Development of Supply Curves for Biodiversity Offsets on Agricultural Land – a Case Study from the Stuttgart Region*

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Abstract

Impacts on nature and landscape are to be offset in accordance with different nature conservation acts in various European countries. In Germany in particular, biodiversity offsets can also be made in advance, for instance, by booking them into eco-accounts, and then allocating them to an intervention. In Baden-Württemberg, these offset measures are assessed in eco credits in accordance with the Eco Account Regulation (ÖKVO). As a means of income diversification, farmers can voluntarily implement offset measures on their land, and then generate and sell corresponding eco credits. Using a geodata-based model, the potential for implementing biodiversity offsets on arable land – areas with major eco credit potential – is analysed from an economic perspective. The Stuttgart Region is a steadily growing conurbation in south-west Germany. It serves as a study region since the loss of farmland due to large-scale construction measures and the related offsetting are a major issue here. In the analysis, the gross margins of the crops grown, their yield capacity, the associated standard land values and the costs of possible offset measures are used to determine the net present value of the arable land at parcel level. From a theoretical point of view and depending on the market price for eco credits, there is a significant potential for offset measures on arable land. Production-integrated compensation (PIC) – an extensification of arable land use – is less economically viable than the conversion of arable land into grassland or its utilisation for nature conservation. There are major spatial disparities between the city of Stuttgart and the surrounding districts. The implementation of biodiversity offsets is not economically viable at a price of less than € 1.00 per eco credit in the city of Stuttgart. By contrast, in surrounding districts, offset measures may be economically viable and implemented on a large scale for less than € 0.30. This is particularly relevant as the districts concerned are located in the same natural area as the city of Stuttgart and the eco credits can, therefore, be attributed in the event of interventions. Based on derived supply curves, decision-makers can see the scale of additional costs of biodiversity offset measures if they are implemented in a spatially restricted region. The analyses presented here can help decision-makers to more easily weigh up the desired natural characteristics and economic effects in the context of agricultural land.

Keywords

production-integrated compensation; eco credits; agricultural income; nature conservation; biodiversity offsets; agri-environmental policy

1 Introduction

The German Impact Mitigation Regulation (*IMR*) is part of the Federal Nature Conservation Act (*BNatSchG*). Like many other nature conservations acts in Europe, it was enacted to achieve a no net loss of biodiversity and soil functions. According to Article 13 *BNatSchG* significant unavoidable adverse impacts on nature and landscape are to be offset by compensatory or replacement measures. Adverse or negative impacts on nature may result, for example, from the development of infrastructure such as railway tracks or other building projects. Such offsetting approaches also exist in other European countries such as Austria, Switzerland, Sweden or the Netherlands. The approaches in Austria and Switzerland are quite similar to the German one (DARBI et al., 2010). In Sweden offset measures can be decreed by the Swedish Environmental Code (PERSON et al., 2015). In the Netherlands biodiversity offsetting is governed by the Environmental Management Act.

In Germany, according to Article 16 *BNatSchG*, measures to offset expected interventions can also be carried out as part of anticipatory offsetting. This form of habitat banking by means of eco-accounts, land

* This paper received a best paper award at the 60th annual meeting of the Gesellschaft für Wirtschafts- und Sozialwissenschaften des Landbaus (GeWiSoLa). It underwent a regular review process and complies with the quality standards of this journal.

DOI: 10.30430/70.2021.2.70-83

pools or other measures is governed by state law (MAZZA and SCHILLER, 2014; WENDE et al., 2018). In Baden-Württemberg it is regulated by the Eco Account Regulation (*ÖKVO*). In terms of nature conservation, an intervention entailing soil sealing leads to a devaluation of the existing habitat type and a downgrading of the soil function. This results in a need for offsetting equivalent to the difference to the initial habitat type. This is assessed in eco credits as stipulated in the *ÖKVO*. Frequently, agricultural land is used for the implementation of offset measures, for instance, by planting woody plants, and is then no longer available for agricultural production. Other 'classical' measures involve conversion of arable land into grassland or a complete transfer of agricultural land to nature conservation objectives. Since arable land is classified as being of low value (four eco credits per m²) in the *ÖKVO* for nature conservation purposes, there is a correspondingly high potential for upgrading. Intensively used grassland has six and more extensively used grassland 13 eco credits per m² as the starting level. As a result, the conversion of arable land into extensively used grassland is often implemented as a classical measure. However, up to now the scale of offset measures on agricultural land in Germany has hardly been recorded statistically (TIETZ et al., 2012).

One type of measure that differs from the 'classical' offset measures mentioned above is production-integrated compensation (PIC). This entails management or maintenance measures pursuant to Article 15 (3) *BNatSchG* on agricultural and forestry land with continued agricultural and forestry use. The goal of PIC is to permanently enhance the natural balance or landscape on the land and to counteract the loss of agricultural land. At the same time, PIC offers farmers the possibility of active participation in the offsetting process, for instance, by means of voluntary implementation of the measures with regard to envisaged interventions (CZYBULKA et al., 2012; DRUCKENBROD and BECKMANN, 2018). The various measures that are possible on agricultural land generate differing numbers of eco credits which can then be freely traded on the market. However, the 'classic' offset measures are generally valued higher than PIC in terms of nature conservation.

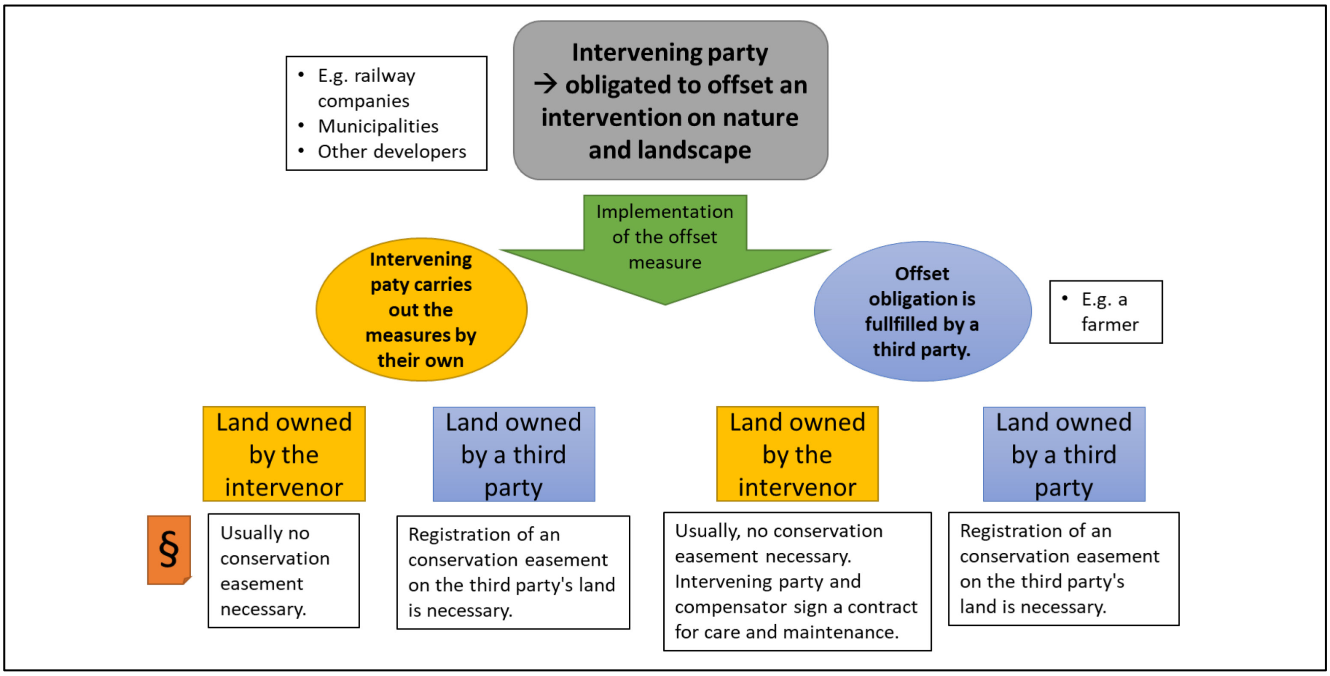
In principle, an offset measure is permanent, depending on the type of intervention, but the maintenance period can be limited to 25 years, for example, if the intended development status of the plot can then be expected to endure without further maintenance (LÜTKES and EWER, 2018; FELLENBERG, 2016). Consequently, pure management and maintenance measures, which also include PIC, are to be implemented for an unlimited period (GIESBERTS and REINHARDT, 2020). In current practice, all measures are associated with permanent maintenance, corresponding care costs and legal security, often in the form of a land register entry, for instance a conservation easement. It can be assumed that the permanent implementation of offset measures in conjunction with a conservation easement on the land will have a negative impact on the market value or mortgage lending value of the 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 may be as much as 70-85%. The economic merit of a measure, therefore, depends on the market price for eco credits, the opportunity costs of agricultural use and the standard land values[1] (*Bodenrichtwert*: BRW).

In contrast to a conservation easement, a so-called institutional assurance of offset measures is possible in some federal states, for instance according to the Bavarian Compensation Regulation (*BayKompV*). In this case, a contract under the law of obligations between the intervening party and an institution such as a recognised foundation guarantees the implementation of offsets, and farmers have the opportunity to implement this (also for a limited period of time) on their land. Another possibility for legal protection would be the use of deposit land. A municipality can earmark parcels of land for offsetting under nature conservation law as part of a development plan. A farmer conducts the measures himself on his own land. This model is implemented by the city of Augsburg, for example (LPV AUGSBURG, 2013). Figure 1 gives a further overview of the circumstances under which an entry in the land register is required for legal protection outside of institutional assurance.

Especially in densely populated urban areas such as Stuttgart, the loss of agricultural land for settlement and transport infrastructure 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, offsetting necessitates additional land take. From the perspective of agriculture, this can further exacerbate farmland scarcity.

[1] According to Article 196 *BauGB* the standard land values (BRW) serve as the average site value for land taking into account the different state of development, e.g. arable land, by observing and comparing their actual prices.

Figure 1. Overview of the options for legally securing biodiversity offsets depending on the ownership of the land covered by the measure



Source: own presentation based on MLR (2011)

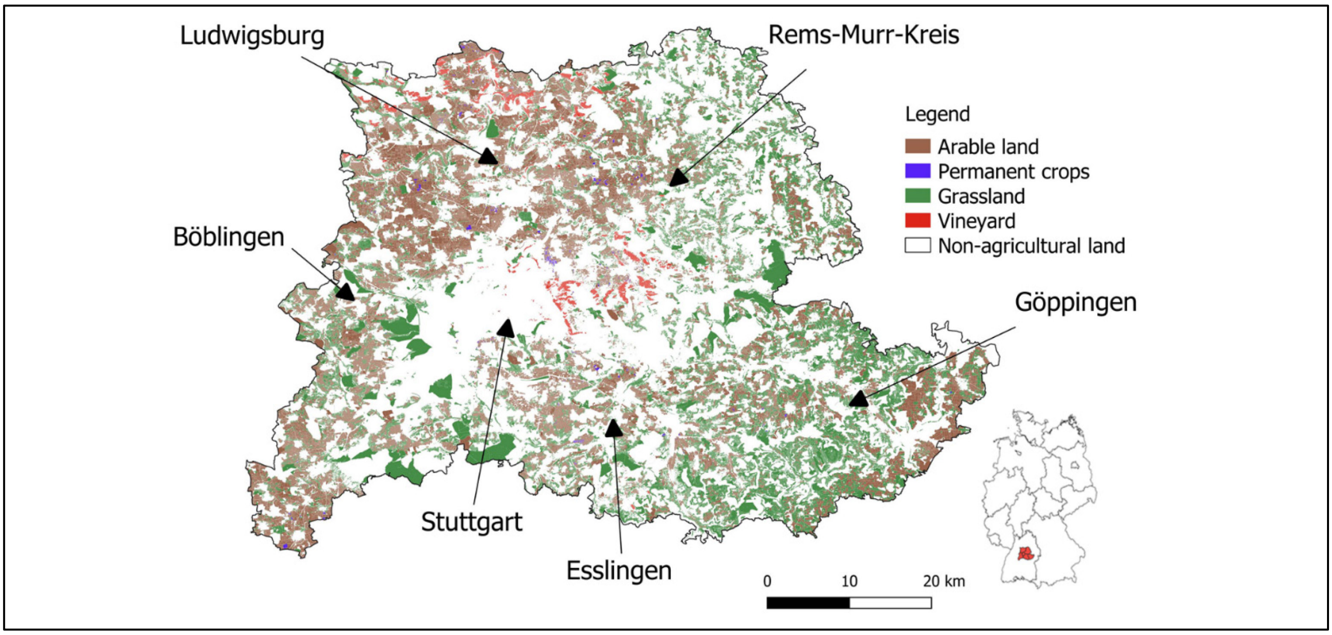
Against this backdrop, we will investigate the potential for biodiversity offsets on arable land that is spatially differentiated and look at different measures such as PIC in the Stuttgart Region. This will enable us to generate insights into the market for biodiversity offsets and the role of agriculture in the offsetting process, i.e. potential opportunities for participation. We start from the hypothesis that there are strong spatial disparities in terms of the general profitability of offset measures especially between the urban district of Stuttgart and the surrounding municipalities (H1). Another hypothesis is that under the current evaluation scheme of the *ÖKVO*, PIC is not very competitive with other measures leading to a complete cessation of agricultural use (H2).

For this purpose, a geodata-based model is used to analyse the merits of various offset measures on arable land in the Stuttgart Region (approx. 73,300 ha), and a spatially differentiated estimate of the potential of offset measures is made. Under static environmental or market conditions and price developments, the model presents the pathways for choosing between three possible offset measures or the retention of previous agricultural land use based on the net present value.

2 General Conditions for Offset Measures in the Stuttgart Region and their Economic Modelling

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 divergence 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 (approximately 56%) of permanent grassland in the utilised agricultural area (UAA) is found. In the city district of Stuttgart this is significantly lower at about 29% (Figure 2). The Stuttgart Region accounts for around 10% of the area of Baden-Württemberg, but 16% of the land taken for settlement and transport infrastructure in Baden-Württemberg between 2000 and 2016 was located there (LUBW, 2018). This means that offset measures under nature conservation law play a major role in this region.

Figure 2. Overview of agricultural land use in the Stuttgart Region



Source: own presentation after BKG (2018)

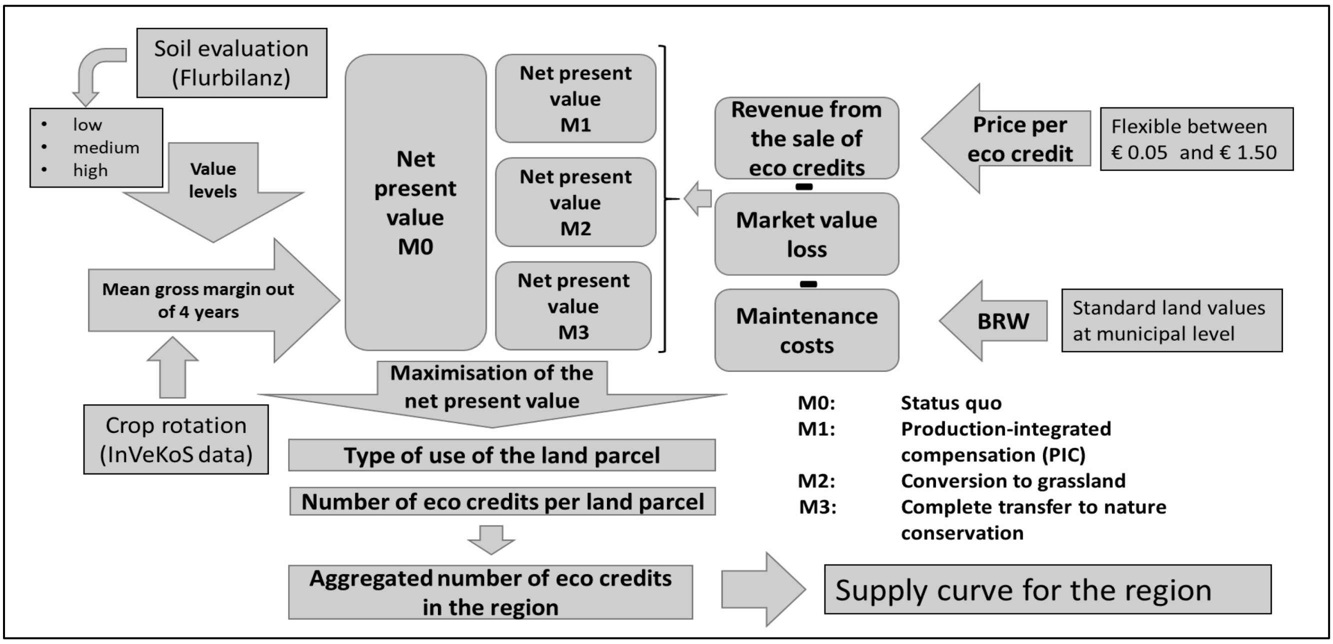
2.1 Structure and Functionality of the Model

Figure 3 gives a schematic overview of the model's structure and functionality. The individual components of the model are explained below.

2.2 Economic Evaluation of Agricultural Production in the Region

For the period from 2015 to 2018, parcel-specific crop rotations and their average gross margins are derived from data in the integrated administration and control-

Figure 3. Overview of the model's structure and functionality



Source: own presentation

ling system (InVeKoS). In total, the considered arable land (ARA) consists of 73,294 hectares and 257,766 parcels and represents about 57% of agricultural area in the region. The remaining UAA consists of 40% permanent grassland and 3% orchards and vineyards.

The individual site conditions and, by extension, the yield capacity are taken into account in a soil evaluation map which is known in German as a *Flurbilanz* (LEL, 2011). The parcels are divided into three value levels that stand for yield capacity: high (priority area 1), medium (priority area 2) and low (boundary and lower boundary). For approximately 11% of the parcels there is no valuation in the *Flurbilanz* which means that the value levels are allocated on the basis of the soil function valuation *Boden als Standort für Kulturpflanzen* of the *Verband Region Stuttgart* ('value level' 4.5 to 5 high, 2.5 to 4 medium and 0-2 low). The calculation of gross margins for the three yield levels per crop (in the following abbreviated as GMs) is based on calculation data and price statistics (LEL, 2018a, 2018b; KTBL, 2010, 2019a, 2019b, 2019c; LFL, 2019; AMI, 2017, 2018, 2019) and on individual publications (LFULG, 2006; AWI, 2019; STATISTIK-BW, 2018). In order to estimate the transformation value of arable fodder via animal use, arable forage crops are valued at € 11.75/GJ or € 0.21/10 MJ NEL respectively depending on their GJ or MJ NEL content, based on the price for maize silage. For land given over to agri-environmental measures and Ecological Focus Areas (EFAs), the average GMs of the main crops in the crop rotation are allocated in a simplified manner. All prices and costs are net amounts from a tax point of view.

As there is uncertainty about future production costs, market prices etc., the GMs may likewise vary. Therefore, we also investigate the sensitivity of the supply of eco credits in the Stuttgart Region to GMs.

The mean GMs differ significantly within the region due to differing crop rotations and yield levels (cf. *Flurbilanz*) (Table 1). For example, the GMs in Stuttgart are about four times higher than in the district of Göppingen. The GMs are capitalised using the perpetual annuity formula and an interest rate of 1.5% based on the LEL (2018a) calculation data.

2.3 Standard Land Values (BRW) in the Stuttgart Region

For about 60% of the districts in the Stuttgart Region, average BRW 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. The missing BRW for the remaining municipalities are calculated 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 municipalities are weighted with the squared inverse distance (TAROSSO et al., 2015).

2.4 Offset Measures under Consideration for the Region

For the estimation of the eco credit potential, it is assumed that, in principle, an offset measure under nature conservation law can be implemented on each plot of land. In addition to current agricultural use (M0), three offset measures – M1 to M3 – are available per parcel (see also Table 2). In accordance with the *ÖKVO*, the M0 to M3 measures are assessed in eco credits. Since measures such as flower strips are not covered as such in the *ÖKVO*, the resulting habitat type must be estimated in practice by the local nature conservation authority. This procedure has been adopted here (GEMEINDE HEDDESHEIM, 2019; GEMEINDE NELLINGEN, 2019; GEMEINDE NECKARWESTHEIM, 2018; DREHER, 2016). Starting from the initial state M0 (arable land with four eco credits per m²), the potential for upgrading M1 to M3 is determined. The maintenance costs of

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 [%]	Mean BRW for arable land in €/m²	Mean gross margins per ha [€]
Böblingen	22,344	66.7	1.3	4.71	952
Esslingen	19,555	50.3	9.2	6.52	1,517
Göppingen	27,828	43.5	0.4	3.15	474
Ludwigsburg	31,429	76.1	2.3	3.90	771
Rems-Murr-Kreis	25,430	45.6	2.9	4.47	953
Stuttgart	2,433	55.7	11	15.97	1,842

Source: own calculation

Table 2. Summary of the possible offset measures M0-M3 in the model with description, evaluation in eco credits, resulting market value losses in scenarios 1 or 2 and the net present value

Measure	Description	Improvement in eco credits per ha ARA	Market value loss of the land (ΔMV_{Mij}) for measure M_i in scenario j		Net present value per ha [€]
			Scenario 1	Scenario 2	
M0	Status quo	0	0%	0%	GM*
M1	PIC	24,000	20%	0%	70% of GM -7,867 - ΔMV_{M1j}
M2	Conversion to grassland	90,000	Difference BRW ARA and grassland	Difference BRW ARA and grassland	3,739 - ΔMV_{M2j}
M3	Transfer to nature conservation	120,000	80%	80%	-3,692 - ΔMV_{M3j}

*GM: The net present value of the gross margin of the crop rotation (2.2) corresponds to the future revenue.
Source: own calculation

the M1 to M3 measures are capitalised with an interest rate of 1.5%. In order to ensure permanent maintenance, it is assumed for all measures in the first scenario that the land use for offsetting is secured by a conservation easement in the land register, which is then taken into account as a loss in market value ΔMV (scenario 1). By way of deviation from this, in the case of M1, it may be possible to waive the land register security for PIC, for instance by means of institutional assurance (scenario 2). Therefore, in the second scenario M1 is calculated without any loss of market value. According to a decision of the European Court of Justice, the conditions for receiving direct payments from the first pillar of the CAP are also met if predominantly nature conservation objectives are pursued (EUROPEAN COURT OF JUSTICE (ECJ), 2010). Therefore, it is assumed that the conditions for receiving direct payments from the first pillar of the EU CAP are equally fulfilled for all measures. The same applies to M3 with complete use for nature conservation (perennial flowering area). In all cases we assume that the land is maintained in Good Agricultural and Ecological Condition and that, in accordance with Article 2 of the Regulation on the implementation of direct payments (*DirektZahlDurchV*), minimum annual management will be undertaken.

M0 corresponds to the status quo, i.e. prior agricultural use is maintained. There is no revaluation in eco credits, there is no loss of market value, and the capitalised average GM is set in accordance with Chapter 2.2.

M1 corresponds to PIC using the example of planting annual or rotating flowering strips on 30% of the plot. Compared to agricultural use, this results in an appreciation of 8 eco credits per m² of measure area. The costs of a one-year flowering strip are estimated at about € 394 per hectare and year (KTBL, 2019a). This corresponds to a measure area of 30% of a parcel and approximately € 118 per hectare and year. The capitalised value is € 7.867. It is assumed that M1 is to be implemented as a maintenance and management measure for an unlimited period of time. In addition, a reduction in market value is assumed due to the entry in the land register of 20% of the BRW for arable land of the respective municipality in relation to the total area of the parcel.

M2 corresponds to the conversion of arable land into grassland with extensive use, i.e. one cut per year. For the target condition 13 eco credits per m² are assumed. This leads to an increase of nine eco credits per m². Based on LFL (2019) and KTBL (2019a), organic grassland management with single mowing is assumed with a yield of 25.8 dt dry matter (DM) per hectare and a price of € 12.96 per dt DM. This results in a positive gross margin of € 60.37 per hectare (net present value of the GM of € 4,025 per hectare). For the establishment of grassland, i.e. seed, tillage and sowing, additional costs of € 286 are assumed in the first year (LFL, 2019). All in all, this leads to a net present value of € 3,739. The loss in market value of the area results from the difference in the BRW for arable land and grassland at the municipal level.

In the case of M3, it is assumed that the entire area is set aside for nature conservation, using the example of the creation of a perennial flowering area on 100% of the parcel area. In practice, such measures are often valued at 16 eco credits per m², i.e. an increase of 12 eco credits per m². The costs are set at € 105 per hectare and year for 25 years (KTBL, 2019a) and capitalised. After that, only minimum maintenance is carried out, which is set at € 33 per annum and capitalised for eternity. The net present value is correspondingly - € 3,692. A market value loss of 80% of the BRW is also assumed.

The revenue from the sale of eco credits is calculated by multiplying the number of generated eco credits per hectare (i.e. the difference between the target condition EC_{Mi} with i=0, 1, 2, 3 and the initial state EC_{M0}) by the net price per eco credit *p*, which is a significant factor. In this way, the net present value of the offset measures (NPV_{Mi}) is calculated as a whole from the proceeds of the sale of the points, minus the loss of market value of the land *ΔMV* in scenario *j* with *j*= 1, 2 and with offset measures *Mi* and the net present value of the GMs (maintenance or management costs and proceeds) NPV_{GM} (formula 1).

$$\boldsymbol{NPV_{Mi} = (EC_{Mi} - EC_{M0}) \times p - \Delta MV_{Mij} +/- NPV_{GM\,(Mi)}} \quad (1)$$

In the model, the use of each individual plot of land is determined individually from an economic point of view by comparing all possible land use options. For each parcel, the model calculates net present values for all measures, and then selects the measure that yields the highest net present value, i.e. either the status quo (M0) or one of the offset measures M1 to M3. The net price is systematically increased at intervals from € 0.05 to € 1.50 per eco credit in steps of € 0.05, and the result is stored with spatial distribution at each step.

In order to analyse the sensitivity of the supply of eco credits with regard to the GMs in scenario 1, the supply is additionally examined in the event of changed net present values of the GMs of +/- 10% or +/- 20%. The market for eco credits is deemed to have unlimited receptivity, i.e. demand and price changes are not taken into account for the time period.

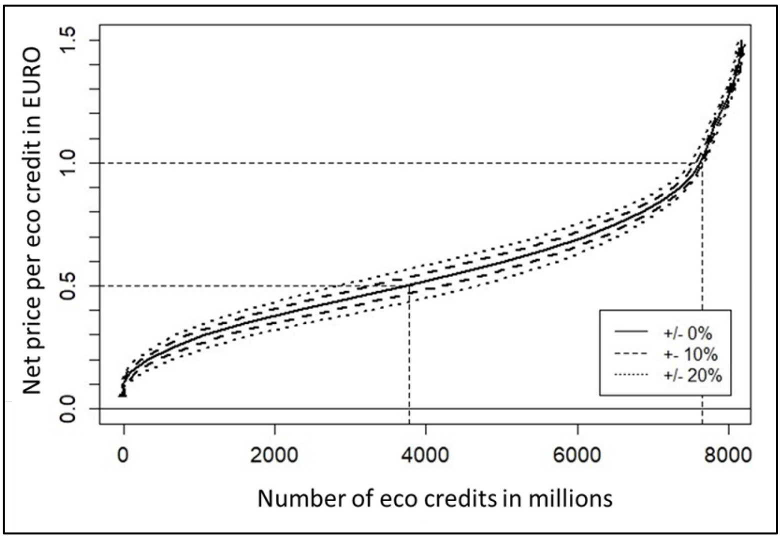
To represent a form of supply for eco credits in the region, a smoothing curve is adjusted to the data using the LOESS method. This corresponds to a local linear regression model (ZUUR, 2012). A smoothing parameter of 0.4 is used.

3 Results

In scenario 1, a maximum of approximately 8.2 billion eco credits can be created at a price of up to € 1.50. From a price per eco credit of approximately € 1.00, however, hardly any additional points can be generated. The supply curve resulting from scenario 1 is equal to a saturation curve (Figure 4).

Table 3 gives the number of eco credits generated in the Stuttgart Region and the impact of changes in the net present values of GMs. As the price per eco credit increases, the influence of GMs on the number of eco credits generated in the region decreases. From € 1.00

Figure 4. LOESS regression curves of the supply for eco credits on arable land in the Stuttgart Region and with a change in the net present value of GM of +/- 10% and +/- 20% depending on the net price for eco credits (scenario 1)



Source: own calculation

Table 3. Total number of eco credits generated on arable land in the Stuttgart Region depending on the price of eco credits and variation as a function of changes in the net present values of the GMs (scenario 1)

Net price per eco credit in €	Total number of eco credits in millions	Relative change in the number of eco credits in percent with a modification of the net present value of the GMs by			
		-20%	-10%	10%	20%
0.25	601.7	68.15	29.53	-22.37	-39.16
0.50	3,776.5	25.56	13.25	-13.32	-25.13
0.75	6,507.3	4.68	2.74	-3.65	-8.19
1.00	7,661.8	0.94	0.51	-0.77	-1.52
1.25	8,026.3	0.76	0.38	-0.44	-0.84
1.50	8,179.0	0.42	0.20	-0.22	-0.59

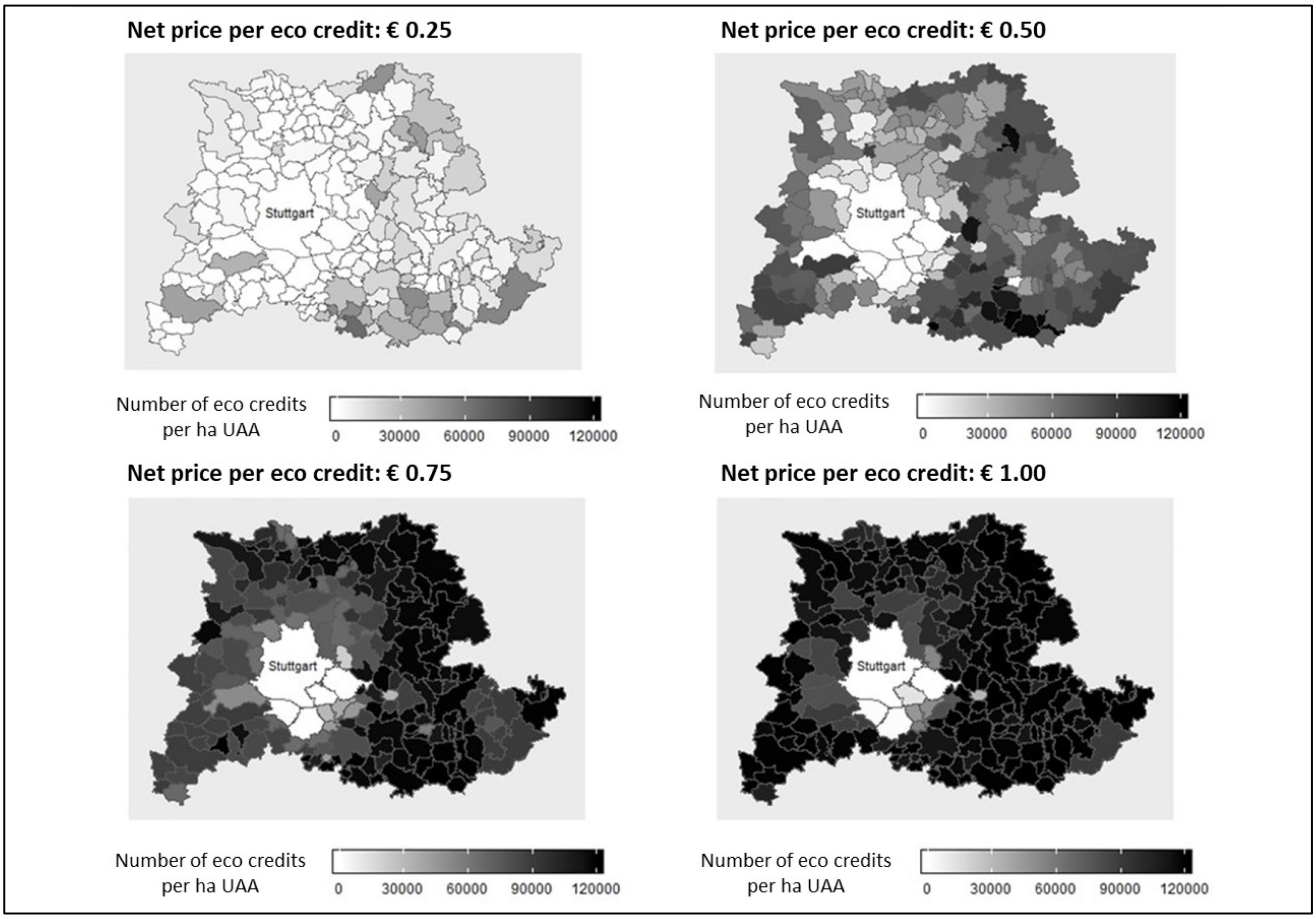
Source: own calculation

per eco credit, the supply hardly reacts to changes in the capitalised GMs.

In no case is PIC (M1) carried out. Also, M3 is hardly ever chosen up to € 0.50 per eco credit. Up to a price of about € 0.60, the preference for conversion to grassland (M2) increases on average. At € 0.60, M2 accounts for about 56% of arable land. As the price continues to rise, the share of M2 decreases again and M3, the provision of the land for nature conservation, becomes more preferable. The additional proceeds from the eco credits overcompensate for the higher capitalised maintenance costs and the higher loss of market value. This means that, at a price of € 1.50, about 90% of the arable land in the Stuttgart Region would be given over to the M3 measure. This corresponds to about 96% of the eco credits generated. The results also show that the high potential for the implementation of offset measures on arable land in the Stuttgart Region is highly differentiated spatially (Figure 5). For example, at a price of € 0.25 per eco credit, many offset measures would already be implemented in the district of Göppingen.

Below a price of € 1.00 per eco credit, no biodiversity offsets would be implemented at all in the Stuttgart urban district. At € 1.25, about 12% of the arable land in Stuttgart would be converted into grassland, at € 1.50 the proportion is about 55%. This would mean that only M2 would take place in Stuttgart. Compared with conversion to grassland (M2) and complete transfer to nature conservation (M3), PIC (M1) entails a relatively low nature conservation value added under the *ÖKVO* in relation to the costs, but allows flexibility in arable farming. Especially at low BRW, PIC is less attractive, as the higher loss of market value in M2 and M3 is more than compensated by the higher revaluation in eco credits in these measures. The adjusted R^2 of the relationship between BRW and the average number of eco credits generated per hectare of arable land at municipal level at a price of € 0.50 per point is 0.33, at a price of € 1.00 it is 0.66 and at € 1.50 it is 0.46. Since, at a price of € 1.00, almost all areas would already be covered by measures, an increase in the number of eco credits could only be achieved by implementing higher value measures.

Figure 5. Average number of eco credits per hectare of utilised agricultural area (UAA) generated in the model by municipality in the Stuttgart Region at four different prices per eco credit (scenario 1)



Source: own presentation after 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 € 0.50 per eco credit and, at a price of € 1.10 per eco credit, to only about 2.6% of the arable land in the region (Table 4). However, in the urban district of Stuttgart, M1, at a price of € 1.10, accounts for the largest share of arable land at just under 70%. It can be observed that, 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, it has a low impact (Figure 6).

A complete transfer of the area to nature conservation (M3) does not maximise the net present value of the GM on any parcel in the city of Stuttgart. In general, PIC faces strong competition from other measures that lead to a higher revaluation in eco credits.

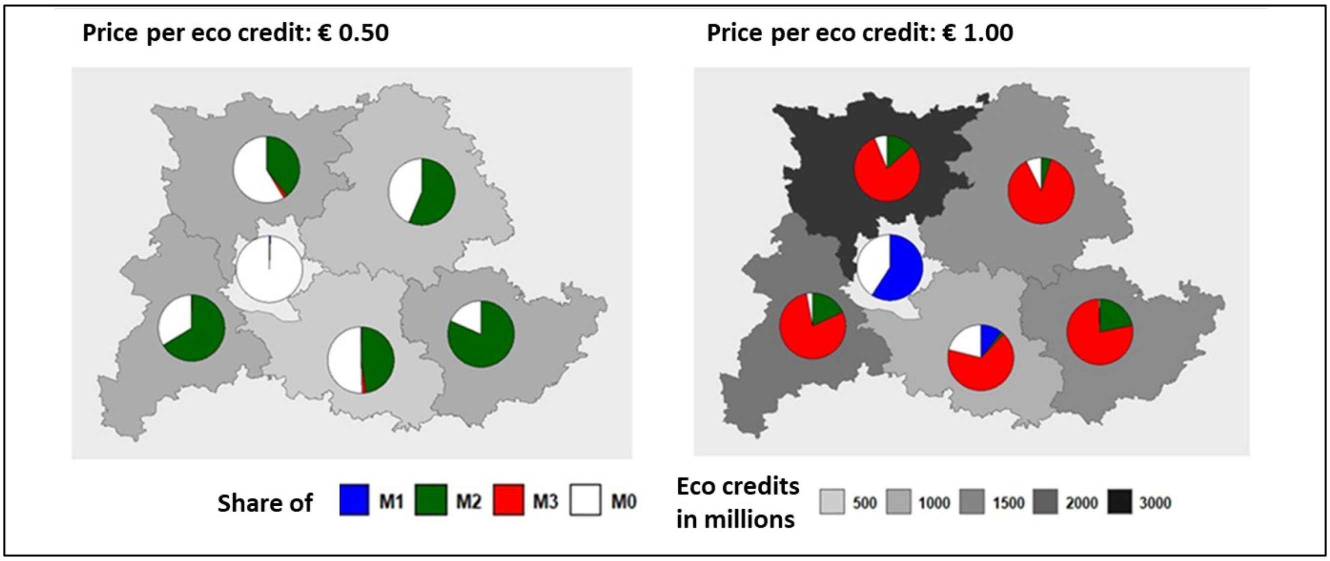
In order to be able to relate the model results to a realistic demand for eco credits, the demand estimate of the *Verband Region Stuttgart* can be used. In this

Table 4. Total number of eco credits generated on arable land in the Stuttgart Region as a function of the price for eco credits and shares of the arable land covered by the measure if no land register entry is made for PIC (scenario 2)

Net price per eco credit in €	Total number of eco credits in millions	PIC (M1)		Conversion to grassland (M2)		Transfer to nature conservation (M3)	
		Share	Area in ha	Share	Area in ha	Share	Area in ha
0.10	9.0	0.0%	0.0	0.1%	100.4	0.0%	0.0
0.20	274.7	0.0%	0.0	4.2%	3,051.8	0.0%	0.0
0.30	1,046.5	0.0%	0.0	15.9%	11,628.3	0.0%	0.0
0.40	2,314.3	0.0%	2.4	34.6%	25,394.5	0.3%	239.4
0.50	3,777.3	0.0%	34.5	51.4%	37,644.3	4.4%	3,237.3
0.60	5,064.6	0.3%	219.6	55.7%	40,794.5	15.8%	11,565.4
0.70	6,106.2	0.9%	636.1	47.9%	35,111.3	33.3%	24,424.4
0.80	6,932.5	1.7%	1,218.0	33.8%	24,742.7	53.2%	38,970.4
0.90	7,389.3	2.1%	1,524.6	22.1%	16,232.5	67.0%	49,098.3
1.00	7,696.8	2.5%	1,799.5	12.7%	9,295.5	77.5%	56,808.7
1.10	7,752.0	2.6%	1,886.8	12.5%	9,177.7	78.2%	57,339.2
1.20	7,849.8	2.4%	1,776.5	10.4%	7,587.7	81.0%	59,369.3
1.30	8,033.4	2.3%	1,671.0	3.7%	2,710.6	88.1%	64,577.7
1.40	8,104.2	2.0%	1,430.0	2.4%	1,776.7	89.9%	65,916.6
1.50	8,141.0	1.4%	1,054.6	2.9%	2,127.3	90.1%	66,035.4

Source: own calculation

Figure 6. Overview of the eco credits generated by district at the price of € 0.50 and € 1.00 per point and the shares of the individual measures after (scenario 2)



Source: own presentation after BKG (2018) estimate, all known development plans in the Stuttgart Region for the period from 2019 to 2030 were evaluated and demand for the whole region and the individual districts was established (JENSSEN, 2020). Assuming that offsetting would take place exclusively on arable land and that the measures could be implemented without spatial restrictions throughout the region, our analyses suggest that the estimated demand of 775 million eco credits could be met at a price of € 0.27 per eco credit. Offset measures would have to be implemented on about 10% of the arable land in the Stuttgart Region, which would mainly be located in the districts of Göppingen and Rems-Murr-Kreis.

However, since the local nature conservation authorities often demand offsetting in the spatial proximity of the intervention, the tradability of eco-points may be partially restricted. Table 5 therefore gives an overview of the possible impact of a spatial restriction on the implementation of offset measures. If the demand for eco credits is to be covered in the respective district, the necessary prices per eco credit according to our model would, in some cases, be substantially higher than the price of € 0.27 with spatially unrestricted implementation. This applies in particular to the city of Stuttgart where € 1.17 per eco credit would have to be paid. However, spatial disparities are apparent here, as demand in the district of Göppingen could already be met at € 0.18 per eco credit, and there would be no impact on the district of Böblingen. This means that if the offset measures are implemented in a spatially unrestricted area, prices per eco credit could even increase in some districts. All in all, based on the results of the analysis, spatially limited offsetting in the respective district would lead to additional costs of about € 20 million outside the district of Göppingen for the period up to 2030.

Table 5. Required prices per eco credit to cover the demand in the respective district and the resulting additional costs compared to unrestricted spatial implementation in the whole region

Urban/rural district	Demand for eco credits in millions	Minimum price per eco credit in euro to meet the demand	Aggregated additional costs of full implementation of offsetting in the district instead of in the whole region in million €
Böblingen	170	0.27	0.0
Esslingen	150	0.28	1.5
Göppingen	120	0.18	0.0
Ludwigsburg	190	0.32	9.5
Rems-Murr-Kreis	140	0.30	4.2
Stuttgart	5	1.17	4.5
Stuttgart Region	775	0.27	19.7

Source: own calculation

4 Discussion

We identified major spatial disparities in terms of profitability of offset measures, which is in line with hypothesis H1. In addition, PIC is not very competitive with other measures leading to a complete abandonment of agricultural use under the current evaluation scheme as defined in the *ÖKVO*. This supports hypothesis H2.

The most cost effective measures would be implemented in the east or south east of the region in the districts of Göppingen and Rems-Murr-Kreis. In the agglomeration of Stuttgart and neighbouring municipalities such as Filderstadt, the BRW for farmland is comparatively high at around € 16/m². This means that the potential loss of market value of the parcel can be very high. In addition, arable use is characterised by a high proportion of special crops with high gross margins. A higher price per eco credit is, therefore, necessary here to implement offset measures than in the more rural or agricultural municipalities located further away from the centre of the region. Furthermore, we used three levels (low, medium, high) of crop yields depending on the soil quality. Hence, at low prices per eco credit the sites with a low yield capacity and low BRW are used for offsetting first.

The attractiveness of PIC can be increased by abandoning conservation easements. It can likewise lead to the carrying out of offset measures closer to intervention in areas with high standard land values. In this context BUSSE et al. (2019) were able to demonstrate a negative effect of a conservation easement on the acceptance of offset measures by farmers, in general.

Eco credits are usually traded at market prices between € 0.50 and € 1.10, depending on the location in Baden-Württemberg (MÖSSNER, 2019). Our derived net prices represent the opportunity costs of the land and the implementation of the measures. The estimated net price of € 0.27 per eco credit for the medium-term demand of 775 million (estimated by JENSSEN (2020)) is much lower than the actual market price. Firstly, the net price of € 0.27 per eco credit assumes the spatially unrestricted establishment of biodiversity offset measures. Secondly, the market price is negotiated between the intervening party and the seller. Consequently, it usually includes a profit margin or a risk premium (KOH et al., 2019) in addition to opportunity costs. This could partly explain the difference. In accordance with this, LE COENT et al. (2017) found that the payments for biodiversity offsets must be higher than the compliance costs to ensure that farmers implement appropriate measures. Therefore, the acceptance by farmers of various offset measures is an important factor, partly because the flexibility of land use could play a key role in the context of intergenerational land use. A risk premium on the price of long-term commitment to certain production systems could be ascertained, for instance, in choice experiments (GILLICH et al., 2019), and then factored into economic models (PETIG et al., 2019). Some farmers might not accept offset measures at all. However, many agricultural stakeholders are aware of an increasing social demand for biodiversity (LANGE et al., 2015; FLEURY et al., 2015). This is reflected in important areas of EU policy through the EU Biodiversity Strategy (EUROPEAN COMMISSION, 2020). Consequently, biodiversity offset measures could also play a role in catering for social preferences for nature conservation while, at the same time, contributing to farm income.

For the economic evaluation of the profitability of offset measures, we have focused on the net present value based on GMs including variable, excluding fixed labour costs. For the farmer, potential labour time savings could also be important, an aspect we have neglected in our study. Taking this time saving effect into account, the complete transfer of farmland to nature conservation (M3) might become more attractive at lower prices per eco credit already. However, this could also strongly depend on the individual opportunity costs (GEISBAUER and HAMPICKE, 2012).

As the assessment of the offset measures may differ between the local nature conservation authorities, this aspect plays a contributory role in the profitability of the measures. We assume an unlimited maintenance period for PIC, and this could be an obstacle for acceptance by farmers. From a nature conservation point of view, a limited maintenance period is possible if a self-sustaining habitat can be assumed. In the case of a PIC measure (M1) normally integrated in the crop rotation, the existence of the habitat largely depends on maintenance. Nevertheless, besides the case of Baden-Württemberg, there are attempts to limit the maintenance period of PIC to 25 years, in Bavaria for example. In order to fulfil the legal obligation of a permanent biodiversity offset, some approaches seek to register an easement for another parcel. This can also be non-agricultural land with high nature conservation value. Thus, the status of this land can be secured although no measures are implemented on it (HIMMLER, 2014). The intervening party, however, has to find an additional parcel and additional costs might be incurred.

The proceeds from the sale of the eco credits may well be higher than the market value of the land on which the offset measure is implemented as, in this case, the measures are voluntary. An intervening party could therefore have a motive to purchase land, and implement offset measures himself. However, the acquisition of eco credits can still be advantageous for the intervening party due to a shortage of land and a time advantage (TEN KATE and CROWE, 2014). It should be borne in mind that, in individual cases, offset measures can be implemented more favourably on forest or other municipal land (which is not arable land), and thus the supply curves can only be interpreted in a limited way.

Our model approach allows simplified, spatially differentiated consideration of the economic merits of offset measures on arable land, and can be extended in the future to simulate different offsetting strategies on a landscape scale (TARABON et al., 2021). One aspect of this will be the reduction of land use by offset measures, and thus the consideration of food production in terms of regional supply. For this purpose, the model could also be coupled with a biophysical crop simulation model to include more spatially explicit yields in the analysis than just three levels from low to high as in our study.

5 Conclusion and Outlook

The city of Stuttgart, for example, aims to implement offset measures mainly within its city limits (KOCH, 2009). Since the spatial location of offset measures in relation to the intervention site can also impact the well-being of the local population (JONES et al., 2019), any additional costs must also be considered from this perspective. Therefore, our analyses can show political decision-makers what additional costs can be caused by offsetting in the immediate proximity of the intervention site. When interpreting the results it must, of course, be borne in mind that there may also be spatial disparities within the districts.

We further conclude that if PIC is (politically) desired, it often necessitates higher prices per eco credit and/or alternative institutional arrangements (takeovers) of the conservation easement. PIC does, however, also imply a certain loss of land as there is usually a decrease in productivity. However, in contrast to other measures that lead to an irreversible conversion of arable land, at least the status of arable land can be maintained. Voluntary participation by farmers may be more likely to encourage the use of low-yield sites, as it allows for targeted management of the measures instead of using areas that are randomly available (WENDE et al., 2018). In this way, the overall loss of productivity can be reduced.

In addition, there might be a potential to reduce the land loss with PIC in the context of species protection. Therefore, PIC could consider the needs of agricultural production and nature conservation at the same time. PIC could, for example, be combined with species protection measures such as a partial forgoing of cereals harvesting to protect field hamsters. The estimation of the achievable eco credits requires integration of additional nature conservation-related technical data in the developed model. In this respect, our economic assessment of the spatial location of offset measures can be placed in the context of other studies that consider this aspect from a planning or ecological perspective, for instance KIESECKER et al. (2010).

Furthermore, in some German states, for instance Nordrhein-Westfalen, organic farming is already a possible offset measure or a form of PIC. In Baden-Württemberg, however, nature conservation enhancement always depends on the initial state and the possible potential target condition of the field site. Since organic farming can be also quite intensive (DAHAN et al., 2014), for instance cultivation of specialty crops, a generalised appreciation in eco credits was rejected during the evaluation of the *ÖKVO* in Baden-Württemberg (PAN, 2018). In addition, management standards may also differ depending on the type of organic certification, for instance, in accordance with EU requirements or organic producer organisations such as Demeter. In order to achieve a certain degree of nature conservation enhancement, it may therefore be necessary to define minimum standards that go beyond this or a combination of measures, for instance, with flower strips. It should be noted that the mere conversion of an individual field to organic farming does not initially permit the marketing of the products grown there as organic. However, it may well be an opportunity for a farm to test organic farming on individual fields before converting the whole farm. Therefore, conversion of the whole farm should be regarded as an option. It should also be noted that conversion to organic farming is also supported by the second pillar of the CAP. Therefore, the profitability of organic farming as PIC also depends on alternative financial support options, as twofold support under biodiversity offsetting and CAP is not possible (FRIEBEN, 2017). If an easement is required, organic farming in particular could possibly lose its excellence status as PIC. In addition, many farmers manage rented land (STATISTISCHES LANDESAMT BADEN-WÜRTTEMBERG, 2017). Landlords would therefore have to accept an easement. In a next step, organic farming could be examined more closely as PIC.

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Acknowledgements

This research was funded by the German Federal Ministry of Education and Research (BMBF) within the project RAMONA (grant ID: 033L201B) within the funding activity Stand-Land-Plus. All knowledge and opinions expressed in the article are solely those of the authors without influence of the funding institution. The authors pursue no commercial interests.

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