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Development of supply curves for environmental compensation measures on farmland on the example of the Stuttgart Region in Germany

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Abstract

Impacts on nature and landscape in Germany must be compensated for in accordance with the Federal Nature Conservation Act. Farmers can participate by voluntarily applying appropriate measures on their land. We used a geodata-based model to analyse environmental compensation measures on arable land from an economic perspective on the example of the Stuttgart Region, a metropolitan area where construction activities and their compensation are huge, exemplary for many European metropolises. In order to estimate a possible realistic potential, the willingness to accept for compensation measures previously determined in a discrete choice experiment with farmers in the Stuttgart region was integrated into the model. The analysis compares the economic viability of current agricultural use with the income generated from the sale of so called ecopoints by supply curve. The results show wide variation in ecopoint potential in spatial terms. The implementation of compensation measures is not economically reasonable, depending on the legal security provided by a land register entry at a price of less than 1.00 € per ecopoint in the Stuttgart city district. In contrast, measures can be implemented economically and on a large scale in surrounding districts for less than 0.60 €, regardless of legal protection. The optimal type of compensation measure from an economic point of view depends on type and land is also important. The model and its results can provide important information for decision-makers in politics, landscape planning and nature conservation.

Keywords

Production-integrated compensation. Ecopoints, Impact mitigation regulation, Stuttgart Region

Presenters Profile

Christian Sponagel studied agricultural science at the University of Hohenheim between 2014 and 2018. He finished his study with a Master of Science degree in Agribusiness. From 2019 he is working as a research assistant and Ph.D. student.

Introduction

The German Impact Mitigation Regulation as a part of the Federal Nature Conservation Act (BNatSchG) has been established to achieve a no net loss of biodiversity and soil functions. According to Article 13 BNatSchG, unavoidable significant adverse impacts on nature and landscape are to be offset by compensatory or replacement measures. Adverse or negative impacts on nature are development of infrastructure such as railway tracks or other building projects, for example. Such compensation approaches also exist in other European countries, like Austria, Switzerland, Sweden or the Netherlands. The approaches in Austria and Switzerland are quite similar to that used in Germany (Darbi et al. 2010). In Sweden compensation measures can be ordered by the Swedish Environmental Code (Person et al. 2015). In England environmental compensation is addressed by the National Planning Policy Framework (Sullivan and Hannis 2015).

According to Article 16 BNatSchG, compensation for expected interventions can also be carried out pre-emptively in Germany. Stocking of advance compensation by means of eco-accounts, land pools or other measures is governed by state law. In Baden-Württemberg this is regulated by the Ökokonto-Verordnung (*ÖKVO*). In terms of nature conservation, an intervention with sealing means a devaluation of the existing biotope type and a downgrading of the soil function. This results in a need for compensation in the amount of the difference to the initial biotope type, which is assessed in ecopoints according to the *ÖKVO*. Frequently, agricultural areas are also used for the implementation of compensation measures, e.g. by planting woody plants, and are then no longer available for agricultural production. Other often used measures are land use changes from arable land into grassland or from agricultural land to nature conservation. Since arable land is classified as low-value in ecological terms (four ecopoints per m^2) in the *ÖKVO* for nature conservation purposes, there is a correspondingly high potential for upgrading. Hence intensively used grassland has six and more extensive grasslands variations from 13 up to 21 ecopoints per m^2. As a result, the conversion of arable land into extensively used grassland is often implemented. However, the extent of compensation measures on agricultural land in Germany is still hardly statistically recorded (Tietz et al. 2012).

According to Article 15 (1) NatSchG Baden-Württemberg as federal state specific concretization of the BNatSchG, the relevant natural areas for the implementation of compensation measures are actually defined. The measure can be carried out either in the same or in the nearest neighbouring third order natural area. The Stuttgart Region lies on the border of two natural areas, so that an intervention within this region could in principle also be compensated for in the entire Stuttgart Region (Appendix 1 NatSchG Baden-Württemberg). Nevertheless, compensation is often required in close proximity to the intervention. Ultimately, the approval authority, usually the lower nature conservation authority, decides whether the compensation must take place close to the site of intervention or also further away, i.e. in the entire natural area (Giesberts and Reinhardt 2020b). In individual cases, however, it must be considered whether compensation at the place of intervention is sensible and possible (Michler and Möller 2011).

In contrast to the often used compensation measures mentioned above there is the production-integrated compensation (PIC). This means management or maintenance measures pursuant to Article 15 (3) BNatSchG on agricultural and forestry land with continued agricultural and forestry use. It is intended to reach a permanent enhancement of the natural balance or landscape on the land and to counteract the consumption of agricultural land. At the same time, PIC offers farmers the possibility of an active participation in the compensation process, e.g. by voluntary implementation of anticipated measures (Druckenbrod and Beckmann 2018; Czybulka et al. 2012). However, it is not always clearly definable whether a certain measure can still be called production-integrated or not, e.g. flower strips. According to Mössner (2019) both forms of land sparing and land sharing are possible for PIC, i.e. production and nature conservation side by side or on the same area. In any case, PIC relies mainly on close coordination of the measure with the farmers and its implementation in consensus with agriculture. From our point of view, flower strips can therefore also be sensibly integrated into the production process, depending on location and arrangement and will therefore be considered as PIC in this study.

With the various measures that are possible on agricultural land, a different number of ecopoints can be generated, which can then be freely traded on the market in the defined regions. However, the often used compensation measures are generally valued higher than PIC in terms of nature conservation. Common to all measures is that in current practice they are predominantly associated with permanent maintenance and corresponding care costs as well as legal protection, often in the form of a land register entry. In principle, a compensation measure is permanent, depending on the type of intervention, but the maintenance period can be limited to 25 years, for example, if the intended development status of the area is stable afterwards (Lütkes and Ewer 2018). Therefore, pure management and maintenance measures, which also include the PIC, are to be implemented for an unlimited period of time (Giesberts and Reinhardt 2020a).

It can be assumed that the permanent implementation of compensation measures in conjunction with land register protection will have a negative impact on the market value or mortgage lending value of a parcel of land (Czybulka et al. 2009). According to Mährlein and Jaborg (2015), a reduction in the market value of at least 15-20% can be assumed as a result of the protection of agricultural land in nature reserves, irrespective of the associated extensification requirements. In extreme cases, the maximum reduction in value can be 70-85%. The economic merit of a measure therefore depends on the market price for ecopoints, the opportunity costs of agricultural use and market value of the parcel of land, which can be estimated by standard land values (BRW). Since the nature conservation value of PIC is often somewhat lower than that of other measures, we assume that the entry in the land register has a high influence on the economic excellence of PIC in particular. Especially in densely populated urban areas such as Stuttgart, land consumption by settlement and transport areas is particularly high and the competition between different land uses is associated with a high potential for conflict. In addition to the loss of land due to construction activity itself, possible compensation measures also can have a land-scarring effect.

Against this background, we investigated the role of agriculture in the compensation process and the associated conflicts, but also the opportunities in the Stuttgart Region. As the acceptance of the farmers plays a decisive role in estimating a realistic compensation potential, a discrete choice experiment (DCE) with farmers was conducted before this study. From the total number of 209 participants, 65 came from five of the 6 districts of the Stuttgart Region. About 50% were part-time farmers, which is slightly below the average of about 61% in the Stuttgart Region (Statistisches Landesamt Baden-Württemberg 2017). In addition, most farmers were between 40 and 50 years old, which is quite representative for Baden-Württemberg (Statistisches Landesamt Baden-Württemberg 2017). Farmsize varied between

21 and 220 hectares with an average of about 67 hectares. Small farms were thus underrepresented ,which was also reported by similar DCEs, e.g. Schulz et al. (2014). However, the farms with more than 50 ha cultivate more than 50% of the agricultural area in the Stuttgart Region. Although the DCE is not generally representative for all farms in the Stuttgart Region, it nevertheless reflects a relatively high proportion of farms. The focus of the DCE was mainly on the legal security of the measure, i.e. the entry in the land register and the preference of the type of measure, e.g. PIC or conversion of arable land into grassland. Other attributes were the potential loss of market value, hence the BRW of the land, the care and maintenance period of the measure, the legal handling (transaction costs) and the annual amount of monetary compensation. From the DCE we derived values for the willingness to accept (WTA) that were used in this study to assess the costs of the measures more realistic, i.e. including a certain risk surcharge on the price (Petig et al. 2019). This means that the possible reduction of the market value is included in the WTA.

The excellence of various compensation measures on arable land in the Stuttgart Region (approx. 73,300 ha) were analysed with the help of a geodata-based model and a spatially differentiated estimate of the potential for nature conservation compensation measures will be made. The future need for compensation up to the year 2030 in ecopoints is derived from an estimate of the Verband Region Stuttgart. Based on the net present value, the model chooses between five possible compensation measures or the retention of the previous agricultural land use.

Our study was motivated by the following hypotheses:

H1: From an economic point of view, agriculture in metropolitan regions can provide compensation areas in consensus with compensation obligors, in principle.

H2: There are strong spatial disparities as regards the economic merit of compensation measures on agricultural land.

H3: In certain parts of the region, PIC is the only way to implement compensation measures at a normal market price for ecopoints.

H4: In the case of abandonment of the land registry safeguards, there would be a high potential for PIC throughout the region.

Methods

Description of the study area

The Stuttgart Region consists of the districts of Esslingen, Ludwigsburg, Rems-Murr-Kreis, Göppingen and the city of Stuttgart. It is characterised by a high spatial disparity of demographic, economic and natural characteristics (IREUS 2011). In the urban district of Stuttgart, crops like vegetables and fruits are cultivated on about 11% of the arable land, whereas the share in the district of Göppingen is only 0.4%. This is also where the highest proportion of permanent grassland in the utilised agricultural area (UAA) is found, at around 56%. In the city district of Stuttgart, this is markedly lower at about 29% (Figure 1). The Stuttgart region takes up about 10% of the area of Baden-Württemberg, but 16% of the land consumption in Baden-Württemberg in the years 2000 to 2016 took place there (LUBW 2018). This means that compensation measures under nature conservation law play a major role in this region.

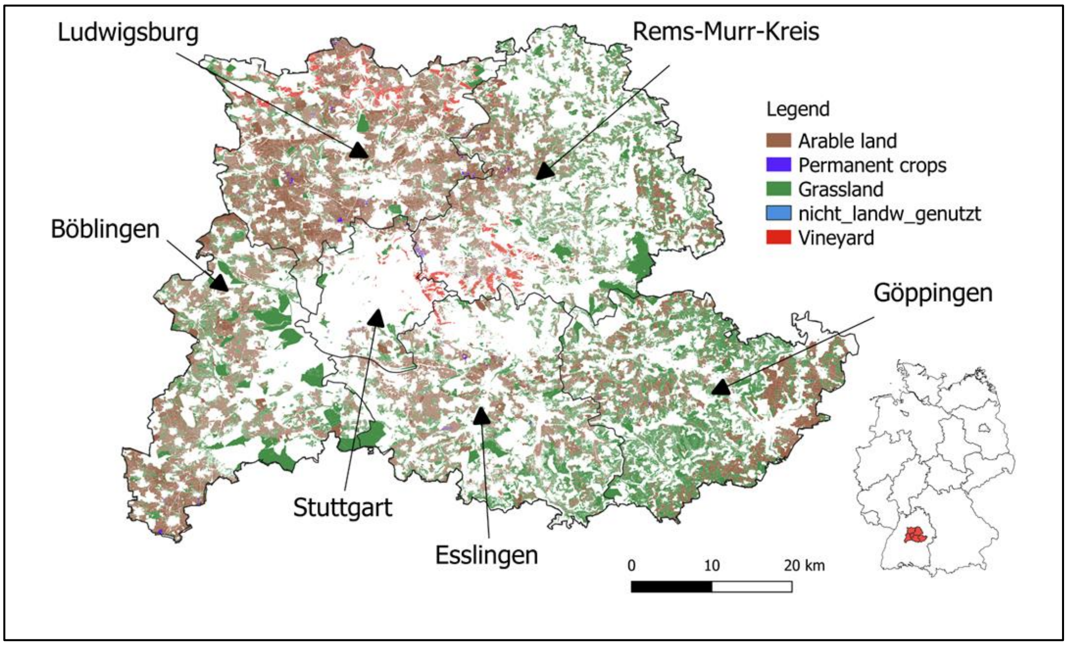

Figure 1. Overview of the agricultural land use in the districts of the Stuttgart Region (BKG 2018).

Economic evaluation of the agricultural production in the region

Based on data from the integrated administration and controlling system (InVeKoS) for the years 2015 to 2018, we derived parcel-specific crop rotations and their average contribution margins. In total, the considered arable land (ARA) consists of 72,494 ha and 265,356 parcels and corresponds to about 56 % of the agriculturally used area in the region. The remaining UAA consists of 40 % permanent grassland and 4 % orchards, vineyards and set aside areas.

The individual site conditions and thus the yield capacity are taken into account by a soil evaluation map, so called Flurbilanz (LEL 2011). The parcels are divided into three value levels standing for the yield capacity: high (priority area 1), medium (priority area 2) and low (boundary and lower boundary). For approx. 11% of the parcels there is no valuation in the Flurbilanz, therefore that these are allocated on the basis of the soil function valuation of the Verband Region Stuttgart ("value level" 4.5 to 5 high, 2.5 to 4, medium and 0-2 low). The calculation of contribution margins (in the following abbreviated CM) is based on standard calculation data and price statistics (LEL 2018a, 2018b; KTBL 2019a, 2019b, 2019c, 2010; LfL 2019; AMI 2017, 2018, 2019; AWI 2019) as well as individual publications (LFULG 2006; Statistik-BW 2018; AWI 2019). In order to estimate the refinement value of arable fodder via animal use, arable fodder plants are valued at 11.75 €/GJ or 0.23 €/10 MJ NEL, depending on their GJ or MJ NEL content, respectively, based on the price for maize silage. As a result, the forage areas are comparatively highly valued and livestock farming is relatively well covered, especially as this does not play a major role in the city of Stuttgart (Statistik-BW 2020). For areas under agri-environmental measures and ecological priority areas (ÖVF), the average CM of the main crops in the crop rotation are allocated in a simplified manner. Set-aside arable land, such as unstocked orchards, were not taken into account, as these probably offer less potential for nature conservation than intensively used arable land. All prices and costs are net amounts from a tax point of view.

The mean CM differ significantly within the region due to the different crop rotations and the yield level (cf. Flurbilanz) (Table 1). For example, the CM in Stuttgart are about four times higher than in the district of Göppingen. The CM are capitalised using the perpetual annuity formula and an interest rate of 2%.

Table 1. Descriptors and economic framework of the structure of agriculture in the Stuttgart Region.

Urban/rural district	UAA in ha	Share of arable land (ARA) [%]	Share of specialty crops on ARA [%]	Share of cereals in the crop rotation [%]	Mean BRW for arable land in €/m²	Mean contribution margin per ha [€]
Böblingen	22,344	66.7	1.3	62.3	4.71	605
Esslingen	19,555	50.3	9.2	51.6	6.52	1.563
Göppingen	27,828	43.5	0.4	49.6	3.15	519
Ludwigsburg	31,429	76.1	2.3	54.3	3.90	814
Rems-Murr-Kreis	25,430	45.6	2.9	45.4	4.47	993
Stuttgart	2,433	55.7	11.0	48.6	15.97	1,922

Standard land values (BRW) in the Stuttgart Region

For about 60% of the municipalities in the Stuttgart Region, average BRW (Table 1) differentiated according to arable and grassland are available from the respective expert committees of the municipalities, mainly from 2018. These were viewed online and serve as estimates of the market value of all parcels of land in a municipality. We calculated the missing BRW for the remaining municipalities by spatial interpolation from the mean values of the neighbouring municipalities. This is done in RStudio (R Core Team 2019) using the "idw" function from the R package "phylin". The available values of all other communities are weighted with the squared inverse distance (Tarosso et al. 2015).

Compensation measures being considered for the Stuttgart Region

For the estimation of the ecopoint potential, it is assumed that with a few exceptions, in principle, a compensation measure under nature conservation law can be implemented on each plot of land. In addition to the current agricultural use (M0), five compensation measures M1 to M5 are available per parcel (see also Table 2). In accordance with the *ÖKVO*, the measures M1 to M5 are assessed in ecopoints. Starting from the initial state M0 (arable land with four ecopoints per m²), the potential for upgrading M1 to M5 is determined. Since measures such as flower strips are not available as such in the *ÖKVO*, the resulting biotope type must be estimated in practice by the lower nature conservation authority. For the evaluation of the measures in ecopoints, the Flächenagentur Baden-Württemberg (www.flaechenagentur-bw.de), as a qualified service agency for the planning and implementation of compensation measures was involved. It has also to be considered that some measures like M4 or M5 might not lead to the aimed target condition if they are implemented on parcels with a relatively high yield capacity value and corresponding potential for natural nitrogen mineralisation (Wagner 5/7/2020). This could even have negative effects on nature conservation, e.g. the proliferation of unwanted weed species (Czybulka et al. 2012). Low nutrient levels and dry soil conditions in particular can promote the development of a species-rich flora (Gilhaus et al. 2017). While extensification of agriculture may not be appropriate in these locations, flower strips can be also successfully implemented even at highly productive sites (Czybulka et al. 2012).

The maintenance costs of the measures M1 to M5 are capitalised with an interest rate of 2%. For all measures, in order to ensure permanent maintenance, it is assumed that there is a securing land register entry, which is taken into account by the WTA values of the DCE. It is also assumed that the conditions for receiving direct payments from the first pillar of the EU CAP are equally fulfilled for all measures.

M0 corresponds to the status quo, i.e. the previous agricultural use is continued. There is no revaluation in ecopoints, there is no loss of market value and the capitalised average CM is set according to the mean contribution margin of the crop rotation (see Figure 2).

M1 corresponds to the PIC using the example of the planting of a permanent flowering strip on 30% of the area of the parcel. Compared to agricultural use, this results in an appreciation of eight ecopoints per m². The costs of a one-year flowering strip are assessed at about 31.5 € per ha (KTBL 2019a) and corresponding to a measure area of 30% of a parcel € per ha and year or capitalised at 1,576.5 €. Hence 70% of the CM of the crop rotation remains. M1 is a maintenance and management measure for an indefinite period.

M2 is the conversion of arable land into grassland with extensive use, i.e. one cut per year. For the target condition 13 ecopoints per m² are assumed. This results in an appreciation of nine ecopoints per m². The annual revenue of the grassland yield is already included in the WTA for this measure, as the farmers in the DCE did take this already into account. It is assumed that the grassland is used also for more than 25 years.

In the case of M3, with the planting of a perennial flowering on 100% of the parcel area, a complete use for nature conservation is realised. In practice, such measures are often valued at 12 ecopoints per m², i.e. an appreciation of eight ecopoints per m². The costs are set at 105.10 € per ha and year (KTBL 2019a) for the duration of 25 years, the capital value is therefore 2,052 €. In contrast to M1 we assume that the biotope created will then no longer require any maintenance.

M4 corresponds to PIC using the example of doubled seed row spacing in cereals with a waiver of the use of pesticides. This measure is carried out in rotation. This results in an appreciation of six ecopoints per m². The actual amount of the measure is based on the current share of cereals in the crop rotation on the respective parcel. Hence a share of cereals in the crop rotation of 50% would lead to an appreciation of three ecopoints per m². It is assumed that the measure will lead to a yield loss of 50% or a loss of CM of 60%. For reasons of nature conservation, this measure is limited to parcels with the yield capacity value levels medium and low. It is assumed that M4 is to be implemented as a maintenance and management measure for an indefinite period as well.

M5 is the conversion of arable land into a lean meadow. This measure is treated as a complete transfer to nature conservation as only marginal quantities and qualities of the growth can be expected. Hence the annual cutting is considered as a pure management measure. Possibly the growth can be used as litter. The appreciation is assessed with 13 ecopoints per m². The costs are set at 278 € per ha and year (KTBL 2019a) for the duration of 25 years, the capital value is therefore 5,432 €. We assume that the biotope created will then no longer require any maintenance. This measure is limited to parcels with the yield capacity value level low.

Table 2. Summary of the possible compensation measures M0-M5 in the model with description and evaluation in ecopoints.

Measure	Description	Improvement in ecopoints per m² ARA	Improvement in ecopoints per ha ARA
M0	Status Quo	0	0
M1 (PIC)	Permanent flower strips (30% of the parcel)	8	24.000
M2	Conversion to grassland	9	90.000
M3	Transfer to nature conservation	8	80.000
M4 (PIC)	Double seed row spacing	6	60.000 x CE*
M5	Lean meadow	13	130.000

*Proportion of cereals in the crop rotation per parcel

The revenue from the sale of ecopoints was calculated by multiplying the number of generated ecopoints per hectare *ÖP* by the selling price per point *p*, which is a significant factor. Thus the capital value of the measures *Mi* with *I* = 0, 1, 2, 3, 4, 5 is calculated as a whole from the proceeds of the sale of the points, reduced by the loss in market value of the parcels *VV* and the capital value of the CP (costs and proceeds) K_{CP} (Formula 1). The maintenance and management costs consist of the pure capitalized costs or revenues from the care of the measure, the WTA 1 as a risk surcharge for the care and management and the WTA 2 for the acceptance of the land register entry (Table 3).

$$\boldsymbol{capital\ value_{Mi}} = \text{Ö}\boldsymbol{P_{Mi}} \times \boldsymbol{p} \pm \boldsymbol{K_{CP\ Mi}} \quad (1)$$

Table 3. Composition of the costs of the measures including the WTA values determined in the DCE.

Measure	Capitalised costs / revenues in € per ha for care of the measure	WTA 1 in € per ha (care and management)	WTA 2 in € per ha (land register entry)
M0	CM*	0	0
M1 (PIC)	-1,576.5 + 0,7 x CM	- 7,417**** – 9,114*** - 500.1 x BRW	- 14.631,1
M2	0	- 25,633**** – 30,380*** - 1,667 x BRW	- 25,427
M3	-2.052	- 21,304**** – 30,380*** -1,667 x BRW	- 25,427
M4 (PIC)	CM – (CMC***** + 0.4xCMC)	(- 7,417**** – 22,607*** -1,667 x BRW) x CE**	- 36,803 x CE
M5	- 5,432	- 32,102**** – 30,380*** -1,667 x BRW	- 25,427

* Contribution margin of the crop rotation

** Proportion of cereals in the crop rotation per parcel

*** For a 100% loss of yield, the participants demanded a compensation of 1560 € per year. However, as the contribution margin is higher for individual parcels, the difference was added. This can be explained by the fact, that farmers did rather not consider, to implement compensation measures on these parcels.

**** Risk surcharge that farmer in general consider to implement compensation measures.

*****Capital value of the cereal production

Scenarios

In the DCE, we found that the entry in the land register has a significant effect on the acceptance of a measure. Under certain circumstances, however, the entry in the land register may be omitted. E.g. according to Article 10 (2) of the Bavarian Compensation Ordinance (BayKompV) a waiver of the entry in the land register would be possible in the case of PIC. In this case, a contract under the law of obligations between the causer of the intervention and an institution such as a recognised foundation guarantees the implementation of compensation and farmers have the opportunity to implement it on their land. Therefore, we differentiated two scenarios. In scenario 1 we assumed that the land register entry is necessary for all compensation measures M1 to M5. In scenario 2 we assumed that it is possible to waive the land register entry for M1 and M4 (both PIC).

In the model, the use of each individual plot of land is optimised from an economic point of view. For each parcel, the model selects the measure that yields the highest net present value, that is, either the status quo (M0) or one of the compensation measures M1 to M5 (Figure 2). The price is systematically increased in the interval from 0.10 € to 1.50 € per ecopoint in steps of 0.10 € and the result with spatial distribution is stored in each step.

Functionality of the model

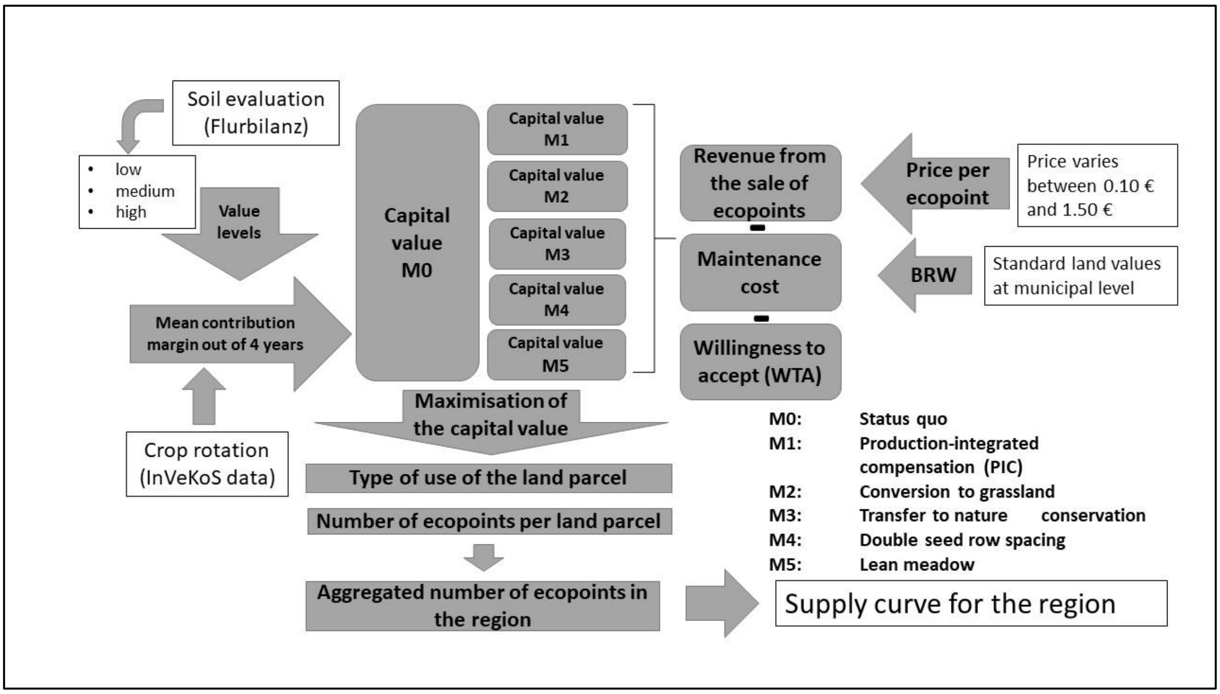

Figure 2. Overview of the structure and functionality of the model.

To represent a form of supply for ecopoints in the region, a smoothing curve is fitted to the data using the LOESS method. This corresponds to a local linear regression model (Zuur 2012). A smoothing parameter of 0.4 is used in order to fit a curve close to the data points. Hence there are three supply curves fitted, i.e. for mean capital value and capital value of M0 with change of minus or plus 20%.

Results

In scenario 1, a maximum of approximately 6 billion ecopoints can be created at a price of up to 1.50 €. From a price per ecopoint of approx. 1.00 €, however, hardly any additional points can be generated. The supply curve as a result of senario 1 is equal to a saturation curve (Figure 3). The sensitivity of the supply curve to the capital value of the crop rotation (M0) highly depends on the price per ecopoint. Up to approximately 1.00 € per ecopoint, variations of 20% of the capital value of M0 have little influence. Below a price of approximately 0.70 € no significant number of ecopoints are generated.

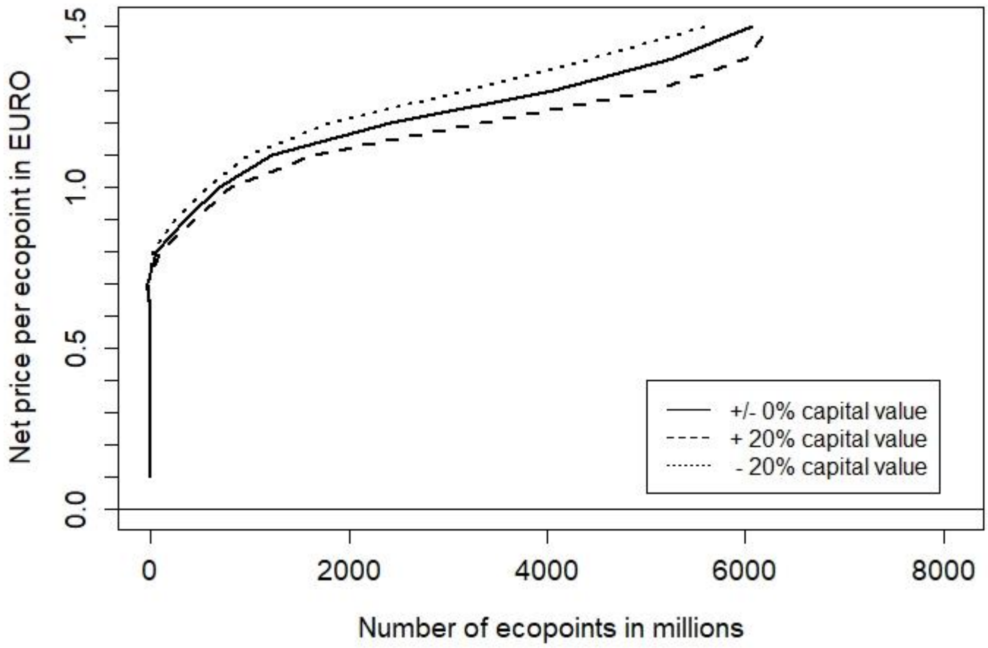

Figure 3. LOESS regression curves of the supply for ecopoints on arable land in the Stuttgart Region with mean capital value, -20% (dashed) and +20% capital value (dashed) as a function of the net price for ecopoints (scenario 1).

Up to a price of 1.30 € no PIC (M4) is implemented in the Stuttgart Region in scenario 1. However, at a price of 1.50 € per ecopoint, M4 accounts for only up to about 7% of arable land in a few municipalities and less than 1% overall in the Stuttgart Region. The measures M1 and M3 are not implanted any price included in the analysis. At a price of 1.00 € per ecopoint exclusively the measures M2 and M5 are implemented, which means a conversion of arable land into grassland. There are also regional disparities, e.g. in the district of Stuttgart no measures would be implemented at all (Figure 4).

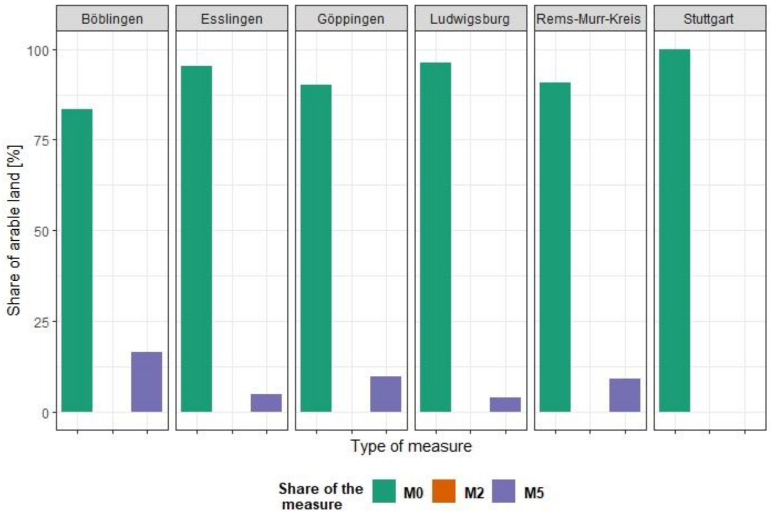

Figure 4. Overview of the type of compensation measures carried out under scenario 1 and a price of 1,00 € per ecopoint in the districts of the Stuttgart Region.

In scenario 2, up to a price of around €1.50 per ecopoint, a slightly smaller number of ecopoints are generated than in scenario 1, at just under 5.2 billion. Now a significant number of ecopoints could be be generated at a price of 0.60 € per ecopoint. Up to approximately 0.90 € per ecopoint the change of 20% of the capital value of the crop rotation seems hardly to have an impact (Figure 5).

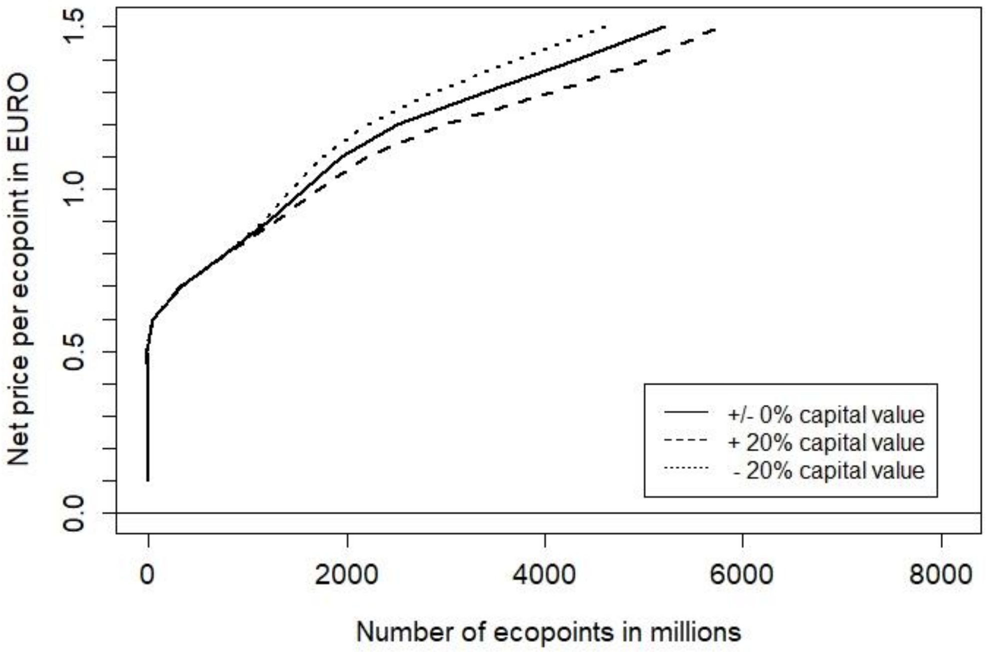

Figure 5. LOESS regression curves of the supply for ecopoints on arable land in the Stuttgart Region with mean capital value, -20% (dashed) and +20% capital value (dashed) as a function of the net price for ecopoints (scenario 2).

Up to a price of around 0.80 € per ecopoint, only measure M4 will be implemented. The share of M4 increases up to a price of about €1.00 per ecopoint to about 40% of the arable land in the Stuttgart Region and then decreases in favour of measures M1, M2 and M5 up to a price of 1.50 € per ecopoint to an average of about 25%. M1 has its highest share of arable land with just under 20% at a price of around 1.20 € per ecopoint. At a price of 1.50 € per ecopoint the maximum shares of M2 and M5 of about 53% and 10% of the arable land respectively are reached. Figure 6 shows as an example the share of M0 to M5 in the arable land at a price of 1.00 € per ecopoint by district. It is obvious that in scenario 2 the regional disparities between the individual districts with regard to the type and scope of the measures are even more evident than in scenario 1. Whereas in the district of Stuttgart only M4 is implemented with a share of approximately 2% of the arable land, in Göppingen more than 75% of the arable land would be occupied with compensation measures.

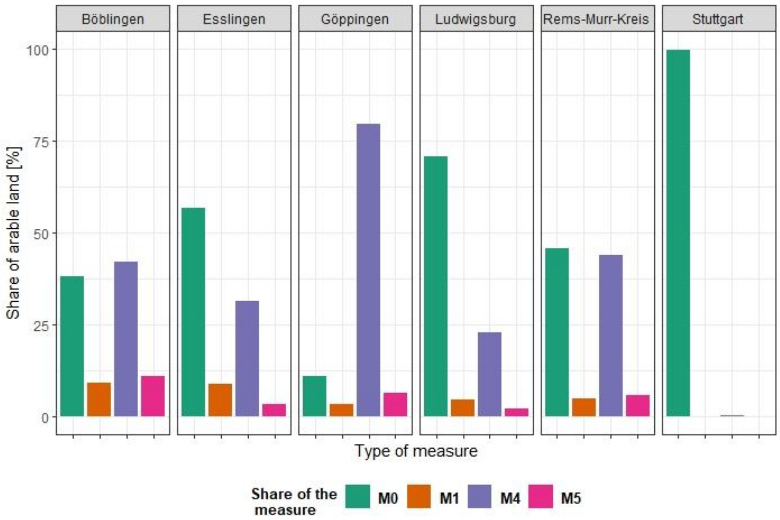

Figure 6. Overview of the type of compensation measures carried out under scenario 2 and a price of 1,00 € per ecopoint in the districts of the Stuttgart Region.

The results show that the high potential for the implementation of compensation measures on agricultural arable land in the Stuttgart Region is spatially highly differentiated (Figure 7). Implementation of compensation measures would probably be most favourable in the eastern districts of the region (e.g. Göppingen and Rems-Murr-Kreis). Higher implementation costs must be expected in the centre of the region.

Discussion

In the city district of Stuttgart and the neighbouring communities, the BRW for farmland is comparatively high at around 16 €/m², hence the potential loss in the market value of the area can be very high. In addition, proportion of highly profitable special crops is high. Therefore, a higher price per ecopoint is necessary to implement compensation measures than in the more rural communities with a greater distance to the centre of the region. Under scenario 1 no compensation measures would be implemented in Stuttgart at a price of 1,00 € per ecopoint, under scenario 2 just in a small amount. Hence, we can accept our hypothesis H2 that there are spatial disparities as regards the economic merit of compensation measures on agricultural land.

In comparison to conversion into grassland (M2 and M5) and complete transfer to nature conservation (M3), production-integrated compensation (M1 and M4) entails a relatively low nature conservation upgrading under the *ÖKVO* in relation to the costs. Especially at low BRW, the PIC is less attractive, as the higher revaluation in ecopoints in M2 and M5 overcompensates the higher loss of market value.

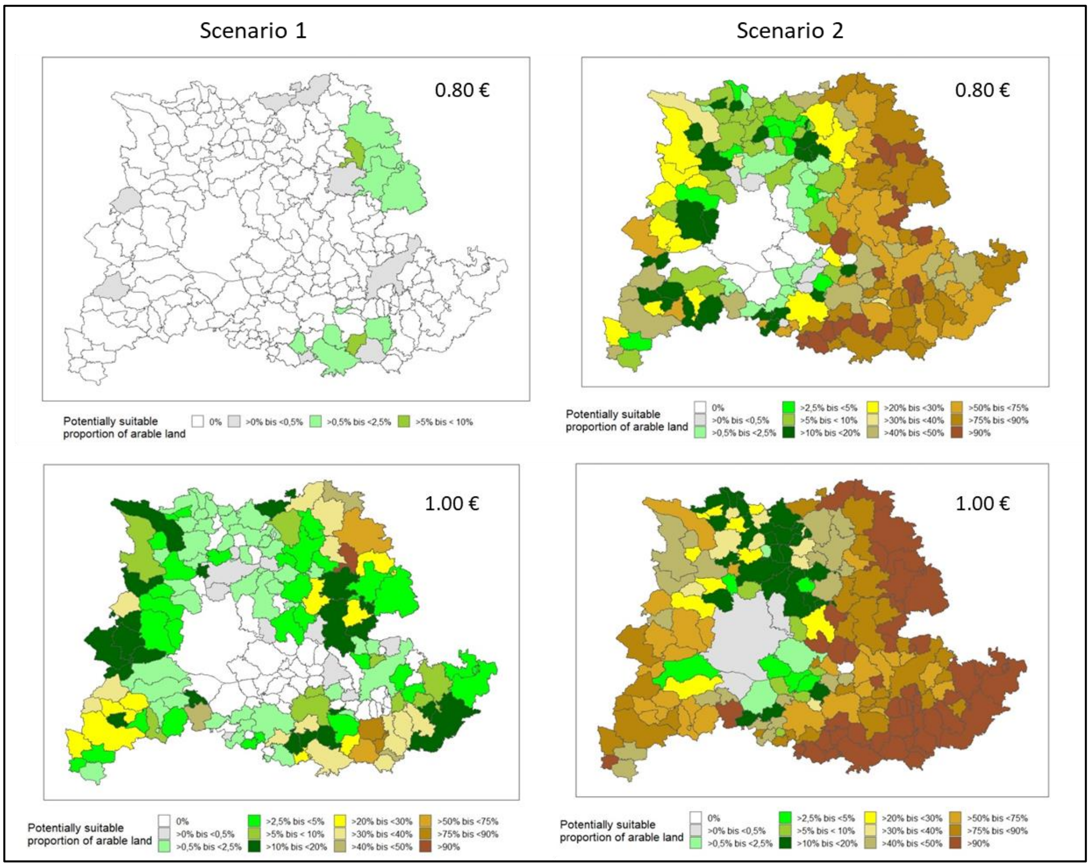

Figure 7. Overview of the spatial distribution of the compensation measures under scenario one and two and prices per ecopoint of 0.80 € and 1.00 € (BKG 2018).

In Scenario 2, where no land registry protection and no loss of market value is applied to PIC (M1), PIC is not applied to any area below a price of 0.60 € per ecopoint. However, in the urban district of Stuttgart, M4, at a price of 1.20 €, accounts for more than 10% of the arable land. Under these conditions, PIC is gaining in relative excellence, especially in the centre of the region. With regard to the peripheral areas of the region, however, the influence is small (Figure 7). The attractiveness of PIC can therefore be increased by not having to secure land registry rights and can also lead to the implementation of compensation measures close to intervention in areas with high BRW. Presumably this will increase the willingness of farmers or landowners to participate in such measures and thus enable compensation in the case of continued agricultural production.

The measures M1 and M3 do not maximise the capital value of CM on any area in Stuttgart. In general, the PIC, which is desirable from the point of view of agriculture, is in strong competition with other measures that lead to a high revaluation in ecopoints, but at the same time no longer allow agricultural use and food production, e.g. M5.

In order to be able to relate the model results to a comparatively realistic demand for ecopoints, an estimate of demand by the "Verband Region Stuttgart" can be used. This estimate, evaluates all known plans for future land development in the Stuttgart Region for the period from 2019 to 2030 and derives a demand of approximately 775 million points

(Jenssen 2020). Based on the results of our analysis, this requirement would be reached in scenario 1 at an ecopoint price of about 1.02 € (0.99 € - 1.06 €) and compensation measures would have to be implemented on about 9% of the arable land in the Stuttgart Region. If we assume that only 60% of all ecopoints are to be generated on arable land that the price will vary between 0.91 € and 0.97 €. At this price, these would mainly be located in the districts of Göppingen and Rems-Murr-Kreis. Under scenario two 775 million ecpoints could already be generated at a price of 0.80 € per ecopoint. In this case the sensitivity to the contribution margin of M0 is with less than 0.01 € not significant and about 30% of arable land would be covered by measures. However, it should be noted that mainly M4 would be implemented as a rotating PIC, i.e. not all areas would be occupied at the same time. With a share of about 50% cereals in crop rotation, this would mean that only about 15% of arable land would be used annually.

Nevertheless, the results of the DCE show that there are also farmers who have not accepted any measures at all, but in general they decided in favour of a conservation compensation measure in about 49% of the cases. On the one hand this somehow limits the interpretability of the results, but on the other hand there are increasing social demands and preferences for biodiversity and nature conservation, which are also observed by farmers (Lange et al. 2015; Fleury et al. 2015) and protection of landscape and the environment becomes part of the farmers` roles (Schmidt and Hauck 2018). Therefore, participation in nature conservation compensation measures could also become more attractive in the future.

Although PIC ultimately leads to a lower nature conservation appreciation of the area, it has a much greater overall spatial impact. According to Mössner (11/18/2019) our derived prices for meeting demand under scenarios 1 and 2 per ecopoint appear to be within a usual price range. Therefore, we can accept our hypotheses H3 and H4 that PIC is the only way to implement compensation measures in certain parts of the region at a usual market price and that there is a high potential for PIC in the whole region if the land register entry is abandoned. It should be noted, however, that the ecopoints will probably be needed successively in the period up to 2030 and that costs may change until then from today's perspective.

As the evaluation of the compensation measures may differ between the lower nature conservation authorities, this aspect also plays a role in the excellence of the measures. For example. In addition, the capital values could be calculated with interest rates different to 2%. It has also to be taken into account that compensation measures can also be carried out in forests or municipal areas which are not used for farming. Therefore, the interpretability of the supply curve is quite limited. It must also be noted that in each case the average values for the WTA were used. Therefore, there may be farmers who are willing to implement compensation measures at lower cost. The ecopoints trade would then take place mainly with these farmers. Finally, we can accept our hypothesis H1 that agriculture can still provide compensation areas in metropolitan areas from an economic point of view. Even if the supply of compensation measures might be overestimated, we show that there is a significant potential.

Our analyses can thus show political decision-makers, among others, what additional costs can be caused by compensation in close proximity to the place of intervention. The city of Stuttgart, for example, has the goal to carry out compensation measures for interventions in the city area mainly within the city limits (Koch 2009).

Outlook

There is still a need for research on the extension of our modelling approach. One aspect is the reduction of land consumption through compensation measures and thus also the consideration of food production in terms of regional supply, e.g. by analysing the resulting import requirements and environmental impacts. PIC could also play a role in this context, but it must be designed in such a way that agricultural production can continue, but at the same time a high degree of upgrading for nature conservation is possible. PIC, for example, could be implemented with species protection measures such as wildflower strips for the targeted promotion of partridges. In order to take effects on local species populations into account, further nature conservation-related technical data are required which can be integrated into the developed model. All in all, however, even PIC cannot prevent land consumption at all, since ultimately there is always a certain loss of yield. In the next step our model could also be linked with a biophysical model to include yield data for the crops with a higher spatial resolution than the three assumed intensity rates (Mitter et al. 2015).

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