Climate change perceptions in Bavaria

Revealing the influence of socio-demographic and local environmental factors

Research on perceptions of climate change has been focused on either social or environmental factors, lacking interdisciplinarity. This study bridges this gap by assessing the influence of both. Our analyses reveal societal actor group affiliation as the strongest predictor for the perception of climate change.

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Abstract

People's perceptions of climate change are crucial for their readiness to engage in mitigation and adaptation. To identify the most influential factors in shaping perceptions of climate change, we conducted a comprehensive survey, carried out in Bavaria, Germany. Overall, 2,594 individuals across four societal actor groups were surveyed, namely 1,413 farmers, 197 foresters, 152 nature managers, and 832 citizens (no specific profession). We explored to what extent environmental factors (climate trends and land cover conditions in interviewees' place of residence – based on geographical data) and socio-demographic factors (age, gender, education, societal actor group affiliation – based on survey data) influence perceptions of climate change. Data analyses, including random forest algorithms, revealed socio-demographic factors, particularly societal actor group affiliations, as most influential variables. Local land cover conditions and climate trends only marginally affected residents' perceptions. Consequently, our results suggest to consider socio-demographic factors for tailoring climate communication, policies and awareness raising campaigns, particularly targeting societal groups most skeptical about climate change.

Keywords

climate change perceptions, environmental factors, Germany, random forest, societal actor groups, survey

Introduction: Climate change perceptions influence climate action

The climate crisis poses a global threat with drastic consequences for all living beings, including humankind. Yet, individuals' perceptions of climate change vary across time (Howe et al. 2019, Pahl et al. 2014, Whitmarsh 2011) and space (Lee et al. 2015, Poortinga et al. 2019, Prokopy et al. 2015). Some perspectives – often associated with the privileged Global North – interpret climate change through a psychologically distant lens, as an issue affecting solely future generations or people in distant locations with lower socio-economic statuses (Guttry et al. 2017, Howe et al. 2019, McDonald et al. 2015, Spence et al. 2012). Regardless, implications of climate change now become increasingly immediate, proximate, and devastating – all over the world. Consequently, not only are the impacts increasing, but so is public awareness. In only five years (2017 to 2023), the proportion of European citizens mentioning climate change as the single most serious problem facing the world as a whole increased significantly (EU average: 11 % to 17 %; Germany: 16 % to 22 %) (European Commission 2023). Among German citizens, in 2022 nearly 90 % considered climate change impacts as a threat (UBA and BMUV 2023).

Perceptions of climate change have been widely recognized as being influential on actions towards climate mitigation and adaptation (Arbuckle et al. 2013, Blennow et al. 2012, Bradley et al. 2020, Hornsey et al. 2016, Van Valkengoed and Steg 2019). Therefore, it is important to explore how individuals perceive climate change. Generally, we follow the definition of perceptions

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based on Bennett (2016), who understands perceptions as a way of individual observations, understandings, interpretations, and evaluations. Hence, the term comprises cognitive (e. g., sensory experiences, knowledge), affective (e. g., emotions), and evaluative (e. g., beliefs) dimensions (Whitmarsh and Capstick 2018). The perceptions of individuals regarding climate change are thus dependent on the extent to which they assimilate information, observe shifts in surrounding ecosystems and how these changes make them feel, as well as the relevance they attach to the process and consequences of such environmental changes.

To identify levers for enhanced climate action, it is crucial to grasp the underlying factors for heterogeneity of perceptions. Yet, many studies aiming to explain perceptions of climate change have focused on either social or environmental factors, lacking interdisciplinarity. Some scholars highlight the importance of actual encounters with climate-change-induced impacts and events (McDonald et al. 2015, Reser and Bradley 2020), hence implicating the influence of environmental factors. In contrast, others emphasize the significance of socio-demographic factors (Barth et al. 2021, Fielding and Hornsey 2016). For instance, the perception of abnormally warm temperatures was found to be more strongly influenced by political orientations and general attitudes towards climate change than by actual temperature changes (Howe and Leiserowitz 2013, McCright et al. 2014).

Reicher et al. (2010) argued that existing perceptual differences among societal actor groups could be best explained using a central environmental psychology concept commonly referred to as "social identity approach"[1]. This approach seeks to explain how individuals are influenced by group memberships and hence conceive the self as consisting of both personal and social identities. Fritsche et al. (2018) applied this approach to the environmental domain and developed the "social identity model of pro-environmental action" to explain how social identity processes affect both people's appraisals of and behavioral responses to large-scale environmental crises. The authors proposed that both environmental appraisals and actions are determined by three main processes including ingroup identification, in-group norms and goals, and collective efficacy[2]. Yet, studies investigating climate change perceptions within and between multiple societal actor groups are still rare. In Germany, for example, only the studies by Barkmann et al. (2017) and Wagner et al. (2019) distinguished different land-user groups in their analyses of climate-change-related perceptions. Detecting the most significant influence factors might reveal stakeholder- and/or space-specific needs and therefore support the design of targeted climate communication, environmental policies, and awareness raising.

The goal of our study is to contribute to this ongoing debate on understanding the main drivers that shape climate change perceptions. Assuming the importance of a range of factors, we examine the role of both socio-demographic (i. e., societal actor group affiliation, education, gender, age) and environmental factors (i. e., local land cover conditions and climate trends) on participant responses in a survey implemented in the federal state of Bavaria, Germany.

GAIA Masters Student Paper Award

Theresa Landwehr is the winner of the 2023 *GAIA Masters Student Paper Award (GMSPA)*[a]. Her paper *Climate change perceptions in Bavaria: Revealing the influence of socio-demographic and local environmental factors* was selected by an international jury and is now published in *GAIA* after successful editorial board peer review.

The *GMSPA* addresses Masters students. They are encouraged to submit their results from research-based courses or Masters theses in the field of transdisciplinary environmental and sustainability science. The winner will be granted a prize of 1,500 euros as well as a free one-year subscription to *GAIA*. The award 2023 was endowed by the by Selbach Environmental Foundation and Dialogik gGmbH.

a For more details see *www.oekom.de/publikationen/zeitschriften/gaia/c-131*.

Methods: Locating survey data in space

To link social- and natural-scientific perspectives, we combined spatially explicit geophysical measures with survey data. We chose a stratified sampling approach to adequately cover climate and land use gradients in Bavaria (figure 1 a, b, p. 314, Redlich et al. 2021). To represent important stakeholders who could impact land-use decisions, we sampled four different groups. The selected societal actor groups were farmers, foresters, and nature managers[3], who have the power to *directly* influence land use, as well as citizens, who have mainly *indirect* influences[4]. We adapted the sampling strategy to each of the respective societal actor groups (figure 1 c, chapter 1 of the online supplementary material[5]).

Survey data

We conducted surveys from January to July 2020. The relevant question items about climate change perceptions followed other survey sections focusing on ecosystem services (Thiemann et al. 2022), landscape elements (Küchen et al. 2023), and agri-environmental schemes. The sample comprises 1413 farmers, 197 foresters, 152 nature managers, and 832 citizens (no specific profession) (figure 1 d)[6]. In order to simplify the survey proce- >

1 This approach comprises two interrelated theories: firstly, the "social identity theory" (Tajfel and Turner 1979) and secondly, the "self-categorization theory" (Turner et al. 1987).

2 The extent to which people perceive their group to be effective in reaching its goals has been described as *collective efficacy* (= belief in the capabilities of the in-group) (Barth et al. 2021).

3 All people working as professionals or volunteers managing near-natural areas and urban green spaces, e. g., at nature conservation authorities or in protected areas.

4 Our sampling approach neglects that respondents can be part of several groups concurrently, e. g., a survey participant could have been invited to participate as a farmer, but also manages a forest.

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6 For sampling details, see chapter 1 of the online supplementary material: *https://doi.org/10.14512/gaia.32.3.8.suppl*.

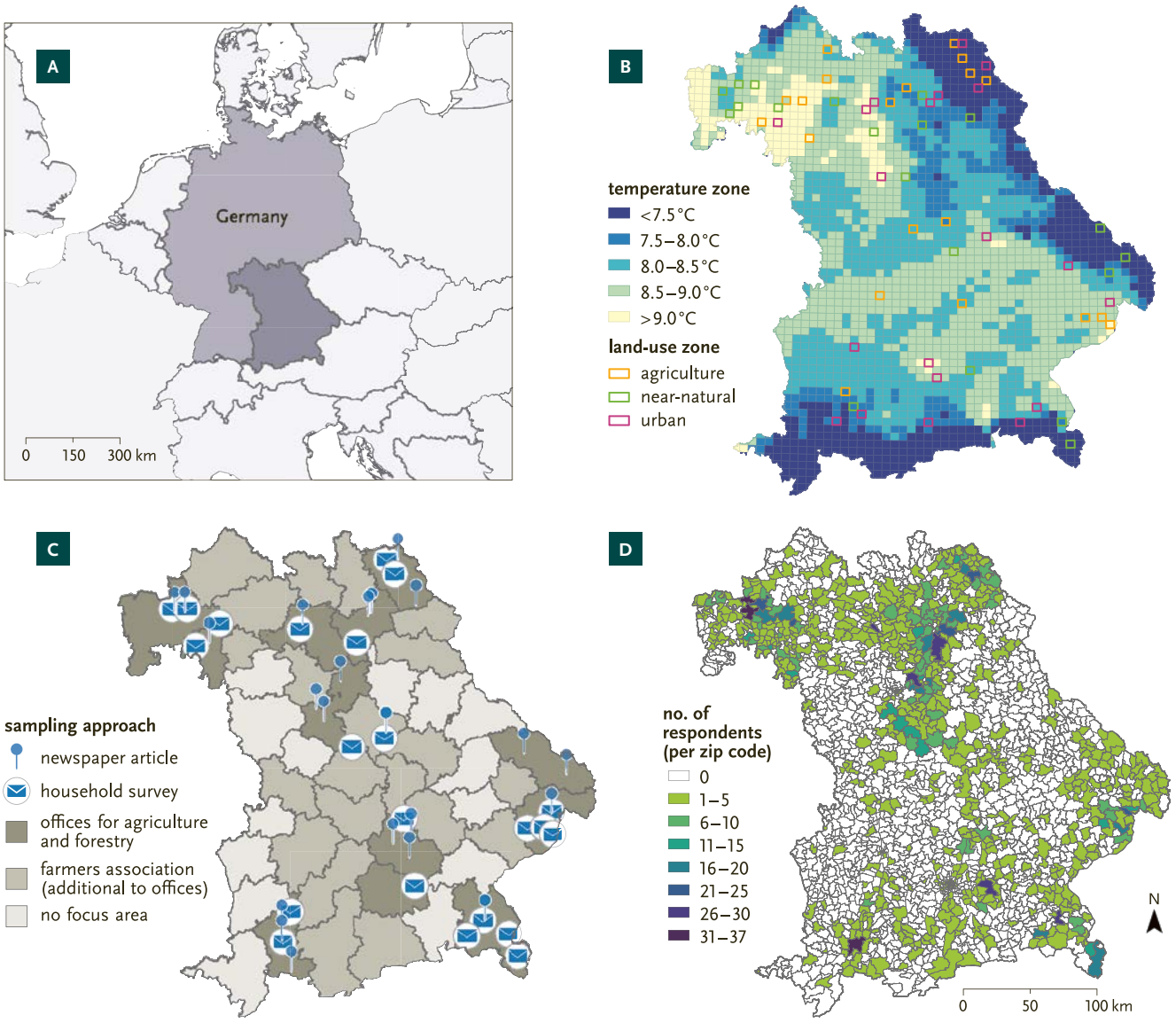

FIGURE 1: **A** Location of the Federal State of Bavaria within Germany and Central Europe. **B** Considered combination of land-use and climate gradient, setting the base for the survey sampling focus. For more details, see Redlich et al. (2021). **C** Spatial targeting of survey for each of the four societal actor groups: farmers and foresters, both in selected areas of offices for agriculture and forestry, with farmers additionally in selected districts of farmers associations, nature managers all over Bavaria, and citizens through invitations per postcards (household survey) and through newspaper articles). See chapter 1 of the online supplementary material for more details: *https://doi.org/10.14512/gaia.32.3.8.suppl*. **D** Survey participation per zip code (722 of 2,594 included survey participants did not indicate a zip code).

dure, each respondent was displayed a random subset consisting of only three out of five questions. The main analyzed statements were: "Climate change is scientifically proven", "Climate change has predominantly natural causes", "Climate change in general is already having a global impact today", "Climate change in general can still be influenced", and "Climate change will only become relevant for future generations". The questionnaire items relate to a skepticism typology developed by Rahmstorf (2004). For instance, respondents who disagreed with the scientific provability of climate change might be classified as "consensus skeptics". Respondents denying or doubting the predominantly anthropogenic causing of climate change can be classified as "attribution skeptics". Participants were asked the overall question: "What do you think about the following statements?" We assessed respondent (dis)approval rates using a five-point Likert scale (Likert 1932) across the response items *no, definitely not (––), no probably not (–), I'm unsure (–/+), yes, probably (+)*, and *yes, definitely (++)*. We additionally recorded the societal group affiliation, age, gender, education, and place of residence (indicated as postal code) of respondents[7] (see chapter 5 of the online supplementary material for a comparison of survey sample characteristics with Bavaria-wide statistics[5]).

TABLE 1: Overview of explanatory variables used for assessing perceptions of climate change.

CATEGORY	EXPLANATORY VARIABLE	VALUES/CHARACTERISTICS	DATA SOURCE/TYPE
socio-demographics	age class	<18, 18–25, 26–30, 31–35, 36–40, 41–45, 46–50, 51–55, 56–60, 61–65, 66–70, >70	survey/categorial
	gender	male, female, diverse	survey/categorial
	education	no school diploma, lower secondary education, middle secondary education, higher secondary education	survey/categorial
	societal actor group	farmers, foresters, nature managers, citizens	survey/categorial
environmental	land cover in place of residence (zip code)	agricultural, near-natural, urban (surface share) [%]	CLC/continuous
	climate trends in place of residence (zip code)	mean temperature [°C], annual precipitation [mm], drought index[a], number of frost days (< 0 °C), number of hot days (≥ 30 °C) (periods 1990[b]–2019 and 2015–2019)[c]	DWD/continuous

a Drought index by Martonne (1926) based on both temperature and precipitation values. | b Time period of the drought index is slightly shorter due to its temporal coverage commencing only in 1995. | c Linear climate trends were calculated using annual datasets of long-term (1990–2019) and short-term (2015–2019) means with the lm functions of the R package *stats*.

Environmental data

We used two geographical data sets to determine the influence of environmental factors on climate change perceptions. On the one hand, land cover data derived from the *CORINE Land Cover (CLC)* dataset (EEA 2018) allowed us to capture land cover conditions in respondents' residence locations (zip codes), summarized as shares of three categories: urban, agricultural, and near-natural[8]. On the other hand, we utilized data provided by German Meteorological Service (DWD 2020) to calculate five different climate parameters for two different time periods (table 1). With this data set, we intended to capture climate change conditions, represented through long- and short-term trends, potentially experienced by survey respondents at their place of residence (as indicated via postal code information), which may in turn influence their perceptions of climate change.

Statistical data analyses

We tailored the analyses of our five survey items to the ordinal nature of the response data – the Likert-scaled items of climate change perceptions[9]. Due to high collinearities of some explanatory variables (R^2 up to 0.74), we chose to build random forest[10] models (Breiman 2001). These models achieve high predictive accuracies and robust ranking of variable importance even among highly correlated predictors. Another main advantage lies in their suitability to cope well with predictors varying in scale of measurement and number of categories (Tutz 2021). These features enable the detection of complex variable interactions between geophysical and socio-demographic variables, which could not be uncovered with bivariate or other multivariate correlation analyses alone. To account for our ordinal response levels, we used conditional inference trees, which belong to the family of recursive partitioning methods, as "base learners"[11]. We based this approach on Ameztegui et al. (2018) and Lee et al. (2015). For the processing of data, we used *QGIS v3.10.12* (QGIS Development Team 2020) and *R v4.0.4* (R Core Team 2020). For the random forest models, we employed the function *cforest* of the R package *party* which uses unbiased trees and an adequate resampling scheme (see Hothorn et al. 2006 and Strobl et al. 2007).

Results: Profession, education, and gender matters

Overall, our results indicate that Bavarian residents exhibit strong perceptions of climate change (figure 2, p. 316). Survey participants showed general consensus about the current global consequences and scientific verifiability of climate change. The large majority rejected that climate change will affect only future generations and disagreed that it has been predominantly rooted in natural causes. Respondents showed the highest uncertainty and ambiguity regarding the question of influenceability of climate change. >

7 The survey was conducted anonymously and analysed separately from any personal data. Non-complete data records were included in the analysis.

8 For classification details, see chapter 3a of the online supplementary material: *https://doi.org/10.14512/gaia.32.3.8.suppl*.

9 For detailed methods, see chapters 6 and 7 of the online supplementary material: *https://doi.org/10.14512/gaia.32.3.8.suppl*.

10 Random forests are an ensemble of decision trees which uses machine learning algorithms to boost predictive performance.

11 The basic principle is to split the dataset into different samples based on test-statistics and p-values. In a first step, each candidate predictor (i. e., explanatory variable) from a randomly drawn data subset is tested for its association with the response (i. e., perception variable), yielding a p-value. Every time, the predictor with the smallest p-value (i. e., strongest association with the response variable) is selected, whereby, only statistically significant variables at $p < 0.05$ are considered. This p-value based threshold must be undercut to perform the second step, a binary split (with the best results) within the selected variable. This procedure is reiterated per tree as long as there is a significant variable to split it by.

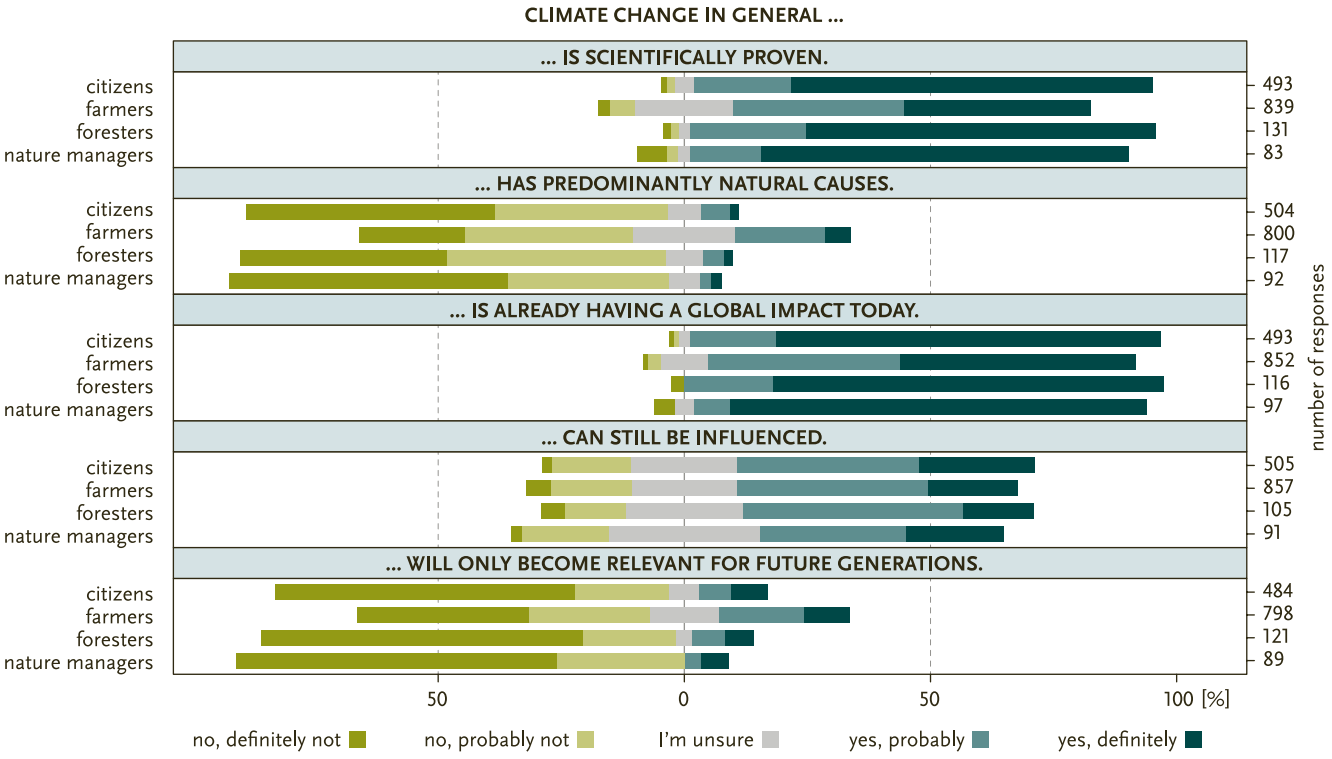

FIGURE 2: Climate change perceptions differentiated by societal actor groups (citizens, farmers, foresters, and nature managers).

Across the four societal actor groups, specifically farmers tended to follow a specific response pattern. Bivariate analysis found environmental factors (land cover and climate variables) to be of marginal importance for influencing respondent's climate change perceptions. Instead, the variable societal group affiliation, followed by education and gender, clearly emerged as the most influential determinants affecting respondent's perceptions about the verifiability, causes as well as current and future relevance of climate change (table 2).

These results were confirmed by our multivariate analysis via the random forest models utilizing conditional inference trees. The exemplary conditional inference tree in figure 3 (p. 318) illustrates that citizens, foresters, and nature managers are significantly more likely to believe in scientific verifiability than farmers, especially individuals with higher secondary education levels and those with younger ages (≤ 26 to 30). In contrast, female farmers with lower secondary education levels are predicted to be relatively unsure about the evidence of climate change compared to lower-educated male farmers. Overall, our analyses showed evidence that being a farmer, having lower education levels, and being male may decrease not only beliefs in the scientific verifiability of climate change, but also in its anthropogenic causes, current global consequences, and its future relevance (see chapter 9 of the online supplementary material[5]).

However, it is important to note the overall high perception rates and intra-group variability among Bavarian respondents in order to avoid overgeneralizations and stigmatizations.

Discussion

Putting climate change perceptions into perspective

Our results concerning climate change perceptions in Bavaria are generally consistent with findings of previous studies on climate change perceptions in Germany (Menny et al. 2011, Metag et al. 2017). For instance, approximately 8 %, 6 %, and 4 % of the surveyed citizens, foresters, and nature managers, respectively, considered the causes of climate change as predominantly naturally induced (figure 2). This is in line with studies of the years 2011, 2016, and 2017, where 7 %, 6 %, and 5 % of the German population, respectively, have doubts about the anthropogenic causes of climate change (Poortinga et al. 2019, Steentjes et al. 2017). Yet, in our study, the proportion of farmers indicating that they perceive climate change as resulting from predominantly natural processes was significantly higher (23 %, figure 2). Surveyed farmers were generally more reluctant about the origins of climate change compared to citizens, foresters, and nature managers. Such higher attribution skepticism percentages among farmers are not unusual, as this finding has also been seen in several other countries (Arbuckle et al. 2013, Baba and Tanaka 2019, Chatrchyan et al. 2017, Findlater et al. 2019, Prokopy et al. 2015).

The influence of socio-demographic factors

We initially hypothesized that both socio-demographic and environmental factors explain climate change perceptions in Bavaria, Germany. Yet, we found that the latter was far less influential

TABLE 2: Correlation coefficients between explanatory response variables. Only significant relationships at $p < 0.05$ (adjusted) are displayed. Coefficients are based on Spearman's rho.

EXPLANATORY VARIABLE		RESPONSE VARIABLE: CLIMATE CHANGE IN GENERAL ...				
		... is scientifically proven.	... has predominantly natural causes.	... is already having a global impact today.	... can still be influenced.	... will only become relevant for future generations.
land cover factors	agricultural land cover					0.12
	near-natural land cover					
	urban land cover	0.11		0.14		−0.07
climate factors	temperature trend 1990–2019					
	precipitation trend 1990–2019					
	drought index 1995–2019					
	no. of frost days 1990–2019					
	no. of hot days 1990–2019					
	temperature trend 2015–2019					
	precipitation trend 2015–2019					
	drought index 2015–2019					
	no. of frost days 2015–2019					
	no. of hot days 2015–2019		0.10			
socio-demographic factors	age			0.05		0.09
	gender	−0.11	0.19	−0.14		0.13
	education	0.28	−0.29	0.21		−0.27
	societal actor group	0.34	−0.35	0.32		−0.24

than the former, with *societal actor group affiliation* as the strongest determinant. The process through which farmers develop significantly lower perceptions of climate change than the other three societal actor groups could be related to the social identity theory and model (see Reicher et al. 2010, Fritsche et al. 2018). Accordingly, Bavarian farmers would have collective emotions and motivations (e. g., anxiety about the future and farm preservation), resulting in specific in-group norms, goals, beliefs (e. g., solid reputation, yield increases, sense of community or self-determination). These would form a self-categorization and thus identification (i. e., being a farmer). This process might consequently cause farmers to have significantly different appraisals of, and hence responses to, environmental issues.

Following societal actor group affiliations, *education* was shown to be the next most important determinant in the present study. Respondents with higher education levels indicated significantly higher climate change perceptions, particularly regarding its scientific verifiability, anthropogenic causes, and current relevance. Previous studies suggest that education has a significant effect on climate change perceptions both in Germany (Metag et al. 2017, Ratter 2018, Taddicken et al. 2018) and abroad (Findlater et al. 2019, Hornsey et al. 2016, Poortinga et al. 2019). However, while Lee et al. (2015) found that educational attainment was the single strongest predictor of climate change awareness worldwide, others identified no significant education effects on climate change related risk perceptions among farmers in the North German Plain (Eggers et al. 2015) or among citizens in the city of Mannheim located in South-West Germany (Menny et al. 2011). Such mixed evidence emphasizes the need for interdisciplinary as well as space- and stakeholder-specific studies.

Furthermore, our study findings indicate significant perception differences among female and male respondents. There is solid support for these perceptual *gender* differences in research literature, indicating evidence for women being less skeptical and more concerned about climate change (Poortinga et al. 2019, Shao et al. 2016, Taddicken et al. 2018). These findings, summarized as the "white-male effect" (McCright and Dunlap 2011), are mainly explained with gender-specific socialization processes, social roles, affective dispositions, worldviews, culture, and power relations, which engender women to be tendentially and comparatively more empathetic, caring, dependent, as well as health- and safety-oriented than (white) men (Pearse 2017, Whitmarsh 2011, Xiao and McCright 2013).

The influence of environmental factors

Our study found only marginal effects of climatic variables (e. g., small influence of decrease in frost days) and land cover conditions on people's perceptions of climate change. Although some researchers highlight the influence of individuals' direct encounters with climatic changes (e. g., Reser et al. 2014), other studies investigating the influence of environmental conditions on perceptions of climate change show that neither temperature trends (Egan and Mullin 2012; Shao et al. 2016) nor anomalies (Kaufmann et al. 2017, Whitmarsh and Capstick 2018, Zaval et al. 2014) play a significant role in shaping these. Hence, actual climatic changes do not necessarily manifest in people's perceptions. Furthermore, any potential influence might decay quickly, given that, for instance, the effect of a heat wave has been shown to perceptually last for only three to twelve days (Egan and Mullin 2012, Shao et al. 2014).

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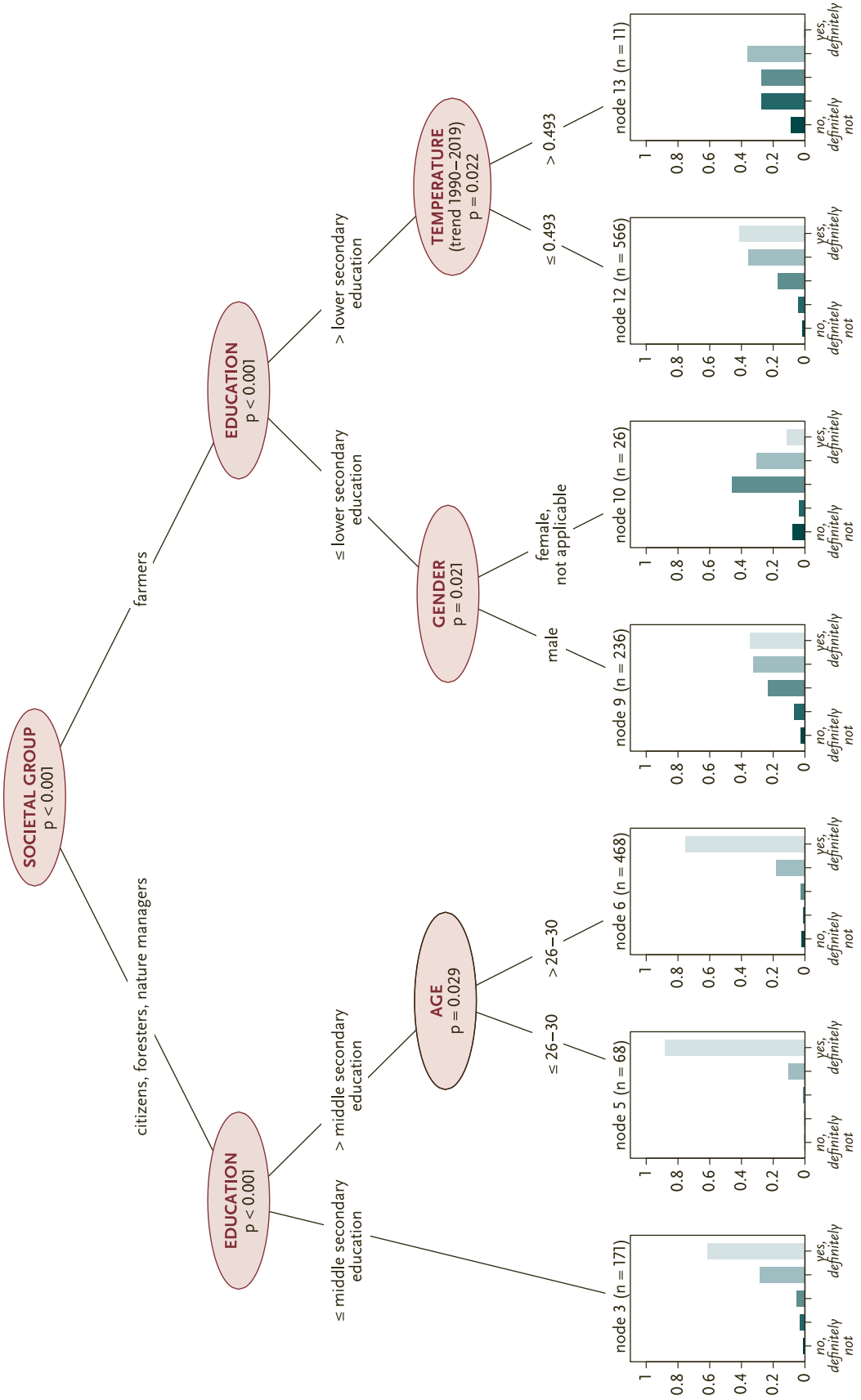

FIGURE 3: Example of a conditional inference tree of the response item "Climate change in general is scientifically proven". Stacked bar plots indicate predicted response distributions, i.e., disagreement (dark green), indecision (medium green), and agreement (light green). For visualization purposes, we specified the depth of the conditional inference trees to a maximum of three subsequent variable selections to display only the most significant variables. The total sample size depends on the response item and can be calculated by adding the sample size of the bar plots (here: 1,546). Yet, it must be considered that the terminal node encompassing lower educated, female farmers (n = 26), and higher educated farmers residing in postal code areas with relatively high linear temperature increases (n = 11) are characterized by small sample sizes.

The low explanatory power of environmental factors may be linked to globalization processes, which make it possible to perceive the effects of climate change beyond one's residence place, at regional (e. g., through higher mobility) or global (e. g., through the influence of communication media; see Brüggemann et al. 2018, Lörcher 2019, Metag et al. 2017) scales. Therefore, it seems reasonable to assume that local land cover and climatic conditions are nowadays less significant in shaping perceptions of change: even persons living in a region not (yet) severely affected by climate change see highly affected regions or people, for example, via TV or internet, and can therefore perceive the changes as a reality.

Methodological considerations

Our interdisciplinary approach entails several limitations that need to be accounted for when interpreting and generalizing the results. Firstly, we acknowledge that climatic gradients were investigated as linear trends of multi-annual parameters instead of anomalies of single years. However, using variation in climate extreme indices as variables were shown to have negligible effects on perceptions about the severity of climate change (e. g., Marquart-Pyatt et al. 2014).

Secondly, the comparability of our results is limited due to a lack of scientific consensus regarding the operationalization of climate change perceptions (Reser and Bradley 2020, Van der Linden 2017). We surveyed only some of the possible items conceptualizing perceptions of climate change. For example, whether respondents are asked about "global warming" or "climate change" has been shown to significantly affect responses obtained (Schuldt et al. 2011). Consequently, we identify a need for a standardized glossary of core terms as well as for a common measurement to systematically survey people's perceptions of climate change.

Thirdly, there are limitations regarding the survey sample. For instance, individuals with an already established interest in environmental topics could be more likely to participate in the survey. This might have been particularly relevant for the group of citizens, where the respondents also showed a higher level of education compared to the Bavarian average. Due to the sampling approach, the group of farmers has a clear bias towards higher shares of organic farming and participation in agri-environmental schemes. For both actor groups, we therefore might have underestimated climate skepticism. Such limitations concerning the representativity of the sample are important to consider when generalizing the results towards a wider population.

Conclusion: Targeting and tailoring intervention strategies

Our analysis of perceptions of climate change across four societal actor groups in Bavaria, Germany, revealed a high level of awareness in relation to the topic overall. Land cover and climatic factors were far less influential in shaping climate change perceptions in Bavaria than socio-demographic factors. Given the low importance of environmental factors in this study, it is likely that current and future climatic change impacts alone are not sufficient to produce remarkable shifts in stakeholders' climate change perceptions. As we identified socio-demographic factors as important explanatory variables in our analysis, it follows that these findings can help tailor awareness campaigns and political measures to those groups with highest uncertainties and doubts in order to enhance effectiveness. In our analysis, the societal actor group affiliation was identified as the most important factor, with farmers being the more climate skeptical group. This offers multiple opportunities for targeted policies, awareness raising, and communication efforts, for example, through awareness campaigns utilizing existing institutions, such as agricultural schools, and trainings offered through agricultural offices. The importance of societal actor group affiliation further suggests the relevance of underlying psychological factors. We therefore emphasize the need for more interdisciplinary and integrated research in the field on climate change perceptions.

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Author contribution: *TL:* conceptualization; *TL, RR, MT:* data curation; *TL, RR:* formal analysis; *TK:* funding acquisition; *TL, RR, MH, MT:* investigation; *TL, RR:* methodology; *TL, TK:* project administration; *TK:* resources; *TL, RR:* software; *TK:* supervision; *TL, RR:* validation; *TL, MH:* visualization; *TL:* writing – original draft; *TL, RR, MH, TK, TS:* writing – review and editing.
Data availability: Data are available on request from the repository of the *LandKlif* project at *https://www.landklif.biozentrum.uni-wuerzburg.de/Download/ShowXml.aspx?DatasetId=12200*.

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