Expert-Based Maps as a Regional Planning Tool Supporting Nature Conservation and Production-Integrated Compensation—A German Case Study on Biodiversity Offsets

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Abstract: Many countries worldwide have developed guidelines for offsetting impacts on nature and landscape. Suitable locations are the prerequisite for the implementation of these measures, and this might lead to conflicts with agriculture. In addition, comprehensive planning is often lacking and potential added values for nature conservation are not exploited. Concepts such as the so-called production-integrated compensation (PIC) have been introduced to give farmers the opportunity to actively participate in the offsetting process and improve cooperation. However, up to now, PIC has only rarely been put into practice. Against this backdrop, we have developed a regional planning tool for the implementation of PIC in practice. Based on geodata such as soil data, agricultural structure, or natural conditions at the field and landscape level, the general suitability, and specific measure-based recommendations for each plot can be verified with the help of a decision support system. These factors are assessed from both a nature and an agricultural perspective. The goal here is to highlight synergy effects and increase the likelihood of the proposed measures being implemented. Our tool facilitates the integrated planning of biodiversity offsets at regional level. In this way, it can promote the bundling and networking of measures. However, on-site analyses should be undertaken to complement the implementation of measures.

Keywords: biodiversity offsets; offset implementation; production-integrated compensation; nature conservation; landscape planning; agri-environmental policy

1. Introduction

Land taken up by settlement and infrastructure development is one of the major drivers of biodiversity loss [1–3]. As part of their so-called "no-net-loss" policies, many countries around the world have implemented regulations for offsetting impacts on nature and landscapes [4,5]. In Germany, this is anchored in the Nature Conservation Law (*BNatSchG*) in what is known as the "Impact Mitigation Regulation" (IMR) and follows a polluter pays principle [6]. Offsetting is actually the last step in the mitigation hierarchy after avoiding or minimizing impacts on nature and landscapes [7]. The requirement for offsetting is usually linked to various related questions, for instance, where and how offset measures can be conducted in the most efficient and effective manner from an ecological

perspective [8,9]. Hence, in addition to the land taken up by impacts, further land is required for the implementation of offset measures [10].

In contrast to strategic planning on a regional level, randomly available sites are often taken up for offsetting [11]. Hence, potential added values for nature conservation generated by pooling and networking measures are often not exploited. In addition, there may be land use conflicts with agriculture as farmland is frequently used for biodiversity offsets [10,12]. Despite this, agriculture in particular could be a potential and important partner in nature conservation, as it occupies the largest area of land in Germany [13]. It is therefore an important stakeholder in biodiversity offsetting [14–17]. Concepts such as the so-called production-integrated compensation (PIC) have been introduced to give farmers the chance to actively participate in the offsetting process, and to improve cooperation between nature conservation and agriculture [18–20]. In general, there is no one single definition of PIC. However, PIC can be broadly defined as management or maintenance measures as set out in Article 15 (3) *BNatSchG* on agricultural and forestry land with continued agricultural and forestry use. It leads to a permanent enhancement of nature or landscapes. However, it is not always possible to clearly distinguish PIC measures from other offset measures on agricultural land in individual cases. In addition to the type of measure, individual farm conditions play a role here. For example, the creation of a meadow orchard or the conversion of arable land into grassland may well be a PIC measure for an individual farm if it fits into the farm concept. For other farms, however, this would not constitute a PIC measure as they would not be able to derive a monetary return from the land.

In general, one goal of PIC is to minimise the loss of agricultural productivity and to preserve agricultural land use [18]. In particular, measures that only take up a small area of a parcel of land and yet lead to an upgrading of the entire area would count as PIC. Therefore, the following conditions should be met from our perspective, according to Mössner [21], to address PIC from an agricultural angle:

I.   The measures are implemented in a consensus with agriculture.
II.   There is still a monetary return from agricultural land through production.
III.   Both forms of "land sparing" and "land sharing" are possible, i.e., spatial separation between extensification and intensification or extensification and production on the same area (e.g., flower strips and extensive cultivation of cereals).

Especially in metropolitan areas, the multifunctionality of agriculture takes on a special significance [22]. In addition to the production of high-quality food, the emphasis is also on the cultivation of cultural landscapes. It is precisely here that PIC could also contribute directly to the diversity of nature and landscapes as a recreational area for the population in a conurbation [23]. Agriculture also recognises the need of these groups especially in these peri-urban areas. Consequently, PIC could also generate added value in the context of social recognition [24]. From a political point of view, the topic of biodiversity and agriculture is currently very much on the agenda and is shaped at EU level by the EU Biodiversity Strategy [25] or the EU Farm-to-Fork Strategy [26]. The main objectives include strengthening protected areas and reducing the use of plant protection products. The political demands, therefore, also present a challenge for many farms from an economic point of view [27]. At this point, PIC measures could, of course, also offer economic options that enable synergies to be tapped into. By means of the guaranteed maintenance of the measures, nature conservation could also benefit from PIC [28]. According to a study by Rabenschlag et al. [29] in Baden-Württemberg, there are often many deficits in the implementation of biodiversity offsets at the present time.

However, production-integrated compensation measures are rarely implemented in practice [21]. As far as agriculture is concerned, PIC measures are particularly in demand and could be expanded in the future [30]. There is often a lack of information and on-site communication, as well as a general lack of overarching planning [30]. In the field of nature conservation and ecosystem services, expert-based assessment approaches using geodata have been used to map the potential for specific ecosystem services [31] or green

infrastructure planning [32], for example. Against this backdrop, we have developed a regional planning map as a tool for promoting PIC in the Stuttgart Region in the German state of Baden-Württemberg based on expert knowledge. In this context, we primarily proceeded from the hypothesis that there may be synergy effects between nature conservation objectives and agricultural interests. This is based on previous studies which have shown that farmers are indeed willing to implement voluntary measures under certain conditions [16,19].

Based on available and suitable geodata for soil conditions, agricultural structure, protected areas, etc., various PIC options have been evaluated at the field level to derive specific recommendations for offset measures. In this context, we focus on measures on arable land and grassland. Both agricultural and nature conservation perspectives were taken into account in order to elucidate the effectiveness and likelihood of implementation. In addition, potential synergy effects have been identified to promote the networking and bundling of measures. This means that our regional map for PIC could be a relevant aid for decision-makers at the municipal level when planning offset measures and could serve as a basis for constructive discussions with farmers. Hence, measures that appear to make sense for both agriculture and nature conservation can be selected.

2. Characterisation of the Study Area

The Stuttgart Region is one of the strongest economic regions in Germany with a high volume of land taken up for settlement and transport infrastructure development [33,34]. It accounts for approximately 10% of the total area of Baden-Württemberg. Moreover, 16% of the total land use for settlement and transport infrastructure in Baden-Württemberg was earmarked here between 2000 and 2016 [35]. Therefore, offsetting is an important factor in this region.

In total, the utilised arable land (UAA) in the Stuttgart Region amounts to approximately 133,766 ha according to the 2019 dataset of the Integrated Administration and Control System (IACS), which was provided by the Baden-Württemberg Ministry of Rural Affairs and Consumer Protection. About 54% of this is arable land (ARA) and 38% grassland. The remaining area consists of vineyards and permanent crops. There are major spatial disparities in the region's agricultural structure. Whereas the districts Böblingen and Ludwigsburg are dominated by arable farming, the eastern districts Rems-Murr-Kreis and Göppingen have a high proportion of grassland. Especially in the urban district of Stuttgart, specialty crops, such as fruits and vegetables, are cultivated on more than 10% of the arable land (Figure 1).
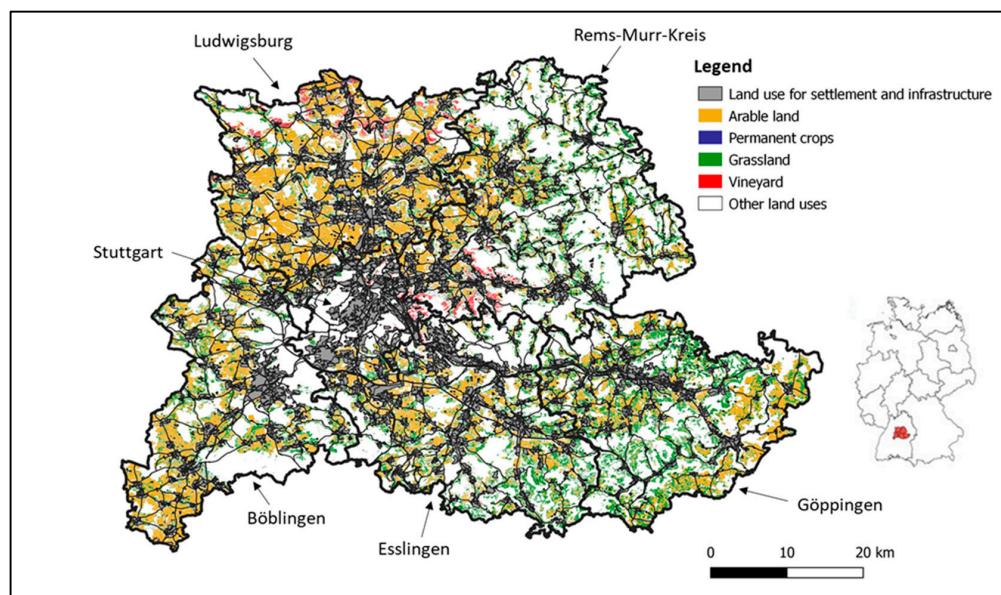

Figure 1. Land use in the Stuttgart Region based on IACS data and BKG [36] and Verband Region Stuttgart [37].

3. Material and Methods

3.1. General Procedure and Input Data for the Regional Map

The site-specific selection of measures plays a major role in the successful implementation of PIC measures [23]. Therefore, both nature conservation and agricultural concerns must be taken into account. For example, a measure may be appropriate and prudent from a nature conservation point of view on the one hand, but acceptance by agriculture may be low on the other. As a result, the likelihood of implementing the measure may be limited. Therefore, in the following, the interfaces between nature conservation and agricultural concerns in the compensation process are examined on the regional level. Figure 2 gives an overview of the entire approach and process that was used to draw up the regional map for the implementation of PIC measures on agricultural land. The aim is to derive recommendations for PIC measures at the plot level. To this end, the immediate surroundings of a plot (field level) and the wider spatial environment (landscape level) are taken into account. In this context, plots mean the arable and grassland plots taken from the IACS dataset. Beside the IACS dataset also agricultural statistical data was used regarding the agricultural perspective. This data is based on the so-called Agrarstrukturerhebung in Germany. This is a nationwide and regularly conducted survey of farms on farm structure, land use, and livestock production, etc. [38].
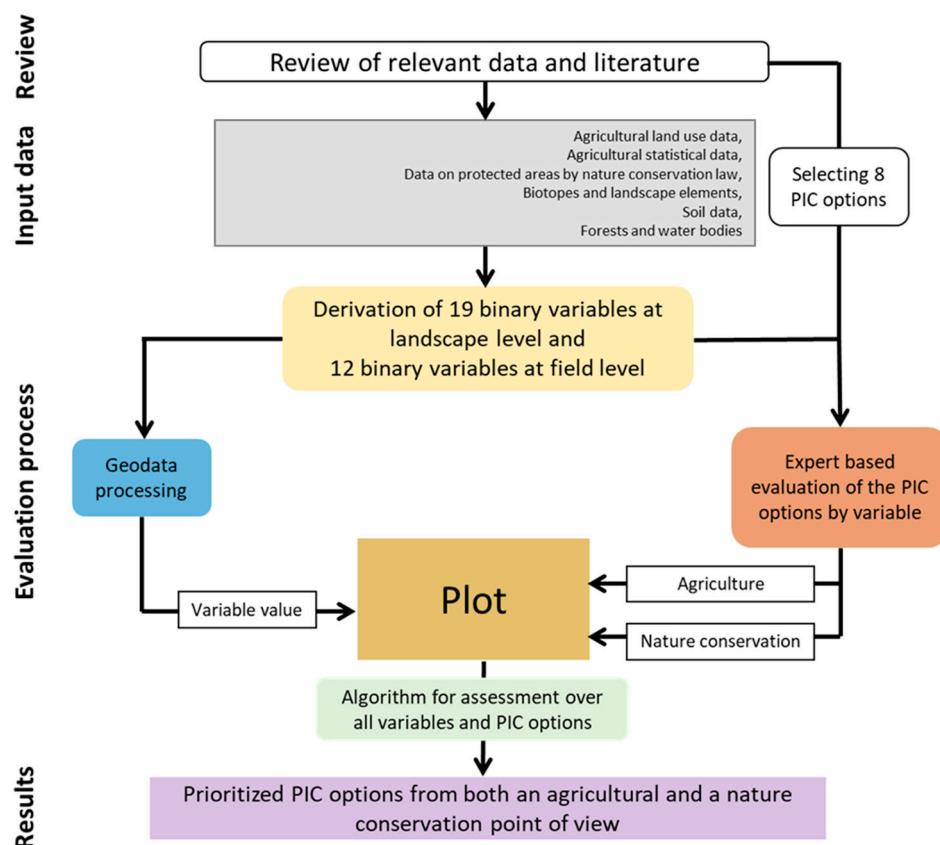
Figure 2. Overview of the entire approach and process of the development of a regional map for PIC measures.

3.2. PIC Options Considered for the Regional Map

Basically, there are numerous proposed measures for PIC that needed to be discussed at the outset [18,23,39,40]. Based on the literature review carried out in this context, 14 potential and typical PIC measures were initially identified, and a description was provided for the model (Table 1).

Table 1. Overview of the selected PIC measures and their description.

PIC Measure	Description
Temporary Greening	Temporary greening is carried out, for instance, of tramlines using a flower mixture in the tramline width of usually 2.50 m to 3.00 m. Fertilisers may be used on these tramlines but not pesticides.
Rotating Perennial Flower Strips	A system of annual/perennial flower strips is developed to ensure that sufficiently developed flower strips are always available. Before a flowering strip is removed, a new flowering strip is planted with sufficient lead time to ensure that the habitat characteristics of the flowering strips are uninterrupted. If, due to crop rotation, it is not possible to establish new flowering strips with annual flowering strips in advance, individual flowering strips must be left for 1.5 to 2 years. The continuous presence of flowering strips enables them to serve as a refuge for several species in the field.
Permanent Flower Strips and Areas	Permanent flowering strips or areas are established on arable land, each of which makes up only a small part of the arable field. This can be done along paths and field edges, for example, where the flower strips are established as green bands. Regular re-establishment takes place (e.g., every 3 to 5 years). In order to regulate undesirable plant species, annual planting can also be undertaken from time to time as an exceptional measure.
Fallow Land	This is arable fallow land with self-vegetation and annual mowing, but no removal. In addition, no fertilisers or pesticides are used. Fallowing is done in rotation with a standing time of 3–5 years on one area.
Extensive Used Arable Land	A field is only cultivated extensively on a permanent basis. Pesticides and synthetic fertilisers are no longer used. Reduced mechanical weed control and organic fertilisation are possible. Seeds are sown with wider or double seed row spacing, for instance 25–30 cm. This encourages the growth of wild herbs on the field. This measure is carried out in rotation in accordance with the crop rotation.
Skylark Windows	In the cereal crop, about 5–6 lark windows per ha are created, each at least 25 m^2 in size. The usual use of fertilisers and pesticides is maintained.
Infield Nature Protection Spots	In an arable field, individual sites with low yield but high conservation potential (e.g., wet sites, small water bodies, dry knolls) are removed from agricultural land use.
Stubble Fallow	After the grain harvest, the stubble is left on the field at a height of about 20 cm until at least February. Fertilisation and synthetic chemical pesticides are used during the growing season of the arable crop. In the period from harvest to February there is no fertilisation, no use of plant protection products and no mechanical weed control.

Table 1. *Cont.*

PIC Measure	Description
Unharvested Strips of Cereals	A portion of a crop is not harvested, but is left on the field until at least February. It serves as a food base or refuge for specific species such as field hamsters. No synthetic fertilisers or pesticides are used in this area.
Reduced Tillage	Only greatly reduced tillage is used, i.e., usually no-till and little tillage before and after harvest.
Conversion of Arable Land into Grassland	Arable land is converted into extensively used grassland. The use of synthetic fertilisers and pesticides is avoided. There is at least one annual mowing with removal.
Extensification of Grassland	A permanent grassland area is only used extensively, i.e., no fertilisers or pesticides are used. In addition, strips of old grass are left when mowing.
Uncut Hay Meadow Strips	In meadows, individual strips are left out during the first mowing. These strips of old grass, about 6 m wide, are then mown from mid-June at the earliest.

Some measures do show similarities with regard to the site conditions. The measures have, therefore, been grouped into a total of eight PIC options for evaluation in the map. In this context, all measures relating to the extensification of arable land or grassland use were combined in each case. Table 2 gives an overview of how the individual measure were grouped in the options.

Table 2. Grouping of the measures in PIC options.

PIC Measure	PIC Option
Greening	Greening
Annual flower strips	Flower strips
Permanent flower strips	Permanent flower strips
Fallow land	Fallow land
Extensively used arable land	Extensive arable farming
Skylark windows	Extensive arable farming
Infield nature protection spots	Extensive arable farming
Stubble fallow	Extensive arable farming
Unharvested strips of cereals	Extensive arable farming
Reduced tillage	Reduced tillage
Conversion of arable land into grassland	Grassland
Extensification of grassland	Extensification of grassland
Uncut hay meadow strips	Extensification of grassland

3.3. Description of Data Input and Processing

Based on a review of relevant and available data, 19 variables were derived at the landscape, i.e., the municipal level, and 12 variables at the field level (Tables 3 and 4). From the perspective of nature conservation, special attention was paid to protected areas under nature conservation law and elements of the biotope networks that may be especially relevant for PIC [23]. From an agricultural perspective, the agricultural structure, for instance the share of grassland or arable land in the utilised agricultural area per municipality or the share of specific crops, such as specialty crops, that also reflect agricultural opportunity costs, for example, were some of the criteria considered [41].

The variables were then treated as binary variables, i.e., a specific characteristic is present or not. Certain limits were set for each variable on the municipal or field level based on expert knowledge. The definition of these limits at municipal level was based on the typical values in the Stuttgart Region. The selected values are predominantly

above the median for all municipalities. For the proportion of grassland at the municipal level, this limit was set at 50%, for example. If a municipality exceeds this proportion, the characteristic of a high proportion of grassland in the municipality is met at the landscape level.

Table 3. Variables used to create the PIC map at the landscape, i.e., municipal level.

Variables	Source of the Data
Share of grassland (>50%)	IACS dataset 2019
Share of specialty crops on arable land (>5%)	IACS dataset 2019
Share of cereals in the crop rotation (>60%)	IACS dataset 2019
Share of root crops in the crop rotation (>10%)	IACS dataset 2019
Share of cattle (>1 GV */ha grassland +forage crops)	IACS dataset 2019; Statistisches Landesamt [42]
Share of dairy cows (>0.5 GV /ha grassland + forage crops)	IACS dataset 2019; Statistisches Landesamt [42]
Share of AEMs ** on arable land (>10%)	IACS dataset 2019
Share of AEMs on grassland (>20%)	IACS dataset 2019
Share of organic farming on arable land (>10%)	IACS dataset 2019
Share of organic farming on grassland (>10%)	IACS dataset 2019
Share of arable land in nature conservation areas (>0.5%)	IACS dataset 2019; BfN [43]
Share of grassland in nature conservation areas (>2%)	IACS dataset 2019; BfN [43]
Share of arable land in Special Protection Areas (>10%)	IACS dataset 2019; BfN [44]
Share of grassland in Special Protection Areas (>20%)	IACS dataset 2019; BfN [44]
Share of arable land in FFH *** areas (>2%)	IACS dataset 2019; BfN [45]
Share of grassland in FFH areas (>10%)	IACS dataset 2019; BfN [45]
Share of arable land in landscape protection areas (>25%)	IACS dataset 2019; BfN [46]
Share of grassland in landscape protection areas (>40%)	IACS dataset 2019; BfN [46]
Share of grassland in legally protected biotopes (>0.5%)	IACS dataset 2019

* livestock unit (1 GV equals 500 kg live weight); ** Agri-environmental measures; *** Flora-Fauna-Habitat areas as defined in the European Union's Habitats Directive (92/43/EEC).

Table 4 gives an overview of the selected variables at field level. As is the case of the landscape level, a characteristic of the plot, such as high soil quality, is either present or absent. This was defined by the intersection of the plot polygons and the respective geodata layer, for instance the soil map using ArcGIS [47]. Some variables at field level were defined by the distance in meters between the respective plot and forest, biotopes, landscape elements, etc. Plots within areas protected under nature conservation law were identified, i.e., a distance of zero meters. For this purpose, the distances between the polygons of the plots and the selected geodata features were analysed using the "Near" Tool in ArcGIS [47]. The outlines of the plots were taken from the Integrated IACS 2019 dataset.

Table 4. Binary variables used to create the PIC map at field level.

Variables at Field Level	Description of the Data		
	Source	Attribute	Attribute Level
Forest (≤20 m distance)	ALKIS [48]	GISELANAME	Forest
Water bodies (≤20 m distance)	LUBW [49]	Stream network	
Biotopes (≤20 m distance)	IACS dataset 2019	IACS code	924 *, 925 *
Woody structures (≤20 m distance)	ALKIS [48]	GISELANAME	Field copse, field boundary, grove, hedge
Wetland areas (≤20 m distance)	ALKIS [48]	GISELANAME	Pond, wetland, grassland, wetland;
	LUBW [50]	Core area	
Dry areas (≤20 m distance)	LUBW [51]	Core area	
Soil quality (low)	LGRB [52]	Soil fertility	1.0, 1.5
Soil quality (high)	LGRB [52]	Soil fertility	3.0, 3.5, 4.0
Within nature conservation area (yes)	BfN [43]	BfN_ID	

Table 4. *Cont.*

Variables at Field Level	Description of the Data		
	Source	Attribute	Attribute Level
Within Natura 2000 network (yes)	BfN [45]; BfN [44]	BfN_ID	
Groundwater and backwater up to 1 m depth (yes)	LGRB [52]	GRUSTAWR	
Risk of soil erosion (yes)	LGRB [53]	Mean long-term soil erosion in t/ha/year	>2

* Agriculturally used and unused biotopes.

3.4. Assessment of the PIC Options According to the Variables

For each field or grassland plot, 31 binary variables are available at the municipal and at the plot level. The respective eight PIC options were evaluated at the municipal and field level in an assessment matrix. It was then decided, from a nature conservation and agricultural perspective, whether a PIC measure is desirable or rather not desirable for a certain expression of a variable. For this assessment, an expert group consisting of three people each from the field of nature conservation and agriculture was formed. The experts in the field of nature conservation were recruited from both local stakeholders (non-governmental organisations) and people who are active as experts in the field of planning offset measures in the Stuttgart Region having specific local knowledge. The agricultural experts came from academia and local administration, i.e., they also have specific local knowledge.

Hence, 248 (8 × 31) combinations of PIC options and variables were evaluated twice from the agricultural and nature conservation point of view, i.e., 496 decisions in total (Table S1 in the supplementary material). The evaluation was made in each case in four integer levels from +1 (desirable) to −2 (rather unsuitable), which is shown schematically in Figure 3. This is designed to anticipate that an unfavourable expression with regard to just one variable can already markedly affect the suitability of the location. The assessment was based on expert knowledge as well as on specific literature studies [19,23,40,54]. For example, due consideration was given to the fact that a measure such as extensification of grassland may have an impact on feed value and that this option may not be optimal in municipalities with a high volume of dairy farming [55].
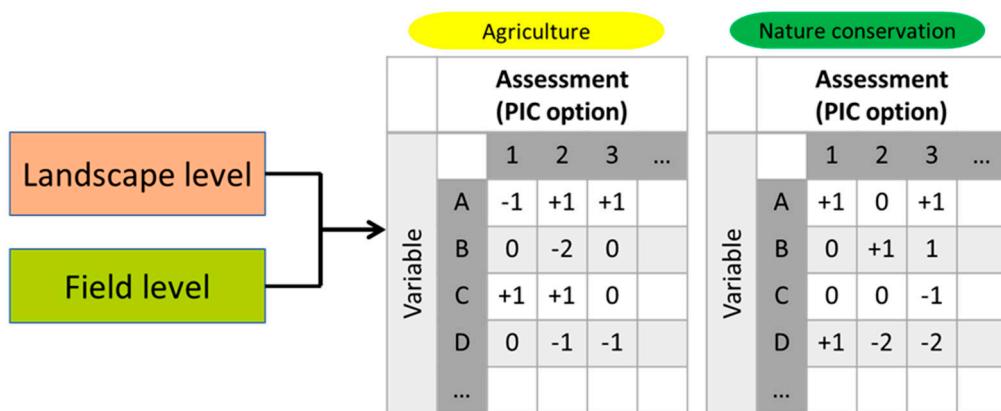

Figure 3. Schematic representation of the valuation of the PIC options in the assessment matrix.

3.5. Plot-Specific Evaluation of the PIC Options

The above-mentioned evaluations of the PIC options by variable were then used in an algorithm to generate the map in R [56]. In the algorithm, the value (1;0) of all 31 variables was recorded for each plot, and the evaluation result was calculated for each PIC option on

each plot as the sum of the products of the value, of the variable and the evaluation in the assessment matrix, according to the example in Table 5.

Table 5. Example calculation of the evaluation of a measure (permanent flower strips from a nature conservation point of view) on a specific field in the model using the field-level variables.

Variable	Presence of the Feature (Binary Variable)	Evaluation in the Matrix (Integer Variable)	Evaluation of the Measure on the Plot (Integer Variable)
Forest (≤20 m distance)	0 (no)	−1	0
Water bodies (≤20 m distance)	1 (yes)	−1	−1
Biotopes (≤20 m distance)	1 (yes)	+1	+1
Woody structures (≤20 m distance)	1 (yes)	+1	+1
Wetland areas (≤20 m distance)	0 (no)	+1	0
Dry areas (≤20 m distance)	0 (no)	+1	0
Soil quality (low)	0 (no)	0	0
Soil quality (high)	1 (yes)	+1	+1
Within nature conservation area (yes)	0 (no)	+1	0
Within Natura 2000 network (yes)	1 (yes)	+1	+1
Groundwater and backwater up to 1 m depth (yes)	0 (no)	−2	0
Risk of soil erosion (yes)	0 (no)	0	0
Sum			+3

In addition to the assessment described above, the current level of intensification is also important for the PIC option extensification of grassland. Based on the information in the IACS dataset, certain grassland areas were excluded from this option because they are most likely already in extensive use. Consequently, grassland areas with agri-environmental measures, orchard meadows, sheep pastures, set-aside permanent grassland areas, or biotopes with grassland use were excluded. Hence, the option was set at zero in the total evaluation of the plot.

3.6. Generation of the Regional PIC Map

Based on the total evaluation, according to Section 3.5, each PIC option was then given two ratings on each plot from an agricultural and nature conservation point of view, for example, from zero to 16 for permanent flower strips from a nature conservation perspective. Since we focused on a regional map, one aim was to select the most suitable plots for the PIC options in the region. Therefore, for each PIC option, the plots with assessment values above the 75% quantile in relation to the entire region were filtered (e.g., scoring > 5 for permanent flower strips). As the assessment values are integer numbers, it is possible that more than 25% of the plots were considered in this way. The remaining plots were then attributed the value "0" for the specific PIC option. This ensures that plots in the region, that are particularly suitable for a PIC option, are represented in the map. Afterwards, the PIC option with the highest score per plot was selected. In the case of the attribution of zero for all PIC options, no option is recommended in the map. In the evaluation, of course, several options were sometimes close to each other. Therefore, to encourage a compromise between agriculture and nature conservation and allow a margin for potential on-site coordination, almost equivalent options should be proposed in some cases. However, the proposed options should not be too general. In this context, Table 6 analyses the range between the best, second best PIC option etc. (1. Max, 2. Max ...) with mean, median, and the 25% quantile. For this analysis, all plots were considered where at

least one option had a higher rating than zero. Based on this, a delta of 3 was selected as the cut-off value for recommending an option.

Table 6. Consideration of the delta between options using the example of the nature conservation perspective, restricted to plots where at least one option is valued higher than zero (1. Max > 0).

Range	Mean Difference	Median	Q25-Quantil
1. Max and 2. Max	4.3	1	0
1. Max and 3. Max	5.1	4	1
1. Max and 4. Max	5.9	5	3
1. Max and 5. Max	7.8	8	6
1. Max and 6. Max	8.1	8	6
1. Max and Min	8.1	8	6

The process described above was carried out from the point of view of both nature conservation and agriculture (Figure 4). Finally, there might be one, several, or even no suggestions for PIC on a specific plot for both sides. The plots and proposed options could be displayed in a GIS-map. Based on the two-sided recommendations for PIC options, it was now possible to identify the overlaps between the agricultural and nature conservation perspectives.
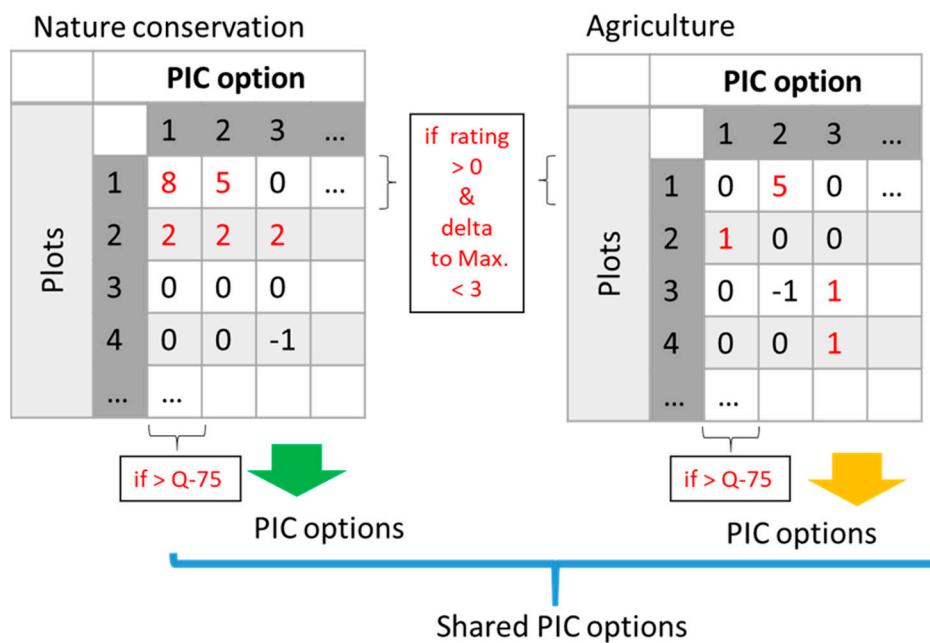

Figure 4. Derivation of plot-specific PIC option recommendations from a nature conservation and agricultural point of view based on the plot-specific overall assessment.

4. Results

PIC Map for the Stuttgart Region

From the perspective of nature conservation, approximately 93% of the arable land and 69% of grassland in the Stuttgart Region seem to be suitable for implementation of at least one of the considered PIC options (Table 7). Especially in the urban district of Stuttgart, almost 100% of arable land and grassland would be suitable for PIC.

Table 7. Proportion of arable land and grassland in % and in ha that is suitable for the implementation of PIC from the perspective of nature conservation.

Urban/Rural District	Land with at Least One Suggested Option from the Perspective of Nature Conservation			
	Proportion in %		In ha	
	Arable Land	Grassland	Arable Land	Grassland
Böblingen	78.3	58.2	11,584	4282
Esslingen	96.8	58.2	9375	5539
Göppingen	95.6	75.6	11,479	11,804
Ludwigsburg	96.0	74.7	22,516	3912
Rems-Murr-Kreis	97.0	71.1	10,825	8824
Stuttgart	100	95.6	1330	656
Stuttgart Region	92.7	68.9	67,110	35,016

Figure 5 shows the PIC map from the nature conservation perspective. The option with the highest rating, or no option, is presented for each plot in the map. Should two measures have an equally high rating, they were presented according to a fixed ranking, ranging from permanent flower strips, flower strips, grassland, extensive used arable land, fallow land, reduced tillage, to temporary greening. The map clearly shows the described agricultural structural features of the region. Hence, for instance in the district of Ludwigsburg with more than 75% utilised arable land (UAA), the extensification of arable land is the major recommended option. In addition, the share of specialty crops there is rather low, and it is mainly cereals that are grown. In the centre of the region, the implementation of permanent flower strips is particularly recommended. The ecological success of flower strips is rather independent of soil quality, and therefore more suitable in areas with very high soil quality, for instance, in Stuttgart. The districts of Göppingen und Rems-Murr-Kreis are characterised by a high proportion of grassland. Consequently, extensification of grassland is also a frequently suggested option in these areas.
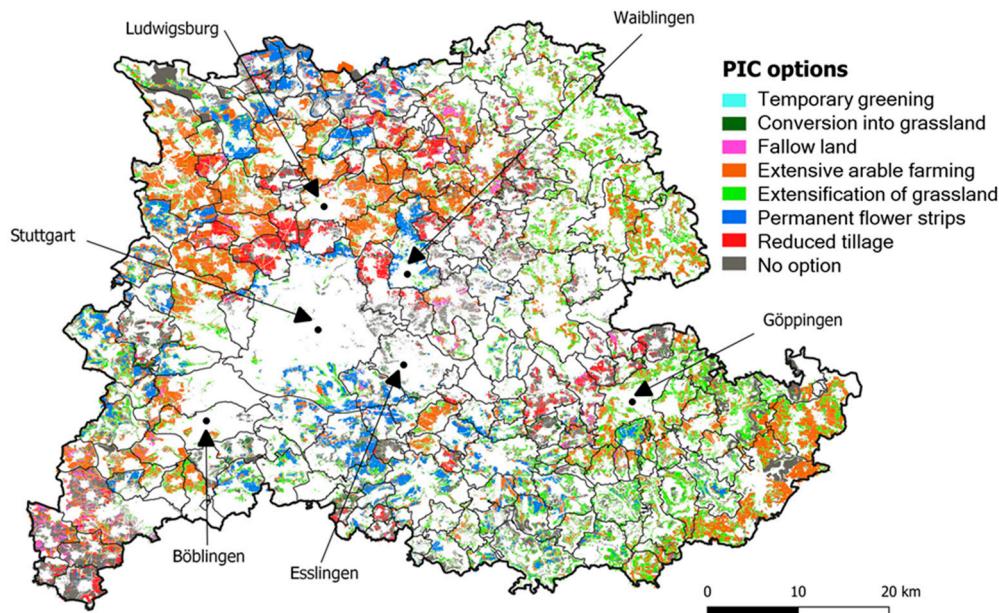

Figure 5. PIC map from the nature conservation perspective showing the priority option based on IACS data and BKG [36].

Generally speaking, PIC is often less recommended from the perspective of agriculture than from the nature conservation perspective. Furthermore, there are also clear regional

disparities. For example, from an agricultural point of view, only about 25% of the areas in Stuttgart would be suitable for PIC. This constitutes a considerable discrepancy vis-a-vis the nature conservation assessment (Table 8).

Table 8. Proportion of arable land and grassland in % and in ha that is suitable for the implementation of PIC from the perspective of agriculture.

| Urban/Rural District | Land with at Least One Suggested Option from the Perspective of Agriculture | | | |
| | Proportion in % | | In ha | |
	Arable Land	Grassland	Arable Land	Grassland
Böblingen	79.2	50.4	11,718	3709
Esslingen	76.3	50.3	7392	4796
Göppingen	86.1	47.8	10,347	7459
Ludwigsburg	82.9	46.7	19,445	2447
Rems-Murr-Kreis	82.8	42.4	9247	5257
Stuttgart	24.2	95.6	321	656
Stuttgart Region	80.7	47.8	58,470	24,325

In addition, the suggested options may differ between the agricultural and nature conservation perspective. Especially from the point of view of agriculture, the option of temporary greening is seen as a preferred option according to the model (Figure 6). There are also spatial differences within the region. In the western part of the region, temporary greening is often the preferred option, while in the centre and eastern part of the region, reduced tillage and extensification of grassland are often recommended.
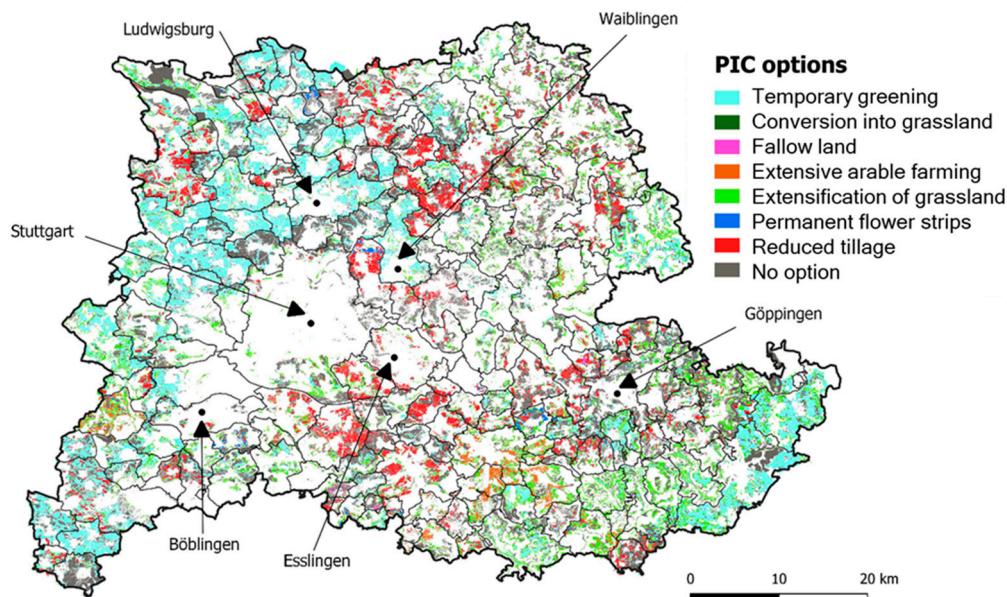

Figure 6. PIC map from the agricultural perspective illustrating the priority option based on the IACS data and BKG [36].

However, there are also overlaps between the nature conservation and agricultural assessments. This applies to about 13% of arable land and 43% of grassland. In this context, there are clear spatial disparities between the districts. Whereas in Esslingen, more than 23% of arable land would be suitable for the implementation of PIC, but in Stuttgart, this figure is only 0.1% of the arable land. Nevertheless, there seems to be a potential for PIC measures on grassland in the district of Stuttgart (Table 9).

Table 9. Proportion of arable land and grassland in % and in ha that is suitable for the implementation of PIC from the perspective of both nature conservation and agriculture.

| Urban/Rural District | Land with at Least One Shared Suggested Option from the Perspective of Agriculture and Nature Conservation | | | |
| | Proportion in % | | In ha | |
	Arable Land	Grassland	Arable Land	Grassland
Böblingen	12.3	43.6	1818	3209
Esslingen	23.8	46.7	2309	4449
Göppingen	15.5	45.5	1857	7112
Ludwigsburg	6.8	43.0	1605	2256
Rems-Murr-Kreis	18	34.4	2005	4275
Stuttgart	0.1	95.6	9	656
Stuttgart Region	13.3	43.2	9602	21,956

Figure 7 shows these overlaps, i.e., land plots with a potential for PIC from both the nature conservation and agricultural perspective on arable land and grassland. Accordingly, the potential for PIC seems to be higher, in terms of area, in the east of the region than in the western districts.
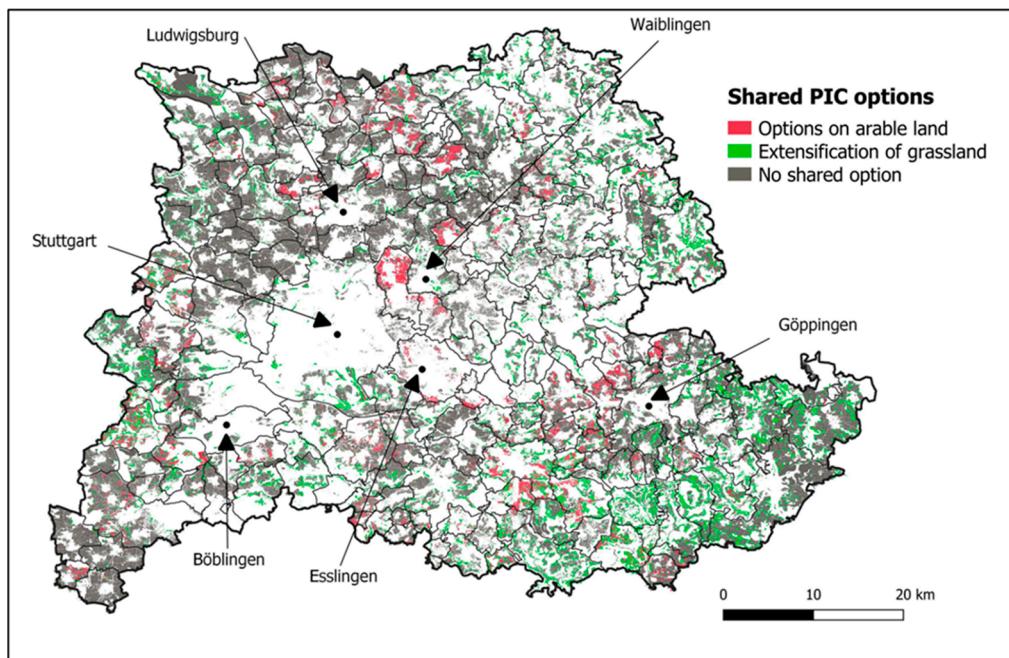

Figure 7. PIC map from both the nature conservation and agricultural perspective based on the IACS data and BKG [36].

On average, 0.23 PIC options per plot are recommended from both a nature conservation and an agricultural perspective. As described in Section 3.6, for each PIC option the plots were selected where the score was above the 75% quantile related to the region. Using the 60% quantile, there are, on average, 0.25 shared PIC options per area. At the 90% quantile, the average number of shared PIC options drops to 0.20 per plot. This sensitivity results specifically from the perspective of the nature conservation assessment since, in the context of the agricultural assessment, Q-60, Q-70, and Q-90 are identical with the exception of temporary greening.

5. Discussion

5.1. Case-Study Application Using the Example of Filderstadt for the Plausibility Check

To prove plausibility, the regional map was applied to individual landscape sections in the urban area of Filderstadt as part of the Stuttgart Region (Figure 8). In the process, the map was assessed by an expert using various aerial photographs and specific site knowledge. Overall, the map yielded plausible recommendations for PIC measures from both a nature conservation and an agricultural perspective. Nevertheless, minor adjustments are worth considering. For example, from a nature conservation perspective, the "conversion to grassland" measure might generally be the first choice over flower strips, especially as a buffer to water bodies (Figure 6). In addition, not all grassland plots with extensive land use seem to be covered, as the data are based on the IACS. Therefore, not all arable and grassland plots are considered, for instance, private land for which no direct payments have been applied for. Furthermore, it might also make sense to recommend the conversion of arable land to grassland in the vicinity of FFH meadows (e.g., 50 m) from a nature conservation perspective. In summary, the conclusion is positive, although minor adjustments are worth considering. Grassland in the floodplain is typical for central Europe. The locations in valleys are often too damp for arable farming or they flood annually, for instance [57–59]. Grassland protects the waterbodies against the entry of phosphate, nitrate, or pesticides. In addition, grassland can prevent soil erosion, serve as a habitat for numerous endangered species, and is important for the biotope network, for instance [60–62].
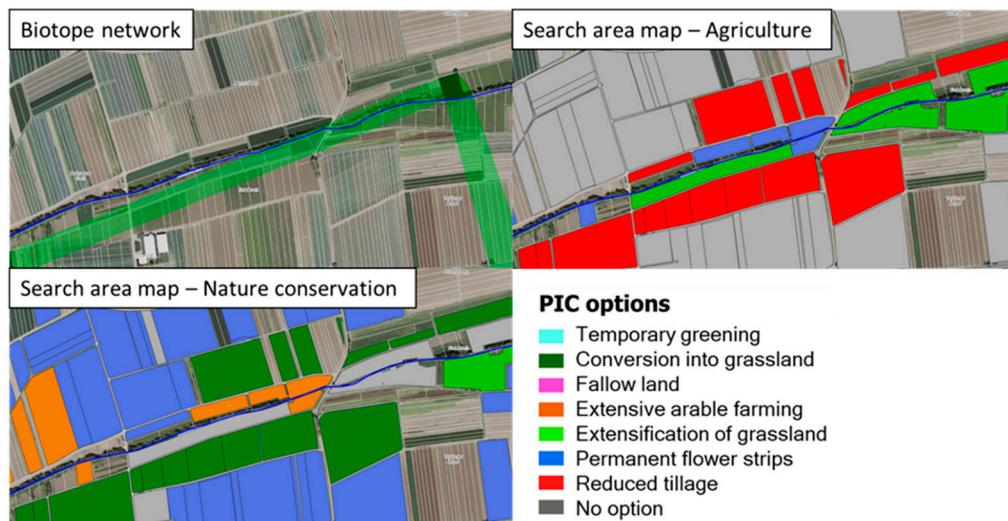

Figure 8. Application of the regional map using the example of an agricultural landscape segment in Filderstadt based on the IACS data and LUBW [63].

5.2. Discussion of the Approach

Based on the hypothesis that there may well be synergies between agricultural interests and conservation objectives in the planning of compensation measures, we produced a regional map for production-integrated compensation measures. We found that, in terms of suitable areas and measures, there is indeed a relevant overlap. This can, therefore, confirm our hypothesis. According to our model, there is significant implementation potential for PIC on more than 10% of arable land and more than 40% of grassland from a nature conservation and agricultural perspective. However, we also identified conflicting interests between nature conservation and agriculture. On the one hand, the PIC option of temporary greening permits good integration into crop rotation, for instance by greening tramlines. It, therefore, offers a high degree of flexibility from an agricultural point of view. On the other hand, this option is viewed critically from a nature conservation perspective as it can have a trapping effect on insects. In addition, we also found spatial disparities

within the region. From an agricultural point of view, PIC measures may be less attractive in the centre of the region, due to a high proportion of specialty crops in the crop rotation with correspondingly high gross margins and high soil quality. This supports the findings of Sponagel et al. [41]. Furthermore, the municipalities in the district of Ludwigsburg have an average share of more than 10% of root crops in the crop rotation, which is markedly above the average for the region and may help explain the regional disparities. In this context, the distribution of protected areas under nature conservation law is also relevant, which differs between the districts. In Ludwigsburg, for example, in the average of all municipalities, almost 5% of arable land are located in FFH areas, whereas, in the Rems-Murr-Kreis, this is below 1%. All in all, there are many potential indicators that influence the spatially differentiated recommendation of PIC-options. In addition, the extensification of grassland might often be a less favourable option due to the reduced amount and quality of fodder [64]. In the context of PIC implementation in practice, it should also be mentioned that the costs of PIC measures may differ in the end due to different land prices. In general, measures require legal certainty, for instance, in the form of a land register entry, which can go hand in hand with a loss of market value of the land plot [65]. Especially in the centre of the Stuttgart Region, land prices for arable land are comparatively high, which might be challenging for the implementation of measures, especially from an agricultural perspective [41,66].

We used relevant, available geospatial data to evaluate the PIC options. In particular, protected areas under nature conservation law, biotope networks and landscape elements were included in the analysis from a nature conservation perspective. From an agricultural perspective, one focus was on the proportions of individual crop types in the crop rotation, such as root crops or cereals, soil quality as an indicator of the yield capacity of the plots, and data on livestock density. The crop sequence influences, for example, the option of arable extensification, which is less recommended from an agricultural point of view if the share of root crops is high [54]. In addition to variables at the landscape level, variables at the field level were also considered. For example, from an agricultural perspective, the proximity of a parcel to a forest edge, water body, or other landscape feature may be associated with management constraints and may predispose the location for PIC implementation. There may be restrictions on the use of pesticides and fertilisers, for example. With the arrival of the Act amending the Nature Conservation Act (*NatSchG*) and the Act concerning agriculture and landscape management (*LLG*) from 22 July 2020 in Baden-Württemberg, future restrictions on the use of plant protection products in protected areas were also adopted. In this context, avoiding the use of chemical pesticides can result in yield losses of about 30% for winter wheat, for example [67]. Therefore, future potential farming restrictions may lower the revenue of agricultural production. In addition, protected areas under nature conservation law often already have a negative impact on land prices [65,68]. In this respect, it can be assumed that the obstacle to implementation of PIC from an agricultural point of view is lower in these cases than in other areas with high productivity and suitability for special crops, etc. In addition, marginal sites with low yield capacity can be generally regarded as appropriate from an agricultural perspective. From the point of view of nature conservation, the strengthening of biotope networks and protected areas is also an important concern. Furthermore, from a nature conservation point of view, lean sites are often suitable for the establishment of fields with wild herbs or species-rich grassland [69]. This overlap of interests is thus also reflected in the model. In the future, for example, the management plans for Natura 2000 sites could be integrated into the model that set development targets for specific areas. In this way, further information related to the specific plot could be integrated.

In addition, it might be worthwhile to also address interests such as regional food supply with regard to the implementation of PIC measures in future studies. On the one hand, measures such as the extensification of arable land might enable further agricultural land use. On the other, they may be linked to rather high yield losses and respective low contributions to food supply [70]. Consequently, the relationship between the improvement in

terms of nature conservation and land occupation is also relevant. In Baden-Württemberg, biodiversity offsets for habitat banking are assessed in eco credits, for example [71].

Some simplifications had to be made when selecting the PIC measures and bundling them into eight options. In addition, there are measures such as short-rotation plantations that were not taken into account because they could not be adequately assessed on the basis of the available data and are also under discussion [72]. Furthermore, there are definitely relevant criteria that could not be taken into account due to poor data availability. When planning measures, the possible presence of rare arable wild herbs, for example, should be checked on site. In addition, the presence of certain species such as partridges (*Perdix perdix*) should be examined on site. In this case, measures such as flower strips in particular would be an appropriate option, although this may not be apparent from the model [73].

Although our regional map is designed for intervention regulation under nature conservation law, there are, of course, parallels to agri-environmental measures or similarities with measures such as flower strips. Biotope connectivity, in particular, is an important political goal that is defined in section 22 *NatSchG* and can be supported by our model. In Baden-Württemberg, in particular, the biotope network is to be expanded to 15% of open land by 2030, and refugial areas are to be created on 10% of agricultural land. Hence, cooperation with agriculture will probably be necessary. Consequently, the activities of individual farmers should be coordinated at the landscape level in order to ensure the delivery of certain ecosystem services [74]. Ecological networks, particularly on a regional level are, therefore, essential for the preservation of biodiversity [75].

Furthermore, this study could not take into account acceptance of the measures. Some farmers may also reject PIC measures outright. In this context, the required compensation payment for the measures may, of course, vary as well [19]. The strength of our model is, therefore, that it can identify the options that have the highest probability of being implemented on the land.

As our study refers specifically to agricultural land, integration into other models or extension is possible at any time. This also allows for adaptation to possibly deviating local conditions. In this way, our model also ties in with other studies that deal with modelling the ecological effectiveness of biodiversity offsets at the landscape level [76,77].

5.3. Feedback from a Stakeholder Workshop

At a workshop on production-integrated compensation within the project RAMONA, as part of the BMBF funding activity Stadt-Land-Plus, the developed PIC map was presented in January 2021 to more than 25 participants from the agricultural and nature conservation administration, relevant ministries, the agricultural professional representation in Baden-Württemberg, as well as cultural land foundations from various other federal states. One question that was raised had to do with whether such a map could contribute to the improved establishment of PIC measures in practice. Of the 21 respondents, 96% answered this in the affirmative, illustrating the need and potential opportunities for a PIC map.

Nevertheless, in the context of the application of such a regional PIC map, essential criteria were mentioned by the participants from agriculture. Firstly, a regional map must not lead to a top-down change in agricultural land use. Secondly, agriculture must always be able to participate in the decision-making process. On-site communication, therefore, plays a central role.

Furthermore, it was mentioned that such a regional map could be helpful especially for municipalities that own a lot of agricultural land in order to come up with reasonable solutions for all the parties involved. In this respect, the map could also serve as a basis for discussing the implementation of PIC. Ultimately, of course, the current land use and the species and habitat endowment on site must be assessed and taken into account. In addition, other existing nature conservation objectives such as the biotope network and existing measures in the surrounding area must be considered. This also includes any

land uses in the surrounding area that could have a negative impact on the success of the offset measure.

5.4. Provision of the PIC Map in a Web Application

The generated regional map is to be made available by the regional planning association, Verband Region Stuttgart, in a web application. This is intended for municipalities in particular. Within the application, suggestions from an agricultural and nature conservation point of view can be retrieved for each plot in the region. Furthermore, it should be possible to display suitable plots for specific PIC options or plots with an overlap between proposals from an agricultural and nature conservation perspective.

6. Conclusions

Geodata were used to create a regional map for production-integrated compensation measures that will be made available for practical use. We found that there may be significant potential for PIC in the Stuttgart Region from an agricultural and nature conservation perspective. The map can thus provide an initial overview when planning and designing biodiversity offsets on farmland. On a regional level, structures for networking and bundling measures can be derived. This can improve the ecological effectiveness of biodiversity offsets. All in all, the final decision on the type of offset measure to be implemented can and must always be made on site. However, in the dialogue between the intervening party, for instance a municipality and a farmer, the map can serve as a foundation for a constructive discussion to determine acceptable solutions for both nature conservation and agriculture. Our regional map can also be integrated into other areas of nature conservation planning such as the biotope network, whereby synergy effects with nature conservation measures, on areas outside agricultural use, can be derived.

A wide range of usable geodata are available, especially for the Stuttgart Region, which could be used to the advantage of this study. In general, the approach requires environmental data such as protected areas under nature conservation law, data on the agricultural structure and land use as well as suitable soil data. Within Germany and Europe, it can be assumed that similar data are available for other regions, for instance, soil maps such as the Corine European soil database [78] or data on agricultural land use. Accordingly, there should be good transferability to individual regions outside the Stuttgart Region with comparable data availability. For this purpose, our chosen approach is generally very flexible, i.e., further variables can be added or it can be adapted for other regions. If the approach is to be transferred to other regions, it should be noted that the selection of the PIC options, the definition of the variables such as distances to water bodies etc. and, at least, the assessment of the options were based on expert knowledge with regard to the rather small-scale agricultural structures in Baden-Württemberg [79]. For regions with less structurally rich agricultural landscapes and larger field structures such as eastern Germany [80], for example, the preselected PIC options should possibly be adjusted. For example, short rotation coppice was not selected for the Stuttgart Region because of the structure of the agricultural landscape. However, it may be a potential PIC option for other regions [72]. Based on our experience, we recommend that new expert groups be set up to roll out the approach to other regions. Ideally, the groups should be made up of equal numbers of people from the field of nature conservation and the field of agriculture. These individuals should be familiar with the specific local conditions, i.e., local stakeholders such as nature conservation authorities and farmers' associations, would be the predestined interlocutors in this case. In addition, a transdisciplinary approach, with cooperation between science and practice, could be advantageous in order to represent different perspectives. From our point of view, it should also be borne in mind that an intensive exchange within an expert group may be necessary over a period of several months.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/land10080808/s1, Table S1: Assessment matrix.

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