Comparing climate change perceptions and meteorological data in rural West Africa to improve the understanding of household decisions to migrate

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Abstract:	Largely dependent on rain-fed agriculture, the West African populations could be severely impacted by climate change and variability. In this paper, we performed a literature review relating to perceptions of climate change and variability in West Africa, followed by an in-depth comparison between perceptions by rural dwellers of Burkina Faso and trends in meteorological data to discuss the importance of perceptions vis-àvis climate trends in migration decision. Results showed that respondents perceived increasing temperature and worsening rainfall conditions over 1988-2007 matching with findings of previous studies but inconsistent with the trends observed in rainfall data. Given that climate change is recognized as a key driver of mobility on the one hand and the fact that climate change perceptions influence decision to migrate on the other hand, our results suggest to jointly include perceptions and climate data in future research on environmental migration in order to improve the understanding of household's decision in response to climate change. Keywords Adaptation, Burkina Faso, Climate Change, Migration, Perception
Response to Reviewers:	See attached file

1. Introduction

Climate change and variability adversely impact the livelihood of populations dependent on rain-fed agriculture (Juana et al. 2013). Rainfall variability and drought, through their negative impacts on crop production and livestock, are significant contributors to poverty and food insecurity (de Sherbinin 2011). A particular attention must be paid to West Africa for three reasons: this region will be among those most highly affected by climate change in the future, there is a prevalence of agriculture in its economy and the majority of its rural population closely depends on the natural environment (Van der Land et al. 2018).

To face climate variability and economic or political changes, the rural populations of West Africa develop adaptation strategies that will vary according to region, type of farming and socio-cultural factors (Adger et al. 2009; Nielsen and Reenberg 2010a). Soil fertility management practices and irrigation contribute to counteract the negative impacts of climate change but some farmers do not adopt these measures due to their unavailability and high cost. Soil and water conservation practices are frequently implemented in the West African Sahel but mainly because of growing land scarcity and new market opportunities rather than climate variability (Barbier et al. 2009). In most places, the only technical adaptations in response to climate change are to use several crop varieties or mix-cropping and/or to postpone seeding dates (Fosu-Mensah et al. 2012). In several regions, farmers choose to integrate crop and livestock and to plant trees (Soglo and Nonvide 2019). Cyclical intraregional migration in response to seasonal variability in rainfall and periodic droughts has long been practiced in West Africa (Cordell et al. 1996). Today, as migration is recognized as an adaptation strategy (Cissé et al. 2010; Mertz et al. 2010), farmers are diversifying their livelihood to avoid relying on a single rainfall-dependent activity and to increase household income, notably used to buy food (D'haen et al. 2011; Nielsen and Reenberg 2010b). In some cases, migrations are rather a failure to adapt, when households fall in the vicious circle of livelihood deterioration by moving to areas where they are exposed to more risks (Afifi et al. 2016).

Over the last three decades, the role of climate change in driving human migration has attracted a growing interest (de Longueville et al. 2019; Kaczan and Orgill-Meyer 2019). Three literature reviews on the environment-migration nexus in West Africa (Brüning and Piguet 2018; Van der Land et al. 2018) and in Africa (Borderon et al. 2018) have recently been published. In the first review, the authors analysed 43 studies about environmental change and migration in West Africa and concluded that it is undeniable that the environment plays a role in decisions to migrate (along with other factors) (Brüning and Piguet 2018). They also highlighted three weaknesses that could guide future research on these issues: (i) strengthen analysis of community contexts, household strategies and individual choices, (ii) use mixed-methods and (iii) focus on perceptions of climate change and variability. The second review analysed 15 empirical case studies that focus explicitly on the complex links between environmental factors and human mobility in West African drylands (Van der Land et al. 2018). The authors noted ambiguous findings on the impact of environmental factors on migration. Nevertheless, they observed that all studies reviewed agree on three relevant aspects: (i) environmental conditions and changes favour temporary migration, (ii) migration is a well-established activity to diversify income and (iii) migration is multi-causal. They also noted that studies which consider multiple variables as drivers of migration find that environmental factors are often not the main driver. The third review analysed 53 studies on the environment-migration nexus in Africa, including 25 in West Africa (Borderon et al. 2018). In this paper, the authors provided a first systematic and comprehensive summary of empirical evidence on environmental drivers of migration in Africa considering direct and indirect pathways through which environmental change influences internal and international migrations. Results showed that environmental change influences migration in Africa in an indirect way i.e. through affecting other drivers of migration (sociodemographic, economic, political factors). This supports the conceptual framework proposed by Black et al. in 2011 for understanding and assessing the effects of environmental change on human migration (see Figure 4, above).

Studies about the environment-migration nexus are largely based on conventional climate data based on recorded measures (Obokata et al. 2014). This was confirmed by two review articles having showed that environmental conditions are exclusively represented by ground-measured climate data, global climatological datasets and/or satellite data (Eklund et al. 2016; Neumann and Hilderink 2015). Historical climate change patterns usually rely on the characterization of long-term trends of key climate indicators and their variability in relation to a reference period (Razavi et al. 2016). While scientists are often skeptical regarding the reliability of climatic observations made by non-scientists, it has been demonstrated that farmers' perceptions of rainfall patterns and variability can add valuable information to conventional meteorological statistics and that only farmers who perceive a climate problem will adapt to it (Simelton et al. 2013). Findings of studies about perceptions of climate change and variability all over the world agree that populations perceive changes in local weather patterns, noticeable in rainfall (seasonality, distribution, amount and intensity) and in temperature. It is argued that climate change perceptions and their impacts on activities and livelihood influence people's decisions regarding whether to act or not (Alessa et al. 2008) and what adaptation measures are taken over both short- and long-terms (Byg and Salick, 2009; Reckien 2014). It is also increasingly recognized that relying more on change perceptions than on observed change accounts for the fact that some people decide to leave their homes when experiencing environmental stressors, while others do not (Black et al. 2013; Hunter et al. 2015). Some authors claim that people's perception of climate change and their own vulnerability to climate variability are factors related to migration decisions (Hunter 2005; Izazola et al. 1998) while others deplore a lack of empirical studies about relation between climate change perceptions and migrations (Brüning and Piguet 2018; Hunter et al. 2015). Recently, researchers have conducted empirical studies in Vietnam, Cambodia, Uganda, Nicaragua and Peru including data on perceptions to provide a more complete representation of the migration decisions. It appears that the individual perceptions of slow-onset events (droughts) decrease the probability to migrate. On the contrary, the perceptions of sudden events (floods, hurricanes) are associated with a higher probability to migrate, but results are not significant (Koubi et al. 2016a). A comparative study of the perceptions between migrants and non-migrants in Vietnam showed that the non-migrants have a better perception of sudden events but underestimate slow-onset events (Koubi et al. 2016b). In the context of the "Where the rain falls" project, questions covering human mobility attempted to identify links between this variable, food and livelihood security and rainfall variability (Afifi et al. 2016; Rademacher-Schulz et al. 2014; Warner et Afifi 2014). Led with the aim to compare opportunities for migration as a successful adaptation strategy in eight countries, these studies use perceptions of respondents instead of observed climate data but provide no check of the consistency between the two sets of data, except in the few cases where it was shown that the perceptions match with climate trends.

Studies on environmental migrations thus traditionally use conventional climate data. A few exceptions can be found in recent literature with the use of climate change perceptions instead of climate data (eg. Afifi et al. 2016; Rademacher-Schulz et al. 2014) but no single study so far has yet systematically combined climate data and data on climate change perceptions. Doing so is, however, needed if we are to understand how perception of climate change and variability are different from or similar to scientifically observed trends, and how the use of both types of data in single studies can improve our understanding of migration decision in rural West Africa. To explore this, the paper starts with an in-depth review of scientific literature relating to climate change perceptions in this region and their matching with climate trend observations. Then, we propose a comparison between climate change perceptions by rural dwellers in Burkina Faso and climate trends based on an original set of indicators performed in optimal study conditions. The discussion draws out some larger implications of our results for the current debate on the adaptation strategies in response to climate change in West Africa, especially concerning decisions to migrate.

2. Literature review

A systematic literature review was undertaken to identify relevant studies investigating perceptions of climate change and variability in arid, semi-arid and sub-humid areas of West Africa, including Senegal, Gambia, Mauritania, Mali, Burkina Faso, Niger, Nigeria, Benin, Togo, Ghana and Ivory Coast. The Scopus and Google Scholar databases were queried using 'Perception' AND 'Climate change' or 'Climate variability' AND 'West Africa' or 'Senegal' (or any country quoted earlier). All papers returned by the search were evaluated and a total of 49 articles were identified as relevant. They have all been published between 2008 and 2019, confirming that perception of climate change is a relatively new field of research (Ozer and Perrin 2014). For each paper, we determined the study area, acquisition method of perception data, perceptions of climate change and variability, use of climate data, study period and findings from comparison between perceptions and observations (See Supplementary material).

The content of the 49 papers returned by the search was analysed. Results highlighted that the most important changes felt by the West African populations are a decrease in total annual rainfall amount, a shorter rainy season, an increase in dry spells during the rainy season, in periodic droughts, in irregular rainfall and in temperature (See Supplementary material). In Burkina Faso, for example, respondents perceived that over the last 30 years the climate had become warmer (73%), the rainfall amount had decreased (97%) with a change in intensity (92%) and frequency (92%). A delayed onset (63%) and early cessation (90%) of the rainy season were also noted (Kima et al. 2015).

Without exception, studies agree that the West African populations perceive changes in weather conditions. However, there is disagreement about consistency with scientifically observed trends. Of the 49 articles returned by the search, 21 did not make any comparison (see Cat.1 in Supplementary material). Of the remaining 28 articles that do introduce a comparison, 17 concluded that there was consistency between what populations perceived and what has been published in scientific reports or observed in weather data (see Cat. 2 in Supplementary material). On the other hand, 11 articles showed that the populations' perceptions are partially or totally inconsistent with scientific observations (see Cat. 3 and 4 in Supplementary material). This did not concern temperature but rainfall change. Discrepancies between perception and observation also exist in the findings of studies led in other African regions (e.g. Meze-Hausken 2004; Sutcliffe et al. 2016) and in other part of the world (e.g. López et al. 2017; Niles and Mueller 2016). In literature, reasons explaining these discrepancies are classified into two groups. The first group is related to limitations of specific used data sources and methods: an irrelevant choice of the study period, a set of imprecise survey questions about climate change perception, the use of a single inappropriate meteorological dataset and/or irrelevant definitions of meteorological indicators can contribute to introduce biases in comparison. The second group includes inherent differences between perceptions and meteorological data, even when both have been measured with accuracy (Dickinson et al. 2017).

Faced with these contradictory results about consistency between perceptions of climate change and variability and scientifically observed trends in West Africa, we used the opportunity provided by access to relevant perception data and reliable daily meteorological data for Burkina Faso, in order to proceed to a new comparison based on an original set of indicators. We tried to optimize study conditions (databases, method) to minimize the risk of obtaining differences between perceptions and observations due to data constraints or methodological choices.

3. Empirical study

In this part, we have compared climate change perceptions of rural dwellers with meteorological records in Burkina Faso. This landlocked country occupying a central geographical position in West Africa, encompasses a diverse range of climates (Figure 1) and is characterized by a unimodal rainfall regime with a peak in August. Burkina Faso is a resource-poor country whose struggling economy is heavily dependent on rain-fed agriculture and has been identified as vulnerable to climate-induced displacements (Gray and Wise 2016; Henry et al. 2004).

3.1. Data

3.1.1. Perception data

Data on perceptions of climate change and variability were extracted from the household survey of the AMMA[1] project carried out in five West African countries between November 2007 and June 2008. These perception data are particularly relevant for the following reasons:

- They were collected on the basis of clear questions covering changes in temperature during dry and rainy seasons and different aspects of rainfall pattern and variability (amount, frequency, intensity, seasonal characteristics…) (Mertz et al. 2012) (see Table 1). Methods differ across studies but it was acknowledged that the use of specific questions has the benefit of eliciting perceptions on each parameter from every respondent, facilitating comparisons with meteorological data (Dickinson et al. 2017).
- The AMMA project made the choice of a time scale of 20 years (1988-2007) before the time of survey in 2008 to collect climate change perceptions. This is consistent with other studies (Bryan et al. 2009; Tambo and Abdoulaye 2012). A period of twenty years is relevant concerning "memory of surveyed people". Interviewers were asked to collect information on changes and trends during this period, rather than a comparison between 1988 and 2007.
- The survey sample size (N=383) was suitable according to previous studies (e.g. Ayanlade et al. 2017; Kima et al. 2015).
- Respondents were members of rural households located in four sites of Burkina Faso (see Figure 1). Thanks to the small spatial size of the surveyed site, we can reasonably argue that people are exposed to the same meteorological conditions within each site. By contrast, the four sites belong to different climate zones, which allows us to make comparisons related to the level of aridity.

In the AMMA database, there are also three categories of information about migration: (i) the number of temporary and permanent migrants in the households at the time of the survey with the main cause of migration, (ii) migration seen as a positive/negative consequence of observed changes, as well as a solution to solve other negative consequences, and (iii) the intention to migrate in the future, temporarily or permanently, in the case of more frequent droughts and in the case of drier or wetter climates (Mertz et al. 2011), among other adaptation strategies. It is important to note that intention to migrate is only a proxy of migration (Lu 1999), but it is

[1] African Monsoon Multidisciplinary Analysis

meaningful because this is the first step in the actual migration process (Macleod 1996). We used these data to complete our analysis.

3.1.2. Meteorological data

Meterological data were provided by the *Direction Générale de la Météorologie du Burkina Faso*. These data include daily rainfall, and minimum and maximum temperatures from January 1988 to December 2007 at a national scale. We retained data from four synoptic stations[2] and two additional rain gauge stations selected on the basis of the proximity to the surveyed villages (Figure 1). This allowed us to compare climate change perceptions with changes calculated from meteorological data measured at the nearest synoptic station(s) to each study site. This criterium of proximity was the same in Osbahr et al. (2011), Sutcliffe et al. (2016) and Ayanlade et al. (2017), who justified this choice to minimize impact of spatial variability. The availability of these data had two advantages:

- It made possible the calculations of an original set of indicators. This was interesting because perceptions of rainfall change can reflect a change in visible variables like frequency of extremes or seasonality rather than total rainfall (Roncoli et al. 2002).
- The daily time-step allowed us to calculate indicators linked to season. In previous studies based on the same perception data as we used here, climate change perceptions had been compared with climatic trends but due to limited data availability, this was only possible for rainfall amounts and dry spells (Mertz et al. 2012; Zampaligré et al. 2014).

Moreover, the use of climate estimates instead of meteorological stations' data was presented as a limitation in some studies (e.g. Dickinson et al. 2017; Kosmowski et al. 2016).

3.2. Method

A set of 20 rainfall indices were defined to be consistent with the 5 questions rural dwellers were asked about rainfall change perception (Table 1). Some of them (TOTR, RD, SDII, R10, R10p, R20, R20p, Rmax and Rmaxp) were based on climate indices developed by the Expert Team on Climate Change Detection Monitoring and Indices (ETCCDMI) and calculated with the RClimDex software (Zhang and Yang 2004). In addition, we developed several indices calculated by season (see Table 1). For this, the method of Sivakumar (1998) was used to determine the start and the end of the rainy season for each year of the study period. The first day of the rainy season at a given location is the date after May 1st when total rainfall over three consecutive days is at least 20mm, with no dry spell exceeding 7 days during the following 30 days. The last day is after 1 September if no rain occurs for a period of 20 days following this date. The values of indices related to season were then calculated for each year.

For temperature indices, we used the definition of average rainfall season in the country (May 1st to October 1st) (Lodoun et al. 2013) and calculated the average daily minimal, maximal and mean temperatures as well as the average daily temperature range separately for each season, that is to say 8 indices (Table 1). There were no missing data in the database, which made it possible to analyse trends.

Trend coefficients were calculated using Spearman's rank correlation over the 1988-2007 period to be in agreement with the survey. We used two significance p level ($p<0.05$ and $p<0.1$) to analyse the hypothesis that the slope was equal or different to 0. Each trend was categorized in six classes according to slope (positive or negative) and statistical significance (not significant ($p\geq0.1$), moderate ($p<0.1$) or significant ($p<0.05$)). Not significant trends were considered as a stability of the parameter. Then, we qualitatively compared climate trends with climate change perceptions by the surveyed population.

3.3. Results

3.3.1. Climate change and variability as perceived by the surveyed rural dwellers

In Burkina Faso, rural dwellers perceived deteriorating climate conditions over the period 1988-2007. The main agreement about rainfall change (86.3%) was the shortening of the rainy season (Figure 2). Only 7% reported an increase in the duration of the rainy season and 2.5% perceived stability. Most of respondents (83.9%) also cited a decrease in the total annual rainfall. In addition to these perceptions reflecting rainfall shortages, other perceptions were related to more erratic rains. About 85% of respondents observed an increase in the length of dry spells during the rainy season and individual rainfall events during the dry season decreased according to 68.9% of respondents. Concerning the intensity of rainfall events, opinions were more divided, with 65% of

[2] The station of Gaoua was only used for rainfall trends because anomalies were detected in temperature data

respondents having reported a declining trend and 27% having reported an increase. Site 4 (see Figure 1) presented the greatest homogeneity in responses (Table 2). More than 92% of respondents mentioned a decrease in the total annual rainfall, the length of the rainy season and the intensity of rainfall events and an increase in the length of dry spells during the rainy season. Moreover, more than 90% reported fewer rainfall events during the dry season. In site 3, more than 90% of the respondents agreed that the total annual rainfall, the length of the rainy season and the occurrence of rainfall events during the dry season had decreased (Table 2). Nearly 87% of the respondents also observed an extension in the length of dry spells during the rainy season. Perceptions were more variable concerning intensity of rainfall events. In the driest surveyed sites (sites 1 and 2), opinions were more divided (Table 2). The decrease in the total annual rainfall, the shortening of the rainy season and the extension of the length of dry spells during the rainy season were also the dominant perceptions but it was less unanimous than in sites 3 and 4. Opinions were sharply divided about rainfall events during the dry season and to a lesser extent about the intensity of rainfall events. In site 1, 64.5% of the respondents perceived a decrease in the intensity of rainfall events, against 28.9% who reported an increase. Trends were reversed in site 2.

Results about perceptions of change in temperature clearly showed a warming perceived by the surveyed population over the study period (Figure 2). An increase in temperature during the dry season was reported by 85% of the respondents and by 72.4% during the rainy season across the four sites. The share of respondents who mentioned stability in these parameters is greater than for factors related to rainfall but remains low. As for the perceptions of change in rainfall, perceptions relative to temperature change were more homogeneous in site 4 than in other sites (Table 2).

3.3.2. Climate change and variability observed in meteorological data

There were few significant trends in rainfall indices over the 1988-2007 period. Only the station of Gorom-Gorom (site 1) recorded a significant ($p<0.05$) positive trends for the total annual rainfall (TOTR), the average rainfall on wet days (SDII) and the annual number of days with rainfall amounting to ≥20 mm (R20). The stations of sites 1 and 2 exhibited a moderate ($p<0.1$) positive trend for the percentage of annual rainfall from days with rainfall ≥20 mm (R20p). Moreover, the percentage of annual rainfall from days with rainfall ≥10 mm (R10p) also showed a positive increase at Gorom-Gorom. These significant positive trends indicated an increase in the total annual rainfall and in rainfall intensity in the North of the country. At the station of Ouahigouya (Site 2), the significant trend illustrated the growing importance of heavy rains in the total annual rainfall. No index had a constant sign for all the studied stations and the observation of opposite signs was common for two stations in the same region. But the slope coefficients were not significant for most indices and stations, which indicated a stability of the conditions over 1988-2007. Actually, the total annual rainfall in West Africa had generally decreased during the latter decades of the twentieth century (Nicholson et al. 2000) before increasing from the 1990s (Lebel and Ali, 2009; Ozer et al. 2003).

Contrary to the trends in rainfall, trends observed in temperature were mostly significant ($p<0.05$) for the two seasons. However, there was disparity among stations because only four indices (TNds, TXds, Tds and TNrs) recorded the same trend everywhere. The increase in minimal temperature was higher than in maximal temperature. Therefore, trends in daily temperature ranges had often been negative and more significant in the Northern and Southern regions than in the central site. The increase in minimal temperature was more marked during the dry season in the driest regions (increase of nearly 2°C recorded in site 1 over the study period) and during the rainy season in the wettest regions (+1°C recorded in site 4).

3.3.3. Comparison between perceptions and climate trends

Our results showed a good fit between perceptions of changes in temperature by rural dwellers of Burkina Faso and recorded trends observed in temperatures (Figure 3). It is interesting to note however that this increased temperature, while matching with climate observation, has not been perceived by all respondents living in the same town (Table 2). As seen in the literature, the number of respondents who perceived increasing temperatures is indeed a majority but lower than the number of respondents who perceived a decrease in total rainfall and a shortening of the rainy season (Figure 2).

We noted inconsistencies between the rainfall change perceptions of rural dwellers and calculated rainfall trends in all the sites, whatever the index considered (Figure 3). These were the most visible in site 1 where significant increases in the total annual rainfall and in the rainfall intensity were observed while people perceived decreases. In the other sites, the signs of the trends were also often in opposition to the perceptions but the slope coefficients were low, which further illustrated a stability of the weather conditions. Consistencies between perceptions and trends were observed for the rainfall events during the dry season and dry spells during the rainy season but the slope coefficients were not significant. Rainfall change perceptions (decline of rainfall conditions) were more pronounced than recorded trends, mostly non-significant. As in other studies, most of the respondents reported that the climate had changed for the worse, even if the used methodology to study perception varies from one study to another (Nielsen and D'haen 2014).

3.3.4 The importance of migration as an adaptation strategy to climate change

In the AMMA database, more than 45% of households have members who were engaged in temporary migration at the time of the survey in 2008 and nearly 14% of households had permanent migrants. In total, 28 households (7.3%) had both permanent and temporary migrants and less than half of the households (48.3%) had no migrant member. Poverty was the leading cause of migration mentioned by respondents (78.1%) while rainfall deficit was stated by only 1.6% of households. This supports the results of Romankiewicz and Doevenspeck (2015) showing that when explicit questions about the possible linkages between environment and migration are avoided, environmental stress was not mentioned as a key driver of migration.

For 53 households (13.8%), migration was seen as a positive consequence of climate variability. Increase of income is the most important aspect mentioned by respondents but money transfers and acquisition of knowledge that can be implemented in the origin area are other positive effects of migration (Cissé et al. 2010). It is also a means to reduce pressure on households' resources (Roncoli et al. 2002). On the other hand, 40 households (10.4%) considered that migration is a negative consequence of climate variability. Because of adverse climate conditions, farmers have to migrate despite their desire to remain in their own communities (Barbier et al. 2009). Loss of labor force in the community of origin and acculturation are the main negative points of migration (Rasmussen et al. 2012).

In response to future changes in rainfall, migration is rarely the first adaptation strategy stated by the respondents but the intention to migrate occupies an important place. In case of drought, rural dwellers plan first to sell livestock and to decrease food intake but respondents generally mentioned several strategies. Migration is cited as the first strategy by 12.7% of the respondents and, in total, 17.5% of the respondents have the intention to resort to temporary migration in response to a drought. In case of a drier climate, the first two strategies planned by respondents are to seek new crop varieties and to sell livestock. About 10% of the respondents mentioned temporary migration and 26% permanent migration; these would be the first strategy respectively for 7.8% and 6.9% of households. The intention to migrate is lower in response to a wetter climate since only 2.4% and 1.6% of the respondents claimed that they would migrate temporarily or permanently. Seeking new crop varieties and increase the cropland area would be the main strategies adopted in this case.

Counting only once the people who answered positively to both questions about the intention to migrate temporarily in a situation of rainfall deficit (drought and/or drier climate), 28.5% of the respondents planned to adopt this strategy. This figure increases by 13% taking into account the intention to migrate permanently in response to a drier climate. According to the fact that more than 40% of the surveyed people in Burkina Faso claimed to have the intention to resort to temporary or permanent migration if the rainfall conditions worsen, this might lead to a change in migration patterns in the future, notably from predominantely temporary to more permanent migration. Moreover, knowing that most of the respondents already considered degradation of rainfall conditions over the period 1988-2007 while it is not clearly observed in the climate data, a significant increase in migration could occur faster than expected, if climate predictions hold.

4. Discussion

4.1. Potential sources of bias remaining in our empirical study

We optimized study conditions to compare perceptions of climate change and variability with climate trends in Burkina Faso but there were still shortcomings. Firstly, rainfalls in the Sahel are highly variable in space (Hulme 2001; Sivakumar and Hatfield 1990). It can rain in one village while another 5 km away remains dry. Hence, the use of data from exactly the same spot when comparing perceptions with scientifically observed trends would be more precise. Such data was unfortunately not available for our study. Secondly, a period of twenty years is short - climatologically speaking - to detect statistical trends in temporal meteorological series but relevant concerning the "memory of surveyed people". Also, the stay duration of respondents in communities would be an important piece of information to ascertain the reliability of their perceptions but we did not have these data. Thirdly, climate indices were relatively stable over the period 1988-2007 in comparison with trends over the long-term or with trends over other short periods, notably the 20-year dry period 1970-1989 (de Longueville et al. 2016; Lebel and Ali 2009). If respondents had no good point(s) of reference for considering only the recent period, it is possible that they were influenced by the fact that they intuitively found the weather better in the past (Mertz et al. 2012). It is also argued that people seem to recall extreme weather events more easily than gradual trends and recent experience appears to influence the perceptions of long-term trends (Howe et al. 2014). Moreover, perceptions that there has been declining rainfall (not observed in climate trends) may be the impact of higher temperature, higher evapotranspiration and greater water stress (Osbahr et al. 2011). Fourthly, it would be interesting to analyse the demographic characteristics of respondents (age, gender, education level, working category…) because it might very likely influence their answers but these data were not collected during the survey. Finally, we cannot exclude several elements which might contribute to a pessimistic perception. Respondents may think that painting a gloomy pictures of the environment could attract funding for local projects (Nielsen et al. 2012). Perceptions may also be strongly influenced by media stories that tend to focus on negative developments in the environment (Mertz et al. 2012; Soglo and Nonvide 2019).

4.2. Local perception of rainfall change is not a reflection of rainfall change and variability

Despite these potential biases, our results highlight that perceptions of rainfall change and variability by the surveyed population are not a reflection of the change and variability measured in rainfall data. Rural dwellers' perceptions of climate change varied considerably and were not systematically consistent with the scientifically observed trends, lending support to the idea that other personal and environmental factors are important for determining climate change perceptions (Niles and Mueller 2016). This matches with the affirmation that local people observe different variables than scientists (Marin and Berkes 2013) and strengthens the conclusions drawn by Roncoli (2006) suggesting that farmers think about rainfall as a process rather than a quantity. At an individual level, perceptions of environmental change not only depend on an individual's exposure to environmental events but also on his/her adaptive capacity. This is perhaps reflected in our analysis considering that even within the exact same location people perceive rainfall changes differently. Kosmowski and colleagues (2016) similarly demonstrated differences of perception between climate-sensitive and non-climate sensitive households confirming that farmers do not perceive climate in meteorological terms but rather as it affects agricultural activities (Akponikpè et al. 2010). As such, meteorological data represent people's exposure to climate change at the community level, while perceptions of climate change are linked to experienced climatic impacts (Leclerc et al. 2013). The analysis of the household survey carried out in the AMMA project shows that nearly 75% of the respondents reported negative impacts of these changes on agriculture and 65% on livestock breeding over the study period even if grain yields have been increasing during this period. Moreover, other factors than climate change, such as population growth and environmental degradation, contribute to hindering socio-economic activities and to worsening living conditions (Rasmussen et al. 2012).

4.3. Consequences for future research on environmental migration

Over the last three decades, an increasing number of empirical studies have highlighted the role of climate change/variation -as other drivers- in migration (See figure 4, above). More recently, a few studies, using a qualitative/ethnographic approach, are rather based on data on perception of climate change (Borderon et al. 2018; Piguet 2010). These studies empirically showed that the perceptions of climate change/variation can influence decision to migrate. Our exhaustive literature review focusing on perceptions of climate change in West Africa, completed by an empirical comparison between perceptions of rural dwellers in Burkina Faso and scientifically observed trends, allow us to confirm that rural populations of this region perceive climate change and variation but not necessarily in consistency with observations. We deduce that perception data cannot replace climate data (and vice-versa) in research on the environment-migration nexus and that both climate trends and perceptions should be considered. The current context of the West African region, with poor socio-economic conditions due to other co-occurring factors than climate change (demographic pressure, environmental degradation) can explain why most of the respondents reported that climate change had been worse than what actually emerges from our analysis of meteorological data. Consequently, we suggest that integrating climate data and data on rainfall change perceptions in future research could add new significant value in the understanding of household decision to move or not, notably in West Africa. One way would be based on including the notion of perception in the conceptual framework of Black et al. (2011) (Figure 4, below) and to test it empirically.

5. Conclusion

In the literature, there is a general consensus that the West African populations perceive climate change and more than half of the studies conducted on this topic in the region concluded to consistency between these perceptions and observed climate trends. Our empirical study provides good evidence of inconsistency between rainfall change perception and climate observations in Burkina Faso. Noting potential biases and lacks relating to used data and method, we concluded however that perceptions of rainfall change are not a reflection of scientifically observed trends. While researchers increasingly consider the effects of climate change on migration, the results of this study highlights the importance of taking into account people's' perceptions of climate change as it affects their adaptation responses. Considering this, we argue that it would be possible to improve the understanding of the decision to migrate on the scale of the household in West Africa by considering jointly climate data and data about perceptions of climate change in future research. This approach would require us to transcend disciplinary boundaries (Nielsen and D'haen 2014; Popke 2016). The results could contribute to a better understanding of the future potential climatic impacts on the decisions to migrate and prove useful in the elaboration of adaptation programs and policies when developing answers to climate change.

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Figure 1. Survey distribution and the location of meteorological stations in the study area with isohyets from 1971 to 2010

Figure 2. Perceptions of change in rainfall and temperature in the four surveyed sites combined (N=383)

Figure 3. Summary of the comparison between change perceptions and observed change in Burkina Faso over the 1988-2007 period

Figure 4. (Above) Simplified version of the conceptual framework showing the influence of climate change on drivers of migration (adapted from Black et al. 2011). (Below) Adapted version including the notion of perception (in orange).

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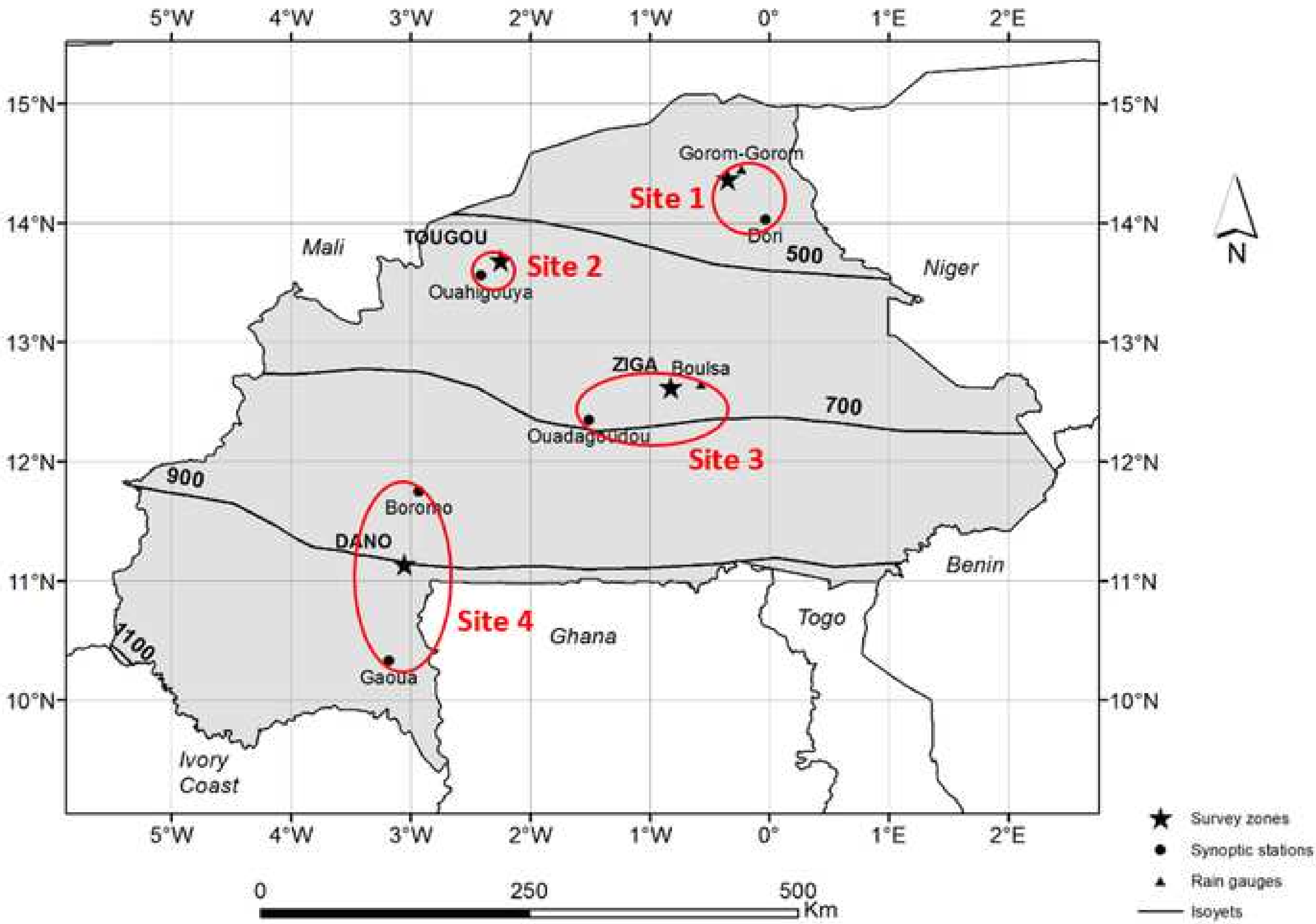
Figure 1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TOUGOU
Site 2
Ouahigouya
500
Mali
Niger
ZIGA
Boulsa
700
Ouadagoudou
Site 3
900
Boromo
DANO
Site 4
Ghana
Togo
Benin
1100
Gaoua
Ivory Coast
N
0
250
500
Km
Survey zones
Synoptic stations
Rain gauges
Isoyets

Figure 2

Click here to access/download;Figure;Figure 2.tiff

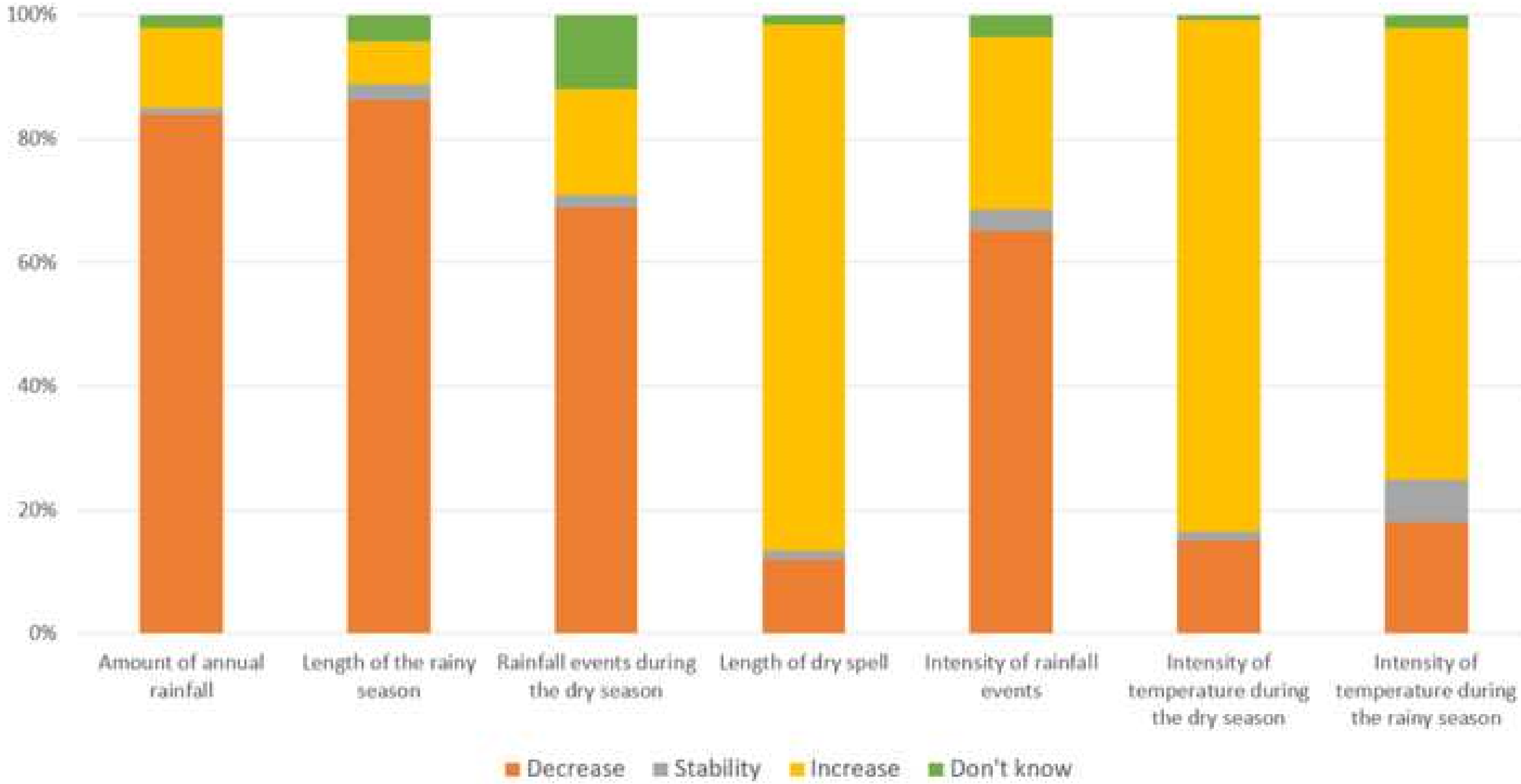

Figure 3

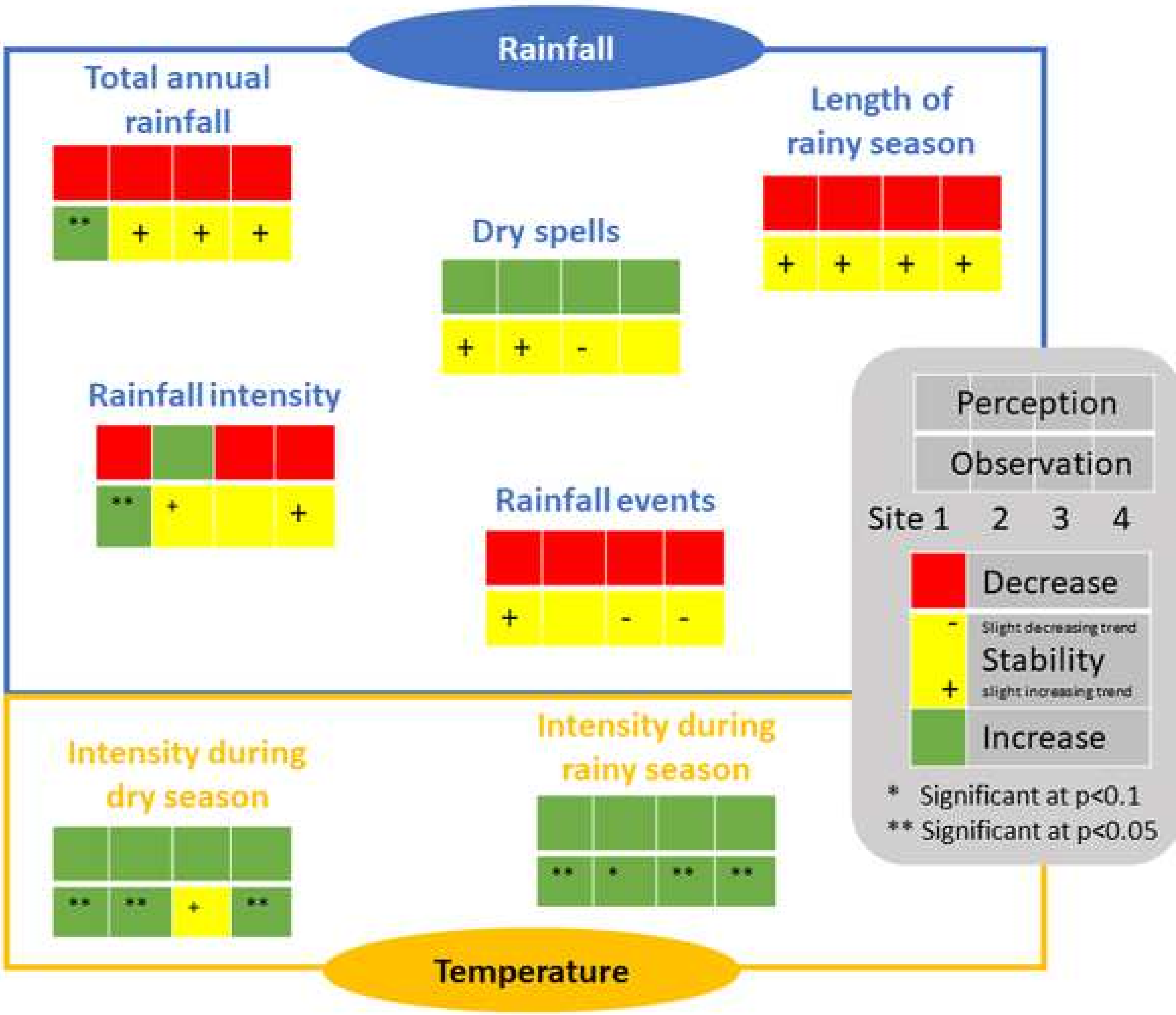
Rainfall
Total annual rainfall
**
+
+
+
Length of rainy season
+
+
+
+
Dry spells
+
+
-
Rainfall intensity
**
+
+
Rainfall events
+
-
-
Perception
Observation
Site 1 2 3 4
Decrease
-
Slight decreasing trend
Stability
+
slight increasing trend
Increase
* Significant at p<0.1
** Significant at p<0.05
Intensity during dry season
**
**
+
**
Intensity during rainy season
**
*
**
**
Temperature

Figure 4

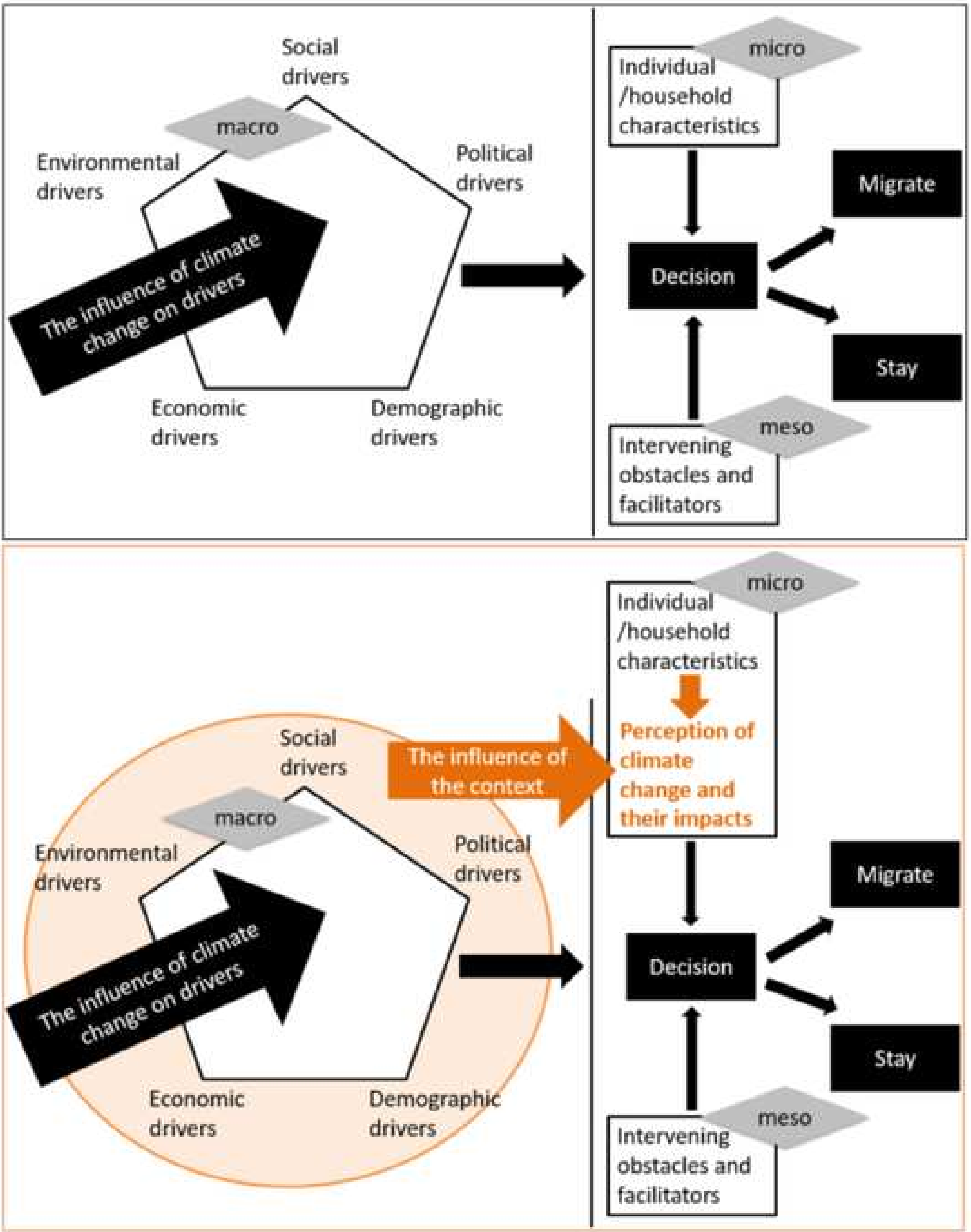
Social drivers
macro
Environmental drivers
Political drivers
The influence of climate change on drivers
Economic drivers
Demographic drivers
micro
Individual /household characteristics
Migrate
Decision
Stay
meso
Intervening obstacles and facilitators
Social drivers
macro
Environmental drivers
Political drivers
The influence of the context
The influence of climate change on drivers
Economic drivers
Demographic drivers
micro
Individual /household characteristics
Perception of climate change and their impacts
Migrate
Decision
Stay
meso
Intervening obstacles and facilitators

Table 1

Table 1. Definition and unit of rainfall and temperature indices reflecting questions of climate change perception in the AMMA survey (rs: rainy season, ds: dry season)

	Perception *From AMMA survey*	**Observation** *From meteorological stations*		
	Parameter	*Translation*		
		Index	Definition	Unit
Rainfall	Total rainfall during the rainy season	TOTRrs	Total rainfall during rs	mm
		RDrs	Total days with rainfall during rs	days
		TOTR	Total annual rainfall	mm
		RD	Total annual wet days (rainfall≥1 mm)	days
	Length of the rainy season	Lrs	Length of rs	days
		Srs	Starting day of rs	day
		Ers	Ending day of rs	day
	Rainfall events during the dry season	RDds	Number of days with rainfall during ds (rainfall≥1 mm)	days
		TOTRds	Total of rainfall during ds	mm
		PRds	Percentage of rainfall during ds	%
		Heug5	Number of days with rainfall≥5 mm during ds	days
	Dry spells	DDrs	Number of dry days during rs	days
		CDDrs	Maximum number of consecutive dry days during rs	days
	Rainfall intensity	SDII	Average rainfall by wet day	mm/day
		R10	Annual number of days with rainfall≥10 mm	days
		R10p	Percentage of annual rainfall from days with rainfall≥10 mm	%
		R20	Annual number of days with rainfall≥20mm	days
		R20p	Percentage of annual rainfall from days with rainfall≥20 mm	%
		Rmax	Annual maximum 1-day rainfall	mm
		Rmaxp	Percentage of annual rainfall from maximum 1-day rainfall	%
Temperature	Intensity during the dry season	TNds	Average value of daily minimal temperature during ds	°C
		TXds	Average value of daily maximal temperature during ds	°C
		Tds	Average value of daily mean temperature during ds	°C
		DTRds	Daily temperature range during ds	°C
	Intensity during the rainy season	TNrs	Average value of daily minimal temperature during rs	°C
		TXrs	Average value of daily maximal temperature during rs	°C
		Trs	Average value of daily mean temperature during rs	°C
		DTRrs	Daily temperature range during rs	°C

Table 2

Table 2. Perceptions of change in rainfall and temperature by surveyed sites (- decrease, = stability, + increase, % of respondents - if the total is not 100%, the rest is in the category 'don't know')

Perception (from AMMA survey)	Oudalan (N=81) Site 1			Tougou (N=98) Site 2			Ziga (N=99) Site 3			Dano (N=105) Site 4		
	-	=	+	-	=	+	-	=	+	-	=	+
Amount of annual rainfall	75.3	1.3	20.8	63.4	4.3	31.2	98	0	0	95.2	0	1
Length of the rainy season	64.9	3.9	16.9	80.6	6.5	9.7	98	0	0	96.2	0	1
Rainfall events during the dry season	35.1	1.3	26	44.1	7.5	40.9	90	0	0	96.2	0	1
Dry spells during the rainy season	26	0	71.4	9.7	2.2	84.9	0.8	0.4	86.9	2.9	0	96.2
Intensity of rainfall events	64.5	0	28.9	28.6	8.8	60.4	69.7	7.1	19.2	92.3	0	2.9
Intensity of temperature during the dry season	26	1.3	70.1	11.8	4.3	83.9	11.1	1	86.9	4.8	0	95.2
Intensity of temperature during the rainy season	41.6	7.8	44.2	18.3	21.5	57	16.2	2	80.8	1	0	99

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