**Original Manuscript**

**What shapes climate change perceptions in Africa? A random forest approach**

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**Abstract**

Understanding individual perceptions about climate change fundamental for policymakers to enact adaptation and mitigation policies. Although Africa is projected to be one of the most vulnerable regions from a changing climate, little research has focused on how climate change is perceived by Africans. Using random forest methodology, we analyse Afrobarometer survey data and precipitation and temperature data from second-order political boundaries to explore what shapes climate change perceptions in Africa. We include 5 different dimensions of climate change perceptions: awareness, belief in its human cause, risk perception, need to stop it and self-efficacy. Results indicate that perceived agriculture conditions are crucial for perceiving climate change. Long-term changes in local weather conditions are among the most important predictors. Moreover, education, access to online information, authoritarian values, religion, and gender have significant influence over individual climate change perceptions. Urgent action is needed to adapt to and mitigate the impacts of climate change in Africa, and these findings orient policymakers on how climatic awareness, concern, policy support and self-efficacy are constructed in the continent.

**Introduction**

Current projections suggest that climate change (CC) will likely have “severe, irreversible and pervasive impacts for people and ecosystems” [1]. Urgent mitigation and adaptation strategies are needed at macro, meso and micro levels to reduce and adapt to those impacts. However, these measures are not being implemented rapidly enough [2]. Apart from material and institutional constraints, there are some relevant cognitive barriers hindering adaptation [3,4]. Among those cognitive barriers, climate change perceptions (CCP) stand out [5].

Despite the strong scientific consensus on the existence and projected impacts of CC, a relevant fraction of the public deny its existence, underestimate its risks or believe it is a natural process that cannot be stopped [6]. Why is the scientific knowledge not translated into individuals’ subjective perceptions? This divergence erodes public support to environmental policy and limits behavioural changes [7]. Therefore, it is crucial to understand how individuals perceive climate change in order to implement effective adaptation and mitigation strategies [5,8].

These strategies are urgently needed across the world, but especially in Africa, as this continent will be among the most affected by CC [1]. Despite this relevance, little research has focused on the cognitive barriers to adaptation and climate change perceptions in African countries. For instance, just 3% of studies meta-analysed by Van Valkengoed and Steg [5] and 1.7% of those meta-analysed by Hornsey et al. [9] were conducted in Africa. As CCP and its predictors vary widely across regions [10,11], the applicability of non-African research is, at least, questionable.

Research on CCP in Africa is scarce. Beyond the local case-study level [12,13], there are few cross-African studies [10,11]. Moreover, these studies rely on the same surveys (Gallup Poll 2007-2010) and, due to data constraints, just include a handful of covariates. For instance, significant predictors such as ideology or local weather changes are not included in those analyses. Building upon that research, this study explicitly addresses what shapes climate change perceptions in Africa. The topic is approached holistically, as the importance of education, access to information, ideology, experience of local weather, religion, demographics, and socio-economic variables to predict individual CCP is assessed simultaneously. To understand the effects of these variables on CCP in Africa, it is convenient to review first the main findings of previous research.

*What shapes CCP in the Global North*

A growing number of interdisciplinary research has addressed the question of how individuals perceive the changing climate, finding a myriad of factors that influence CCP [9,14,15]. In other words, if climate change is a well-established fact, why do some individuals deny and underestimate it? The first plausible explanation is straightforward: this fact may not be accessible to everyone. Indeed, access to information has been found to be basic for individuals to be aware of the causes and potential consequences of climate change [10]. Likewise, higher levels of education have been associated with greater awareness and concern, as education enables a better access and understanding of climate information [11,16].

However, other studies find that information, scientific literacy or education level are not correlated to CCP [17–19]. In other words, some people access and correctly understand rigorous information about CC, but they interpret it subjectively and incorrectly. Why? To reduce cognitive dissonance, individuals process novel information about climate change in a way that matches and reinforces their previous beliefs [20]. This phenomenon, called motivated reasoning, has been shown to influence CCP, mainly for political and religious motivations [4,18]. When presented with the same information, people interpret it differently, depending on their political ideology. For instance, Hart and Nisbet [19] presented the same news stories about possible CC impacts on health to Americans who identified as Democrats and Republicans. The news stories increased CC risk perceptions and policy support among Democrats, but they resulted in a “boomerang effect” among Republicans, who left more convinced of their previous scepticism. Other studies have also find that ideologically motivated reasoning influences CCP [16,21].

Likewise, religious individuals may interpret novel information about climate change through their religious frame, avoiding conflict with their previous beliefs. For instance, an individual who believes in an almighty God is more likely to attribute climate change to God's will rather than to human activity [22]. In this line, attending religious services and having religious beliefs have been linked with reduced CCP [23–26]. Therefore, even when people have access to rigorous information and the ability to understand it, politically or religiously motivated reasoning can lead to incorrect perceptions.

Besides motivated reasoning, other mechanisms may explain why rigorous information is not correctly processed. Most individuals believe that climate change is a distant phenomenon and will probably affect people living in other regions and in the future [15]. Thus, climate change is psychologically distant. Due to this psychological distance and the statistical nature of climate change, information about it does not usually elicit emotional responses [27,28]. This can lead to attribute substitution: the irrational use of related and emotionally salient cues, such as local weather, instead of rigorous but abstract information [15]. In other words, seeing can be more convincing than informing oneself. Personal experiences about local weather are sensory and emotionally salient, so people commonly but wrongly use them to infer their perceptions of CC [4,29]. Individuals that experience an extreme climate-related event such as hurricanes, floods, or temperature anomalies tend to perceive CC to a greater degree [23,30–37]. Therefore, personal experience of local weather can replace rigorous information about climate change and, in turn, influence CCP.

We have seen how information might be processed and perceptions constructed through biased mechanisms such as motivated reasoning or attribute substitution, but information can also be directly ignored. The psychological distance of CC contrasts with daily material concerns, which may relegate CC to irrelevance. In other words, people may have a “finite pool of worry" which may be full of more immediate concerns than CC, limiting its perception [14]. In line with the finite pool of worry hypothesis, proxies of material situation at different levels such as GDP and GDP growth, unemployment and household income have been related to CCP [10,11,13,38,39].

Finally, demographics such as gender, age or race do not have consistent effects over CCP. Some studies suggest that women are less aware of CC but have higher risk perceptions [21,24,27,40], whereas other studies have found no relationship at all between gender and awareness [11,41,42]. Similarly, some studies have found small negative effects for age on CCP [9,11,21,23,41], while others have found positive effects in rural areas, as experience with weather and agriculture increases with age [13,43]. Race, at least in North America, seems to have a more consistent influence on CC risk perceptions. Non-white individuals show more concern and higher risk perceptions than whites [40,44,45]. When combined with gender, these findings suggest a “white male” effect on CC risk perceptions. However, it seems that these demographic effects are eclipsed by ideology or access to information [9,21].

To sum up, although scientific knowledge about climate change is increasingly reliable and available, individual perceptions of climate change are not yet as consistent. Individuals may be unable to access or understand rigorous information about climate change. They may incorrectly interpret that information to avoid conflict with their political or religious worldview – motivated reasoning. They might substitute rigorous but abstract information for emotionally salient personal experiences of local weather – attribute substitution. They may not perceive climate change as they may be already worried by other more urgent material concerns – finite pool of worry.

**Materials and Methods**

*Data*

For extracting CCP variables and most predictors, we use the 7th round of the Afrobarometer [6], conducted between 2016 and 2018. It comprises more than 45,000 observations from 34 African countries. Except for some small countries, it is georeferenced at the second administrative level (see SI 1). This allows a high resolution for relating CCP to climatic variables, a link unstudied beyond the first administrative level across Africa.

For constructing local weather variables, we use two different datasets. First, we obtain monthly precipitation, maximum and mean temperature for the period 1961-2019 from the CRU 4.0 dataset [46]. Second, we complement those variables with the standardized precipitation evapotranspiration index (SPEI), which measures drought, from the SPEI 2.6 database [47]. Both datasets offer a spatial resolution of 0.5º x 0.5º.

*Operationalization*

Climate change perceptions are the dependent variables in this study. Specifically, we include the following CCP variables. *CC awareness* measures whether the individual knows about the existence or CC or not. Those aware were further surveyed. *Human cause* accounts for the knowledge about the anthropogenic nature of CC. *CC risk perception* measures the perceived effect of CC over daily life. *Need to stop CC* accounts for the perceived necessity of countermeasures. Finally, *self-efficacy* measures how individuals perceive their own margin of action to stop CC. The actual questions asked and further information on these variables is available in the SI 1.

For climatic variables, we first superimpose the CRU and SPEI data grids on the GADM second level political boundaries for the countries in our sample. As some administrative areas intersect with more than one pixel, we aggregate their values using two alternative functions: mean and maximum. While the mean values more accurately reflect aggregate trends across the spatial area, news of extreme maximum values at some point of the grid can reach the rest of the area and influence individual perceptions there. Hereafter, further analysis is made using mean values, but it is also robust to the use of maximum values across grids. Second, we compute the long-term anomalies for temperature and precipitation data (SPEI is already standardised against a long-term baseline). We use annual values (the year before the individual was surveyed) standardised against the 1961-1990 baseline.

Additionally, 67 potential correlates to CCP are extracted from the Afrobarometer, as suggested by previous research. They account for access to information, education, political ideology, religion, economic conditions, demographics, intention to migrate or agricultural perceptions, among others. Adding Afrobarometer and climatic variables, we have 71 potential predictors of CCP for each model. Descriptive statistics and their corresponding questions are included at the SI 1.

*Methods*

We analyse what shapes climate change perceptions in Africa using Random Forest methodology [48]. This machine-learning approach uses non-parametric recursive partitioning to produce models with high predictive accuracy [10]. It can handle high-dimensional (with a large number of predictors) multilevel datasets with high-level interactions and non-linear relations [49], so it is ideal for our dataset. For each dependent variable, we grow a random forest composed of 1,000 trees with a minimum node size of 5, using the *ranger* package in R [50]

Despite its advantages, Random Forest models are not easily interpretable on their own. To interpret them, we use some additional measures. First, we compute the variable importance measure, that ranks predictors by their predictive power (including direct and indirect effects on the dependent variable). We use the corrected Gini method to do so, because it shows no bias towards predictors with more classes, in contrast to the impurity importance, at a similar computational cost [51]. This measure shows which are the most important predictors that shape CCP but does not assess whether they are significant or not. We use the *ranger* package in R [50] to compute it. Second, we use partial dependence plots to illustrate the magnitude and direction of the direct effects of significant predictors. Partial dependence plots work like marginal effects in logistic regression models: they predict responses for each level of the predictor while holding the rest of the variables constant. We use the *randomForestSRC* package for generating these plots [52].

We organize the rest of the study as follows. First, results from the Random Forest models are presented, separately for each dependent variable. This allows to comment the specifics of each CCP variable, as they have different predictors. We then discuss these findings in general, aggregating the effects of each important predictor across models.

**Results**

Fig 1 presents the most important predictors for respondents’ climate change awareness (whether they know its existence or not). Education level, internet use and the frequency of access to online news are fundamental for CC awareness. Higher education levels and access to information are related to higher CC awareness. Perceiving that climate conditions for agricultural production (*agric. cond.*) have changed in the last decade is positively related to CC awareness, but the effect is higher for worsening values (positive), as Fig 1B illustrates. We find a gender gap for awareness, as women are about 5.5% less likely to know about climate change. Authoritarian ideology and interest in politics are also important covariates. Being supportive of one-party systems significantly decreases awareness, while talking about politics has the opposite effect. Long-term changes in weather conditions at the second administrative level are important predictors of being aware of CC. Higher temperatures, less rainfall, and more severe droughts (SPEI) are associated with higher CC awareness, but their direct effects are of less magnitude than education, information, or ideology. Speaking a western language has a significant impact of almost +4% on CC awareness. Regarding religion, we find mixed results: while being religious (any denomination) has a positive relation, supporting the rule of religious law reduces CC awareness.

Gráfico

Descripción generada automáticamente

**Fig 1. Key predictors of climate change awareness.**

(A) Top 15 predictors of CC awareness. (B) Partial dependence plot of direct effects of access to online news (*news tech*), being favourable to one-party rule (*authoritarian*) and perceived agricultural conditions (*agric. cond.*)

Fig 2 shows the most important predictors of believing in the human causation of CC. Local weather changes are the main predictors, above education, access to information or ideology. A 0.5 SD mean temperature anomaly is associated with a 3% increase in the belief that CC is caused by human action, as illustrated in Fig 2B. Changing precipitations have the opposite effect but with less magnitude. Education level and access to online information also have important positive effects over the belief in the human causation of CC. We observe again a language gap in CCP: those who speak a western language are up to 4% more likely to believe CC is human-induced. The perception of more severe droughts and worsening agricultural conditions increase the belief in the anthropogenic nature of CC. Finally, while being religious is insignificant for predicting the belief in the anthropogenic nature of CC, there are some significant differences between religions. Catholic and Orthodox Christians are more likely than Sunni Muslims to believe in human causation of CC, but this difference amounts to less than 1%. Other denominations oscillate around the mean.

Gráfico

Descripción generada automáticamente

**Fig 2. Key predictors of belief in human causation of climate change.**

(A) Top 15 predictors of belief in human causation of CC. (B) Partial dependence plot of direct effects of mean temperature anomalies (*temp. anom.*), precipitation anomalies (*precip. anom.*), trust in institutions (*trust* institutions) and access to online news (*news tech*).

The key predictors of CC risk perceptions are presented in Fig 3. Perceived agricultural conditions, followed by drought perception, are crucial for assessing the risks CC poses to citizens in Africa. Those who perceive better agricultural conditions are less likely to consider CC as a risk than those who perceive no changes, whereas those who perceive worse conditions are significantly more likely. The belief that CC is human-induced positively related to risk perceptions. Local weather changes maintain their importance. Temperature anomalies have a positive effect, while the effect is the opposite for precipitation. Authoritarianism ―supporting one-man, one-party or military rule, is negatively related to perceived risks. Poverty, on the other hand, shows the opposite effect: households with fewer resources perceive greater risks from CC than wealthier ones, both in urban and rural areas. Ethnic group is among the most important predictors: Black Africans are 5.5% more likely to perceive climatic risks than Arab Africans, and 4% more than the other groups.

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**Fig 3. Key predictors of climate change risk perception.**

(A) Top 15 predictors of CC risk perception. (B) Partial dependence plot of direct effects of belief in human causation of CC (*CC human cause*), perceived severity of droughts (*drought percep*.), perceived agricultural conditions (*agric. cond.*) and being favourable to one-man rule (*authoritarian*).

As Fig 4 shows, CC risk perceptions and the belief in human causation of CC are the top predictors of the need to stop it. Both have important positive impacts on the belief that action is needed, with a maximum effect of more than 13% for risk perception and 12% for human cause. Like other dimensions of CCP, support for action against CC is positively related to worse agricultural conditions and higher temperature anomalies, and negatively to rainfall anomalies. Individuals with fewer resources are more convinced of the need to stop CC, while speakers of western languages and those who frequently read newspapers are less convinced. In this case, easier access to information seems to have a negative effect on CCP. Finally, religion is among the most important predictors, as there are significant differences among faiths. Muslims (no denomination) and Catholic and Orthodox Christians are more supportive of stopping CC, while Christians of no denomination are less supportive.

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**Fig 4. Key predictors of believing climate change must be stopped.**

(A) Top 15 predictors of need to stop CC. (B) Partial dependence plot of direct effects of mean temperature anomalies (*temp. anom.*), belief in human causation of CC (*CC human cause*), and perceived risk from CC (*CC risk percep.*) on the need to stop CC.

Fig 5 presents the key predictors of self-efficacy ― the perceived effectiveness of ordinary African citizens’ environmental action. Logically, believing that CC is caused by human action is the most important covariate of thinking that human action can mitigate its impacts. Far behind it, we find temperature anomalies, education level, CC risk perceptions and access to information, which also increase self-efficacy. Intolerant (regarding other religions) and authoritarian values are associated with reduced self-efficacy. Households with fewer resources feel less empowered to fight against CC. Regarding ethnicity, Black Africans are 3% more likely of showing self-efficacy than other races, 4% more than Arab Africans. Also, in this model, sexist values regarding gender violence or land inheritance by women are negatively related to self-efficacy. Finally, religiousness has a positive effect of about 1.5%, and Catholics and Orthodox Christians believe significantly more in their self-efficacy than Sunni Muslims.

Gráfico

Descripción generada automáticamente

**Fig 5. Key predictors of environmental self-efficacy.**

(A) Top 15 predictors of self-efficacy. (B) Partial dependence plot of direct effects of mean temperature anomalies (*temp. anom.*), belief in human causation of CC (*CC human cause*), perceived risk from CC (*CC risk percep.*) and being favourable to one-man rule (*authoritarian*) on self-efficacy.

**Discussion**

These results show what shapes climate change perceptions (CCP) in Africa. Although each dimension of CCP has its unique set of predictors, some common patterns emerge from the analysis. First, the importance of perceived agricultural conditions stands out. Those individuals who perceive worsening agricultural conditions show higher awareness and perceived risk, more support for stopping CC and are more likely to believe it is caused by human action. The huge importance of the primary sector in terms of employment and export revenues makes agriculture a close and great concern to African citizens [2]. Thus, perceiving how CC is already affecting agriculture may reduce the psychological distance to CC. It is not a problem for “others" in space and time, it is happening here and now [53]. However, this relation also poses a challenge. CC has uneven impacts, and agriculture in some regions may benefit from changes in local climate [2]. Those who perceive those improvements are less likely to perceive CC and support or take environmental action. More efforts should be made to highlight the global nature of climate change and its overall negative impacts. These findings suggest environmental discourse in Africa could focus on the negative impacts of CC on agriculture to raise CCP, impulse individual adaptation and mobilise public support.

Second, attributing climate change to human activity increases risk perceptions, support for mitigation, and self-efficacy. If CC is *unnatural*, it is *extraordinary* and thus riskier, but also stoppable. Besides, attributing the cause of CC to human action might increase personal responsibility and, therefore, induce corrective responses [54,55]. This points to the convenience of spreading and highlighting the human origin of CC to impulse behavioural changes and mitigation strategies in Africa.

Risk perceptions are positively associated with self-efficacy and the need to stop CC. While some previous studies in the US and UK pointed to fatalism or climate despair [3,56,57]―where higher risks discourage self-efficacy and action support, the opposite seems to be true for Africa. This could be the result of motivated control ―feeling more empowered in order to feel secure from a greater risk [58], or increased personal concern with CC [59]. Either way, framing CC as a critical risk will not discourage the African public, but it might encourage policy support and personal action [5].

Information and education have great predictive power for being aware of CC and believing it has a human origin, the most analytical dimensions of CCP. On the other hand, they have less predictive power for more affective dimensions, such as risk perception or the need to stop CC, where they have a slight negative effect. The limited emotional salience of climatic information compared with personal experience or motivated reasoning might account for this divergence [15,27,28]. Nevertheless, the importance of information is contingent on language. Not speaking French, English or Portuguese hinders the understanding of climate terminology, which frequently lacks accurate translations to African languages [24]. Greater efforts should be made to translate to African languages the nature, causes and impacts of CC.

Local weather conditions are among the most important predictors in all models, and on average they are more important than access to information, ideology or gender. Previous research had found that *perceived* changes in local temperature were the most important predictor of CC risk perception in some African countries [10]. Building upon it, this study shows that *actual* long-term anomalies in temperature, rainfall and drought at the second administrative level predict individual CCP across various dimensions. Attribute substitution and emotional salience may explain the importance of personal experience with local weather conditions for CCP [15,31]. Besides, qualitative evidence suggests that some communities in Africa understand climate change not as a global but a local phenomenon [24]. Therefore, local weather changes may be used to prime CC and encourage mitigation and adaptation, but the link between those local changes and the global nature of CC should be highlighted.

Material conditions had previously been found to influence CCP, mainly by the mechanism known as the “finite pool of worry" [14]. According to it, worse material conditions limit CCP, as they create more urgent and pressing concerns to worry about. However, poverty has significant positive effects on risk perceptions and the need to stop CC across African countries. In contrast with the finite pool of worry hypothesis, households with fewer resources are the most concerned about the present and future effects of climate change. CC is an urgent concern for them, as their income and assets are the most vulnerable to climatic risks [53,60].

Ideology has a significant impact on CCP in Africa. Authoritarian and intolerant ideologies are related to reduced CC awareness, belief in its human origin, risk perceptions, the need to stop CC and self-efficacy. These values have been consistent and negatively linked to CCP in other regions of the world [9]. Ideology influences what information people access, and how they process and assimilate it [18–21]. Authoritarians, through these mechanisms, disregard CC to justify their support for

maintaining the status quo. These findings suggest it could be convenient to shape CC discourse to engage the authoritarian public. To do so, environmental discourse can frame policy and individual action as patriotism, innovation, or prosocial behaviour [61], and focus risk communication on the possible effects of CC on security and public order.

Like ideology, religion has been shown in previous research to prompt motivated reasoning, influencing thus CCP. Overall, religiousness itself is mostly insignificant to predict CCP. However, we do observe some significant differences across religions in Africa: Catholic and Orthodox Christians are generally more aware the anthropogenic nature of CC and more likely to believe it must be stopped, while Sunni Muslims show the opposite trend. These findings illustrate the importance of actively engaging religious leaders to communicate environmental messages, giving them the tools for doing so effectively and rigorously [24,26].

Demographic variables such as gender or race have some importance. We find an important gender gap for CC awareness, as well as slightly negative effects for other dimensions of CCP. Women are less likely to be aware of climate change, as previous case studies in Africa had suggested [24,62]. Moreover, race is related to CC risk perceptions and self-efficacy. Overall, Black Africans show more concern and self-efficacy than other groups, among whom Arab Africans are the less concerned. However, we cannot talk about a “white male” effect [45] because White Africans do not especially neglect risks (in contrast to Arab Africans) nor women show more concern, rather the opposite. Finally, age is insignificant across all models.

Urgent action is needed to limit the impacts of CC on ecosystems, economies, and political institutions in Africa. Knowing what shapes individual climate change perceptions across the continent contributes to the endeavour of raising awareness and policy support and encouraging self-efficacy and adaptive behaviour.

**Acknowledgements**

We want to thank Stefano Nembrini for his useful comments on methodology.

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