops that do not consequently reflect a planned rotational order. Furthermore, due to changes in allocations of fields according to size and shape, many data entries could not be properly traced over time. To ensure that only fields of unambiguous data quality were analysed, a remarkable proportion of data entries had to be omitted from analysis. Overall, 772 939 hectare were available for calculations. Crop rotations were then identified by analysing the order of all crops grown on each single field.

When arable crops are grown in a planned order, pre-crop and following crops are often combined specifically. Brinkmann named this crop rotation elements "Fruchtfolgeglieder" (Brinkmann, 1950). According to Brinkmanns theoretical approach a rotation element consists of a nutritious leaf crop and one or more nutrient-exploiting cereal crops. A set of different rotation elements over time on the same field could be considered as a crop sequence and a recurring sequence as a crop rotation (Thenail et al., 2009). In this study, we distinguish between crop sequence pattern (any sequence, that could be identified generally) and crop rotation (a recurring pattern representing meaningful agronomical background) (Castellazzi et al., 2007, 2008).

Results and Discussion

The share of maize acreage has increased from 19% in 2005 to more than 32% of the whole arable area in Lower Saxony in 2012. In comparison the winter wheat area remained constant about 22%. Except from oilseed rape, which increases from 4.7% of the arable area in 2005 to 6.6% in 2012, all the main crops remained almost stable. So the acreage of maize generally increased at the expense of the acreage of crops with a small proportion of the total area, e.g. fodder plants.

The combination of the crop data with soil information shows that maize is cropped mainly on fields with a lower yield potential and rarely on fields with a high yield potential. Those fields where maize was introduced the first time in the most recent years (2009 – 2012) had a tendency towards higher yield potential.

During the seven years (2005-2011) a total of 24 118 combinations of 14 crops (single crop or crop groups, e.g. spring cereals) were determined on 772 940 hectares, showing that farmers use diverse crop sequence patterns. However, the vast majority of these combinations did not fit into rotation schemes according to the traditional framework (e. g. Brinkmann 1950). Furthermore, just a small number of combinations (sensu crop sequence patterns) cover a large proportion of the arable area. Continuous maize cropping already covers 8.6 % of the whole arable area in Lower Saxony and must be seen as the dominant crop sequence pattern (Tab. 1).

Table 1: Most prevailing crop sequence patterns and rotations calculated for the seven year period (2005-2011) in Lower Saxony, Germany (basis = 772 939 ha). AA = arable area.

Crop Sequence Pattern	**Share of AA (%)**
maize 5-7 times	8.6
oilseed rape - winter cereals - winter cereals	7.6
sugar beet - winter cereals - winter cereals	6.8
winter cereals 4-7 times	3.8

Considering the development of the maize acreage since the 1980s the increase in the north and north-western part of Lower Saxony is most evident. This is mainly ascribable to the intensification of dairy farming and the demand for high energy forage crop (DMK, 2011). Especially in the north-western part the high share of grassland has to be mentioned (>50% of the agricultural area). So, these landscapes are not completely covered by maize, since grassland plays an important role, but arable land is dominated by maize.

For almost ten years a new trend has been observed. The most important production areas for maize spread from the traditional growing areas to regions where maize was not common before. These regions are located in the middle and northeast of Lower Saxony where the livestock density is less than one livestock unit per hectare. These classical farming regions were core areas for investments in new biogas plants. With the amendment of the Renewable Energy Law in 2004 the buyback price for biogas power out of energy crop was added. About 65% of all new bioenergy reactors built after the amendment are located in arable farming regions or mixed farming regions, mainly the counties Rotenburg, Celle and Heidekreis (MUEK, 2012) and require raw material for fermentation.

Maize is often grown in a self-sequence. Even in regions with a low density of maize acreage this crop was grown more often in self-sequence than wheat or rye (Steinmann & Dobers, 2013). Obviously, the economic benefits of short intervals of maize in the rotations are of higher preference than the threat of negative impacts on crop health. So, a remarkable proportion of arable area is potentially endangered by outbreaks of pest and disease (Steinmann & Dobers, 2013). Climatic changes will enforce the risk for potential diseases and could have negative effects on unilaterally managed fields of the sandy soil regions in the north-western part of Lower Saxony (Porter et al., 1991). For integration of climate change adapted crop rotations it is essential to understand the current rotation management. The knowledge about the location of typical crop combinations facilitates the integration in the single region.

Conclusion

One aim of this analysis was to check the potential of IACS data for the study of crop sequence pattern. The IACS is a treasure trove for large scale field survey on real crop rotations and crop sequences (Leteinturier et al., 2006, Schönhart et al., 2011).

The combinations of crops are multiform. Over the time period of seven years we could not identify any crop rotation, especially those taking six or more years. Typical crop rotations with oilseed rape or sugar beet as the starting leaf crop are underrepresented on only 7% of arable land, respectively. One conclusion may be that today crop rotation is no longer a common agricultural practice (Schmit & Rounsevell, 2006). On the other hand, there is evidence, that diverse crop sequence patterns play a bigger role than “classical” rotations. Obviously, crop rotation is an agricultural practice in transition.

Maize is the crop with the strongest growth. This crop increases in nearly every region observed over the study phase. The arable areas which were under maize the first time after 2009 show a new preference for fields with high yield potential. So a shift from less fertile soils to high fertile soils is on the way. With respect to the design of crop rotations, maize could offer chances for regions of higher yield potential, but the sandy soils of the northwestern part of the region are threatened by simplified rotations with higher risk for pests and a possible degradation of farmland biodiversity.

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