Small is beautiful? Is there a relation between farmed area and the ecological output?
- Results from evaluation studies in Germany

Norbert Röder, Andrea Ackermann, Sarah Baum, Hannah Böhner, Sebastian Rudolph, Thomas Schmidt

andrea.ackermann@thuenen.de

Paper prepared for presentation at the 172nd EAAE Seminar
'Agricultural policy for the environment or environmental policy for agriculture?'

May 28-29, 2019.

Brussels.

SMALL IS BEAUTIFUL? IS THERE A RELATION BETWEEN FARMED AREA AND THE ECOLOGICAL OUTPUT? - RESULTS FROM EVALUATION STUDIES IN GERMANY

Abstract

During the last decades biodiversity in agricultural landscapes was strongly decreasing in the EU and also in Germany. Loss in species often results from loss of habitats as a result of intensification as well as abandonment of agricultural land. This trend occurs despite the promotion of environmentally friendly farming practices in the Common Agricultural Policy (CAP). A common public supposition is that small farms operate more environmentally sensitive. This prejudice is mirrored by the European Commission's legislative proposals for the new CAP.

In recent years we conducted studies in Germany evaluating if there is a linkage between farm size and environmental output. These studies analysed support instruments of the 1st and 2nd pillar, in particularly Greening and agri-environmental and climate measures (AECM). We analysed agricultural land use and triggers for land use change in Germany based on data of the Integrated Administration and Control System (IACS). We present results for the management of environmental focus areas (EFA), the enrolment of grassland in dark green AECM, the distribution of organic farming and high nature value (HNV) grassland.

From our various analyses we can see no evidence that smaller full time family farms behave per se more environmentally sensitive compared to larger farms. We therefore strongly recommend not cofounding aspects of environmental targeting of payments with social or structural considerations.

Keywords

CAP, Greening, agri-environmental and climate measures, High Nature Value farmland, farm size

1. Introduction

During the last decades biodiversity in agricultural landscapes was strongly decreasing in the EU and also in Germany. For farmland birds this is well documented, as in the European Union they have declined by 30% since 1990 (Leopoldina, 2018; EBCC, 2017). Loss in species often results from loss of habitats as a result of intensification as well as abandonment of agricultural land previously managed extensively (Henle et al., 2008). This trend occurs despite the promotion of environmentally friendly farming practices in the Common Agricultural Policy (CAP). The latest invention in this respect was the Greening which entered into force in 2015. The aim of Greening was to support farming practices that help to meet environmental and climate goals, thereby also improving biodiversity on farmland. In political discussions the question of biodiversity protection is often linked to the question of farm size. A common public assumption is that small farms operate more environmentally sensitive (Heinrich-Böll-Stiftung et al., 2019). This assumption is mirrored by a) the European Commission's legislative proposals for the new CAP (COM, 2018) as the newly introduced environmental measure, the Eco-Schemes, should be subject to capping of direct payments (art. 28 in combination with art. 15) and b) frequent political statements e.g. by commissioner Hogan (AgE 17/19, EU-Nachrichten p. 1). Also in the design of specific agri-environmental and measures (AEM) distributional aspects frequently play a non-negligible role. In many federal states of Germany the area that could be enrolled in a specific AEM per farm is strongly limited with respect to absolute area. In the following we use the term AEM if we refer to area related management contracts in general and agri-environmental and climate measures (AECM) if we refer to management contracts financed according to Art. 28 of (EU, 2013a).

However, when it comes to the empirical back-up for such political claims, the available literature is surprisingly slim and ambiguous. Ruto and Garrod (2009) and Alló et al. (2015) determine that owners of large farms have a higher probability to participate in AEM. Vanslembrouck et al. (2002) show that in Belgium, with increasing farms size (measured in ha) the willingness of farmers to extensify their field margin increases, while the willingness to establish additional trees or hedgerows decreases. In a study based on Irish farms the likelihood to participate in AEM increased, if one controls for the path dependency in the participation in AEM (Hynes and Garvey, 2009). If one is not controlling for path dependency the likelihood to enrol is negatively correlated with farm. In Switzerland expanding farms tend to decrease their share of grassland enrolled in AEM, while in shrinking farms this share is often increasing (Mann, 2005). The overall tendency that larger farms tend to have higher participation rates is frequently linked to lower proportional transaction costs, economies of scale and the greater flexibility in land management (Uthes and Matzdorf, 2013). Regarding the implementation of environmental friendly farming practices, a recent study from Neuenfeldt et al. (2019) shows that in 2010 the likelihood to let dairy cattle graze more than 6 hours per day follows an inverse u-shape distribution. The likelihood to graze was greatest for farms keeping 20-49 dairy cows and continuously declined with increasing farm size. However, also for farms keeping less than 20 dairy cows the likelihood to let their cows graze was markedly lower. To our knowledge, all studies analysing the relationship between farm size and the uptake of AEM used survey data, or data from the farm accounting data network (FADN). These data sources have some caveats. In surveys one frequently relies on intentions instead of acting, while in FADN data some groups of farms are frequently very poorly represented and the differentiation of AEM is limited.

While the participation in AEM seems to increase with farm size, an increasing farm size is in the most existing studies linked to decreasing biodiversity (Belfrage et al., 2005; Belfrage et al., 2015; Marini et al., 2009). Unfortunately, most of these studies have a very limited regional focus and analyse only a few farms.

In this paper we analyse agricultural land use and triggers for land use change in Germany, based on data of the Integrated Administration and Control System (IACS). We combine results from two data sets, the IACS data and data from the German high nature farmland (HNV) monitoring (Benzler, 2012). We focus on four issues: implementation of (1) environmental focus areas (EFA), (2) AECMs, (3) organic farming as well as (4) share of HNV-farmland in dependence of farm size.

2. Material

We analyse the agricultural land-use data and support instruments of the 1st and 2nd pillar, in particularly Greening and AECM, for the year 2015 based on data of the IACS of nine federal states (Brandenburg / Berlin, Baden-Wuerttemberg, Rhineland-Palatinate, Schleswig-Holstein / Hamburg, Lower Saxony / Bremen, North Rhine-Westphalia). The data set covers 51% of the agricultural land in Germany. IACS is part of the Common Agricultural Policy of the European Union (CAP) managing the area-related payments to farmers by establishing an annual database on land use and animal stocks. The advantage of IACS is its high temporal and spatial accuracy related to land use and the additional information on farm structure and animal stocks. To enable time series and spatial analysis we created a national 10 x 10 m point matrix. To each point of the matrix, we assigned relevant information like IACS land use or nature conservation status (NCS), based on geographic location and spatial shares within the 10 x10m cell surrounding each point of the matrix (Nitsch et al., 2017).

For the following analysis we take four geographically related aspects into account:

1) the federal state in which a given area / farm is located,
2) in which soil-climatic region a given field is located in,
3) whether a given plot is located within or outside of an area with high NCS,
4) for grassland areas located in HNV sample grid, the HNV status of the grassland.

To account for regional and site specific effects with respect to the implementation of environmental friendly farming practices we include the first three variables.

We include the federal state in our analysis as the rural development programs are designed on this level. The foci of the different federal states in their rural development programs vary substantially, in particular with respect to the share of funds allocated to agri-environmental and climate measures, as well as organic farming (Stratmann et al., 2018).

The soil-climatic regions stratify Germany into areas with comparable soil and climatic conditions (Roßberg, 2013). These regions are e.g. used for the stratification of agronomic experiments e.g. testing of new varieties.

Based on data provided by the Federal Agency for Nature Protection we determine for each plot whether it is located inside, or outside of an area with high NCS. We classify areas designated as Natura 2000 sites (Sites of Community Importance, Special Areas of Conservation), biosphere reserves or nature reserves (‘Naturschutzgebiet’) according to national law as high NCS.

The first two factors, federal state and soil-climatic region, cover a share of interregional intensity gradients, whereas the third (NCS) depicts a more local gradient. Previous studies have shown that in areas with more marginal conditions or more obligations on farming, environmentally friendly farming practices are generally more frequent compared to the average (e.g. Nitsch et al., 2018).

Since 2009, agricultural areas and other open land with a high natural value (High Nature Value HNV Farmland) have been mapped throughout Germany using a unified sampling protocol (Benzler, 2012; Hünig and Benzler, 2017). The sampling protocol distinguishes four quality levels, reaching from extraordinarily high (I) to no HN-value (IV). The sampling is conducted on survey plots of 1 x 1 km. In these plots a list of plant species is used to determine the HN value of the agriculturally used land. Homogenous areas are delineated in the field and georeferenced. In the analyzed federal states a total 666 survey plots are located. We excluded survey plots without grassland. This left us with 582 HNV survey plots in our analysis.All data refer if not indicated otherwise to the year 2015.

3. Methods

We analyze the relation between four indicators and their relation to farm size. Three of these indicators measure the degree of implementation of environmentally sensitive farming practices and the fourth one an environmental impact. The selected indicators are:

1) The share of ecological focus areas with a high environmental value, like fallow, field margins or buffer stripes (from now called ‘dark green EFA’) on the total provision of EFA (***E***),
2) The share of land with dark green AECM on the total agricultural area (***M***),
3) The share of organic farming on the total agricultural area (***O***),
4) The share of HNV grassland on the total farmed grassland (***H***).

We refrain from constructing sophisticated statistical models explaining the implementation of environmental friendly farming practices or achieving an environmental result. Instead, we focus on factors that could be easily accounted for by national or regional administrations, when designing their agri-environmental schemes. Therefore, we opted for the following procedure:

First, we classify all farms based on their area using an exponential function to define the class limits (e.g. ≤ 10, 13, 16, 20, 25, 32,… ,501, 631, 794, 1’000, > 1’000 ha).[1]

[1] For the later analysis we sometimes merged the adjacent classes if the number of observations was extremely low (less than ~ 100 for analysis based on farm level data, ~ 40 for analysis based on regional aggregates).

Second, we calculate for the different indicators the respective regional averages. In all cases the regional aggregates are unequivocally identified by the federal state $\boldsymbol{f}$, the soil-climatic region $\boldsymbol{s}$ and the location in or outside an area of high NCS $\boldsymbol{c}$.[2]

For indicator $\boldsymbol{E}$ (share of EFA with a high environmental value) only farms are considered that are legally obliged to provide EFA according to Art. 46 of (EU, 2013b 1307 / 2013). On the regional aggregate:

$$(1)\ E_{f,s,c} = \frac{E^d_{f,s,c}}{E^t_{f,s,c}},$$

where $\boldsymbol{E^d}$ is the area with dark green EFA on productive land weighted by the respective weighting factors defined in Annex X of (EU, 2013b 1307 / 2013) and $\boldsymbol{E^t}$ is the area of all EFA weighted with the respective factors.[3] For each farm *n*, we calculate

$$(2)\ E_n = \frac{E^d_n}{E^t_n} - \left(\frac{A_{n,1}\times E_{f,s,1} + A_{n,2}\times E_{f,s,2}}{A_n}\right),$$ for each farm $\boldsymbol{n}$ located in state $\boldsymbol{f}$ and soil climatic region $\boldsymbol{s}$.

$\boldsymbol{E^d_n}$ and $\boldsymbol{E^t_n}$ are the respective values for the area dark green and all EFA on farm level. $\boldsymbol{A_n}$ is farm $\boldsymbol{n}$'s total arable land. $\boldsymbol{A_{n,1}}$ and $\boldsymbol{A_{n,2}}$ are the respective acreages of arable land and located in (*c=1*) and outside (*c=2*) areas with a high NCS. As EFA must only be provided for arable land the farms are classified according to their arable area.

Analogous to the EFA we treat the areas with dark green AECM. We classify AECM as dark green, if they have a significant impact on biodiversity and imply normally a strong deviance from normal agricultural management. The classification of AECM is based on Annex 9 of Schoof et al. (in press).

On the regional level:

$$(3)\ M_{f,s,c} = \frac{M^d_{f,s,c}}{U^t_{f,s,c}},$$

where $\boldsymbol{M^d}$ is the area with dark green AECM $\boldsymbol{G^t}$ is the total grassland. For each farm *n*, we calculate

$$(4)\ M_n = \frac{M^d_n}{G_n} - \left(\frac{G_{n,1}\times M_{f,s,1} + G_{n,2}\times M_{f,s,2}}{G_n}\right),$$ for each farm $\boldsymbol{n}$ located in state $\boldsymbol{f}$ and soil climatic region $\boldsymbol{s}$.

$\boldsymbol{M^d_n}$ is the area of dark green AECM on farm level. $\boldsymbol{G_n}$ is farm $\boldsymbol{n}$'s total grassland area. $\boldsymbol{G_{n,1}}$ and $U_{n,2}$ are the respective grassland areas and located in and outside areas with a high NCS.

[2] The federal states of Hamburg, Bremen and Berlin are assigned to the federal states of Schleswig-Holstein, Lower Saxony and Brandenburg, respectively.

[3] $\boldsymbol{E^d}$ includes land lying fallow, buffer strips, field margin, and strips of eligible hectares along forest edges; while $\boldsymbol{E^t}$ does not include terraces and landscape features as those reflect primarily the layout of the landscape and less a current decision by the farm manager.

For the indicator ***O*** (share of organic farming) the definition is a little bit different as a partial conversion to organic farming is rather rare. Therefore the calculation of farm specific shares is rather pointless. Instead we compute on the regional level:

$$(5)\ O_{f,s,c} = \frac{U^{o}_{f,s,c}}{U^{t}_{f,s,c}},$$

where $\boldsymbol{U^o}$ the organically farmed utilised agricultural area (UAA). For all regions ***f, s*** and size class ***a*** the standardized share of organic farming is calculated as

$$(6)\ O_{a,f,s} = \frac{U^{o}_{a,f,s}}{U^{t}_{a,f,s}} - \left(\frac{U_{a,f,s,1}\times O_{f,s,1} + U_{a,f,s,2}\times O_{f,s,2}}{U_{a,f,s}}\right),$$

where $U_{.,.,.,1}$ and $U_{.,.,.,2}$ are the UAA in and outside of areas with a high NCS. The classification of ***a*** is based on the UAA.

With respect to HNV-farmland, we restrict our analysis to HNV-grassland, as it accounts for over 2/3 of the HNV-farmland in the considered states. The remaining HNV-farmland is distributed over a wide variety of open habitats, frequently not adequately covered by the IACS or cannot be attributed to a specific farm (esp. landscape elements like hedges).

Based on the HNV-survey plots we calculate

$$(7)\ H_{f,s,c} = \frac{G^{h}_{f,s,c}}{G^{t}_{f,s,c}},$$

where $\boldsymbol{G^t}$ and $\boldsymbol{G^h}$ are the total grassland area and the HNV-grassland area accounted for in IACS. For all regions ***f, s*** and size class ***a*** the standardized share of HNV-grassland on total grassland is calculated as

$$(8)\ H_{a,f,s} = \frac{G^{h}_{a,f,s}}{G^{t}_{a,f,s}} - \left(\frac{G_{a,f,s,1}\times H_{f,s,1} + G_{a,f,s,2}\times H_{f,s,0}}{G_{a,f,s}}\right),$$

where $G_{.,.,.,1}$ and $G_{.,.,.,2}$ are the total grassland area in and outside of areas with a high NCS. As the indicator refers to grassland only the farms are classified according to their grassland area.

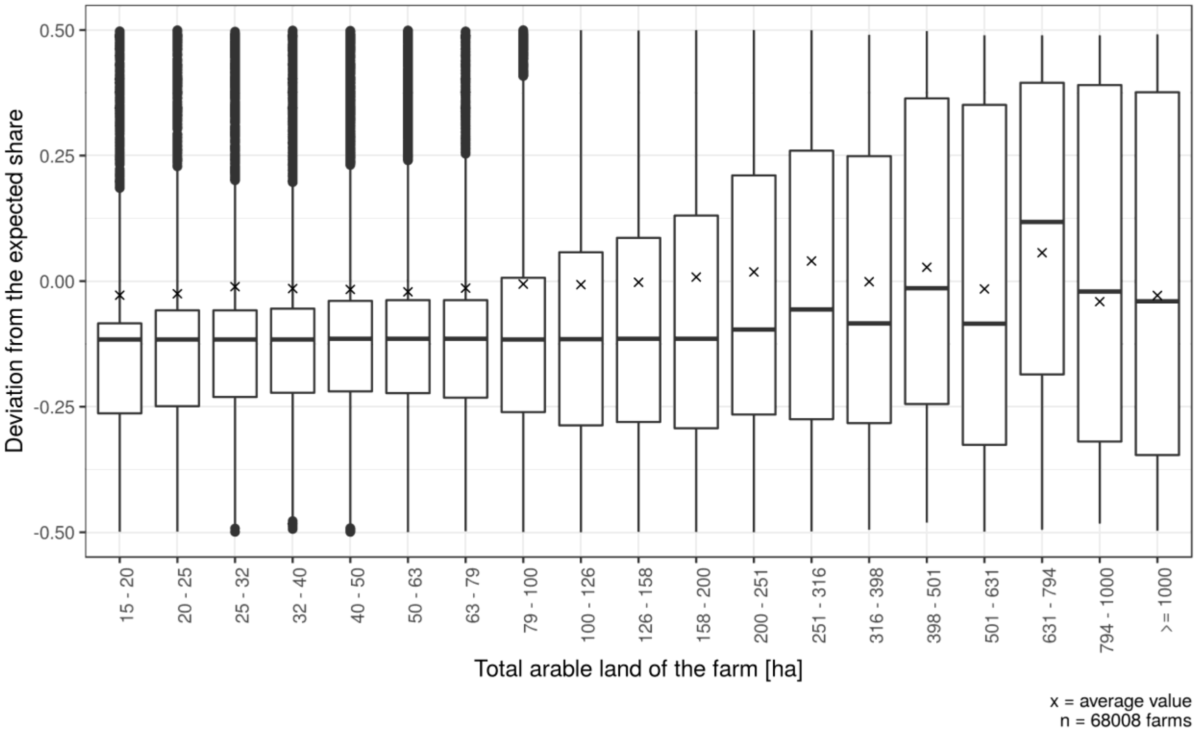
The analyses were conducted by PostgreSQL (version 9.5) and R (version 3.2.3).

3. Results

Regarding all of the observed indicators we observe a very high level of heterogeneity between farms or aggregates of farms belonging to the same farm size class and located in the same soil-climatic region.

Fig. 1 depicts the relation between the deviations from the expected share of dark green EFA related to the total area of EFA in dependence of the farm size. All in all the average effect of farm size is fairly small. We find the highest class average in implementation of dark green EFA in farms managing something between 17and 900 ha of arable land (+2 to +5% compared to the expected share), while the lowest share is recorded for farms managing less than 50 ha (-2%). To get a better understanding of the magnitude of difference consider the following example: 10’000 ha of arable land are in case a) be managed by 200 farms, each farming 50 ha, and in case b) be managed by 20 farms, each farming 500 ha. Based on the data the provision of dark green EFA would be roughly 20 to 35 ha lower in case a, if all other things are equal. Almost irrespective of the farm size the average value of the deviation is markedly higher than the median, indicating a right skewed distribution of farms implementing dark green EFA. This is due to fact that three forth of the farmers select only one or two options to fulfil their EFA obligation (Nitsch et al., 2018).

Fig. 1: Deviation of the realized share of dark green ecological focus area on the total provision of ecological focus area from the expected share in dependence of the farm size (based on farm level data)



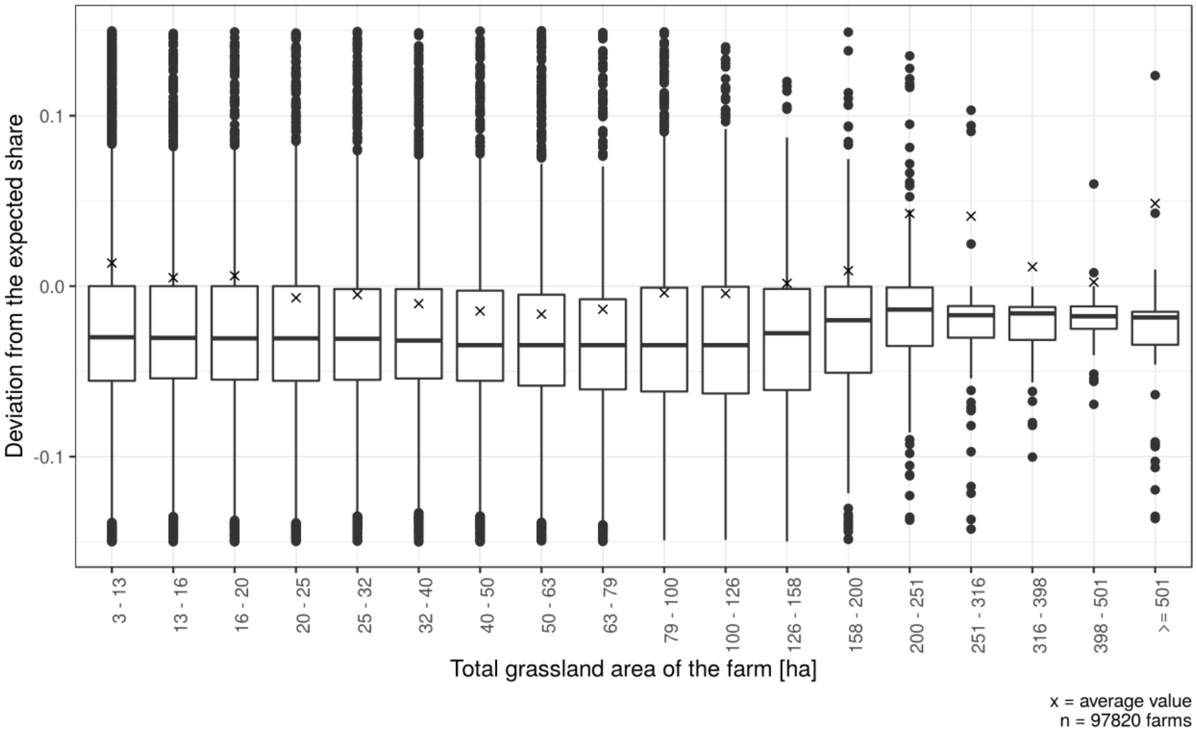
Source: Author

Accounting for the effect of regional and local factors markedly lowers the influence of farm size on the implementation of dark green EFA. When the regional and local factors are not accounted for the implementation of dark green EFA is roughly twice as high in large compared to small farms (Nitsch et al., 2018).

Fig. 2 shows the deviation of the farms' shares of grassland enrolled in dark green AECM on their respective total grassland area from the expected value. In particular with respect to the average value a slight u-shaped pattern is apparent. For farms managing less than 20 ha of grassland, on average roughly 1% is more enrolled in dark-green AECM higher than expected, for farms with up to 126 ha the respective value is 1-1.5% lower. In farms managing more than 200 ha of grassland about 3% more of the grassland area is enrolled than expected. In contrast to the average, the median is barely affected by changes in the farm size, if farms manage less than 126 ha of grassland. The median value for the larger farm size classes is roughly 2% higher compared to the smaller farms. What is apparent is that the median value is for all farm groups lower than the average value indicating specialization.

Especially for the larger farm size classes the difference between the average and median values becomes very pronounced in certain cases e.g. for farms with 200 to 316 ha. For farms larger than 500 ha the difference exceeds 5%. This difference can be linked to a group of large low input farms specialised in managing sensitive grassland areas.

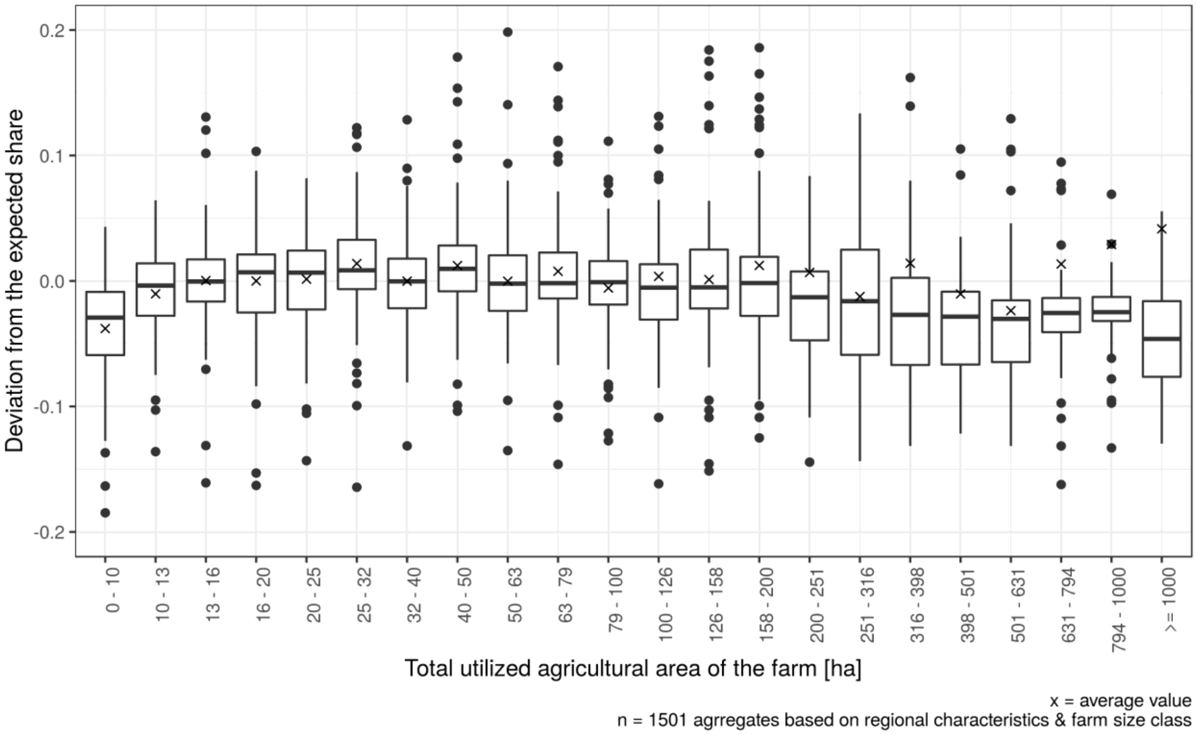
Fig. 2: Deviation of the realized share of grassland enrolled in dark green AECM on the total grassland area from the expected share in dependence of the farm size (based on regionalized averages)



Source: Author

For the share of organic farming, the deviation from the expected value shows a different picture than the previous indicators. In contrast to the previous indicators the median and average shares for a given farm size class are almost identical for farm size classes containing farms managing less than 400 ha. For small farms farming less than ~16 ha of UAA the observed shares of land managed organically is below the expected value. Whereas for farms with up to 400 ha the share managed organically is marginally higher than expected. However, for large farms the median and average shares diverge substantially. While the mean value per farm size class is in tendency rising, the median value is negatively correlated with the farm size. This is caused by the fact that in most regional aggregates (defined by Land, soil climate region and NCS) the share of large farms managed organically is below average and that the larger the farm gets the less likely it is that the farm is managed organically. However, in certain regional settings a very high share of the large farms is managed organically. Especially UAA in NCS is overproportionally managed by large and very large farms (Röder et al., 2018).

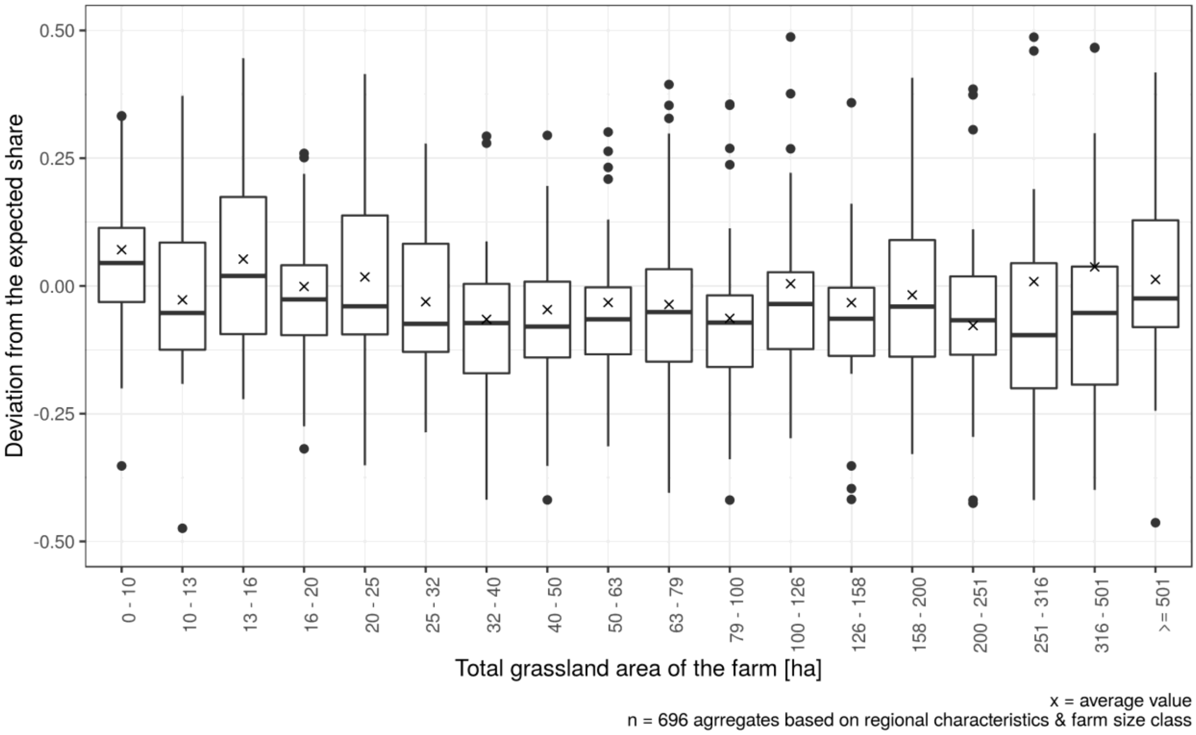
Fig. 3: Deviation of the realized share of UAA managed organically on the total UAA from the expected share in dependence of the farm size (based on regionalized averages)



Source: Author

The analysis of the share of HNV habitats on grassland is based on 582 HNV sampling plots having at least some grassland. In these plots 10'226 ha of IACS grassland are managed by 3'225 farms and 18% of this grassland area is classified as HNV grassland. Looking at the average deviation from the expected share Fig. 4 shows a very slight u-shape reflecting the effect seen for the implementation of dark green AECM on grassland. While in farms managing either less than 16 ha or more than 316 ha of grassland the share of HNV on the grassland is roughly 4 to 5% higher than expected, the share is 2 to 3% lower in farms managing between 30 and 300 ha of grassland. The main reason for the low share of HNV grassland in the respective size class is that many farms in this category are intensive dairy farms characterized by a high stocking density and the stocking density being negatively correlated with the share of HNV grassland (Ackermann et al., in press, p. 226).

Fig. 4: Deviation of the realized share of grassland classified as HNV from the expected share in dependence of the average regional farm size (based on region level data)



Source: Author

4. Discussion and Conclusion

With respect to the four studied indicators we cannot see a relationship between farm size and environmental impacts if we adjust for regional and local site conditions. One indicator (share of dark green EFA), farms is positively correlated with farm size. For two indicators (share of grassland enrolled in dark green AECM and share of grassland classified as HNV) we see a u-shaped distribution, with very small and very large farms showing higher values. Only organic farming is more frequent in mid-sized farms compared to the large farms.

As the relations to farm size are diverse, as depicted in our study, the frequent approach used in ecological studies to analyse the effect of farm size by splitting the observed sample data in two groups one with the larger and the other with smaller farms (e.g. (Belfrage et al., 2015; Happe et al., 2018) might not allow valid conclusions in general.

Habitat heterogeneity and field size are features with a strong positive impact on biodiversity (e.g. Berg et al., 2015; Fischer et al., 2011; Happe et al., 2018; Jerrentrup et al., 2017). Plot size increases with farm size in Germany, albeit at a very low rate (Röder et al., 2018): The average plot size increases only by the factor of 2 to 2.5 if a farms total UAA increases 10 times .

We interpret the results in the following way:

1) The increasing consideration of labour costs in larger farms (paid vs. family labour) is a decisive argument for a higher adoption of low-input management options in larger farms. Especially in grassland farms, the consideration of labour costs can shift the economical optimal input level strongly to the extensive side.

2) Especially in smaller full-time family farms the attainable income is limited by available land resources. These farms frequently focus on intensive crops or on intensive livestock farming. The associated input intensity levels are frequently not in accordance with a high environmental output.

3) For larger farms the relation between more or less constant transactions costs per farm to granted support payment for participation in AEMs can be more favourable for biodiversity, especially if the supported area is not tightly restricted in absolute terms.

4) Especially under marginal conditions farms tend to manage larger tracts of land to (partly) compensate for the lower attainable revenues per ha.

We plan to expand the analysis to factors of impact with respect to farmland birds and the presence and quality of structural elements such as hedges and to include more years to allow for dynamic analysis. This seems crucial as the participation rate in AEM changes if sfarm size grows or shrinks (Mann, 2005) or some dramatic environmental impacts occur, especially when plots change hands (like the conversion of grassland to arable land (Osterburg et al., 2011).

From our various analyses so far we see no evidence that full-time family farms behave per se more environmentally sensitive compared to larger farms. We therefore strongly recommend not to cofound aspects of environmental targeting of payments with social aspects or structural considerations.

Acknowledgements: The work presented in this study was partly funded by the Federal Agency for Nature Conservation (Bundesamt für Naturschutz, BfN) within the project ÖVForsch 2 (FKZ 3517 84 0200) and the Federal Environment Agency (Umweltbundesamt, UBA) within the project GAPEVAL 2 (FKZ 3717 11 2370). Further, we thank the federal states for providing IACS data.

References

Ackermann, A., Baum, S., Böhner, H., Röder, N., Rudolph, S., in press. InVeKoS-Datenanalyse, in N. Schoof, Rainer Luick, Andrea Ackermann, Sarah Baum, Hannah Böhner, Norbert Röder, Sebastian Rudolph, Thomas Schmidt, Guy Beaufoy, Gwyn Jones, Peter Einarsson, Jabier Ruiz, Vyara Stefanova, Daniel Fuchs, Tobias Windmaißer, Hermann Hötker, Heike Jeromin, Herbert Nickel and Maria Ukhanova, eds. *Auswirkungen der neuen Rahmenbedingungen der Gemeinsamen Agrarpolitik auf die Grünlandbezogene Biodiversität.,* Bonn, pp. 159–232.

AgE 17/19, 23.04.2019. Unabhängiger europäischer Presse- u. Informationsdienst für Agrarpolitik u. Agrarwirtschaft.

2019. *Agrar-Atlas: Daten und Fakten zur EU-landwirtschaft.* Heinrich-Böll-Stiftung, Berlin.

Alló, M., Loureiro, M. L., Iglesias, E., 2015. Farmers' Preferences and Social Capital Regarding Agri-environmental Schemes to Protect Birds. *Journal of Agricultural economics.* **66**, 672–689.

Belfrage, K., Björklund, J., Salomonsson, L., 2005. The Effects of Farm Size and Organic Farming on Diversity of Birds, Pollinators, and Plants in a Swedish Landscape. *Ambio.* **34**, 582–588.

Belfrage, K., Björklund, J., Salomonsson, L., 2015. Effects of Farm Size and On-Farm Landscape Heterogeneity on Biodiversity—Case Study of Twelve Farms in a Swedish Landscape. *Agroecology and Sustainable Food Systems.* **39**, 170–188.

Benzler, A., 2012. Measuring extent and quality of HNV farmland in Germany, in . *High Nature Value farming in Europe : 35 European countries - experiences and perspectives,* Seite 507-510.

Berg, Å., Wretenberg, J., Żmihorski, M., Hiron, M., Pärt, T., 2015. Linking occurrence and changes in local abundance of farmland bird species to landscape composition and land-use changes. *Agriculture, Ecosystems & Environment.* **204**, 1–7.

European Bird Census Council (EBCC), 2017. Agri-environmental indicator - population trends of farmland birds, available at https://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_population_trends_of_farmland_birds.

European Commission (COM), 2018. Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing rules on support for strategic plans to be drawn up by Member States under the Common agricultural policy (CAP Strategic Plans) and financed by the European Agricultural Guarantee Fund (EAGF) and by the European Agricultural Fund for Rural Development (EAFRD) and repealing Regulation (EU) No1305/2013 of the European Parliament and of the Council and Regulation (EU) No 1307/2013 of the European Parliament and of the Council, available at https://eur-lex.europa.eu/resource.html?uri=cellar:aa85fa9a-65a0-11e8-ab9c-01aa75ed71a1.0003.02/DOC_1&format=PDF.

European Parliament and Council (EU), 2013a. REGULATION (EU) No 1305/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 december 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) No 1698/2005.

European Parliament and Council (EU), 2013b. Regulation (EU) No 1307/2013 of the European Parliament and of the Council of 17 December 2013 establishing rules for direct payments to farmers under support schemes within the framework of the common agricultural policy and repealing Council Regulation (EC) No 637/2008 and Council Regulation (EC) No 73/2009.

Fischer, C., Flohre, A., Clement, L. W., Batáry, P., Weisser, W. W., Tscharntke, T., Thies, C., 2011. Mixed effects of landscape structure and farming practice on bird diversity. *Agriculture, Ecosystems & Environment.* **141**, 119–125.

Happe, A.-K., Riesch, F., Rösch, V., Gallé, R., Tscharntke, T., Batáry, P., 2018. Small-scale agricultural landscapes and organic management support wild bee communities of cereal field boundaries. *Agriculture, Ecosystems & Environment.* **254**, 92–98.

Hünig, C., Benzler, A., 2017. *Das Monitoring der Landwirtschaftsflächen mit hohem Naturwert in Deutschland.* Deutschland / Bundesamt für Naturschutz, Bonn.

Hynes, S., Garvey, E., 2009. Modelling Farmers' Participation in an Agri-environmental Scheme using Panel Data: An Application to the Rural Environment Protection Scheme in Ireland. *J Agricultural Economics.* **60**, 546–562.

Jerrentrup, J. S., Dauber, J., Strohbach, M. W., Mecke, S., Mitschke, A., Ludwig, J., Klimek, S., 2017. Impact of recent changes in agricultural land use on farmland bird trends. *Agriculture, Ecosystems & Environment.* **239**, 334–341.

Mann, S., 2005. Farm Size Growth and Participation in Agri-environmental Schemes: A Configural Frequency Analysis of the Swiss Case. *J Agricultural Economics.* **56**, 373–384.

Marini, L., Fontana, P., Klimek, S., Battisti, A., Gaston, K. J., 2009. Impact of farm size and topography on plant and insect diversity of managed grasslands in the Alps. *Biological Conservation.* **142**, 394–403.

Nationale Akademie der Wissenschaften Leopoldina, acatech – Deutsche Akademie der Technikwissenschaften, Union der deutschen Akademien der Wissenschaften (Leopoldina), 2018. Artenrückgang in der Agrarlandschaft: Was wissen wir und was können wir tun? Accessed March 2019, available at http://www.leopoldina.org/uploads/tx_leopublication/2018_3Akad_Stellungnahme_Artenrueckgang_web.pdf.

Neuenfeldt, S., Gocht, A., Osterburg, B., 2019. What explains dairy pasture farming in Germany, in EAAE, ed.

Nitsch, H., Röder, N., Oppermann, R., Milz, E., Baum, S., Lepp, T., Kronenbitter, J., Ackermann, A., Schramek, J., 2017. Naturschutzfachliche Ausgestaltung von Ökologischen Vorrangflächen, available at 10.19217/skr472.

Nitsch, H., Röder, N., Oppermann, R., Milz, E., Baum, S., Lepp, T., Kronenbitter, J., Ackermann, A., Schramek, J., 2018. Ökologische Vorrangflächen: gut gedacht - schlecht gemacht? *Natur und Landschaft : Zeitschrift für Naturschutz und Landschaftspflege.* **93**, Seite 258-265.

Osterburg, B., Laggner, Birgit, Nitsch, Heike, Roggendorf, W., Röder, N., 2011. Analysis of grassland conversion to arable land in Northwest Germany. *Grassland Science in Europe.* **16**, 350–352.

Röder, N., Ackermann, A., Baum, S., Rudolph, S., 2018. Status quo und aktuelle Entwicklungen der landwirtschaftlichen Flächennutzung in Deutschland. *Natur und Landschaft : Zeitschrift für Naturschutz und Landschaftspflege.* **93**, Seite 250-257.

Roßberg, D., 2013. Erhebungen zur Anwendung von Pflanzenschutzmitteln in der Praxis im Jahr 2011. *Journal für Kulturpflanzen.* **65**, 141–151.

Ruto, E., Garrod, G., 2009. Investigating farmers' preferences for the design of agri-environment schemes. A choice experiment approach. *Journal of Environmental Planning and Management.* **52**, 631–647.

Schoof, N., Rainer Luick, Andrea Ackermann, Sarah Baum, Hannah Böhner, Norbert Röder, Sebastian Rudolph, Thomas Schmidt, Guy Beaufoy, Gwyn Jones, Peter Einarsson, Jabier Ruiz, Vyara Stefanova, Daniel Fuchs, Tobias Windmaißer, Hermann Hötker, Heike Jeromin, Herbert Nickel, Maria Ukhanova, eds., in press. *Auswirkungen der neuen Rahmenbedingungen der Gemeinsamen Agrarpolitik auf die Grünlandbezogene Biodiversität.,* Bonn.

Stratmann, U., Pabst, H., Horlitz, T., 2018. Wieviel Naturschutz steckt in der zweiten Säule - nur zweite Wahl? *Natur und Landschaft : Zeitschrift für Naturschutz und Landschaftspflege.* **93**, Seite 266-272.

Uthes, S., Matzdorf, B., 2013. Studies on agri-environmental measures: a survey of the literature. *Environmental management.* **51**, 251–266.

Vanslembrouck, I., Huylenbroeck, G., Verbeke, W., 2002. Determinants of the Willingness of Belgian Farmers to Participate in Agri-environmental Measures. *J Agricultural Economics.* **53**, 489–511.