# A Novel Approach to Determining Spatially Explicit Values of Natural Capital

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**Abstract**

Despite the urgent need to preserve natural capital, little is known about the direct benefits people receive from it. Reliable benefit estimates are required to incorporate the complex values of natural capital in national capital accounting, cost-benefit analyses, project appraisal, and international policy agreements. The study employs a spatial-explicit choice experiment approach, which estimates benefits people receive from changes in natural capital conditional on the current endowment in their places of residence. Studying changes in protected areas and high nature value farmland across Germany, we identify significant use and non-use values of natural capital stocks. We find that the marginal values of natural capital are conditional on the spatial endowment and on whether the type of natural capital is use or non-use related. We use our estimates together with geographic information system data to aggregate and map the distribution of the demand for protected areas and high nature value farmland across Germany. The results are easily transferable to other regions and contexts and allow trading off the benefits and costs of restoring natural capital and biodiversity. Our findings enrich the discussion on the loss of natural capital and biodiversity and can significantly contribute to broader policy discussions in the context of the interlinked climate and biodiversity crises.

**Keywords:** Natural Capital Valuation, Discrete Choice Experiment, Biodiversity Values, Spatial Preference Heterogeneity, Benefit Transfer

*The full list of authors has not been finalized yet. The paper is based on the collective work within the ValuGaps project. Current contributors and potential further authors are Stefan Baumgärtner, Aletta Bonn, Marie Meemken, Kevin Rozario, Maximilian Föhl, Moritz Drupp, Björn Bos, Pier Basaglia, Simon Disque, Jonas Grunau, Britta Tietjen, Fanny Langerwisch, Harry Gölz, Veronika Liebelt, Björn Bünger, Jan Philipp Schägner and Burkhard Schweppe-Kraft.

# 1 Introduction

Natural capital plays a critical role in sustaining human life and economic activities (Chiesura and De Groot, 2003; Dasgupta, 2021). However, the value of natural capital remains poorly understood (Guerry et al., 2015; Costanza, 2020) and obtaining accurate economic values of natural capital is challenging. Unlike market-based assets, natural capital's worth cannot be easily derived from conventional markets (Costanza et al., 1997). This difficulty is compounded by the uncertainty associated with existing valuation methods, which often do not capture the full range of benefits of natural capital, particularly in relation to spatial heterogeneity in natural capital endowments. In contrast to most conventional forms of capital, the stock and flows of natural capital are highly spatially dependent (Addicott and Fenichel, 2019). Thus, spatial variation in the stocks and flows of natural capital must be considered in the valuation process to obtain accurate estimates.

To capture use and non-use values of natural capital stated preferences methods are particularly suited (Alpizar et al., 2003). However, spatial complexities in the distribution of the environmental good to be valued are often neglected in the study design (Glenk et al., 2020). In recent years, researchers have attempted to incorporate spatial dimensions into the economic valuation of natural capital stocks and flows such as rivers, forests, or various ecosystem services using discrete choice experiments (Czajkowski et al., 2017; Sagebiel et al., 2017; Badura et al., 2020; Toledo-Gallegos et al., 2021; Johnston et al., 2023; Vossler et al., 2023). Despite the progress in studying spatial heterogeneity in natural capital values, there is no study that fully captures, visualizes, and thus incorporates the respondents' endowment of natural capital in the valuation task. Further, there is no approach that ensures that the proposed changes in natural capital are feasible and directly visible to the respondents.

In our study, we present a novel approach in which high-resolution data from geographic information systems (GIS) are used directly in a discrete choice experiment. We show respondents their status quo endowments with protected areas and high nature value farmland as well as proposed extensions to these areas on interactive maps. With this unique technical feature of the discrete choice experiment, we enable the respondents to incorporate their endowment with natural capital around their place of residence in the decision process and ensure that all proposed landscape changes are feasible, visible, and relevant in distance to the respondents. Further, we vary the accessibility of new protected areas, the visibility of the new high nature value farmland areas, and the distances to both of these new areas to partly disentangle the use and non-use values of these forms of natural capital. Additionally, by incorporating socio-demographic and spatially explicit variables, we seek to identify how different populations and regions perceive substitutes and complements of natural capital. The sample size of $N = 15,000$ allows us to conduct an in-depth analysis of the major drivers in heterogeneity for preferences of natural capital.

The core research question guiding this study is: *How do people value changes in the stock of natural capital, in the form of protected areas and high nature value farmland, across regions?* To explore this, we focus on the following specific inquiries:

- What is the value of protected areas and high nature value farmland and how does it differ across regions?

- What are the determinants (socio-demographics, landscape features, substitutes and complements of natural capital) of these values?
- To what extent does the distance of natural capital to human settlements impact welfare estimates?
- To what extent do spatial endowments of protected areas and high nature value farmland affect its marginal value?
- What differences emerge between use-related values and non-use-related values?

Studying two different forms of natural capital stocks, which both provide major potential to mitigate further biodiversity loss, our study is highly relevant to policymakers.

## 2 Study design and survey data

### 2.1 Data collection and questionnaire

The survey was developed together with an inter- and transdisciplinary team of experts on biodiversity from ecology, social sciences, and economics. Two federal German institutes were actively involved in the development of the questionnaire: The German Federal Agency for Nature Conservation (BfN) and the German Environmental Protection Agency (UBA). Additionally, we incorporated feedback from the section for Environmental Economic Accounts at the German Federal Statistical Office into our study set-up. The questionnaire is divided into six progressively structured sections, using simplified language and a user-friendly design. To enhance information absorption, we reduced the content on each screen and included bullet points and info-boxes where feasible. Graphical illustrations help clarify key concepts, while images and examples aim to reflect regional diversity in order to improve accessibility and relevance for a broader audience. Presenting additional information in the form of foldable text elements allows interested readers to clarify unresolved questions about concepts and content, while allowing others to move on more quickly. In this way, we aim to reduce drop-out rates due to time constraints and to provide a supportive environment for those who require additional information. The parts of the questionnaire are as follows: 1) collection of personal information, 2) introduction of the concepts of protected areas and high nature value farmland, 3) description of the policy setting of the choice experiment, 4) the choice experiment, 5) follow-up questions. Additionally, two-thirds of the respondents receive questions on nature-relatedness and travel cost. The other third does an experiment. The survey ends with socio-demographic questions and an open text field for comments.

To ensure comprehensibility and validity of our survey, we conducted ten focus groups. Participants were divided into two groups according to a) whether they had a university degree or not and b) whether they lived in an urban or a rural area. Each group consisted of between four and nine people, and each session lasted 90 minutes. To facilitate the adaptation of the questionnaire to the current development phase, the focus groups were

| Variable | Mean/Share | Median | SD | Min | Max | Germany |
|---|---|---|---|---|---|---|
| Age | 51.30 | 52.00 | 16.09 | 19.00 | 93.00 | 44.70 |
| Share of Females | 0.5 | - | - | - | - | 0.51 |
| Higher Education | 0.35 | - | - | - | - | 0.33 |
| Net Household Monthly Income | 3197 | 3250 | 1465 | 250 | 5500 | 3650 |
| Share with children | 0.56 | - | - | - | - | - |
| Life Satisfaction | 6.66 | 7 | 2.12 | 0 | 10 | - |
| N | 15044 | - | - | - | - | - |

Table 1: Sample Characteristics

conducted in three separate waves, with each wave targeting a different focus area. The survey was pretested in two rounds with a total sample size of $N = 424$. The survey was slightly adjusted between the different pretests and the final survey. We preregistered the survey and analysis at the Open Science Framework[1].

The main study was carried out all over Germany between September 2024 and March 2025. We collected the data via an online questionnaire which was distributed by different online panel providers through the company SurveyEngine. After removing respondents that either failed the attention check or completed the survey in less than one third of the median respondents' survey time, we obtained a total sample size of $N = 15,668$[2]. The sample is a random sample of the adult population in Germany with hard quotas for age and gender and additional soft quotas for income and region. However, the survey company was unable to fulfil all quotas, resulting in our sample not being representative regarding age and income. A descriptive overview of the summary statistics of the final sample is provided in Table 1[3].

## 2.2 Spatially explicit choice experiment

In the discrete choice experiment, respondents were set in a referendum setting, in which they could choose between two options: the status quo or a proposed landscape modification. The framing of the referendum was a regional program conducted by the local municipalities, which aimed at improving biodiversity and environmental conditions in the region of the respondent. Each choice was accompanied by two interactive maps, illustrating the spatial distribution of the respective areas, a table detailing relevant information, and a budget reminder. Figure 1 provides an example choice card. Respondents were asked to indicate whether they would vote for the program or not. This process was repeated over ten consecutive pages, with each page presenting a unique proposal. As attributes, we included the size of protected areas, the area of high nature value farmland, the accessibility of newly created protected areas, the visibility of newly created high nature value farmland from paths or roads, and an annual payment into a nature conservation fund as

[1]The preregistration is currently embargoed but will be available from August 2025 onward under https://osf.io/xf7jh.

[2]The sample includes respondents from two soft launch phases which are not used for model estimation as described in detail in the pre-registration.

[3]The summary statistics table only presents information for the respondents who provided voluntary information about their net household monthly income.

| Attribute | Levels | Description |
|---|---|---|
| Size of protected areas | Vector A*: Status quo, +100, +200, +300, +500, +800; hectares | The total area designated as protected area. Levels indicate the expansion in hectares from the current status. |
| High nature value farmland | Vector B*: Status quo, +200, +400, +600, +1000, +1600; hectares | The total area of high nature value farmland. Levels indicate the expansion in hectares from the current status. |
| Accessibility of new protected areas | Not accessible, Half accessible, Fully accessible | The extent to which the public can access newly designated protected areas, ranging from no access to full access. |
| Visibility of new high nature value farmland | Barely visible, Clearly visible | Indicates how visible the new areas of high nature value farmland are from public roads or paths. |
| Annual payment into a nature conservation fund | 5, 10, 20, 40, 80, 60, 120, 150, 200, 250; euros | The amount each household contributes annually to a fund dedicated to nature conservation efforts. |

*Note: For the size of protected areas and high nature value farmland the attribute levels are either vector A or vector B for a respondent for both attributes.

Table 2: Attributes and levels in the choice experiment.

payment vehicle. The attribute levels for the protected areas and the high nature value farmland were the status quo level plus either the vector of (100, 200, 300, 500, 800) or (200, 400, 600, 1000, 1600) hectares. In the choice card, respondents saw absolute hectare values and the percentage shares, which both refer to the area of 30 km around the place of residence of the respondent. Respondents were not explicitly told about the reference area, but they could see it on the map. The accessibility of the protected areas could be 'not accessible', 'half accessible', or 'fully accessible'. The visibility of high nature value farmland was either 'barely visible from roads or paths' or 'clearly visible from roads or paths'. The cost vector was defined as: (5, 10, 20, 40, 80, 60, 120, 150, 200, 250) euros per household and year. Table 2 provides an overview of the attributes and levels.

The core feature of our study design was the direct link between the respondents' spatial endowment with natural capital and the valuation task. We provided the respondents with an interactive leaflet-based open street map, which showed the status quo of protected areas and high nature value farmland around their place of residence, as well as the newly proposed extensions of these areas. Respondents could zoom and move the map, restricted to their region. To allow for this novel feature in our survey, we set up a real-time computation of the different GIS layers by coupling our survey to an R server via an API. For the status quo of protected areas and high nature value farmland, we used data from European Environment Agency (2017) and German Federal Agency for

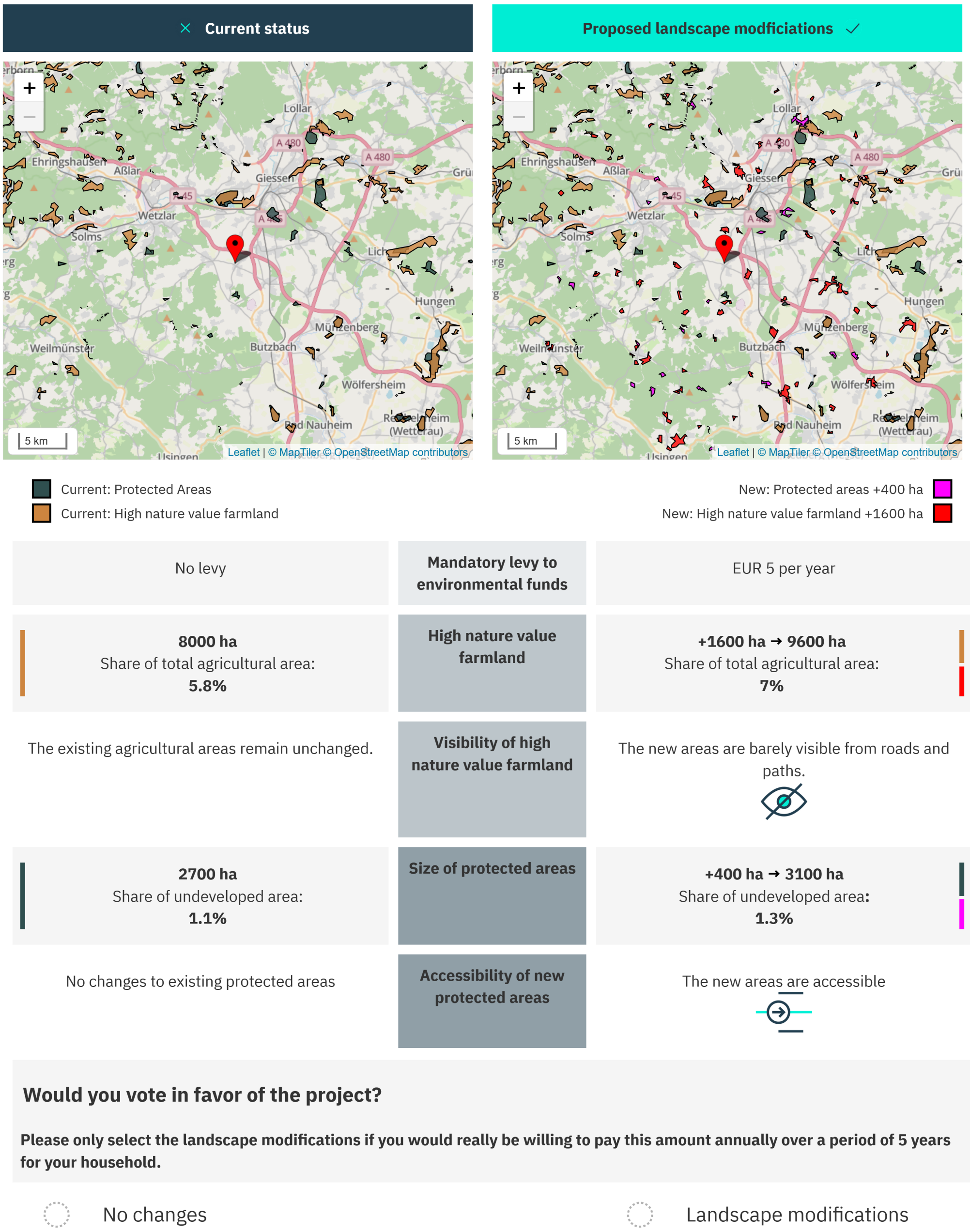


Figure 1: Example choice card (translated).

Nature Conservation (2021), respectively. The exact location and distribution of the newly created areas were randomly determined with an algorithm written in R. To derive the new areas, the algorithm relied on CORINE land cover data from 2018 (Copernicus Land Monitoring Services, 2019) and used only non-build area for new protected areas and only agricultural area for new high nature value farmland areas[4]. Therefore, we ensured that all proposed increases in natural capital were theoretically feasible, directly visible, and relevant in distance to the respondents.

[4]The minimum size per patch was 10 hectares and the maximum size was 500 ha. The algorithm allowed for deviations of ± 5 % of the displayed newly created areas on the map. The location of the new areas did not vary within respondents for the same levels.

To assess the robustness of our estimates with respect to small changes in the valuation scenario, we implemented various between-subject manipulations. Regarding the payment vehicle, we varied the duration of the payment period and the distributional impact of the payment. To control for embedding effects, we manipulated the distance of the proposed changes to the place of residence. To investigate potential scope effects, we applied two different vectors for the sizes of the proposed changes in natural capital. To control for ordering effects in the discrete choice experiment, we implemented split samples for the order of the attributes and the alternatives.

To reduce hypothetical bias, we followed best practices from the literature (Haghani et al., 2021; Mariel et al., 2021). First, we repeatedly emphasized the possibility of implementation of an analogous approach to the presented hypothetical referendum in a real-world context. Second, we reminded respondents at different locations in the survey that the results will be used to inform political decision-making, highlighting the potential influence their responses could have on actual policy outcomes (Vossler et al., 2012). Third, we repeatedly included a budget reminder (Börger et al., 2024). On each choice set, an accompanying remark highlights the fact that respondents should vote in favor of the proposed measure only if they are willing to pay the specified amount for the given period. Fourthly, we reminded respondents to regard each choice set separately and independently of the choices made earlier (Vossler et al., 2024).

We created our experimental design using a full factorial, which resulted in 1,500 different choice cards. We randomly assigned each respondent to ten of those choice cards. By using a full factorial, we aim to avoid undesired effects of the experimental design on the estimates. To compare the efficiency of our design to conventional efficient designs we tested different efficient designs with Monte-Carlo simulations in R and compared them to the full factorial.

## 3 Methodology

To analyze the results of the choice experiment, we apply random utility theory, where individuals choose the utility maximizing alternative (Train, 2009). We employ a mixed logit model to allow for unobserved preference heterogeneity in the estimated parameters (Hensher et al., 2015). Formally, we assume that an individual $n$ chooses alternative $i$ over alternative $j$, whenever $U_{ni} > U_{nj}$. The utility of alternative $i$ can be generally described by:

$$U_i = f(\mathrm{NC}, \Phi) + \beta_c \cdot C + \beta_Y \cdot Y + \epsilon_i \tag{1}$$

$f(\mathrm{NC}, \Phi)$ defines the exact specification of how natural capital $NC$ enters utility. Thereby, $NC = \{\mathrm{PA}_a, \mathrm{HNV}_v\}$ and $a = \{1, 2, 3\}$ is the level of accessibility of newly created protected areas and $v = \{1, 2\}$ is the level of visibility of newly created high nature value farmland. $\mathrm{PA}_a$ is the area of protected areas within 30 km around the place of residence of the respondent including potential new areas, where $a$ indicates the accessibility of the protected areas ("not accessible" = 1 to "fully accessible" = 3). Accordingly, $\mathrm{HNV}_v$ denotes the area of high nature value farmland including the visibility attribute via

$v$ (“not visible” = 1, “visible” =2 ). Since the area for both attributes always refers to a constant base area for each respondent, it can be interpreted directly as a corresponding density measure of the endowment. $\Phi$ is a vector of parameters to be estimated. In the mixed logit model, we assume all parameters in $\Phi$ as normally distributed. $C$ and $\beta_C$ is the annual cost for the policy and the respective parameter. For $\beta_C$, we assume a negative log-normal distribution. $\epsilon$ is the unobserved error term which is assumed to be identically and independently extreme value distributed. $Y$ is a vector of control variables which include the different split sample treatments such as the radius of the area where the new $NC$ areas are created. For the status quo alternative, $NC$ is the current size of natural capital. For the policy scenario, $NC$ is the current size plus the newly created area. $\epsilon_i$ is the random component of utility, which cannot be observed. In the following, we display potential specifications for $f(\text{NC}, \Phi)$. We will estimate these specifications and identify the optimal model using measure-of-fit statistics and Likelihood-ratio tests.

| Function Type | Function $f(\text{NC}, \Phi)$ | Parameters (‘$\Phi$‘) |
|---|---|---|
| Linear | $\beta_{\text{NC}} \cdot \text{NC}$ | $\{\beta_{\text{NC}}\}$ |
| Quadratic Utility | $\beta_{\text{NC}} \cdot \text{NC} + \beta_{\text{NC}_{\text{sq}}} \cdot \text{NC}^2$ | $\{\beta_{\text{NC}}, \beta_{\text{NC}_{\text{sq}}}\}$ |
| Logarithmic | $\beta_{\text{NC}} \cdot \log(\text{NC})$ | $\{\beta_{\text{NC}}\}$ |
| Box-Cox | $\beta_{\text{NC}} \cdot \frac{\text{NC}^{\lambda}-1}{\lambda}$ | $\{\beta_{\text{NC}}, \lambda\}$ |
| Log-Linear | $\beta_{\text{NC}} \cdot \text{NC} + \beta_{\text{NC}_{\log}} \cdot \log(\text{NC})$ | $\{\beta_{\text{NC}}, \beta_{\text{NC}_{\log}}\}$ |

Table 3: Mathematical functions for utility specification.

In a more advanced model, we include interactions of the natural capital variables with spatial varying factors and socio-demographic variables in the vector $X$ in the model. As an example, the quadratic model has the form:

$$U = \beta_{NC} \cdot \text{NC} + \beta_{NC_{sq}} \cdot \text{NC}^2 + \beta_{NCX} \cdot \text{NC} \cdot X + \beta_{NCX_{sq}} \cdot \text{NC}^2 \cdot X + \beta_C \cdot C + \beta_Y \cdot Y + \epsilon \quad (2)$$

where the vectors $\beta_{NCX}$ and $\beta_{NCX_{sq}}$ capture the respective interaction effects on the utility related to natural capital. To reduce the number of coefficients both interaction vectors enter the model as non-random components. For all model estimations, we use the *Apollo* package in R (Hess and Palma, 2019) with the `bgw` algorithm (Bunch et al., 1993) and 2,000 `Sobol` draws. The full code of our analysis is provided on `GitHub`.[5],

# 4 Results

## 4.1 Estimation results

Table 4 presents the results of the quadratic model estimated in willingness to pay space. The results indicate a significant positive willingness to pay for protected areas, ranging

[5]Link to the `GitHub` repository https://anonymous.4open.science/r/valugaps-DD6D/.

between about 9 and 21 euros per 1,000 hectares per year for a status quo of zero. The mean willingness to pay is highest if the protected areas are fully accessible, followed by half accessible and lowest if the areas are not accessible. The WTP is decreasing for accessible and non-accessible protected areas, but not endowment-dependent for half accessible protected areas as the squared term is not different from zero. The estimated mean willingness to pay for high nature value farmland is 12.11 in case of non-visibility and 15.53 in case of visibility. The squared terms for the high nature value farmland attributes are significant and negative, indicating decreasing marginal utility. The coefficient for the annual payment is significantly negative. We observe a significant negative coefficient for the alternative specific constant, indicating that people generally prefer landscape modifications over the status quo. The distance to the proposed landscape changes negatively impacts the willingness to pay for these changes. The dummy scope high is significant and large in magnitude, meaning that respondents faced with the vector of larger changes are more likely to choose the status quo. We identify significant preference heterogeneity for all attributes.

Comparing the willingness to pay values for the different types of natural capital in Figure 2 for an endowment of zero, we see that there is a significant difference between the willingness to pay for non-visible versus visible high nature value farmland areas based on 95% confidence intervals, where the respondents prefer visible over non-visible high nature value farmland areas. The willingness to pay for protected areas is linearly increasing in accessibility. The patterns clearly suggest that the rather use-related values of natural capital are higher than the rather non-use related values. Comparing the willingness to pay values of high nature value farmland with protected areas, we see that the WTP for protected areas is only higher if they are fully accessible or when the high nature value farmland is non-visible and the protected areas are at least half-accessible.

Figure 3 illustrates the relationship between the status quo endowment and the marginal willingness to pay functions. Further, the distribution of the endowments in the sample is displayed with the median plotted as a dashed line. The marginal value of protected areas is decreasing with endowment for non-accessible and fully accessible protected areas. For half accessible areas, the WTP is increasing but not significant, thus WTP is estimated to be status quo independent for half accessible areas. Depending on the accessibility the marginal value of protected areas is turning negative with a status quo endowment between about 75,000 to 100,000 hectares within the area of 30 km around the place of residence. For the value of high nature value farmland, the willingness to pay is factually non-decreasing and strictly positive, irrespective of the visibility of the changes from paths or roads.

### 4.2 Aggregation

To derive aggregated WTP values for a one hectare change within a $1km^2$ raster cell, we follow a five-step procedure. The main assumption we make for the aggregation is that people are only willing to pay for hectare changes within $15km$, thus the computed aggregated WTP values are clearly a lower bound estimate. We later vary these assumptions

| | Mean | SD |
|---|---|---|
| Protected Areas NA | 9.32*** | −3.44*** |
| | (0.65) | (0.14) |
| Protected Areas NA Squared | −0.06*** | 0.16*** |
| | (0.01) | (0.01) |
| Protected Areas HA | 15.64*** | −2.72*** |
| | (1.08) | (0.34) |
| Protected Areas HA Squared | 0.02 | 0.02** |
| | (0.02) | (0.01) |
| Protected Areas FA | 20.84*** | 6.31*** |
| | (1.18) | (0.19) |
| Protected Areas FA Squared | −0.11*** | −0.05*** |
| | (0.03) | (0.01) |
| HNV NV | 12.11*** | −5.96*** |
| | (0.55) | (0.14) |
| HNV NV Squared | −0.11*** | 0.01 |
| | (0.01) | (0.01) |
| HNV V | 15.53*** | −5.53*** |
| | (0.66) | (0.21) |
| HNV V Squared | −0.11*** | −0.02*** |
| | (0.01) | (0.00) |
| ASC SQ | −52.26*** | −133.03*** |
| | (0.45) | (0.62) |
| Annual Payment | −3.25*** | −1.92*** |
| | (0.03) | (0.04) |
| Radius | −1.03*** | −1.40*** |
| | (0.04) | (0.01) |
| Scope high | 0.44 | −9.79*** |
| | (0.64) | (0.27) |
| No Observations | 142250 | |
| No Respondents | 14225 | |
| Log Likelihood (Null) | −98600.19 | |
| Log Likelihood (Converged) | −64239.65 | |

$^{***}p < 0.005$; $^{**}p < 0.025$; $^{*}p < 0.05$ (one-sided). Robust standard errors in parentheses.

Table 4: Results of mixed logit model with quadratic utility function.

and incorporate the effect of distance on the WTP. First, we use the same GIS data as in the discrete choice experiment to calculate the status quo endowment with protected areas and high nature value farmland within the area of $30km$ around the cell. Second, we employ the mixed logit model estimates from Table 4 to derive marginal WTP values (in euros per 1,000 hectares per year) for each cell. Third, we multiply the marginal WTP by the number of people living in a cell, which we obtain from population density data from the latest German census (Statistische Ämter des Bundes und der Länder, 2025). The value from this step is the WTP for each cell to pay for an increase in the surrounding of this cell. To derive the aggregated WTP for a one hectare change within a cell, we compute for each cell all other cells where people would benefit from a change within this cell. Lastly, we sum up the aggregated WTP values for each associated cell, providing us

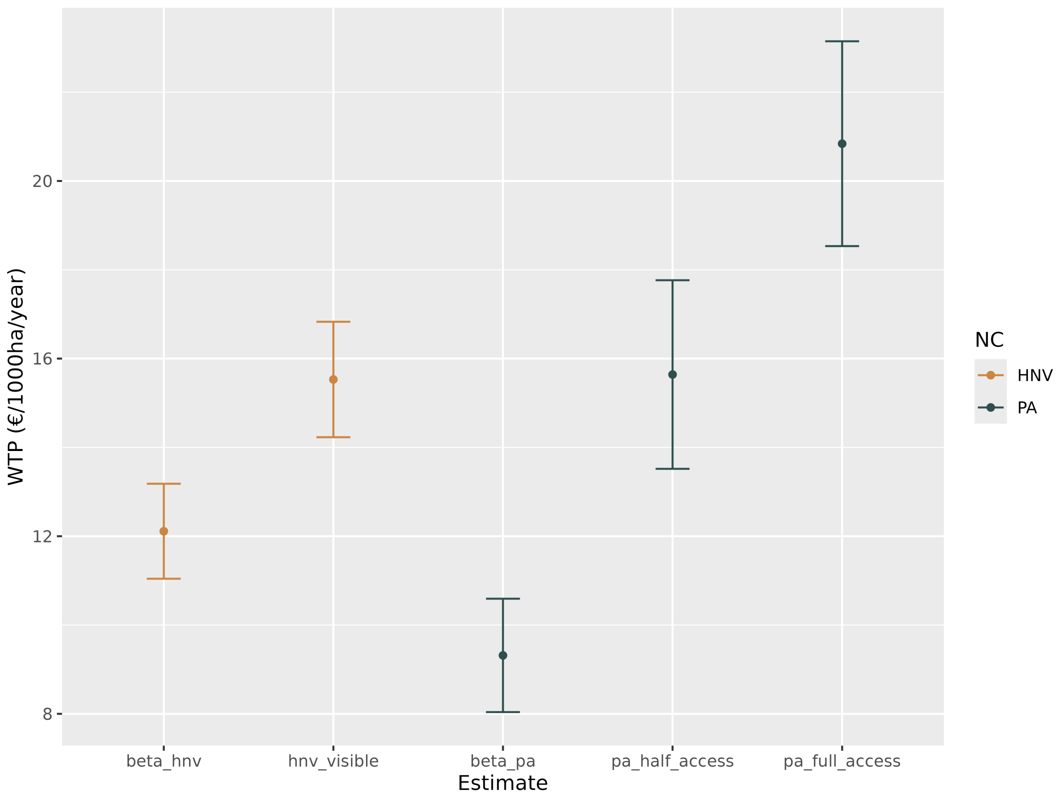


Figure 2: Estimated mean willingness to pay for natural capital attributes with 95% confidence intervals.

with the aggregated marginal WTP for a one hectare increase within a cell.

Figure 4 shows the distribution of the different aggregated WTP values for non-accessible protected areas across Germany. The map on the left shows the marginal WTP per person based on the status quo endowment in the respective surrounding of the $1km^2$ cell. The values vary between less than zero to more than 9 euros per year. The map in the middle shows the aggregated WTP per raster cell for an 1,000 hectare increase in the surrounding of the cell. There is a large variation in aggregated cell WTP values originating from variation in population density and status quo endowment. The map on the right displays the distribution of the aggregated WTP per hectare of non-accessible protected areas for each $1km^2$ cell in Germany. The per hectare values vary from negative WTP values up to more than 20,000 euros, with the most values in the range of 1,000 to 5,000 euros. The WTP hot spots are centered around the main populated areas in Germany.

## 5 Outlook

With the results from the main study, we will be able to compute spatially explicit values for protected areas and high nature value farmland for a high-resolution raster grid. Using collected information on socio-demographics and available land cover data, we can identify the main drivers for heterogeneity in these values. The large sample size and the various implemented split samples will allow us to extensively test the robustness of derived values.

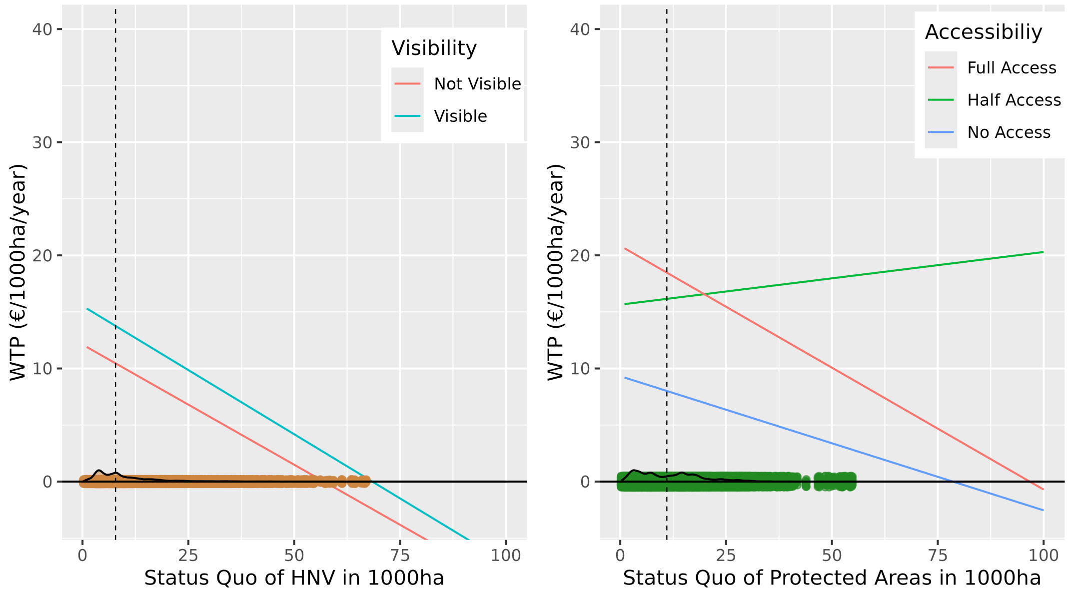


Figure 3: Marginal willingness to pay for high nature value farmland and protected areas as functions of status quo endowment.

In the end, we will map the spatial distributions of the marginal and aggregated values of protected areas and high nature value farmland in Germany, which is highly relevant information for policymakers and natural capital accountants. We are convinced that the findings of our paper will provide various insights for functional benefit transfer of natural capital values and contribute to a better understanding of the complex values of natural capital.

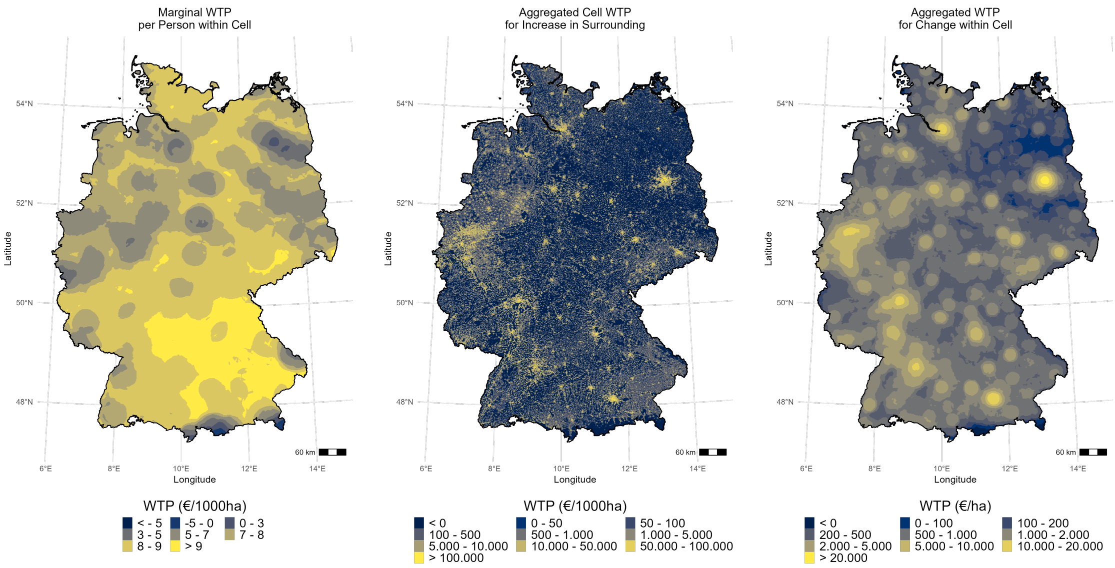


Figure 4: Aggregation of WTP values for an increase in non-accessible protected areas of 1,000 hectares, moving from marginal WTP per cell (*left*) via aggregated cell WTP for a change in the surrounding (*middle*) to aggregated WTP for a one hectare change within the cell (*right*).

## References


Addicott, E. T., & Fenichel, E. P. (2019). Spatial aggregation and the value of natural capital. *Journal of Environmental Economics and Management*, *95*, 118–132.

Alpizar, F., Carlsson, F., & Martinsson, P. (2003). Using Choice Experiments for Non-Market Valuation. *Economic Issues Journal Articles*, *8*(1), 83–110.

Badura, T., Ferrini, S., Burton, M., Binner, A., & Bateman, I. J. (2020). Using individualised choice maps to capture the spatial dimensions of value within choice experiments. *Environmental and Resource Economics*, *75*, 297–322.

Börger, T., Glenk, K., Rehdanz, K., & Meyerhoff, J. (2024). Mitigating cost vector effects in stated choice experiments using cheap talk and opt-out reminders. *Journal of the Association of Environmental and Resource Economists*.

Bunch, D. S., Gay, D. M., & Welsch, R. E. (1993). Algorithm 717: Subroutines for maximum likelihood and quasi-likelihood estimation of parameters in nonlinear regression models. *ACM Transactions on Mathematical Software (TOMS)*, *19*(1), 109–130.

Chiesura, A., & De Groot, R. (2003). Critical natural capital: A socio-cultural perspective. *Ecological Economics*, *44*(2-3), 219–231.

Copernicus Land Monitoring Services. (2019). *Corine land cover 2018*. Retrieved November 21, 2024, from https://land.copernicus.eu/en/products/corine-land-cover/clc2018

Costanza, R. (2020). Valuing natural capital and ecosystem services toward the goals of efficiency, fairness, and sustainability. *Ecosystem Services*, *43*, 101096.

Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'neill, R. V., Paruelo, J., et al. (1997). The value of the world's ecosystem services and natural capital. *nature*, *387*(6630), 253–260.

Czajkowski, M., Budziński, W., Campbell, D., Giergiczny, M., & Hanley, N. (2017). Spatial heterogeneity of willingness to pay for forest management. *Environmental and Resource Economics*, *68*, 705–727.

Dasgupta, S. P. (2021). The economics of biodiversity the dasgupta review abridged version.

European Environment Agency. (2017). *High nature value (hnv) farmland*. Retrieved November 21, 2024, from https://www.eea.europa.eu/en/datahub/datahubitem-view/1bd26e8f-8ea0-45e0-b6bf-9ed2baff5d28?activeAccordion=1070000

German Federal Agency for Nature Conservation. (2021). *Schutzgebiete*. Retrieved November 21, 2024, from https://gdk.gdi-de.org/geonetwork/srv/api/records/bec888f9-ba0c-42dc-846e-177b8265dafa

Glenk, K., Johnston, R. J., Meyerhoff, J., & Sagebiel, J. (2020). Spatial dimensions of stated preference valuation in environmental and resource economics: Methods, trends and challenges. *Environmental and Resource Economics*, *75*, 215–242.

Guerry, A. D., Polasky, S., Lubchenco, J., Chaplin-Kramer, R., Daily, G. C., Griffin, R., Ruckelshaus, M., Bateman, I. J., Duraiappah, A., Elmqvist, T., et al. (2015). Natural capital and ecosystem services informing decisions: From promise to practice. *Proceedings of the National academy of Sciences*, *112*(24), 7348–7355.

Haghani, M., Bliemer, M. C., Rose, J. M., Oppewal, H., & Lancsar, E. (2021). Hypothetical bias in stated choice experiments: Part ii. conceptualisation of external validity, sources and explanations of bias and effectiveness of mitigation methods. *Journal of choice modelling*, *41*, 100322.

Hensher, D. A., Rose, J. M., & Greene, W. H. (2015). *Applied choice analysis* (2nd ed.). Cambridge University Press.

Hess, S., & Palma, D. (2019). Apollo: A flexible, powerful and customisable freeware package for choice model estimation and application. *Journal of choice modelling*, *32*, 100170.

Johnston, R. J., Moeltner, K., Peery, S., Ndebele, T., Yao, Z., Crema, S., Wollheim, W. M., & Besedin, E. (2023). Spatial dimensions of water quality value in new england river networks. *Proceedings of the National Academy of Sciences*, *120*(18), e2120255119.

Mariel, P., Hoyos, D., Meyerhoff, J., Czajkowski, M., Dekker, T., Glenk, K., Jacobsen, J. B., Liebe, U., Olsen, S. B., Sagebiel, J., et al. (2021). *Environmental valuation with discrete choice experiments: Guidance on design, implementation and data analysis*. Springer Nature.

Sagebiel, J., Glenk, K., & Meyerhoff, J. (2017). Spatially explicit demand for afforestation. *Forest Policy and Economics*, *78*, 190–199.

Statistische Ämter des Bundes und der Länder. (2025). *Zensus 2022*. Retrieved June 17, 2025, from https://www.zensus2022.de/EN/Home/_node.html

Toledo-Gallegos, V. M., Long, J., Campbell, D., Börger, T., & Hanley, N. (2021). Spatial clustering of willingness to pay for ecosystem services. *Journal of Agricultural Economics*, *72*(3), 673–697.

Train, K. E. (2009). *Discrete choice methods with simulation*. Cambridge university press.

Vossler, C. A., Dolph, C. L., Finlay, J. C., Keiser, D. A., Kling, C. L., & Phaneuf, D. J. (2023). Valuing improvements in the ecological integrity of local and regional waters using the biological condition gradient. *Proceedings of the National Academy of Sciences*, *120*(18), e2120251119.

Vossler, C. A., Doyon, M., & Rondeau, D. (2012). Truth in consequentiality: Theory and field evidence on discrete choice experiments. *American Economic Journal: Microeconomics*, *4*(4), 145–171.

Vossler, C. A., Keiser, D. A., Kling, C. L., & Phaneuf, D. J. (2024). Information scripts and the incentive compatibility of discrete choice experiments. *Journal of the Association of Environmental and Resource Economists*, *0*(ja), null. https://doi.org/10.1086/731527