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The influence of the 2021 European flooding on pro-environmental attitudes and partial behaviour transition

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One of the reasons why people do not act pro-environmentally might be a lack of experience with the consequences of climate change. Studies have shown that higher levels of environmental attitudes and more environmentally friendly behaviours have been observed among people affected by extreme weather events. It is unclear, however, whether the events caused the changes or whether the affected people simply differed in their characteristics from those who were unaffected. We draw on a natural experiment to examine the causal link between flooding experiences, pro-environmental attitudes and pro-environmental behaviour using national survey data collected from 2058 individuals aged 16-29 years across Luxembourg. After people experienced the 2021 European flooding, their pro-environmental attitudes increased significantly. The effect was stronger in regions that were more affected by floods. Higher levels of environmental attitudes partly translated into greater willingness to act in a pro-environmental way. The results have important implications for advancing efforts to address climate change by demonstrating links between extreme weather events attributed to climate change and higher levels of environmental attitudes.

Due to climate change, the frequency, intensity and severity of extreme weather events such as heat waves, cold waves, storms, floods and droughts are increasing, elevating the risk of harm to people and their ecological livelihoods in many parts of the world[1]. Although extreme weather events in Europe have been and continue to be less disastrous than on other continents, they are also becoming increasingly intense[2]. In July 2021, heavy rainfall caused the natural disaster of the century, with severe flash floods and flooding in several river regions in Central Europe. Parts of Germany, Austria, Switzerland, the Netherlands and Luxembourg, among others, were particularly affected[3]. The flood disaster caused the deaths of more than 220 people.

A large body of research focuses on the question of how local extreme weather conditions affect opinions about climate change and environmental attitudes[4–10]. The experience of such a locally occurring catastrophe can produce strong affective associations with environmental problems and acceptance of the reality of climate change among those affected and cause experiential learning of relevant scientific knowledge[11,12]. In contrast, scientific information on the effects of climate change is primarily conveyed in a highly abstract way that is somewhat detached from everyday life and can therefore only be processed with a high level of awareness and cognitive effort[13–15]. However, being directly affected by a local extreme weather event attributed to climate change can minimise the psychological distance between abstract causes and stochastic effects and overcome temporal and spatial dissonance, thus changing an individual's perception of risk[16].

Personal exposure can increase the perceived risk that more adverse effects will occur in the future, leading to more pro-environmental behaviour. This effect can be particularly prominent during recent or salient events as an effort to manage risk[17].

Social psychological studies have advanced our understanding of the affective, cognitive, and conative dimensions of environmental consciousness. Nevertheless, these studies are often based on observational designs with limited options for causal inference on personal experiences with extreme weather events. This leaves the link between personal experience and more complex attitudes critically unexplored[18,19]. Some previous experimental studies suffer from nonrandom treatment assignment and were collected a posteriori and thus are subject to self-selection bias[5,17,20]. Whether people who might be directly affected by the consequences of climate change, or at least perceive that they are affected, also change their perceptions or express themselves through corresponding political behaviour is still relatively unclear as the corresponding evidence is mixed. Previous studies have shown effects between the experience of extreme weather events and increased risk perception, climate change beliefs,

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environmental concern, intended environmental behaviour and voting behaviour[4,6,17,19,21,22]. However, a few studies did not find any systematic effects, and other research has failed to demonstrate causal relationships[11,23]. There is evidence that people's beliefs about climate change influence their interpretation of extreme events rather than the other way around[18,23,24]. Overall, very few studies have been able to include validated and reliable multidimensional survey instruments to measure environmental attitudes and behaviour. Furthermore, these instruments are rarely found in longitudinal studies, making it difficult to draw causal inferences[25].

In summary, the identified research gaps underscore the need for more rigorous and systematic research on a) the relationship between personal experiences of extreme weather events and attitudes towards climate change, b) whether extreme weather events contribute to closing the attitude behaviour gap, and c) the extent to which environmental attitudes mediate the effect of natural events on environmental behaviour.

This study addresses these research gaps. We consider a major flooding event in Luxembourg in 2021 as a natural experiment to investigate the impact of exogenous shocks on environmental attitudes and pro-environmental behaviour. The data come from a general national survey that started before the flooding and ended weeks later. Due to the particular constellation of events in the field phase of our study, we can plausibly assume that our design is mostly unaffected by nonrandom treatment assignment and that we can therefore draw causal conclusions.

This article contributes to the literature in at least three ways. First, we present evidence on the causal linkages between exposure to extreme climate events, environmental attitudes and behaviour by exploiting a natural experiment. Second, the analysis is conducted at the subnational community level, thus providing leverage to study geographical proximity effects. Third, we use validated and reliable survey instruments to measure environmental consciousness and environmentally friendly behaviour, extending previous studies that used single items for measurement.

Results

Using a multivariate model, we regressed environmental attitudes on the treatment variable while adjusting for several sociodemographic variables and known predictors of the outcome (see Supplementary Table 1 for summary statistics). The treatment divided the sample into pre- and post-event strata. The geographic proximity to floods was binary coded using the 102 communes in Luxembourg as the variable "close" to approximate this influence. For this purpose, the official hydrometric data of the Luxembourg Land Registry and Topography Administration on the flood areas at the time of the event were used[26]. The detailed geographic location and coding of this variable can be found in Supplementary Fig. 1.

The environmental attitudes measure proposed by Diekmann & Preisendörfer[27] was used. It consists of 9 items and is intended to map the social-psychological affective, conative and cognitive dimensions of latent environmental consciousness. We subjected the nine items to a factor analysis and then calculated factor scores as the "environmental scale" (Cronbach's $\alpha = 0.82$). The affective, cognitive and conative subscales were standardised and calculated as a mean index due to the low number of items.

The effects of flood events on environmental attitudes

The impact of flooding is modelled on the three dimensions of environmental attitudes and scale (Fig. 1). As shown in (a), the strongest effect is shown for the affective dimension, $t(101) = 3.410$, $P < 0.001$, $\beta = 0.190$, 95% CI [0.079, 0.301], and for the whole scale, $t(101) = 2.947$, $P < 0.01$, $\beta = 0.169$, 95% CI [0.055, 0.283]. The effect is weaker for the cognitive dimension, $t(101) = 2.018$, $P < 0.05$, $\beta = 0.123$, 95% CI [0.002, 0.244], and is not significant for the conative dimension (see Supplementary Table 2). Given that the experience of such an event primarily affects the psychological and emotional levels, the results are consistent in that the affective dimension is most affected.

Next, we address the question of whether affected people who lived directly or at least very close to the floods were more affected by the events. For this purpose, we compared people who lived very close to the floods with those who were not directly affected.

Here, we can see in (b) that the differences are stringent and almost always statistically significant. The strongest difference is found in the conative dimension $t(101) = 3.206$, $P < 0.01$, $\beta = 0.360$, 95% CI [0.137, 0.583]. This difference is somewhat weaker for the affective dimension $t(101) = 2.967$, $P < 0.01$, $\beta = 0.333$, 95% CI [0.110, 0.556] and even weaker for the scale $t(101) = 2.399$, $P < 0.01$, $\beta = 0.271$, 95% CI [0.047, 0.496]. The effect is weakest for the cognitive dimension $t(101) = 2.967$, $P < 0.01$, $\beta = 0.373$, 95% CI [0.124, 0.622] (see Supplementary Table 3).

The effects of flood events on environmental behaviour

We examined whether, in the wake of the flood disaster, self-reported pro-environmental behaviours changed in addition to changes in environmental attitudes. For this purpose, we examined the following seven self-reported behaviours: (1) buying organic food; (2) shopping for products with an environmental seal; (3) eating less meat; (4) using the car less often for short distances; (5) conscious use of heating at home; (6) paying attention to energy efficiency when buying household appliances; and (7) using a reusable water bottle (see Supplementary Table 4 for the full model specifications).

Although flooding experiences were linked with higher environmental attitudes, this did not directly relate to reported behaviours. Figure 2 presents the estimates for the effect of flooding on pro-environmental behaviour. As environmental attitudes are naturally the strongest predictor of pro-environmental behaviour, the models are adjusted for this to determine the direct effect of the event.

Based on the analysis, it appears that no significant effect of the treatment on environmental behaviour dimensions can be observed after adjusting for the treatment and covariates.

The moderating effects of flood events on environmental attitudes and behaviour

Next, we address the question of whether the psycho-social effects of floods have a moderating effect on the relationship between environmental attitudes and environmental behaviour. To illustrate the heterogeneous effect, the sample was divided by the moderating variables as illustrated in Fig. 3. The estimated models of the two-way interaction effect for (a) and the three-way interaction effect for (b) can be found in Supplementary Tables 5 and 6.

Based on (a), no statistically significant moderating effect of the floods on the relationship between attitudes and behaviour could be identified (see Supplementary Table 5 for the full model). In (b), the two-way interaction effects were first calculated for those who lived near the flood areas and separately for those who did not live directly in these areas. This showed that the moderating effect of this experience was moderated by spatial proximity for individual behaviours. Here, we find a significant effect for buying organic food $t(101) = 2.269$, $P < 0.05$, $\beta = 0.230$, 95% CI [0.029, 0.432] and a significant effect for buying energy-saving electronics $t(101) = 2.745$, $P < 0.01$, $\beta = 0.270$, 95% CI [0.075, 0.465] (see Supplementary Table 6).

The causal effects of flood events on environmental attitudes and behaviour

Finally, we used the natural experiment treatment to investigate the causal link between environmental attitudes and pro-environmental behaviour. For this purpose, we used the treatment and spatial proximity as instrumental variables. The results of the two-stage instrumental variable regression are presented in Fig. 4. We found a significant causal effect only between attitudes and behaviour, $t(101) = 2.199$, $P < 0.05$, $\beta = 0.468$, 95% CI [0.046, 0.889], for dietary behaviour (less frequent meat consumption) and energy saving behaviour, $t(101) = 2.218$, $P < 0.05$, $\beta = 0.391$, 95% CI [0.041, 0.741] (see Supplementary Table 7).

Discussion

The Intergovernmental Panel on Climate Change (IPCC) has recognised that global warming can only be limited by widespread changes in society, including changes in human behaviour and lifestyle[28].

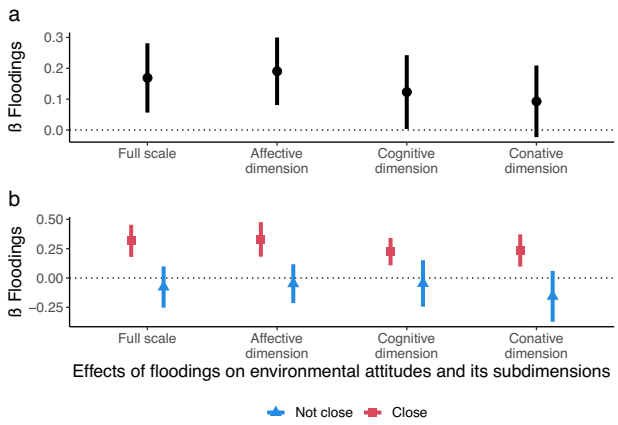

Fig. 1 | Effects of flood events on environmental attitudes. a Standardised estimates for the full environmental scale and subdimensions. **b** Sample stratified by spatial proximity to the floodings. The vertical dashed line gives the point estimate for no effect. Error bars provide 95% confidence intervals. Two-sided test with cluster robust standard errors (clustered by commune).

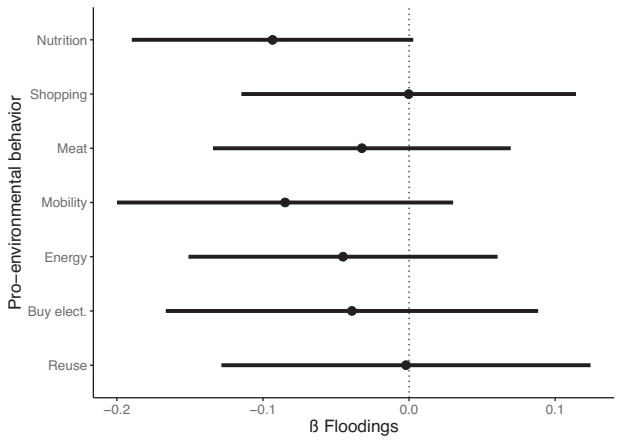

Fig. 2 | Effects of flood events on environmental behaviour. Standardised estimates of the flooding on pro-environmental behaviour. The vertical dashed line gives the point estimate for no effect. Error bars provide 95% confidence intervals. Two-sided test with cluster robust standard errors (clustered by commune).

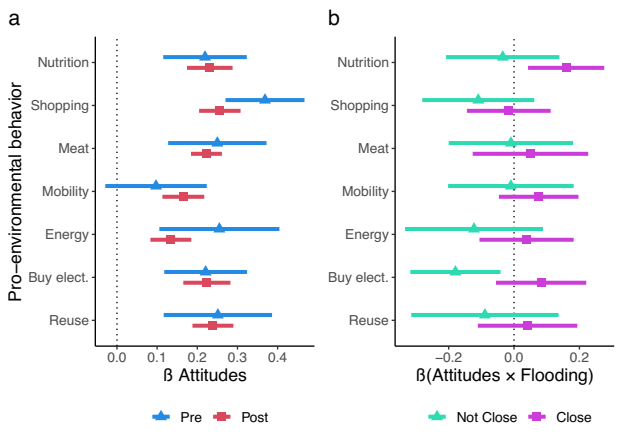

Fig. 3 | Moderation effects of flood events on environmental attitudes and behaviour. a Standardised estimates for the environmental scale on environmental behaviour moderated by floodings. **b** Standardised estimates for interaction effects moderated by spatial proximity to the flooding. The vertical dashed line gives the point estimate for no effect. Error bars provide 95% confidence intervals. Two-sided test with cluster robust standard errors (clustered by commune).

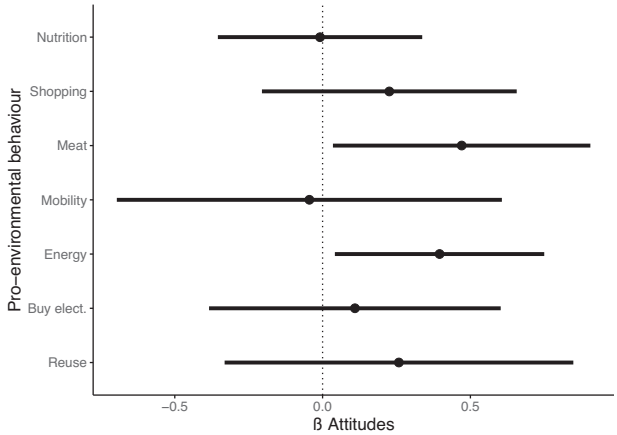

Fig. 4 | Causal effects of flood events on environmental behaviour. Standardised two-stage instrumental variable estimates of environmental attitudes on pro-environmental behaviour. The vertical dashed line gives the point estimate for no effect. Error bars provide 95% confidence intervals. Two-sided test with cluster robust standard errors (clustered by commune).

Previous studies have suggested that there is a link between extreme weather events and environmental attitudes[14,16,19,29]. The aim of this study was to improve our understanding of the impact of extreme weather events on people's environmental attitudes and behaviours beyond existing research findings. To this end, we utilised a natural experimental design derived from floods in the field phase and adopted validated social psychological multidimensional test instruments to broadly disaggregate attitudes and behavioural dimensions. Our findings showed that severe, locally significant environmental changes and events, such as floods, provide significant opportunities to engage people in climate change and encourage them to take action. Our study showed that, in line with experiential learning theory, the environmental attitudes of the people concerned increased, even more so in relation to spatial proximity. In addition, we were able to show that the relationship between the attitudes and behaviour of spatially proximate subjects was significantly stronger with respect to their environmentally friendly purchasing behaviour after the floods. Using the natural experiment, we also identified a causal effect of environmental attitudes on meat consumption and energy saving behaviour. Nevertheless, these correlations tended to be weak, so it can be concluded that higher environmental attitudes are far from being causally expressed in more environmentally friendly behaviour such as energy savings or reduced car use. This has ambivalent implications for attempts to instrumentalise psychological distance as political framing, as, evidently, relying on climate change impacts as a means to foster public concern and pro-environmental behaviour is not an optimal approach. However, even if the translation of environmental consciousness into pro-environmental behaviour tends to be expressed in only a few dimensions, environmental consciousness is also relevant for the support of green policies[21]. While the growing awareness of climate change can contribute to bolstering support for environmentally friendly policies, the implementation of well-designed political instruments is necessary to effectively guide individual behaviour towards more sustainable practices[30].

There are several limitations of this study. Pro-environmental behaviour is based on self-reported behaviour and should be examined in further studies on actual behaviour. Furthermore, the heterogeneous effects with respect to environmental behaviours and their seemingly noncongruence need to be investigated in more detail. Additionally, it is important to note that our sample consisted of respondents aged between 16 and 29 years. This focus on a younger demographic may introduce a specific perspective on environmental attitudes and behaviours, potentially limiting the generalisability of our findings to broader populations. Finally, to study the causal effects of increased environmental attitudes on environmental behaviour, larger samples are necessary as the relation turns out to be

heterogeneous. Nevertheless, our study contributes to a nuanced understanding of how environmental attitudes, shaped by firsthand experiences of extreme weather events, are associated with pro-environmental behaviour.

Methods

Analytical strategy

We estimate several multivariate cluster-robust linear models including adjustment sets. The standard errors are clustered at the commune level. All *P* values refer to two-sided *t*-tests. The treatment is a binary coded variable that stratifies the sample in time before and after the event.

Given that flooding occurred randomly in the survey period, a natural experiment can be assumed. Natural experiments are naturally occurring events or conditions that affect part of a population and combine features of experiments and observational studies. What distinguishes this experiment from traditional observational studies is the use of random or quasi-random assignment of subjects to treatment and control groups. Therefore, it can be assumed that systematic differences between individuals who received the treatment and those who did not receive it prior to the intervention are either nonexistent or minimal[31,32]. Studies that exploit natural experiments are usually more generalisable to the populations, contexts and conditions of interest to researchers and policymakers than laboratory experiments since the sample tends to be more representative and the treatments are real-world events that cannot be artificially manipulated for practical, ethical or political reasons[33]. The *R* package *estimatr*[34] was used for the estimation of the cluster-robust models, and *ggplot2*[35], *tmap*[36] and *modelsummary*[37] were used for presentation.

Sample

We referred to the cross-sectional data from the survey "Young people and COVID-19" (YAC+), a stratified random sample of all residents aged between 12 and 29 in Luxembourg. Data were collected from 13 July to 1 October 2021[38]. Participants provided electronic consent and study approval was obtained from the University of Luxembourg Ethics Review Panel (ERP) on 18 June 2021 (ERP20-041-C-A (YAC+ (amendment 1)). Additionally, the office of the Data Protection Officer of the University of Luxembourg was informed about the YAC survey data collection and their consent for the survey conduction was granted.

The floods started on the night of July 14 to 15. Prior to the event, we surveyed approximately 500 respondents as a control group, while afterwards, we surveyed 2000 individuals who were treated. We analysed the data of respondents aged between 16 and 29 as the questionnaire answered by younger respondents did not include key variables required for our analysis. After further excluding missing values and people aged between 12 and 15, our analytical sample comprised 2058 respondents. The main reason for focusing on young people in the study of environmental attitudes is that this age group does not yet have fully consolidated attitudes and is, therefore, more adaptive. Consequently, it is plausible to assume that experiencing an extreme weather event has a greater impact on young people's attitudes towards the environment[39].

Measures

Social science environmental research has a long history of defining and conceptualising environmental awareness to explain environmental behaviour without a general consensus on how to express it. Definitions of environmental awareness vary depending on the professional backgrounds of the researchers and over time[40]. Heberlein pointed out the challenge of finding a uniform definition for an object, such as the environment, because it is ambiguous, and its aspects can only ever be grasped in part by subjects[41]. Environmental awareness can therefore be theoretically conceived in many ways, starting with the perception of environmental problems and ending with individual and activist behaviour for environmental protection. For example, it can be conceptualised as values, cognitive attitudes, emotional perceptions, ecological ontologies and intentions to behave in an environmentally friendly way[42]. The operationalisation of environmental attitude in this study is based on the definition of Diekmann and Preisendörfer and consists of all nine items of the scale[43]. This definition is characterised by a general attitude that includes affective concerns about environmental protection, cognitive awareness of environmental threats and conative support for environmental action (see Supplementary Notes for the survey items used).

The operationalisation of environmental sustainability is based on the following seven activities: (1) buying organic food; (2) shopping for products with an environmental seal; (3) eating less meat; (4) using the car less often for short distances; (5) conscious use of heating at home; (6) paying attention to energy efficiency when buying household appliances; and (7) using a reusable water bottle. These were taken from the study by Geiger and Holzhauer and tested with the help of validation studies and in the field[44]. In line with existing research findings, it can be said that environmental behaviour is not a unidimensional construct that consistently reflects environmental attitudes. Rather, it should be thought of in terms of many different dimensions and areas of need. Environmental behaviour is not completely determined by corresponding attitudes. In addition to environmental awareness, several other factors influence environmental behaviour. For example, environmentally sound behaviour can be assumed if there are no other divergent goals in addition to environmental awareness.

In a natural experiment, the exposure is assigned externally, so we do not have to worry about selection bias. As in any observational study, the exposed and control groups can differ in other pre-treatment characteristics. Thus, even if we assume a quasi-experimental assignment of the treatment variable through the natural experiment, it is necessary to adjust for pre-treatment characteristics of the individuals. This should not affect the magnitude of effects but should enable a more efficient estimation of the size of the effect[45].

Although we assume that the floods had an impact on pro-environmental attitudes all over the country, we suspect a stronger effect for people who lived closer to the events and were thus more affected or perceived a higher personal risk of being affected in the future. Indeed, studies show that environmental attitudes not only vary geographically but also change differently during extreme weather events depending on geographic proximity to the disaster[19,46,47].

For this reason, the spatial dimension was also included in the analysis as an indicator variable. For this purpose, the 102 communes of Luxembourg were divided into two groups and coded. Respondents living in communes that were directly affected by flooding and extreme water levels were coded with 1, and those that were not affected were coded with 0. The detailed geographic location and coding of this variable can be found in Supplementary Fig. 1.

Social trust is generally strongly associated with pro-environmental concern and behaviour[48,49]. Since mitigating climate change is ultimately also a collective action problem, social trust and the expectation of reciprocity are seen as key to solving this commons problem since individuals would be better off if everyone behaved in an environmentally friendly way, although typically with public goods, the problem of free riders is inherent[50]. For the social trust survey, we used the scale from the World Value Survey and asked a set of six questions[51]. The scale measures two-dimensional forms of specific and generalised social trust on a 5-level Likert scale[52].

Governments and public agencies play an important role in mitigating climate change and its impacts as coordinative risk managers. Even though anthropogenic climate change is considered certain, the appropriate countermeasures are less obvious to individuals and more complex[49]. For this reason, state institutions function as complexity-reducing agents for actors[53]. Furthermore, public support for various climate-related measures, such as the introduction of carbon taxes, requires confidence in the appropriate and fair handling of taxation[49]. In general, positive associations between institutional trust and pro-environmental attitudes and behaviours can be found in the literature[49,54]. To measure trust in institutions, trust in a broad range of institutions was surveyed using a 5-point Likert scale[55].

Research has increasingly shown that perceptions of fairness play a significant role in shaping individuals' environmental attitudes and pro-environmental behaviour[56–59]. A Likert scale consisting of six items was used

to assess fairness perceptions in this study[51].The basic social justice orientations measure individuals' attitudes towards the following four basic distributive principles: equality, need, equity, and entitlement[60].

Research to date generally shows significant differences between men and women in environmentally friendly behaviour[61]. Women are more environmentally aware than men, even in international comparisons[62–64]. Moreover, women differ from men in their more pronounced environmental attitudes, which can also be observed relatively consistently across time and countries[65,66].

We adjust for household size and dwelling type as past studies have found this to be a relevant factor for environmental consciousness[19,67].

The general trend in environmental awareness is that earlier studies found that older individuals are less aware of environmental issues than younger individuals. Younger people are exposed to more intensive public interest in environmental protection during their socialisation than older people, which manifests in more pronounced environmental awareness[48].

Studies have consistently shown that higher education levels are linked with more pro-environmental attitudes and behaviours[68–70].

Whether and to what extent income and wealth have an effect on environmental attitudes and behaviour has not been clearly clarified in the literature. For clearer statements, a differentiated analysis of the theoretical and measured attitudes and behaviour is needed. While the so-called "luxury good thesis"[71] was still very widespread in early environmental awareness research, it has increasingly lost its persuasive power in recent years[72]. The thesis postulates that a higher level of environmental awareness and behaviour is more likely to be found in the wealthier or higher-income sections of the population. On the one hand, environmentally conscious actions are usually associated with higher costs, which would be compensated by a higher disposable income. On the other hand, postmaterialistic attitudes should be expressed that would only play a role after material needs have been satisfied. While tendencies can be shown in the individual dimensions, there is a discrepancy when considering environmental behaviour as an aggregate of these aspects. The increased consumption of consumer goods such as electricity is relativised by environmentally friendly measures such as the consumption of environmentally friendly goods, so the effect is difficult to measure and experiences a certain dependence on the operationalisation of environmental behaviour[73].

Reporting summary

Further information on research design is available in the Nature Research Reporting Summary linked to this article.

Data availability

The dataset analysed during the current study is not publicly available. Access to the data is subject to approval and a data-sharing agreement due to privacy concerns.

Code availability

All code for data cleaning and analysis associated with the current submission is available at https://doi.org/10.6084/m9.figshare.25119707.

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H.B. and R.S. designed the research. H.B. analysed the data. All authors co-wrote and revised the manuscript.

Competing interests

The authors declare no competing interests.

Additional information

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