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On-farm pesticide use in four Northern German regions as influenced by farm and production conditions

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ABSTRACT

In scientific and public communities pesticide use in arable cropping is a strongly discussed management measure. Nevertheless, information about on-farm pesticide use intensities is scarce. We studied the contribution of regional and farm effects to average pesticide use and its variability and major influencing factors. Data on chemical plant protection measures of 60 farms in four regions of Northern Germany were examined for twelve field crops between 2005 and 2014. The regions correspond to administrative districts of similar size located on gradients of climatic, soil, and structural production conditions. First, we analysed pesticide use intensity described as Standardised Treatment Index (STI) per district and crop. Second, we estimated the variance components on STIs ('District', 'Farm', 'Field', 'Year') for total and groups of pesticides. We found a decreasing gradient in pesticide use intensity from the west to the east in Northern Germany. STIs were lower in districts with less favourable conditions for arable land use. However, analysis of variance components showed that the influence of the natural gradient is smaller than the influence of the farm. Hence, differences in farm management and socio-economic characteristics superimpose the production conditions. Finally, we checked the meaningfulness of our results by comparing them with previous and on-going large scale surveys. We determined differences (lower STIs) to the statistical means of the German reference farm network Plant Protection. We assume that this is caused by the higher aggregation level of regions of the German reference farm network Plant Protection.

1. Introduction

Agricultural production differs between regions in farm specialisation, crops, intensity (fertiliser input, pesticide use, tillage) and productivity - all are influenced by the local natural production conditions, traditions and historical developments. Soil and climate determine possible cropping systems as well as their productivity (Roßberg et al., 2007). History and political developments have influenced farm structures and economy; traditions are present through experience and local advice on farming practices.

One major factor within these influences on cropping systems is pesticide use. Chemical crop protection has a key role in safeguarding crop productivity against competition and losses from weeds, pests, pathogens and viruses (Oerke, 2006). In 2011, European sales of pesticides amounted to € 7.7 million (ECPA, 2013). Drawbacks for using pesticides arise as they pose a risk for the environment when entering soil, water or air. They affect non-target organisms and biodiversity (Sauders et al., 1991; Geiger et al., 2010) and represent a potential danger to human health (Pfeil, 2010). For these reasons there is an on-going debate about pesticide use in Europe. It is the most criticised one within the given set of agricultural measures (Heyer et al., 2005; Cooper et al., 2009).

Pesticide use intensity depends on many factors, mainly the abundance of harmful organisms. These are influenced by local climate, soil type and regional density of a crop. However, farmers can also influence them by cultivation measures, such as tillage, choice of sowing date, choice of variety, the amount of nitrogen fertilisation and crop rotation (Glen, 2000; Bürger et al., 2008; Kirkegaard et al., 2008; Günther, 2010). Furthermore, pesticide use intensity may be influenced by individual farming conditions like expected yields, on-farm economic and financial situation. Advice through agricultural consultants and the experience of the decision maker about pesticides are more individual influencing

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factors. Pesticide use intensity as one part of cropping systems is therefore a good example to study the importance of natural and socio-economic differences for production intensity in regions.

This paper focusses on the analysis of on-farm data on pesticide use in twelve arable crops. A study was carried out in four districts of Northern Germany (each approx. 2000 km^2) with differences in natural and socio-economic conditions, which occur on gradients from East to West. We collected a singularly comprehensive data set including all pesticide measures of the period 2005 to 2014 on fifteen farms per district. Beside the description of pesticide use averages, we analysed the contribution of district, farm, field and year effects to its variability.

With the Standardised Treatment Index (STI) we used an indicator to quantify pesticide use that has been applied in Germany through the last fifteen years with the objective to gain insight into real usage of pesticides and analyse trends (Burth et al., 2002; Roβberg et al., 2002; Roßberg et al., 2007). Freier et al. (2008, 2009, 2010, 2011, 2012, 2013) established a reference network of 80–90 arable farms scattered over Germany to collect annual data on pesticide use. The reference farm network for plant protection is one outcome measure with particular relevance to IPM implementation of the German National Action Plan on Sustainable Use of Plant Protection Products (NAP) (Directive 2009/128/EC on Sustainable Use of Pesticdes). According to the NAP, the Standardised Treatment Index (STI) is used to describe the status quo in terms of the pesticide treatment intensity in the respective crop and year for which data are collected. The data are obtained from the above mentioned network of reference farms and the farming sector's Industry Panel for Regulation (EC) No 1185/2009 on statistics. These PAPA analyses (Panel Plant protection products Applications) survey 100 farms per crop to comply with European statistics requirements (Roβberg, 2013).

The data collection effort for these studies is enormous; therefore sample size is limited to some fields from a small number of representative farms in each of the administrative counties of Germany. Statistics give general results for Germany in total as well as for four geographical regions. However, they also show a high variability between farms under similar conditions (Roβberg et al., 2002; Freier et al., 2008, 2009, 2010, 2011, 2012, 2013). Some limitations of using statistical values from large reference regions for the evaluation of a farm's pesticide use intensity were addressed for example by Verch and Kächele (2005). They found that the spatial demarcation of the regions may be inappropriate especially for farms close to the periphery. Through the large sample size of our data set we are able to compare regional means derived from many fields in a smaller area to the statistical values of the large scale surveys. Thus, we can address the question of how well large-scale average statistics represent regional pesticide use intensity.

We hypothesise that pesticide use intensity decreases under less favourable production conditions, like lower precipitation and higher temperatures. We further expect that these relationships may be superimposed by regional differences in farm management and socio-economic characteristics, implying that effects of the natural gradient on pesticide use are smaller than the influence of the farm management.

Finally, we assume that statistical values of large scale pesticide use surveys do not adequately represent pesticide use in all parts, including small scale regions.

2. Materials and methods

2.1. Study regions

Our study relies on pesticide use data from four administrative districts of Northern Germany: Diepholz (DH) and Uelzen (UE) in the West, Fläming (FL) and Oder-Spree (OS) in the East (Fig. 1). All districts are situated in the Northern German lowlands, but differ in climate, soil, and production structure (Tables 1 and 2).

There is a climatic gradient from West to East with decreasing precipitation and increasing differences between summer and winter temperatures. Gradients of soil quality and water availability result in a gradient of decreasing yields towards the East.

Some differences in the production structure of the districts are at least partially due to history. While the socialist government of East Germany encouraged collectivisation of farms during the 1960s and 1970s leading to large, specialised farms with large fields, many farms in West Germany remained privately owned, relatively small family farms. All these gradients consequently resulted in differentiated production specialisations of each district. Grassland and livestock farming are most important in the West. In Diepholz, mainly cereals, potatoes and maize are grown. Farmers in Uelzen are specialized in production of potatoes, for that purpose about 90% of fields will be irrigated. Fläming is characterised by cereal production, while Oder-Spree is characterised by winter rye and oilseeds.

2.2. Data

Data were collected from 15 farms per district for the period 2005–2014. Contact to farms was arranged by the regional agricultural authorities and authors' own contacts through the activities in the collaborative project (acronym: NaLaMa-nT). Within this project changing ecological, economic and social parameters are investigated and analysed in order to prepare them for future changes in a transdisciplinary process. The investigated districts perform a gradient. Pesticide use is one of indicators to describe land management (for more information visit www.nalama-nt.de (in German)).

We collected data of all crops cultivated in each region, including the autumn sown crops winter wheat (*Triticum aestivum* L.), winter barley (*Hordeum vulgare* L.), winter rye (*Secale cereal* L.), winter triticale (*Triticale*), winter oilseed rape (*Brassica napus* L.) and the summer crops potatoes (*Solanum tuberosum* L.), sugar beet (*Beta vulgaris* subsp. *vulgaris*), maize (*Zea mays* L.), spring barley (*Hordeum vulgare* L.), oats (*Avena* L.), sunflowers (*Helianthus annuus* L.) and Field peas (*Pisum sativum* L.). However, not all crops were grown in each region.

We used data from farmers' records on all treatments with fungicides, herbicides, insecticides and growth regulators. Overall, 100,000 treatments on 20,000 fields were recorded. Each treatment record comprised of date, area, full name of the plant protection product, the indication and the dosage. Documentation quality differed between the farms. The data were examined for plausibility and excluded from analysis in case of implausibility.

2.3. Analysis

We used the Standardised Treatment Index (STI) to quantify pesticide use intensity (Roβberg et al., 2002). In Germany, this indicator is calculated field-wise per cropping period. The Standardised Treatment Index aggregates the number of treatments on a field, corrected for the effect of reduced doses and treatments on parts of a field. It is calculated as:

$$STI = \sum_{cropping\ period} \frac{used\ dosage}{maximum\ approved\ dosage} \times \frac{treated\ area}{study\ area} \quad (1)$$

Data on the approved application rates were taken from the