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D4.3 Mapping of ESS / biodiversity / socioeconomic bundles into policy indicators

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Mapping of ESS / biodiversity / socioeconomic bundles into policy indicators

Deliverable D4.3

31st January 2023

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BESTMAP
Behavioural, Ecological and Socio-economic Tools for Modelling Agricultural Policy

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Summary

Most of the agricultural policies, such as the new CAP, or the European Union Sustainable Development Goals, already present their list of associated indicators to monitor impacts. As BESTMAP biophysical models aim to map the impacts of these types of policies, each of the model outputs have a range of associated policy indicators. This deliverable includes the results of an exhaustive review of policy indicators from different sources linked to agricultural practices, associated with or translated to BESTMAP model results. In some cases, BESTMAP models return an output that can be directly considered an indicator. In other cases, BESTMAP model results can support partially existing indicators.

1. CAP policy indicators and other related indicators

The new post-2020 CAP policy shifts from a compliance-based to a performance-based system. Since this is a more result-oriented policy, it requires the establishment of a solid Performance Framework (PF) that, based on a set of common indicators, could allow assessment of the performance of the new CAP and the promotion of a learning process (art. 116 (COM(2018)392 final) (Cagliero et al 2021). The new Performance Monitoring and Evaluation Framework (PMEF) has been designed, and includes the use of a set of common indicators: Context indicators (remain pertinent), Result indicators (annual performance), Output indicators (annual performance) and Impact indicators (multi-annual performance).

- Context indicators remain pertinent in the intervention logic, set up and follow up
- Common Output indicators relating to the realised output of the interventions supported
- Result indicators will be used to reflect whether the supported interventions contribute to achieving the EU specific objectives
- Multiannual assessment of the overall policy is proposed based on common impact indicators.

The final list of indicators is available in the Annex I of the Regulation (EU) 2021/2115. There are 49 context indicators, 29 impact indicators, 44 result indicators and 37 output indicators.

Therefore, each CAP strategic plan presented by each State member of the EC, should refer to some interventions linked to specific objectives. These should be accessible through the indicators defined by the EC, so progress towards targets can be demonstrated across all Member States. For example, in Spain, the Strategic Plan concerning the Specific Objective (SO) 6: to preserve Biodiversity, includes a high priority sub-objective of mitigating or reversing the declining trend in populations of agricultural birds (06.02). A list of suggested interventions is provided, which includes associated output indicators to perform application of the intervention. For instance, one intervention is “Eco-Schemes; Carbon Farming and Agroecology: Extensive grazing, mowing and biodiversity in Mediterranean Pastures", linked to the output indicator “*O8. Number of hectares or of livestock units benefitting from eco-schemes* “. It also includes a list of the result indicators for each specific sub-objective. Continuing with the same example, it includes result indicator “*R.311^{PR} Preserving habitats and species: Share of utilised agricultural area (UAA) under supported commitments for supporting biodiversity conservation or restoration including high-nature-value farming practices”*, as with the report already provides a general value of 16%.
All these indicators are designed to be computed as a single value at the Member State level, NUTS2 or NUTS3, but are not considered as spatialised outputs at the farm level, characterising the performances carried out at the farm level and its impacts (as it is the case of BESTMAP).

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Apart from the specific CAP indicators, there are other sources of indicators that can be adopted as indicators related to BESTMAP models. In order to ensure the monitoring of impact simulated in BESTMAP models, we also reviewed indicators from the European Union Sustainable Development Goals (EU SDG Indicators)(Goals 2, 6, 10, 13 and 15) and Environmental Indicator Catalogue (EEA).

2. Targeted indicators related to BESTMAP models

A thorough review of CAP indicators, EU SGD indicators and EEA indicators has been performed in order to identify the most relevant indicators related to BESTMAP models of ecosystem services (biodiversity, carbon sequestration, water quality, food production and socioeconomic effects), and which indicators are satisfied by the models (Table 1, 2 and 3). Further discussion of how these indicators fit the models is included in Section 3.

Ecosystem services /models	**Linked impact / result indicator (v. 17/12/2021)**
Carbon sequestration	C41/ I.11 Soil organic carbon in agricultural land R.14 Carbon storage in soils and biomass
Water quality	I.15 Gross nutrient balance on agricultural land - Nitrogen and phosphorous
Biodiversity / habitats	I.19 Farmland Bird Index I.20 Percentage of species and habitats of Community interest related to agriculture with stable or increasing trends
Socio-economic [*based on food production*]	I.4 Supporting viable farm income I.5 Contributing to territorial balance - Farm income by type of farming, region, by farm size, in areas facing natural and other specific constraints'. *[I.2 Comparison of agricultural income with non-agricultural labour costs* *I.3 Agricultural factor income* *R.4 Share of utilised agricultural area (UAA) covered by income support and subject to conditionality]*

Table 1: New CAP Indicators related to BESTMAP models

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Ecosystem services /models	**EU Sustainable Development Goals indicator set 2022**
Carbon sequestration	*15_XX (on hold): Topsoil organic carbon content*
Water quality	06_40 Nitrate in groundwater 15_50 Estimated soil erosion by water
Biodiversity / habitats	15_10 Share of forested area 15_20 Terrestrial protected areas 15_60 Common bird index 15_61 Grassland butterfly index
Socio-economic [*based on food production*]	02_20 Agricultural factor income per annual work unit (AWU)

Table 2: EU SDG indicators related to BESTMAP models

Ecosystem services /models	**EEA indicators (v. Nov/22)**
Carbon sequestration	Gross nutrient balance in agricultural land (Eurostat_t2020_rn310)
Water quality	Nitrate in groundwater (Eurostat_sdg_06_40, source: EEA)
Biodiversity / habitats	Common farmland bird index (Eurostat_env_bio2) Common bird index by type of species - EU aggregate (Eurostat_sdg_15_60, source: EBCC)
Socio-economic [*based on food production*]	Share of main land types in utilised agricultural area (UAA) by NUTS 2 regions (Eurostat_tai05)

Table 3: EEA Environmental Indicator catalogue indicators related to BESTMAP models

3. Translating ESS, biodiversity & socioeconomic models into indicators

3.1. Biodiversity model

All the sources of indicators consulted include the *Farmland Bird Index* as an indicator of biodiversity. However, the European Farmland Bird Index represents temporal trends of population sizes based on annual national bird surveys, and therefore can not be spatialised at sub-national level. Moreover, as the index has a yearly time resolution, it is not meaningful for interpretation over short time periods, such as the 4 years for which the IACS/LPIS data were available in BESTMAP. The *EEA Common bird index by type of species - EU aggregate (Eurostat_sdg_15_60, source: EBCC)* for farmland species is similar and therefore can also not be spatialised. Finally, the I20. *Percentage of species and habitats of community interest related to agriculture with stable or increasing trends* is a relation of the number of species and habitats on the number of biogeographic regions where they are represented, so it does not make sense to compute it at farm level.

In this context, the BESTMAP biodiversity model has been designed so that its results can be used or transformed to indicators. As its main objective, it must detect the effects of agri-environmental practices (AEP) in a spatially explicit way, and one that could be compared across case studies. In this context, the BESTMAP biodiversity indicator developed consists of a relative species richness index that ranges from 0 to 1. The relative species richness index is derived from the habitat suitability maps of individual farmland bird species, which were converted to binary maps (presence/absence) by using a threshold that maximises both sensitivity and specificity of the model. The binary maps were then stacked and summed together, and the result was divided by the total number of modelled bird species per case study, so that a relative species richness index of 0 indicates unsuitable habitat for all modelled species, whereas 1 indicates that the habitat is suitable for all modelled species. For instance, in Catalonia, 38 farmland species used in the European or the Spanish Farmland Bird Index were modelled. The indicator shows higher suitability in areas that are dominated by agriculture, especially those in the north-east, central-west and south-west, which are the main areas of agricultural production (Figure 1).

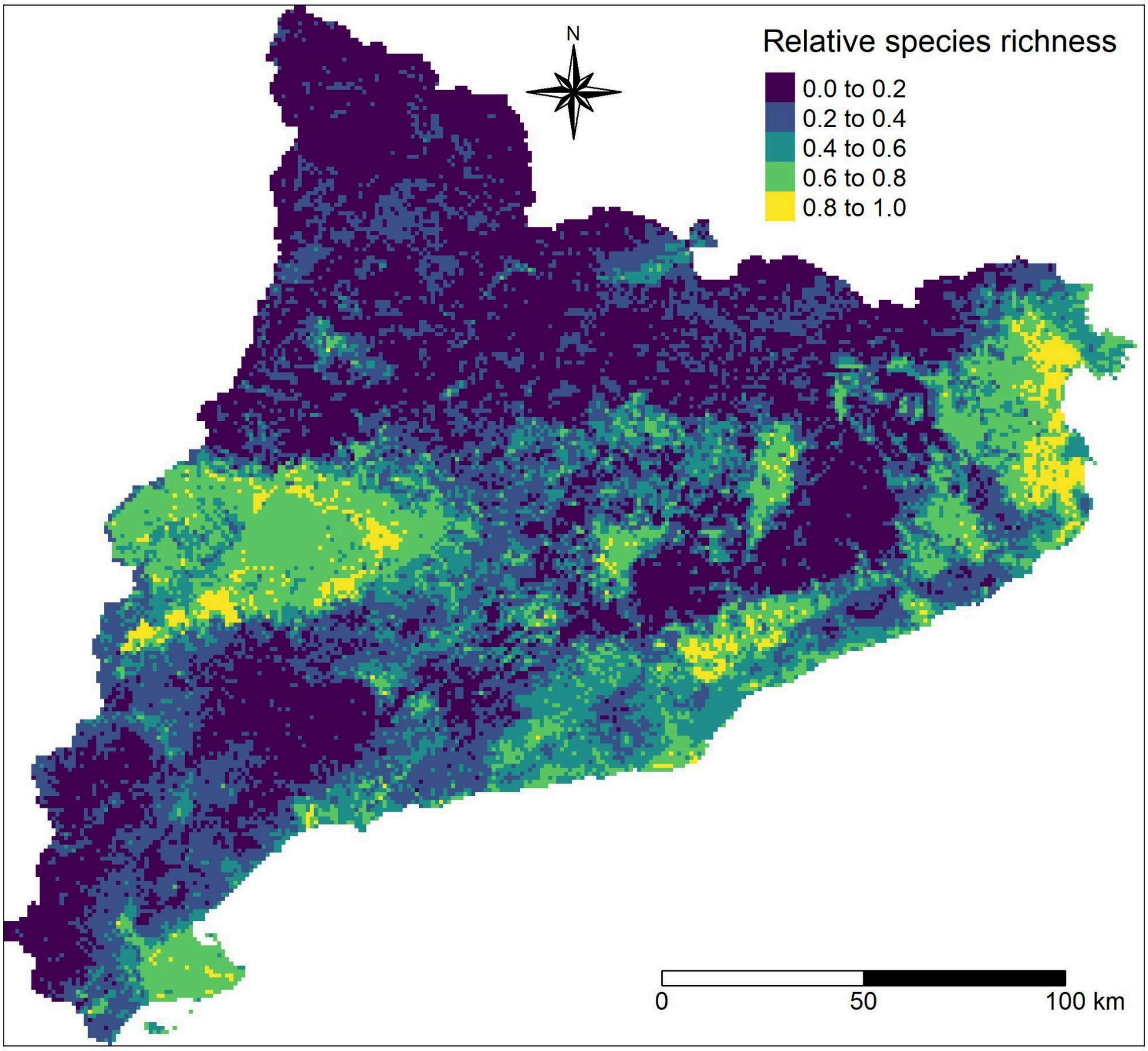

Figure 1: The biodiversity indicator for Catalonia. More details on its calculation and the species included can be found in the biodiversity model factsheet in D3.3.

3.2. Carbon sequestration

The main objective of this model is to estimate how the adoption of AEP affects soil carbon sequestration at the field level. The model output, (which includes the assumptions described in D3.3), returns maps of soil organic carbon (in t/ha) per field under different scenarios, current and alternative.

From all the carbon related indicators explored, the one that fits best is the new CAP indicator C41 (I11) - Soil organic carbon in agricultural land (indicator estimating the total organic carbon content in arable soils). The indicator consists of 2 sub-indicators: i) the total estimate of organic carbon content in arable land and ii) the mean organic carbon content. The indicator is expressed as an estimate of the total SOC stocks (Mg) in topsoil (0-20 cm) at the European Union scale and is not intended to be a substitute for national scale or local maps that are based on more detailed spatial information.

In this case, the BESTMAP model was designed to be computed at local scales, so the results obtained (in t/ha) can be linked to the first sub-indicator, but present better spatial resolution.

Therefore, the carbon sequestration model returns a direct partial indicator at a more detailed scale (Figure 2).

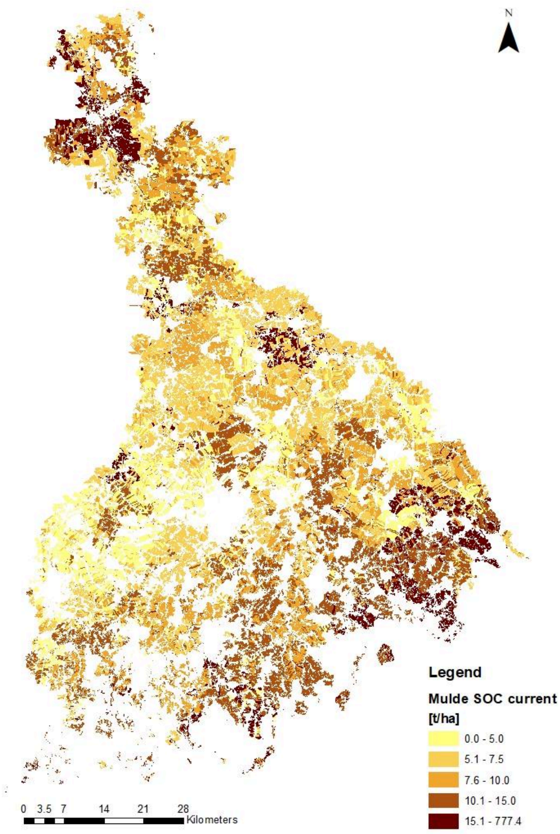

Figure 2: Estimated SOC [t/ha] (current situation scenario) for each parcel of Mulde river basin (Germany)

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3.3. Water quality

From all the water indicators potentially related to the BESTMAP water model, the *EEA Gross Nutrient Balance indicator (Eurostat aei_pr_gnb)* (GNB) denotes the flow of nutrients, specifically nitrogen and phosphorus, on agricultural land. By identifying the factors contributing to nutrient surplus or loss, the indicator highlights the relationship between different agricultural activities and environmental impact. The indicator inputs include the amount of fertilisers and manure application, and seeds and planting material. There are several additional inputs for the nitrogen balance indicator, such as livestock production, biological nitrogen fixation and atmospheric nitrogen deposition. The outputs for both nutrient models include the removal of nutrients from crop harvesting, nitrogen emissions, crop residue removal, and fodder harvesting/grazing by livestock.

The NatCap Nutrient Delivery Ratio (NDR) model run for five case studies as part of the BESTMAP project, has many similarities to the Gross Nutrient Balance indicator, as its main goal is also to explore the flow of nitrogen and phosphorus in accordance with agricultural activities. In this specific model, the different agricultural activities include the two scenarios of the adoption and the non-adoption of agri-environmental practices. The NDR also explores various types of inputs, mainly focusing on fertiliser application, and when data is available, such as in Catalonia, it also includes manure, atmospheric deposition, biological fixation, seeds, and livestock dropping inputs, which make it closer to the EEA indicator. However, most case studies did not explicitly focus on livestock numbers as an input, although the presence of grassland land-use could be indicative of their presence (and would potentially be reflected in nitrogen application loads for some case studies). Similarly, most case studies, (except Catalonia), do not explicitly include the atmospheric depositions of nutrients that the indicator does.

Whilst the NDR and the indicator both focus on the loss of nutrients to the environment, the indicator focuses on loss caused by local activities (as explained in the previous paragraph) and the NDR centres around how nutrient loss occurs through (surface and subsurface) runoff, which is dependent on factors such as elevation, watersheds and precipitation. Furthermore, the NDR only looks at phosphorus and nitrogen exports (kg/10 m in Catalonia), and it does not explicitly break these down into variants of the nutrients, such as ammonia and nitrous oxide, as mentioned as the nitrogen sources for manure and fertilisers in the indicator.

As mentioned above, the NDR model and the Gross Nutrient Balance indicators are not exactly the same. However, the NDR outputs can be considered an indicator themselves or could contribute towards the GNB indicator by displaying how much nitrogen and phosphorus flows from a particular piece of agricultural land (with or without agri-environmental schemes) into freshwater (Figure 3). Whilst there is more research on the effect of nutrients on lentic water sources, it is known that nutrients, alongside altered nutrient ratios, cause multiple and complex changes in all aquatic ecosystems (Rabalais, 2002). For example, high levels of nitrogen and phosphorus can lead to algal blooms in rivers, which eventually results in hypoxic zones that plants, fish and shellfish cannot survive in (Hirsch, 2012). Conversely, nitrogen and phosphorus are primarily limiting nutrients, causing lower productivity if there is not a high enough supply of them (Turner, 2001). Not to mention that the flow of nitrogen and phosphorus into streams and rivers has an impact on the global flux of nutrients in the oceans (Rabalais, 2002). By being able to use the NDR results to understand the amount of N and P flowing from agricultural land to streams, we could explore how nutrient flow impacts the environment, which is the goal of the indicator.

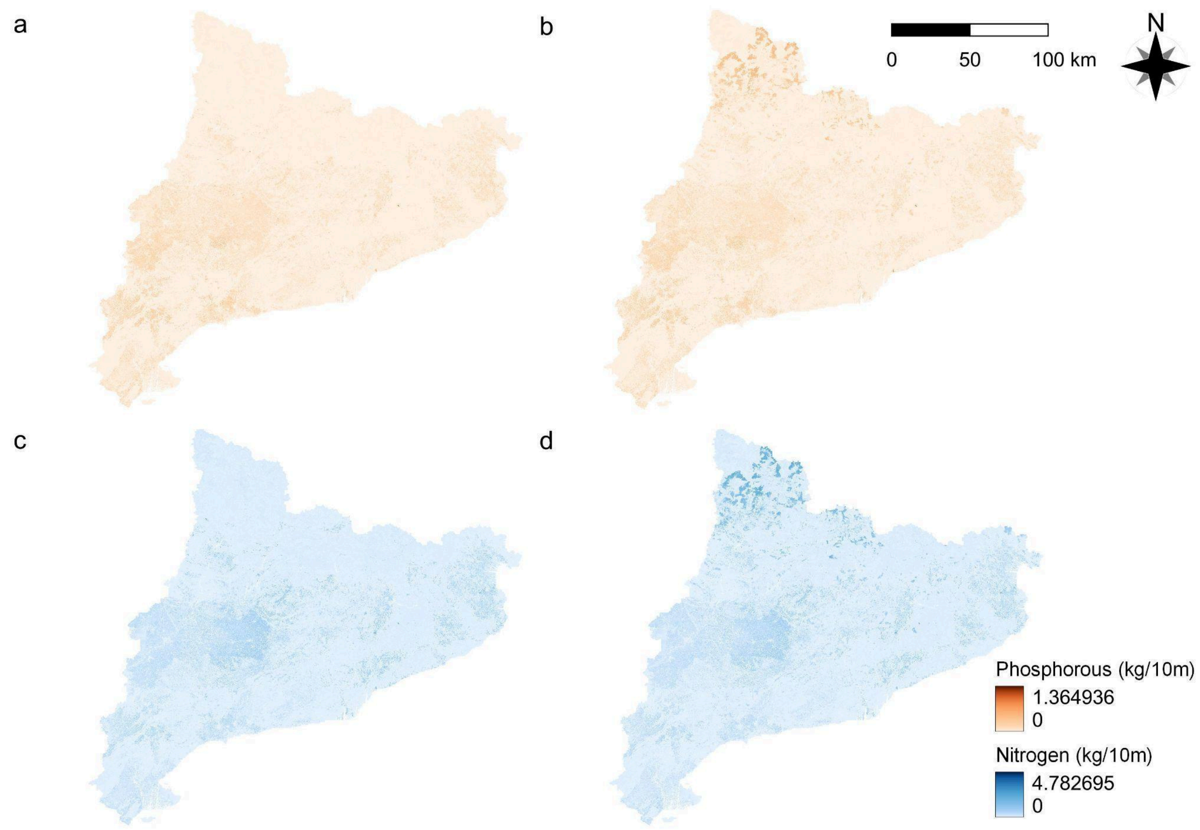

Figure 3. Nutrient Delivery Ratio model results [kg/10m] in Catalonia for (a) phosphorous surface export in a scenario with no AEP; (b) phosphorous surface export in a scenario with AEP; (c) nitrogen surface export in a scenario with no AEP; (d) nitrogen surface export in a scenario with AEP. More details on the model and calculations can be found in the nutrient model factsheet in D3.3.

3.4. Socioeconomic effects (based on food production model)

Results from the socio-economic model, originally resulting in change in Farm Net Value Added (FNVA) described in the corresponding model factsheet of D3.3, can be linked to the following policy indicator in European Commission (2022) CAP PMEF:

C.27 I.4 Supporting viable farm income / I.5 Contributing to territorial balance: 'Farm income by type of farming, region, by farm size, in areas facing natural and other specific constraints'.

As for the general task of modelling socio-economic effects in the format of a CAP indicator, this has already been accomplished for farm income in the results presented in the BESTMAP Deliverable 3.3 in which change in Farm Net Value Added is analysed for all case study regions. For farms who adopt agri-environmental schemes, we can use the modelling approach outlined in BESTMAP Deliverable 3.3 for farm income to estimate standalone farm income receipts (*CAP PMEF C.27 I.4 Supporting viable farm income*). In addition, we can also extend this approach though across an appropriate regional scale so that our results offer insight into how this process extends over different spatial areas (*CAP PMEF C.27 I.5 Contributing to territorial balance: Farm income by region*), which is what we offer here in Deliverable 4.3.

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In doing so, though, we do highlight the ways in which our modelling approach is incomplete, and cannot fully capture the picture of farm income. This is different to the modelling outlook presented in D3.3 on farm income as there the indicator was *change* in FNVA which could be claimed to account for all factors on the *assumption that they do not change* between AEP adoption scenarios. Here, meanwhile, in the presentation of estimates for only some components of FNVA (estimated *Value of Agricultural Production* including Pillar II AES subsidies), we are exposing the extent to which other elements of Farm Net Value Added (FNVA) are not incorporated into the results. This is an inherent limitation in modelling based on crop revenue and clearly income from activities such as farm diversification (e.g. farm tourism / farm shops / branded produce) cannot be captured. We claim that our modelling approach yield results for 'farm income' (e.g. C.27 I.4/I.5) rather than 'farm revenue' (e.g. C.27 I.3) as the potential for excluded financial factors and/or errors in modelling and data to cancel out is far greater for 'farm income' than 'farm revenue'.

Nevertheless, to demonstrate the capacities we have developed within the BESTMAP project, we take the Humber case study region and map estimated farm income (in EUR per Annual Work Unit) for both the scenarios of AEP non-adoption and AEP adoption, for those farms who have in fact adopted AEP (Figure4). Methodologically we follow most of the steps outlined in the farm income modelling in D3.3, except that we stop before calculating 'change in FNVA' and instead calculate the mean values for the estimated *Value of Agricultural Production* component of FNVA where these can be calculated in a robust and non-disclosive way across a given set of spatial units.

For our spatial units, we have chosen the Dec 2021 boundaries for Middle Layer Super Output Areas (MSOAs) in England and Wales. MSOAs represent a suitable resolution at which to investigate territorial balance across the Humber CS region, as they will offer meaningful granularity whilst also mitigating against the risks of statistical disclosure and the risks of unreliability through small number problems where appropriate. This is to say that the ratio of spatial polygon units to farm income estimates (as understood from D3.3) is anticipated to be appropriate at the MSOA scale. In theory, any spatial scale could have been applied for aggregation, given our programme uses geospatial operations to determine spatial unit allocations rather than predetermined column values. To adhere to best practice on statistical disclosure risks, we have suppressed the values of MSOA units in which the sample of farms did not equal or exceed 10 farms.

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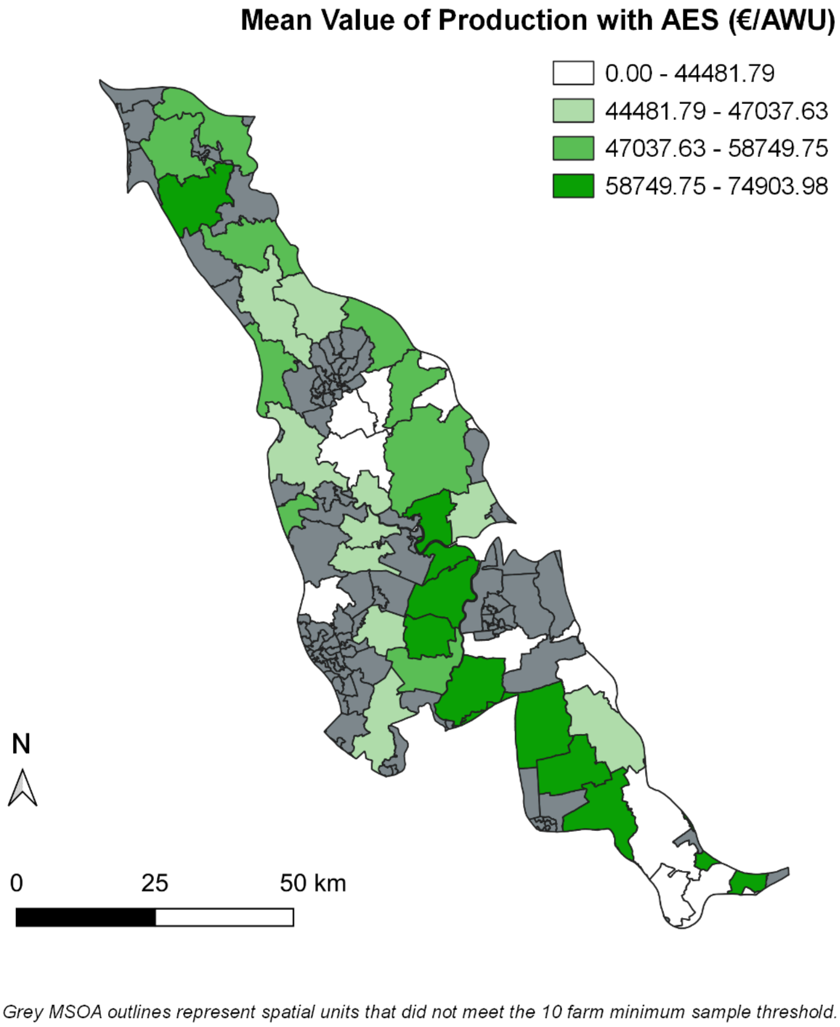

Figure 4. Mean average estimated Values of Agricultural Production from FNVA indicator, as presented at the MSOA scale of aggregation for the Humber case study region, UK. Results are estimations for 2017. MSOA spatial units with less than 10 farms modelled are excluded from the choropleth scale and mapped in grey. We used 'IACS/LPIS' data sourced from the UK Rural Payments Agency, FADN UK data from the European Commission (see D3.3 documentation) and MSOA boundary data from the Office for National Statistics licensed under the Open Government Licence v.3.0.

As documented in D3.3, this modelling capacity would not be possible without the support of the inputs and outputs from the BESTMAP food and fodder modelling in each given case study region. For the farms that adopt agri-environment schemes, this modelling lays the groundwork by estimating total revenues for the scenarios of AEP non-adoption and AEP adoption, harnessing research into land use changes and yield changes to model how the adoption of AEP can affect total revenues from crops as initially calculated through the use of EUROSTAT (2021) standard outputs per crop as available at the regional scale. So through the combination of the food and fodder and the farm income models, we are able to offer the capacity to map results with formal relation to the CAP PMEF C.27 indicators.

4. From model indicator to bundle indicator

ESS bundles are defined as "sets of services that appear repeatedly together" (Raudsepp-Hearne et al., 2010), and can include both synergies and trade-offs (Spake et al. 2017). The concept of ESS bundles is often used in spatially-explicit frameworks for identifying and mapping ESS associations (Dittrich et al., 2017; Spake et al., 2017). A better understanding of ESS associations is crucial to inform management decisions, so that sustainable levels of all services are maintained across the landscape. Recent research suggested that more effort should be put into identifying drivers of change (such as changes in land-use management), as well as the underlying mechanisms linking such drivers to ESS (Dade et al., 2019). Indeed, suggested policy solutions will likely be more effective if based on an improved understanding of the response of ESS to a given driver of change.

BESTMAP's original plan was that each of the bundles identified in Task 4.2 will have a range of policies associated, meaning that policy impacts can be directly linked to certain combinations of ESS, biodiversity and socio-economic conditions. However, while conducting the bundle analysis in Task 4.2 we decided to follow an alternative methodological route by focusing on two scenarios (without AEP, current AEP adoption). We then used Principal Component Analysis (PCA) to identify bundles of co-occurring services and to describe their interrelationships. PCA was chosen as the statistical method to quantify the primary multivariate connections among Ecosystem Service Supply (ESS), biodiversity, and socio-economic outcomes due to its numerous advantages for analyzing complex relationships. These include dimensionality reduction, which transforms data into a smaller set of variables (the principal components) that retain most of the variability of the original data. Additionally, PCA facilitates the interpretation of results by providing linear combinations of the original variables that are easier to understand.
Thereby, the originally planned translation between policy indicators and bundles was not possible and the plan to do the translation was abandoned. In this new scenario, indicators from the new CAP and from several other sources, have been analysed from the perspective of the model results. All BESTMAP models can be associated with indicators included in the most important European policies, demonstrating the utility of BESTMAP results.

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