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Original paper

The impact of biogas plants on regional dynamics of permanent grassland and maize area—The example of Hesse, Germany (2005–2010)

Nicola Lüker-Jans[a,*], Dietmar Simmering[b], Annette Otte[a]

[a] Justus-Liebig-University Giessen, Division of Landscape Ecology and Landscape Planning, Heinrich-Buff-Ring 26-32, 35392 Giessen, Germany
[b] Ingenieurbüro für Umweltplanung Dr. J. Karl, Staufenberger Straße 67, 35460 Staufenberg, Germany

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ABSTRACT

The fostering of bioenergy by European and German energy policies in recent years has led to a strong increase in the cultivation of energy crops, especially maize for biogas production. Contemporaneously, in Germany the area of permanent grassland has significantly decreased. In this context, energy maize is often discussed to affect the conversion of grassland. The aim of this study was to examine the area changes of maize and permanent grassland and to analyse if there is a relationship to biogas plants. For comparison, livestock farming as another possible influencing factor was implemented, too. The study was conducted at two spatial levels: the first was the German federal state Hesse as a whole, the second were five Hessian sub-regions clustered by prevailing agricultural land use and land-use change from 2005 to 2010. Correlation and regression analyses revealed the association of biogas plants and livestock density to three variables of agricultural land use, i.e. maize area, expansion of maize area and conversion of permanent grassland to arable land. Negative correlations between biogas plants and maize area were significant for Hesse and three sub-regions (−0.21 to −0.42). However, the positive correlations between livestock density and maize area were higher (0.33–0.66). Biogas plants were considerably negative related to the expansion of maize area on all spatial levels (−0.29 to −0.42). Conversion of grassland was less but still significantly related to biogas plants and livestock density. Biogas plants and livestock density can serve as an indicator for land-use change, especially for permanent grassland and maize area.

1. Introduction

The production of renewable energies is politically and consequently financially supported within the European Union with the aim of reducing CO_2 emissions and to achieve climate aims (Troost et al., 2015). Biomethane from anaerobic digestion of crops and manure is a renewable energy source. Hence, electricity production based on biogas is considered a promising way to contribute to environmental protection aims, and therefore has considerably and rapidly increased in recent years (Svoboda et al., 2013). In Germany, the production and utilisation of biogas (and also other renewable energy sources like wind and solar) has been promoted by the Renewable Energy Act (German: Erneuerbare-Energien-Gesetz, EEG). The EEG was passed for the first time in 1991 and then reformed in 2004 and 2008, and gives feed-in tariffs for electricity generated from biogas which are higher than the feed-in tariffs for electricity from fossil fuels and guarantees these subsidies for a fixed time period of 20 years (Lupp et al., 2014). Since the subsidies for biogas production represent a profitable new income possibility for farmers (Amon et al., 2007), this support policy of the EEG has resulted in a considerable increase in the number of biogas plants and also in the average plant size (Delzeit et al., 2012). From 2004–2013, the number of biogas plants in Germany increased from 2010 to 7772, and the average electrical power per plant grew from 123 to 454 kW_{el} (BMELV, 2013).

Biogas plants represent a good opportunity for farms to dispose of surplus animal manure in an environmentally friendly way which is especially important in areas of intensive livestock farming. Thus, the occurrence of biogas plants correlates with the distribution of livestock farms (Delzeit and Kellner, 2013). However, biogas plants do not only occur in regions where livestock farming is practised. Since maize (*Zea mays*) is the dominant feedstock used for methane production due to its high

* Corresponding author.
E-mail addresses: nicola.lueker-jans@umwelt.uni-giessen.de (N. Lüker-Jans), dietmar.simmering@ibu-karl.de (D. Simmering), annette.otte@umwelt.uni-giessen.de (A. Otte).

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methane yield during digestion and additionally due to its low soil requirements, good silage ability and high crop yields per area which results in a high profitability compared to other crops (Schulze Steinmann and Holm-Müller, 2010), biogas plants occur in regions where maize is cultivated. Indeed, the biogas boom of recent years coincided with a significant expansion of maize cultivation and the area of silage maize has increased continuously (Britz and Delzeit, 2013). However, it is not clear to what extent biogas plants (and associated financial subsidies) are the causal driver of this development. In Germany, in the year 2012 the area of silage maize grew by 28,000 ha to a total of 2.1 million ha, of which approximately 900,000 ha were used as bioenergy maize (DBV, 2012). The remaining amount was used as fodder and as corn maize. The continuing increase of silage maize area in recent years is considered to be a result of bioenergy production (DBV, 2012; Lupp et al., 2014). Concerning the proportion of silage maize on arable land, there are significant differences by region. In some regions of Germany, the maize area can occupy up to 70% of arable land (Svoboda et al., 2013). Growing controversy attends this development, since the cultivation of maize is known to have some possible negative environmental effects like soil erosion, high nitrogen inputs followed by nitrogen spill-overs, less biodiversity, habitat loss, reduced landscape aesthetics etc. (Wiehe et al., 2009; Pedroli et al., 2013; Söderberg and Eckerberg, 2013; Lupp et al., 2014; Jomaa et al., 2016). The cultivation of maize has a high relevance not only for biogas production, but also for cattle farming, since silage maize is an important cattle fodder. As a result, cattle farming promotes maize cultivation especially in regions with intensive milk production. However, the number of cattle in Germany has increased by only 0.9% to 12.7 million from 2013 to 2014 (DBV, 2014), therefore cattle farming is considered to be only a minor reason for the rapid increase in maize cultivation (Laggner et al., 2014). Altogether, these indications suggest that there are interactive influences among biogas plants, maize cultivation and livestock farming.

The promoting of biogas plants via financial subsidies is a policy which has surely affected agricultural land use (Britz and Delzeit, 2013). Policy support instruments are known to be important drivers for changes in land use (van Delden et al., 2010). In recent years, the discussion is to what extent the development of biogas plants and the associated cultivation of silage maize has contributed to the conversion and therefore the loss of permanent grassland (Laggner et al., 2014). Permanent grassland can belong to the most species-rich habitat types (Wilson et al., 2012; Lewis et al., 2014) if managed traditionally by non-intensive management practices (Wellstein et al., 2007) which means it has great importance for preserving biodiversity (Bruun et al., 2001). Additionally, permanent grassland is part of the cultural landscape in Europe. It combines ecosystem functions like storage of high carbon stocks, protection from soil erosion, water retention and nutrient holding (Conant et al., 2001; Chen et al., 2009; Prochnow et al., 2009), and it contributes to recreation and tourism (Hopkins and Holz, 2006; Stoate et al., 2009). Hence, permanent grassland is important in terms of nature, environmental protection and recreation (Pykälä, 2003; Rösch et al., 2009), but its quantity and quality are endangered due to intensification of land use and abandonment as well as conversion into arable land (Hopkins and Holz, 2006). These processes were not only reported for Germany but for many European countries, for example Romania (Schmitt and Rákosy, 2007), Hungary (Biró et al., 2013), Scotland (Lewis et al., 2014), Italy (Bracchetti et al., 2012) and Switzerland (Gellrich and Zimmermann, 2007). In Germany from 1993 to 2012, the area of permanent grassland decreased from 5,251,000 ha to 4,631,000 ha, an absolute loss of 620,000 ha (−11.8%). In contrast, the area of arable land has remained rather stable. In 1993, it comprised 11,676,000 ha, and in 2012 11,834,000 ha (BMELV, 2013). The loss of permanent grassland in recent years coincides with the promotion of biogas production and increased maize cultivation. This area loss is also evident in regions with high or constant livestock density, hence it is not clear if biogas plants are a causal driver or a temporal coincidence in the loss of permanent grassland. If permanent grassland was converted into fields for silage maize used as feedstock for biogas plants, this change in land use would mean a causal relationship between development of biogas plants and loss of permanent grassland (Laggner et al., 2014). Another important driver for loss of permanent grassland could be cattle breeding and especially milk production since these sectors of agriculture are known to have been intensified in recent

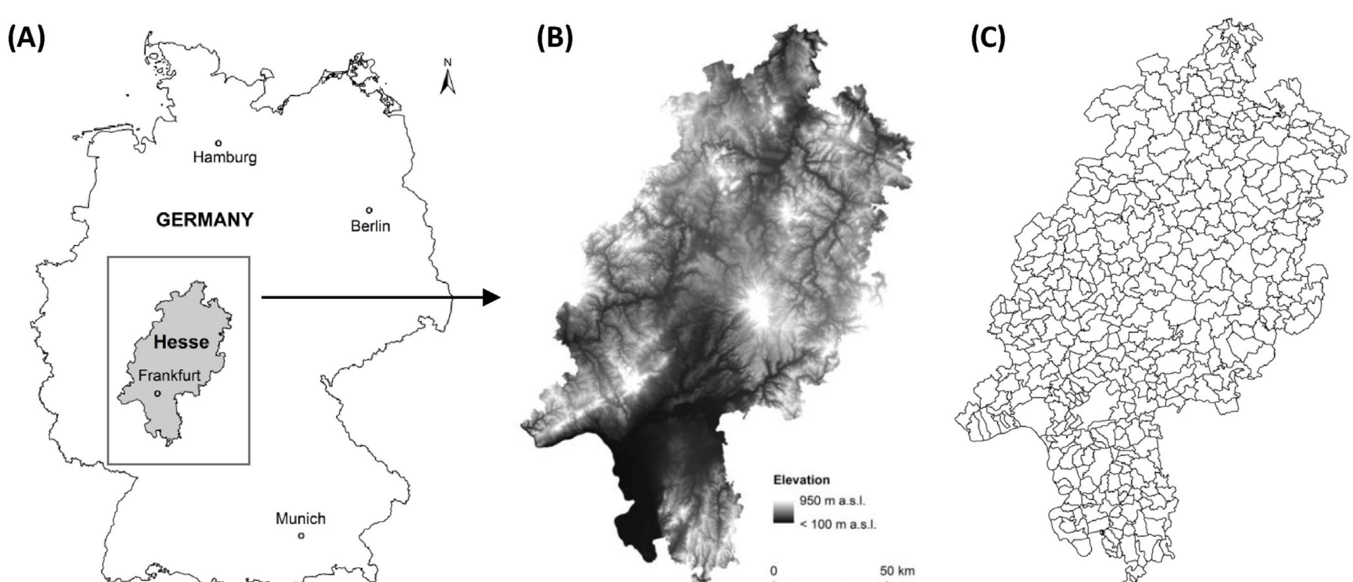

Fig. 1. Study region: (A) Hesse in Germany, (B) topography of Hesse: elevation from <100–950 m a.s.l. (C) administrative structure: 430 municipalities.