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Misalignment of perceptions with records and resources for responding to climate change risk

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Climate change risks like extreme temperatures and high variability in rainfall adversely affect livelihoods, particularly for farmers in Burkina Faso where the primary sector is agriculture. Decisions on whether to adapt to these risks depend on how farmers perceive each risk and the resources they have available. In this study, we examine how long-term changes in temperature and rainfall are perceived by farmers in Burkina Faso. We also compare the extent to which these perceptions align with actual recorded changes in temperature and rainfall for multiple periods between 1991 and 2014. We use a logistic regression model to analyze the role of resources, such as asset ownership and perceived standards of living, along with household size, age, and gender of the household head to explain differences in perception and ultimately the decision to adapt. Our results show that the vast majority of farmers in Burkina Faso perceive changes in temperature and rainfall; however, only about half of those individuals perceive changes in ways that align with recorded long-term trends in their local temperature or rainfall. The extent to which those perceptions align with recorded changes depends on the time frame selected. Older farmers and those with assets were less likely to perceive temperature and rainfall trends in ways that aligned with climate records; however, farmers' perceptions of temperature change aligning with records and their perceived standard of living were both associated with the decision to adapt. This misalignment of perceptions with records and resources has significant implications for efforts to inform and support climate risk mitigation and adaptation.

KEYWORDS

climate change, adaptation, risk perception, farming, Burkina Faso, rainfall

Introduction

Anthropogenic climate change has already resulted in over 1.1°C of warming (IPCC, 2022), significant increases in the frequency, intensity, and duration of heatwaves and cyclones, and extreme variability in rainfall, flooding, and drought (Eckstein et al., 2021). Projected increases in temperature are expected to result in more frequent and severe extreme events (IPCC, 2022). Such changes are especially impactful in sub-Saharan Africa (SSA), where large numbers of farmers and pastoralists rely on natural resources that are vulnerable to increases in temperature and variability in rainfall (Huq and Reid, 2004). In countries like Burkina Faso, development challenges including rising populations, extreme poverty, and poor institutions and infrastructure, exacerbate these climate risks, weakening locals' adaptive capacity (Alvar-Beltrán et al., 2020).

The adaptive capacity of a community depends on how well individuals understand the anticipated impacts (Huq and Reid, 2004) and thus perceive the risk of climate change. People's risk perceptions vary considerably across age, gender, culture, politics, personal experiences, education, income, and wealth (Finucane et al., 2000; Eckel and Grossman, 2008; Akerlof et al., 2013; Booth et al., 2014; Lee et al., 2015). The goal of this study is to better understand the contribution of these factors, particularly those associated with wealth, age, and gender, as well as local long-term climatic trends on farmers' perceptions of climate change and adaptation strategies in Burkina Faso. Different climate risk perceptions mean different adaptation strategies. Alvar-Beltrán et al. (2020) found that farmers in Burkina Faso were aware of the hazards resulting from climate change including increased temperatures, change in rainfall, and delayed and premature rainy seasons, but the number of farmers who adopted conservation strategies depended on their agroclimatic zone and location.

Here we examine how farmers' perceptions of climate risk in Burkina Faso align with actual climate data and the extent to which their perceptions inform the actions they take to adapt. We focus on a country that is heavily dependent on agriculture and natural resources. Eighty percent of Burkina Faso's economy is based in agriculture (World Bank, 2021). The country ranks as one of the most vulnerable to climate risks, and it has regional differences in its topography and climatic conditions, as well as climate hazards (World Bank, 2021). With about 40 percent of its population living below the poverty line, the country is ranked 184th of 191 countries in the Human Development Index (HDI) as of 2021–2022 (UNDP, 2022b). The country is expected to experience about a 1.4–1.6°C increase in temperature from climate change (UNDP, 2021) resulting in increased drought, flash floods, windstorms, and disease outbreaks (World Bank, 2021). Some adaptation efforts have been taken, including creating flood-risk maps to increase flood resilience and for city planning and investments (Conway and Vincent, 2021). As part of The National Adaptation Program of Action (NAPA), Burkina Faso has also prioritized disaster risk reduction among other measures to improve capacities for climate change adaptation (UNDP, 2022a).

To better understand the alignment of recorded climatic change, farmers' perceptions, and their adaptation choices, we use empirical studies of climate change perceptions. These studies show both convergence and divergence between perceptions and climate records (e.g., Vedwan and Rhoades, 2001; Meze-Hausken, 2004; Osbahr et al., 2011; Piya et al., 2013; Kabir et al., 2017; Mulenga et al., 2017). Kabir et al. (2017) reported that farmers in Chuadanga, Bangladesh perceived temperature increases and rainfall decreases that aligned with climate records; however, their perceived risk varied considerably across individuals and was rarely aligned with the estimated probability and potential consequences associated with a hazard. Meze-Hausken (2004) found that Ethiopians' perceptions of reduced rainfall were mostly in line with the underlying climate data, but the gap was in part due to people's expectations of actual rainfall needs. Similar conclusions are reported by Osbahr et al. (2011) in southwest Uganda where farmers' perceptions of rainfall were judged against and derived from their actual rainfall needs. Mulenga et al. (2017) explained that such inconsistencies between perceptions and actual data occur when farmers recall and associate unique events with climate change, as opposed to recalling incremental changes over the long run. Farmers also use their personal experiences to perceive climate change, which may not align with actual data (Moyo et al., 2012). Foguesatto et al. (2020) explained such divergences, particularly concerning variability in rainfall, using expected utility theory (Bernoulli, 1738; Von Neumann and Morgenstern, 1947) and the availability heuristic (Tversky and Kahneman, 1973); farmers recall extreme events, particularly the ones highlighted by the media (Whitmarsh and Capstick, 2018) and thus perceive greater variability in temperature and rainfall than climate records show.

Perceptions about climate change are also influenced by socioeconomic factors (Weber, 2016; Foguesatto and Machado, 2021). Age, education, and personal beliefs about climate change can influence perceptions (Piya et al., 2013; Ansari et al., 2018). In select Amazonian communities, 72 percent of the sampled population perceived changes in climate, and that perception increased with age (Funatsu et al., 2019). Others report the impact of wealth on farmers' perceptions of climate change, measured either, as material assets and farmland owned by farmers (Hou et al.'s, 2015) or as all farm and non-farm assets combined (Singh et al., 2017). In this study, we include asset ownership and farmers' perceived standard of living as proxies for wealth in Burkina Faso. Wealth can have interesting effects; Hou et al.'s (2015) found that wealthier farmers in China were less likely to accurately perceive temperature changes, perhaps because they could afford to protect themselves from high temperatures or because they were involved in management rather than actual farm work.

Both perceptions and adaptations likely differ by gender as well. Singh et al. (2017) studied how men and women of the Adi community in Arunachal Pradesh, India perceived climate variability differently and adapted their livelihood activities to it. While both men and women noticed common changes such as fewer rainy days, shorter winters, longer summers, and more variability in rainfall, women and men noted specific changes in their areas of work. Gender continues to be an important factor in climate change adaptation because farmers have been noted to choose adaptation techniques based on agricultural tasks specific to their gender (Darabant et al., 2020). Women are also considered to be more vulnerable than men to climate change impacts since extreme climate events tend to exacerbate existing gender inequality (UN Women, 2018).

Religious and cultural factors also play a role in perceiving risk. Moyo et al. (2012), in a participatory research study of Zimbabwean farmers in two semi-arid areas, showed that farmers perceived climate changes like increased temperatures, more variability, and a decrease in rainfall, but believed the weather changes were caused by cultural and religious factors such as their belief that God was punishing them for ignoring cultural norms or that their ancestors were angry. Bessette et al. (2017, 2019) showed that people often rely on their values to inform their beliefs, and when faced with uncertainty and a complex situation, like long-term temperature and rainfall trends, they use those values to simplify their understanding, leading to inconsistency between their priorities and their choices and likely perceptions and recorded data.

Finally, a lack of information about risk can influence perceptions, and that information need not always be in the form of formal education or expert training. Knowledge and expertise gained by farming are also important (Soubry et al., 2020), and education is often shown to be a strong predictor of climate change awareness and its risks (Lee et al., 2015). Experts and laypeople often perceive risk quite differently (Siegrist et al., 2007). Even when individuals' perceptions of climate change align with trends predicted by climate data, identifying the role that climate change plays alongside other perhaps more pressing concerns like political, economic, and social factors remains difficult (Mertz et al., 2009). Ultimately people's different risk perceptions impact their adaptation strategies. When perceptions align with reality, one would expect such perceptions to lead to stronger intentions to adapt (Abid et al., 2019) and different types of adaptation strategies chosen (Hasan and Kumar, 2019). We examine this supposition below.

The objective of this study is to understand how socio-economic factors, in particular those related to wealth and resources, such as asset ownership and perceived standard of living, along with the age and gender of the household head, inform the perceptions of climate change risk in farmers of Burkina Faso. To determine the extent to which those perceptions align with actual change, we compare farmers' perceptions with two decades of recorded climate data. We examine whether the factors mentioned above can predict the extent to which those perceptions align with recorded climate data and influence farmers' choices to adapt. This results in four research questions, which we also use to structure our methods and results. First (RQ 1), do farmers in Burkina Faso perceive a long-term change in temperature and rainfall? Next (RQ 2) how do those perceptions align with recorded trends in climate data? Third (RQ 3), what factors explain the alignment of perceptions with recorded climate data? Finally (RQ 4), how do those perceptions impact farmers' choices to adapt?

Methods

Study population

We relied on two datasets for this study. The first is a quantitative household survey of farmers (and fishers) carried out by the United Nations Development Programme in 2015—2015 being the most recent household survey data we had available. This survey consists of demographic questions and questions about individuals' climate perceptions and adaptations [e.g., perceptions of long-term changes in temperature and precipitation, perceptions on specific temperature changes (warmer or cooler), and rainfall (wetter or drier)], and if and how they adapted [i.e., What type of adaptation choices they use? (see Supplementary Table 1 for a list of the adaptation choices)]. 1,724 observations exist for Burkina Faso, all of which are male and female household heads (see Table 1). Most of the respondents in the study are smallholder farmers with low incomes who earn an average of USD 52.76 per acre. This is considerably low when compared to the average earnings of USD 187.04 per acre of African farmers from 11 countries noted in a study by Kurukulasuriya and Mendelsohn (2008).

TABLE 1 Summary statistics of key variables.

Variables	
Age of household head (Yrs)	48.3
Net revenue per acre (USD)	52.76
Asset ownership (1-Yes/0-No)	0.95
Gender of household head (1-Female/0-Men)	0.02
Percentage of farmers who did not adapt	79.4
Percentage of farmers whose crops are exclusively rainfed	92.8
Percentage of farmers who have less than sufficient income	85.2
LTTemp[i] (1-Yes/0-No)	0.90
TempCoolerWarmer[ii] (1-Warmer/0-Cooler)	0.98
LTRain[iii] (1-Yes/0-No)	0.84
PreceptDrierWetter[iv] (1-Wetter/0-Drier)	0.06

All statistics are mean values unless otherwise noted (n = 1,724).
i. Have you noticed a long-term change in temperature?
ii. Has the temperature become warmer/cooler? n = 1,551.
iii. Have you noticed a long-term change in precipitation?
iv. Has the precipitation become drier/wetter? n =1,445.

Climate data

Our second dataset is sourced from the Climatic Research Unit (CRU) of the University of East Anglia (University of East Anglia, 2021) and accessed through the World Bank's Climate Change Knowledge Portal. It consists of monthly average temperature and rainfall for specific locations in Burkina Faso (amongst other countries) for the years 1991 to 2014. For the geographic location of each respondent in the UNDP survey, we used Python to extract the data from this portal available as a NetCDF file. We obtained the mean monthly temperature and monthly rainfall for every year between 1991 and 2014. Figures 1A,B provide time-series plots of the mean monthly temperature and rainfall, respectively. Note that both temperature and rainfall show an increasing trend over the study-time period (1991–2015), but those trends are not consistent across farmers' specific locations, and rainfall shows considerable variability.

Data analysis

To answer our first research question (RQ1), we consider the survey question "Have you noticed any long-term shifts in temperature in your area?". We use boxplots to graph the distribution of the slopes of temperature and rainfall change for four timeframes: 5 years (2011–2015), 7 years (2009–2015), 10 years (2006–2015), and 25 years (1991–2015). Our choice of timeframes was guided by existing studies and the availability of data. We chose our shortest timeframe of 5 years as Moyo et al. (2012) find that the farmers in their study were able to recall only up to 5 years. We chose 25 years as the longest timeframe because at the time of data extraction, 25 years was the maximum timeframe for which climate data was available. We then chose 7 and 10 years as reasonable medium-term timeframes to analyze farmers' perceptions. We provide separate boxplots for farmers who report noticing a long-term change in temperature and rainfall, and farmers who did not (Figures 2A,B).

To answer RQ 2, we assess the direction of farmers' perceptions (Has it become cooler or warmer? Has it become wetter or drier?) and create a new variable that categorizes whether or not farmers' perceptions align with local recorded temperature and rainfall trends. To do this, we divided the full range of potential slopes of temperature and rainfall change for each timeframe into quartiles. If a respondent indicated that they perceived that it has become warmer (or wetter, in the case of rainfall) and the slope of the temperature/rainfall change fell in the top two quartiles, then their perception was classified as aligning with recorded data. If a respondent indicated that they perceived that it has become cooler (or drier, in the case of rainfall) and the slope of the temperature/rainfall change fell in the top two quartiles, then their perception was classified as not aligning with recorded data. The four cases of alignment across both temperature and rainfall are shown in Table 2. We use boxplots to compare the slope of the temperature and rainfall change and alignment for each of the four timeframes (Figures 3A,B). While examining the medians helps us understand alignment as the slope of temperature and rainfall change varies, we also perform a two-sample *t*-test to determine if the mean estimated slope of temperature and rainfall are statistically different for groups whose perception aligns with recorded data (*Align*) and for groups whose perception does not (*Not Align*). The results are given in Tables 3A, 3B.

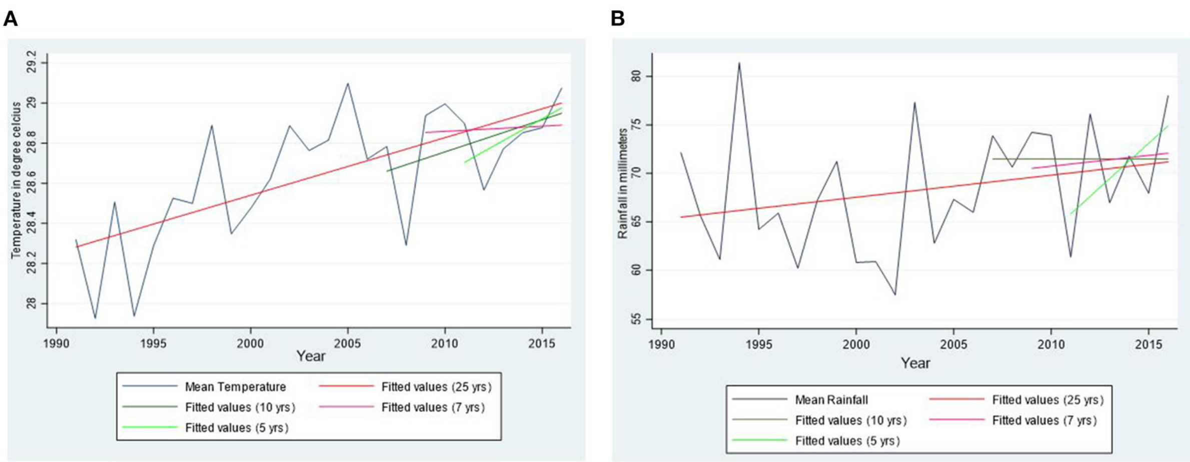

FIGURE 1
(A) Mean monthly temperature from 1991 to 2016. **(B)** Mean monthly rainfall from 1991 to 2016.

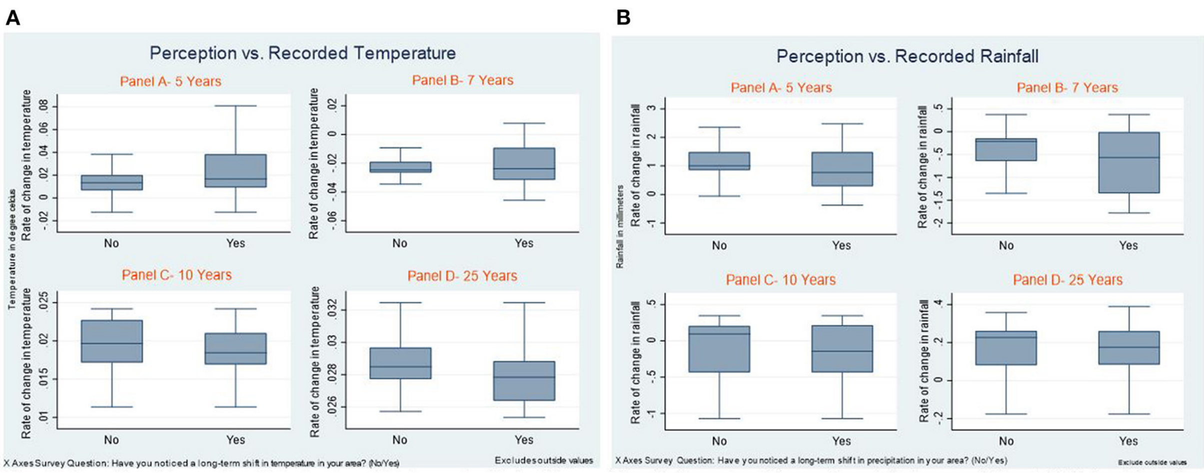

FIGURE 2
(A) Comparison of farmers who noticed a long-term shift in temperature (Yes) and those who did not (No) against the rate of change in temperature. **(B)** Comparison of farmers who noticed a long-term shift in rainfall (Yes) and those who did not (No) against the rate of change in rainfall.

TABLE 2 Categorization of alignment variable.

Quartile of recorded change (temp or rain) at farmer's location[i]	Farmer's perception of temperature change	Aligned/not aligned	Farmer's perception of rainfall change	Aligned/not aligned
1st or 2nd	Cooler	Aligned	Drier	Aligned
3rd or 4th	Warmer	Aligned	Wetter	Aligned
1st or 2nd	Warmer	Not aligned	Wetter	Not aligned
3rd or 4th	Cooler	Not aligned	Drier	Not aligned

i. The quartiles were calculated based on the total range of the recorded rate of change of temperature or rainfall (mean annual rate) for each timeframe and across the entire country.

For our third research question (RQ3), we analyze the factors potentially contributing to the alignment of a person's perception with recorded climate data. To do this, we select the timeframe which had the highest proportion of alignment between farmers' perceptions and climate data. These are provided in Table 4. We then use logistic regression with the dependent variable being alignment of farmers' perceptions with recorded data. Since the survey responses in our dataset were binary in nature in both farmers perceiving the change (Yes/No) and the direction of that change (Hotter/Colder), this model is well suited to understand probabilities of response variables. Similar studies in climate change perception and adaptation have also used the logistic regression (Fosu-Mensah et al., 2012; Joshi et al., 2017). Our explanatory variables for RQ3 include those examined in the literature review above, i.e., asset ownership, the age and gender of the household head, and household size. The results of the regression are given in Table 5.

For our final research question (RQ4), we examine how farmers adapt to changes in temperature based on their perceptions. The UNDP survey asked if farmers had deployed an adaptation strategy for changing temperatures or not (see Supplementary Table 1). We use logistic regression to analyze the factors that affect this choice to adapt (or not) including whether they perceived temperature changes in line with recorded data, the size of the household, age, and gender of the household head, and the minimum standard of living as indicated by the farmers. These results are given in Table 6.

Results

RQ1: Do individuals perceive a long-term change in temperature and rainfall?

The vast majority, i.e., 90 percent, of farmers reported observing a long-term change in temperature, and 83.8 percent of farmers reported observing a long-term change in rainfall.

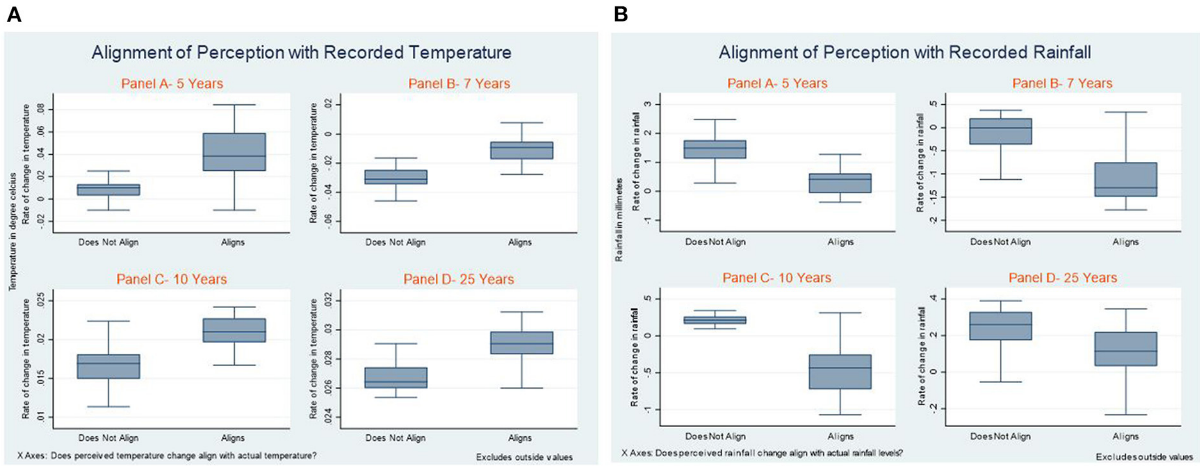

FIGURE 3
(A) Alignment of perceived temperature change with recorded rate of change in temperature. **(B)** Alignment of perceived rainfall change with recorded rate of change in rainfall.

TABLE 3A Results of two-sample *t*-tests with unequal variances—Temperature.

	Group	*n*	Mean annual rate of temp change	se	*t*
5-year slope	Not align	816	0.008	0.01	−39.49***
	Align	735	0.044	0.02	
7- slope	Not align	777	−0.031	0.01	−43.97***
	Align	774	−0.011	0.01	
10-year slope	Not align	806	0.016	0.00	−46.84***
	Align	745	0.021	0.00	
25-year slope	Not align	794	0.027	0.00	−47.80***
	Align	757	0.029	0.00	

***$p < 0.01$.

TABLE 3B Results of two-sample *t*-tests with unequal variances—Rainfall.

	Group	*n*	Mean annual rate of rainfall change	se	*t*
5-year slope	Not align	655	1.439	0.39	38.60***
	Align	790	0.371	0.65	
7-year slope	Not align	630	−0.077	0.33	46.59***
	Align	815	−1.132	0.53	
10-year slope	Not align	697	0.151	0.19	48.72***
	Align	748	−0.484	0.30	
25-year slope	Not align	729	0.253	0.13	31.36***
	Align	716	0.037	0.13	

***$p < 0.01$.

Temperature

Figure 2A shows the slope of the temperature change for each of four time periods across respondents who noted a long-term shift in temperature in any direction (*Yes*) and those who did not (*No*). Note the different scale (y-axis) used in each panel in Figure 2A. The range of temperature change is greater in the 5-year (−0.01°C to 0.08°C) and 7-year timeframes (−0.04°C to 0.01°C) than it is in the 10-year (0.01°C to 0.02°C) and

TABLE 4 Percentage of respondents whose perception aligns with climate data over each timeframe.

Timeframe	Temperature	Rainfall
5 years	47.4	54.7
7 years	**50.0**	**56.4**
10 years	48.0	51.8
25 years	48.8	49.5

Numbers in bold indicate the highest proportion of alignment between farmers' perceptions and climate data.

TABLE 5 Regression results of factors determining alignment over a 7-year timeframe.

Variable	Temperature	Rainfall
Household size	−0.056***	−0.061***
	(0.01)	(0.01)
Age	−0.012***	−0.014***
	(0.01)	(0.01)
Gender	−0.057	−0.416
	(0.37)	(0.39)
Asset ownership	−1.162***	−1.291***
	(0.29)	(0.32)
Constant	2.321***	2.879***
	(0.35)	(0.38)
Observations	1,551	1,445

Standard errors in parentheses.
$^{***}p < 0.01$.

TABLE 6 Regression results of the logit model examining household and individual characteristics and the choice to adapt to temperature change ($n = 1{,}494$).

Variable	Coefficient
Perception aligned	0.957***
	(0.21)
Household size	−0.005
	(0.01)
Age	0.002
	(0.01)
Gender	0.571
	(0.50)
Min. std.	0.764***
	(0.23)
Constant	−3.165***
	(0.41)

Standard errors in parentheses.
$^{***}p < 0.01$.

25-year timeframes (0.025°C to 0.032°C). The median values of the slope are higher for the *Yes* group (0.018°C) than for the *No* group (0.01°C) only in the 5-year timeframe. For the 7-, 10- and 25-year timeframe, the results are not consistent. For example, the median slope for individuals who did and did not perceive a difference is equal in the 10-year (0.02°C) and 25-year (0.03°C) timeframes, respectively.

Rainfall

Figure 2B shows the slope of the rainfall change for each of four time periods across respondents who noted a long-term shift in rainfall in any direction (*Yes)* and those who did not (*No)*. The range of slope values are wider in the 5-year (−0.5 to 2.7 mm) and 7-year timeframe (−1.75 to 0.5 mm) than the 10-year (−1.1 to 0.3) and 25-year timeframe (−0.1 to 0.3 mm), similar to that of temperature. However, differences between the median slopes for the *Yes* and *No* groups do not follow similar trends. The median rainfall change for the *No* group (1.0 mm) is greater than the *Yes* group (0.77 mm) in the 5-year timeframe and all subsequent timeframes.

RQ2: How do individuals' perceptions of temperature and rainfall compare with recorded data?

Temperature

Using the steps described in Section Data analysis, we plot the distribution of the slope of the temperature change in Figure 3A using boxplots. Similar to Figures 2A,B, we adjusted the values in the y-axis to reflect the range of values specific to each timeframe. The range of slope values for the 5-year timeframe is wider than the rest of the timeframes. In the 5-year timeframe, the values range from −0.01°C to 0.08°C. This contrasts the much narrower range of values for the 25-year timeframe—from 0.026°C to 0.032°C.

Across all four timeframes, the median rate of temperature change for the *Align* group is higher than the median rate of temperature change for the *Not Align* group, signifying individuals were more likely to perceive temperature change in line with recorded data the greater their local temperature change. We next conducted a two-sample *t*-test to ensure the mean slopes (mean annual rate of change) for the *Align* and *Not Align* groups followed a similar pattern for each time frame. The results for temperature are provided in Table 3A. For every timeframe, there is a statistically significant difference in the mean slope of temperature change between the *Align* and *Not align* groups. For example, in the 5-year timeframe, the mean slope of temperature change for the *Not Align* group was 0.008°C ($se = 0.01$°C), compared to 0.044°C ($se = 0.02$°C) for the *Align* group. Like the median values, the mean values for the *Align* group are significantly higher than that of the *Not Align* group in every timeframe.

Rainfall

Figure 3B shows the distribution of the slope of rainfall changes in each timeframe. For example, in the 5-year timeframe, the slope values range from −1 mm to 2 mm while in the 25-year timeframe, the values range from −0.4 mm to 0.4 mm.

The median rate of rainfall change is lower for the *Align* group than it is for the *Not Align* group across all four timeframes. In the 7-year and 10-year time frame, the *Align* groups experienced more rapidly drying conditions than the *Not Align* groups, while in the 5-year and 25-year timeframe, the *Not Align* groups experienced more rapid increases in rainfall. Farmers were thus more likely to perceive rainfall changes in line with recorded data the less rainfall increased over the short and long-run. Our two-sample *t*-test to compare the mean estimated slopes for the *Align* and *Not Align* groups for each time frame are provided in Table 3B. In every timeframe, there is a statistically significant difference in the mean slope of rainfall change between the *Align* and *Not Align* groups. The mean values of the *Not Align* group are higher than that of the *Align* group in every timeframe [the opposite of temperature change (See Section Temperature above)]. For example, the 25-year mean slope value is 0.25 mm for the *Not Align* group, which is higher than 0.04 mm for the *Align* group.

RQ3: What factors determine perception of temperature and rainfall changes?

Table 4 provides the percentage of respondents whose perception of temperature and rainfall changes align with recorded data over each timeframe (slopes of mean annual temperature and rainfall change, respectively). For our regression model, we selected the 7-year timeframe for temperature and for rainfall because respondents' perceptions aligned most often with the recorded climate data for that timeframe. Table 5 provides the regression results from the logit model examining household and individual characteristics associated with the alignment of individuals' perceptions of temperature and rainfall change with climate records. In the case of temperature, the results from the model show that household size ($\beta = -0.056^{***}$, $se = 0.01$)[1], the age of the household head ($\beta = -0.012^{***}$, $se = 0.01$), and asset ownership ($\beta = -1.162^{***}$, $se = 0.29$) are statistically significant and negatively affect the alignment of farmers' perceptions. Gender is not statistically significant. Similarly, when considering rainfall, household size ($\beta = -0.061^{***}$, $se = 0.01$), the age of the household head ($\beta = -0.014^{***}$, $se = 0.01$), and asset ownership ($\beta = -1.291^{***}$, $se = 0.32$) are statistically significant and negatively associated with alignment.

1 $^{***}p < 0.001$.

RQ4: How do individuals' adaptation choices differ based on their perceptions?

Seventy-nine percent of farmers in Burkina Faso chose not to adapt to rising temperatures (see Table 1). Table 6 provides the regression results for the logit model examining household and individual characteristics associated with that choice to adapt (or not) to temperature change. Due to the low data quality regarding responses to rainfall adaptation choice questions in the UNDP survey we do not examine them here. Similar to RQ3, the 7-year timeframe was used due to it being best aligned with residents' perceptions. The alignment variable ($\beta = 0.957^{***}$, $se = 0.21$), and whether individuals perceived they had met a minimum standard of living ($\beta = 0.764^{***}$, $se = 0.23$) were statistically significant and positively correlated with the choice to adapt. Household size, age, and gender were not statistically significant.

Discussion

This study links localized long-term temperature and rainfall data trends in Burkina Faso to UNDP household survey results to examine farmers' perceptions of and adaptation to climate change risk. In doing so, it generates a number of provocative results. The first is that while the vast majority of farmers in Burkina Faso noticed a long-term change in temperature and rainfall, only about half of those who did so perceived change in a way that aligned with recorded local climate data. Second, those who reported not perceiving any climatic change had on average experienced greater temperature increases and greater rainfall change than did their counterparts. Third, those who did perceive climate trends that were in line with recorded data had experienced greater temperature increases across all four timeframes and less rainfall change over the last 5 and 25 years than did those whose perceptions did not align with recorded climate trends. Fourth, older farmers and those who owned assets, and thus were wealthier, were actually less likely to perceive trends that aligned with records (both temperature and rainfall change) than younger farmers without assets. And finally, when it came to the decision to adapt to rising temperatures, the vast majority of farmers had not adapted, perhaps as a result of being without the necessary resources to do so. This last finding is supported by our regression results, which showed that perceiving temperature trends in line with data and perceiving oneself to have met a minimum standard of living (i.e., being wealthier) were positively associated with the decision to adapt.

Many of these counterintuitive results are not wholly dissimilar from previous studies. For example, Mulenga et al. (2017) found that Zambian farmers' perceptions of temperature change overlapped with meteorological data, but they noted inconsistencies with respect to rainy seasons beginning earlier in the past. Similarly, Marin (2010) noted that Mongolian herders had considered only *significant* rains (>5 mm) when quantifying rainfall. Abid et al. (2019) in their cross-sectional study of 450 farmers in Pakistan found that while farmers' perceptions of increasing mean temperature aligned with recorded data, their perceptions of rainfall change were inconsistent with recorded data. Niles and Mueller (2016), in their study of farmers' perceptions of climate change in Malborough and Hawke's Bay in New Zealand, find that farmers who had irrigation were more likely to perceive an increase in rainfall compared to rainfed and non-irrigated sheep and beef farmers. They note that inaccurate perceptions about rainfall were likely to have been influenced by the availability of water resources and irrigation infrastructure. In this study, recorded data for Burkina Faso shows that rainfall has increased over 25 years as well as in every timeframe used in the study. Despite this, 94 percent of the farmers perceive that the climate has been drier. Also, since 93 percent of the farmers indicate that their crops are exclusively rainfed (see Table 1) it is highly likely that the misalignment is due to the actual rainfall falling short of farmer's expectations, similar to that of Meze-Hausken (2004) and Osbahr et al. (2011). Other studies have shown people perceive changes in rainfall more accurately than they do temperature. Piya et al. (2013) found 5 percent more Chepang community residents in Nepal perceived rainfall patterns accurately than did so for temperature. And Vedwan and Rhoades (2001) found similar results in the Western Himalayas of India, arguing that individuals there may perceive changes to rainfall (or snowfall specifically) more accurately compared to temperature because of the former's visual salience, i.e., it is observable.

The time frames used in this study extend backward from the time of the UNDP survey, i.e., 2015. Farmers' perceptions were slightly better aligned with data from shorter timeframes, 5 years and 7 years in particular, and thus likely more dependent on recent experience. This supports earlier work by Moyo et al. (2012), who noted farmers were best able to recall climate from the past 5 years. The extent to which farmers were relying on and recalling unique events to inform their perceptions of temperature and rainfall change however is unclear. Mulenga et al. (2017) argued that farmers were more apt to recall and associate unique events with climate change as opposed to recalling incremental changes over a long run. When we examine the temperature record, we see an unseasonably cool year in 2008 (7 years previous) and the hottest year on record in 2005 (10 years previous), but steadily increasing mean monthly temperatures between 2012 and 2015. For rainfall, we see extremely dry years in 2002 (13 years previous) and 2011 (4 years previous), but relatively steady wetter years on average since 2011. Recent experience suggests on average that it is getting hotter and wetter; yet of those who noticed either a change in temperature or rainfall, 98 percent identified it as getting hotter, while 84 percent identified it as getting drier. Yet temperature increases are also related to soil moisture and therefore can lead to misperceptions (Mulenga et al., 2017). Those authors note that farmers may focus on agricultural drought rather than meteorological drought and thus as temperature increases lead to a decrease in soil moisture, farmers perceive this as a decrease in rainfall. As heatwaves, which have increased in number and severity across the globe, coincide with steadier long-term increases, individuals' recent experiences are simply more likely to coincide with both recorded long and short-term trends. But regarding rainfall, farmers may be intuitively altering their perception based on their rainfall needs, leading to an inconsistency between perceptions and recorded data (Osbahr et al., 2011).

While Funatsu et al. (2019) found in their study that perception of climate change increased with age, here age was negatively associated with farmers' perceptions aligning with recorded data for both temperature and rainfall. While temperatures have steadily increased on average, no matter the timeframe examined—though not necessarily consistently across farmers' locations, rainfall actually declined over a 10-year timeframe, the only timeframe in which rainfall didn't increase. Without further qualitative research, it remains unclear whether older farmers are recalling steady declines in rainfall over the past 10 years or the extremely dry seasons of 2003 and 2011, perhaps relying on the availability heuristic. Younger farmers may not remember 2003 or these steady declines in rainfall, perhaps recalling wetter more recent years. While some studies show gender differences in perception (Singh et al., 2017; Darabant et al., 2020), our study found no differences between gender, at least with regard to perceptions. We posit that men and women in our study potentially engaged in similar farm activities. We also acknowledge that women made up a relatively small proportion of household heads here, and so additional research is necessary.

Our results show that the alignment of farmers' perceptions with recorded data is positively associated with adaptation. Put simply, perceiving climate change is key to adapting. And adaptation is not only necessary but beneficial. Ojo and Baiyegunhi (2020) show that compared to farmers who did not adapt, the ones who adopted at least one strategy had higher farm revenue. Yet we find an intriguing result with respect to the effect of resources on the accuracy of farmers' perceptions; namely, that owning assets led to perceptions less aligned with recorded trends. At the same time, farmers who indicated that they had more than a sufficient standard of living were more likely to adapt to temperature changes. In our study sample, farmers were asked to self-report their standard of living: 88 percent of individuals reported making less than sufficient income. This result is not dissimilar to Hou et al.'s (2015) results and suggests that those individuals engaged in the less affluent aspects of farming may be those most likely to notice it—and yet also find themselves without the means to adapt. While those with enough wealth, which Singh et al. (2017) note helps farmers switch to improved varieties of crops, use costlier inputs, and receive more training and advice than poorer individuals, may be less likely to notice that such decisions are necessary. Other socioeconomic factors such as household size, the age of the head of the household, and gender were not statistically significant with respect to the decision to adapt. Since age and household size were statistically significant for the alignment of perception and recorded data, our results indicate that when it comes to adaptation, here alignment of perceptions and the capacity to adapt were the most important factors.

There are three limitations to this study. First, the study does not consider the extreme events that took place in these timeframes due to non-availability of such data specific to farmers' geographic region. Since extreme events can influence how people perceive if and to what extent climate change has occurred (Whitmarsh and Capstick, 2018), this could potentially help us understand why farmers perceived climate change the way they did. Second, the education level of the farmers, which has been found to influence both perception (Debela et al., 2015) and adaptation (Abid et al., 2019) has not been included in our model due to anomalies in survey responses. For example, the number of years of education were greater than the respondents' age in several cases. This could be from farmers considering their years of experience in farming (practical learning) as opposed to formal schooling. Finally, studies and common sense suggest that adaptation choices depend on more external factors than simply the alignment of people's perceptions with climate data. These decisions depend on credit constraints, information (or the lack of), institutional support, access to extension services, and the availability of stress-tolerant crop varieties (Kabir et al., 2017; Singh et al., 2017; Khanal and Wilson, 2019; Ojo and Baiyegunhi, 2020). Even if the materials and services are available to farmers, individuals may lack the technical knowledge regarding how to use them (Khanal and Wilson, 2019). Yet across SSA, while the urgency of widespread adaptation increases, adaptation policies continue to have a narrow focus, and there remains limited engagement with local expertise or their adaptation responses (Adenle et al., 2017). This gap not only warrants policies to be tailored to conditions that are unique to each country and to the climate risk for which the country is most vulnerable, but adaptation policies that consider variability at the community and *individual* level. This variability exists not just in the ways people experience changing temperature and rainfall, but also, as we examine here, in how they perceive and internalize that change.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: data ownership is held by UNDP, New York. A written request is required for access. Requests to access these datasets should be directed to babatunde.abidoye@undp.org.

Author contributions

SK contributed to idea formation, data analysis, paper writing, and revisions. DB contributed to idea formation, paper writing, and revisions. BA contributed to data collection and revisions. All authors contributed to the article and approved the submitted version.

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Conflict of interest

Author BA was employed by United Nations Development Programme.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fclim.2022.1038320/full#supplementary-material

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