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# Efficiency in sugar beet cultivation related to field history

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ABSTRACT

The concept of sustainable intensification in crop production has become more and more important over the last years. Calls for an efficient production demand an increase in yield without extending the agricultural area or increasing the amount of agricultural inputs. Thus, our study aimed to identify which variables influence the efficiency in crop cultivation in Central Europe and how we can explain the variances between fields. The data base for the present study was a survey among sugar beet farmers in all parts of Germany in the years 2010–2014. In order to structure the fields, variables representing environment, management and farm characteristics were extracted. The performed analysis according to components (principal component analysis) did not result in a nationwide structure of the data. Thus, fields were grouped according to similar preconditions such as regions and crop rotations. Sugar yield ranged from 12.5 t $ha^{-1}$ in 2010 to 15.4 t $ha^{-1}$ in 2014 on nationwide average. The median value for N fertilization over all fields and years was 137.4 kg $ha^{-1}$, the median treatment index (TI) reached 3.7, the median field evaluation index (Ackerzahl) was 70 and the median field size 8 ha. We found that over 50% of the variance among the data was explained by environment, management and farm characteristics. The comparison of fields on a regional basis was more sensible than on a nationwide basis as the variance of farms and fields was too broad for a useful clustering. It was concluded that the adaption of the farmer's management to regional specific conditions is an opportunity to reduce yield gaps and to increase efficiency in terms of a sustainable intensification in sugar beet production.

## 1. Introduction

As the demand for food will rise over the coming decades, there are calls for an environmentally sustainable increase of agricultural productivity (Evans, 2009). The approach to increase the yield of an arable crop while reducing environmental harm is widely known as sustainable intensification (Godfray and Garnett, 2014). The origin of gaps between potential and average yield is discussed frequently (Van Wart et al., 2013) as well as the question of differences between top and averagely managed farms (Hanse et al., 2011a,b).

In crop production in Europe, the last decades were characterized by the use of larger and heavier vehicles, the development of more effective pesticides and the introduction of high-yielding varieties (Foley et al., 2005; Matson et al., 1997). But still, Wießner et al. (2010) showed on the example of sugar beet that the output in crop cultivation can even improve without using more input. In other words, efficiency can increase. They determined efficiency by means of different production factors such as N fertilizer rate and pesticide use from survey data. This lead to the question if the situation in sugar beet cultivation concerning efficiency changed nowadays and if an adjustment of the production factors would be useful and possible. Data based on facts from practice are necessary to be prepared for the current discussion about sustainable intensification. Germany with its location in Central Europe, its heterogeneous landscapes with diverse soil and climatic conditions and its specific history concerning the former state division of Germany offers a very broad scale concerning the economical and structural preconditions in agriculture. It is therefore very well-suited for analysis.

Additional to the study based on praxis data by Wießner et al. (2010), there are diverse studies based on field trials dealing with agricultural inputs in sugar beet cultivation like the form of N fertilizer and its effects on $CO_2$eq emissions (Brentrup et al., 2004) or the effects of pesticides on sugar yield (Bezhin et al., 2015). These approaches represent the current situation considering not more than one agricultural input under standardized trial conditions. But the results are difficult to transfer to the heterogeneous conditions of commercial farms. It is therefore not easy to identify separate influences on commercial yield and to classify them according to their importance. Moreover, results from field trials do not offer the possibility to assign the outcome to such an interaction of contexts known from actual practice.

We developed a survey among sugar beet farmers and collected

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management data of 1785 fields from different farms in all regions of Germany during 2010–2014. The survey offers a wide range of issues concerning all parts of sugar beet cultivation. Data were collected on crop rotations, catch crops, sowing, tillage, use of pesticides and fertilizers, yield, machinery and the technological quality of the sugar beet (Stockfisch et al., 2013). Based on this unique database, it was demonstrated that real farm data could match results from field trials (Trimpler et al., 2016).

The variance of sugar beet cultivation based on survey data in Germany was analyzed by Reineke et al. (2013) before. Their study focused on energy balance parameters by means of a cluster analysis and was confined to one year. Aim of our study was to find fundamental principles that correlate with the large differences in efficiency between different sugar beet fields. The specific objectives were to determine how components representing basic environmental conditions, management and farm preconditions influence the performance of sugar beet crop. There was no priority to measure and calculate the efficiency per se in sugar beet cultivation in Central Europe. As the field-related histories and the factors influencing sugar beet cultivation are rather diverse, we structured the data based on environment (region and year) and crop rotations for the objective to bundle fields with homogeneous preconditions. The main effects in crop rotations are associated with the previous crop (Götze et al., 2016), which are not really diverse as cereals are grown before sugar beet on nearly 80% of the fields (Stockfisch et al., 2013). We considered the whole crop rotation based on the assumption that, on the one hand, the farmer's knowledge varies according to experiences with specific crop rotations. A specific attitude out of habit concerning the management may be transferred to the sugar beet. Moreover, the equipment, e.g. the machinery, in the farm may be diverse depending on the crop rotation. On the other hand certain crops grown in rotation with sugar beets might cause a higher risk for pests and diseases and, therefore, might result in a higher intensity in plant protection.

Consequently, the objectives of the present study are (1) to examine if the field history plays a major role regarding the efficiency, (2) to proof which variables, in addition, have an important influence on the efficiency in sugar beet cultivation and (3) to figure out whether the variance regarding efficiency between sugar beet fields can be anticipated?.

## 2. Material and methods

### 2.1. Survey

The survey included 1785 sugar beet fields in Germany and was carried out in 5 seasons, from 2010 to 2014. The farmers were asked about their biggest sugar beet field independent of size of farm and acreage of sugar beet on the farm, in order to exclude the possibility of choosing the most profitable field (Stockfisch et al., 2013).

The data were collected through a questionnaire sent to ± 360 sugar beet farmers per year. The farms were distributed over all regions of Germany according to the area under sugar beet. To focus on the cultivation process, all steps from the harvest of the preceding crop until the storage in field clamps were included in our study.

The questionnaire covered information on the farm in general (e.g. field size, arable acreage, soil type), management practices (e.g. crop rotations, catch crops, sowing, tillage, pesticide use, amount of mineral and organic fertilization, harvest) as well as yield and quality of the sugar beets (e.g. root yield, sugar content).

### 2.2. Variables of sugar beet cultivation

Sugar yield refers to the root yield multiplied with the sugar content (%) of the fresh matter of the beets delivered to the sugar factory and is expressed in t $ha^{-1}$ (Hoffmann, 2006). The total N input consists of the total N amount applied with organic and mineral fertilizer. N application to catch crops was included. For organic fertilizer, the N content was calculated according to default values (Landwirtschaftskammer Niedersachsen, 2016). Pesticide use was expressed by the treatment index (TI) (Sattler et al., 2007). It is defined as the number of pesticides and their application rate per ha in relation to the maximum application rate determined by registration.

$$\text{Treatment index} = \Sigma\left[\left(\frac{\textit{actual application rate}}{\textit{maximum application rate}}\right)*\left(\frac{\textit{treated acreage}}{\textit{total acreage of field}}\right)\right]$$

Soil quality is measured according to diverse national inventories (Warkentin, 1995; Carter et al., 1997). The German "Ackerzahl" considers the soil's quality and the natural conditions of the site, ranging from 1 (very poor quality, theoretical value for cropland) or about 20 (low quality) to 120 (highest quality). It is used here and termed field evaluation index below. The soil types considered were sand, slightly loamy sand, loamy sand, heavy loamy sand, sandy-loamy soil, loam, heavy loam and clay (classification according to soil appraisal). The variable livestock farming indicates whether animals were kept on the farm.

### 2.3. Regions and crop rotations

For further analysis of fields under similar preconditions, farms were regionalized according to the postal code of the farm's address: region North comprises the federal states Schleswig-Holstein and Lower Saxony, region East includes Mecklenburg-Vorpommern, Brandenburg, Thuringia, Saxony-Anhalt und Saxony, North Rhine-Westphalia forms the region West, and region South consists of Hesse, Rhineland-Palatinate, Baden-Wuerttemberg und Bavaria (Fig. 1).

As crop rotations with sugar beet varied across regions, we compared rotations with cereals, rapeseed, maize and potato within the regions.


**Fig. 1.** Geographical allocation of 1785 sugar beet fields, farm survey sugar beet cultivation in Germany 2010–2014, into four regions according to postal code, no farmers asked in Bremen, Hamburg, Berlin and Saarland.