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REVIEW

Understanding the divergences between farmer's perception and meteorological records regarding climate change: a review

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Abstract How farmers perceive climate change is linked to whether they are responding and adapting to it. However, often this perception does not correspond with what actually happens. Based on a search of empirical studies carried out in Africa and Asia, this paper analyzes two factors that can influence farmers' perception regarding climate change: expected utility maximization and availability heuristic. While expected utility maximization refers to an expected change in farmers' well-being, the availability heuristic is a mental shortcut based on the memory of occurrence of events. Generally, empirical studies show that farmers' perceptions are aligning with meteorological records regarding an increase in temperature. However, while there are no significant variations in rainfall trends, farmers perceive a reduction in rainfall in the last few years. The recent increase in drought frequency and severity may cause this divergence, because it affects farmers' well-being, and extreme droughts have a central position in peoples' memory. In this context, our findings suggest that farmers' perceptions are influenced by economic and psychological issues. Policymakers, extension workers and developers of climate projects need to pay attention to farm and farmers' characteristics in order to develop mitigation and/or adaptation practices regarding climate change.

Keywords Agriculture · Availability heuristic · Climate risk · Expected utility theory · Drought · Global warming

1 Introduction

Climate change is one of the most challenges facing contemporary society, impacting several regions worldwide. Extreme weather events, such as droughts, floods, storms, hurricanes, heat waves and cold waves, are expected to increase in frequency and severity

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in next coming years (Intergovernmental Panel on Climate Change—IPCC 2012). The occurrence of these extreme events represents several threats. In agricultural activities, it increases the risk of economic losses and food insecurity for billions of people, particularly in developing countries (Meze-Hausken 2004; Seaman et al. 2014; Abas et al. 2017; Elum et al. 2017). With regard to it, African and Asian countries are among the most vulnerable regions regarding climate change due multiple factors (Kibue et al. 2016).

Africa's sub-Saharan region, for instance, has several limitations in the adaptation measures' development in the context of climate change (Ochieng et al. 2016; Ayal and Leal Filho 2017; Mkonda and He 2017). Increasing temperatures and changes in rainfall variations are making farming activities in this region even more challenging, negatively affecting the economy—the economy of sub-Saharan region is largely dependent on rain-fed agriculture (Juana et al. 2013). Climate change risk scenarios also pointed out that food distribution will be affected (Müller et al. 2011), impacting food security and increasing the level of malnutrition. In addition, climate change might contribute to the intensification of mosquito-borne diseases (Conway 2009), such as malaria and dengue epidemics.

As in Africa, many Asian countries have the economy based on agricultural production. Therefore, the occurrence of extreme weather events results in several losses of food production (Panda, 2016), inducing social vulnerability (Dang et al. 2013). Projections indicate that with rising sea levels coastal regions of India and China will suffer significant social and economic impacts in the coming years, affecting the lives of millions of people (see Hallegatte et al. 2013). In addition, China also deserves to be highlighted for others reasons. China is a *giant* in global economy, being one of the largest food producers, as well as one of the biggest importers and exporters worldwide. China has approximately 8% of arable land of the world (Food and Agriculture Organization—FAOstat 2014) and almost 1.4 billion people (World Bank 2017), climate changes in this country can affect a large part of the Chinese and world's population. On a country level, Chinese agriculture employed around 300 million people in the productive sector (Chen et al. 2016). On a global level, China is the largest rice producer and is among the largest producers of commodities such as wheat, corn, soybeans and sorghum, as well as meats and vegetables (FAOstat 2014). For the coming years, the increase in drought periods is estimated to result in a higher incidence of insects, diseases and soil degradation, compromising food production (Ju et al. 2013).

Given this backdrop, to understand farmers' perception[1] it is essential to better analyze adoption and mitigation practices regarding climate change (Simelton et al. 2013; Hou et al. 2015; Ayal and Leal Filho 2017; Yuan et al. 2017) because farmers are the ones who make the decision to adopt (or not adopt) these practices. A body of research provides empirical results about farmers' perception divergence regarding climate change (typically analyzing meteorological records such as rainfall and temperature) (Zampaligré et al. 2014; Gichangi et al. 2015; Mulenga et al. 2016; Alam et al. 2017). However, there is a gap about why in some cases, farmers' perception diverges to what has really been happening, i.e., some studies present general findings where farmers' perception does not align with meteorological records. In study carried out by Mulenga et al. (2016), for instance, meteorological data analyzed do not support the farmers' perceptions regarding decreasing rainfall amount. A similar situation occurs in Meze-Hausken (2004), Simelton et al. (2013), Chen and Whalen (2016), Ochieng et al. (2016) and Panda (2016). Therefore, we highlight that

[1] Perception is defined in this study as the subjective manifestation of the farmers' experiences and may be influenced by personal characteristics and socioeconomic factors.

with exception of a few cases (see Meze-Hausken 2004; Simelton et al. 2013) studies that compare farmers' perception and meteorological records do not explain in deep details the reasons for these divergences regarding climate change.

Expected utility theory (EUT) and availability heuristic can help to explain these divergences. EUT and availability heuristic are, respectively, mentioned by Meze-Hausken (2004) and Simelton et al. (2013), as possible causes for the divergences on farmers' perception. EUT refers to the decision process when people compare their expected utility values with purpose of maximizing their utility (Mongin 1997). Availability heuristic is a mental shortcut based on the memory of the occurrence of events, i.e., the ease in which one can bring to mind examples of an event (Tversky and Kahneman 1974; Folkes 1988). Given it, a negative variation in farmers' expected utility and/or a particular event considered as striking can affect farmers' perception.

In light of the foregoing, this paper reviews studies on perception regarding climate change in Africa and Asia. The objectives of this paper are twofold: i) to compare farmers' perception of climate change with meteorological records and ii) to explain divergences between farmers' perception and meteorological records using expected utility theory and availability heuristic. Our findings contribute to the literature presenting an update on this subject and providing theoretical evidences of EUT and availability heuristic on farmers' perception.

2 Climate change and its impacts on agriculture

The concept of climate change is generally related to statistically significant variations in the mean state of the climate, occurring for decades or centuries (IPCC 2014). These changes can occur from natural or anthropogenic causes. Anthropogenic causes refer to emission of greenhouse gases (GHG), including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) through human actions. These emissions have been affecting the climate mainly from the eighteenth and nineteenth centuries, with the development of the Industrial Revolution (IPCC 2014).

Between 1750 and 2011, the atmospheric concentration of CO_2, CH_4 and N_2O increased by 40, 150 and 20%, respectively (IPCC 2014). Analyzing CO_2 concentration in the atmosphere in parts per million (ppm), Canadell et al. (2007) point to an increase of 280 ppm from the 1750 s to 381 ppm in 2006. In June 2017, this level increased to 406.56 ppm, according to National Aeronautics and Space Administration (NASA 2017) (Fig. 1). These levels of CO_2 concentration in the atmosphere are probably the highest in the last 400 thousand years (NASA 2017). An increase in the levels of CO_2 and the other GHG could lead to global warming (Fig. 2), which, in turn, could have an impact on the world's climate (the average temperature rose approximately 1 °C from 1880 to 2017), leading to the phenomenon known as climate change (Nema et al. 2012; VijayaVenkataRaman et al. 2012).

In general, climate change affects agriculture and agriculture also affects climate change (through the emission of GHG) (Deressa et al. 2011). In this context, land-use change affects climate change through, for instance, deforestation and conversion of forests in agricultural areas. According to IPCC (2014), food systems and land-use change produce about 24% of the world's GHG.

In all regions of the world, plants and animals are adapted to prevailing climatic conditions (Blanco et al. 2017), and when changes in climate occur, they are impacted. Plants, for instance, may become less productive. Changes in temperature in the short term can

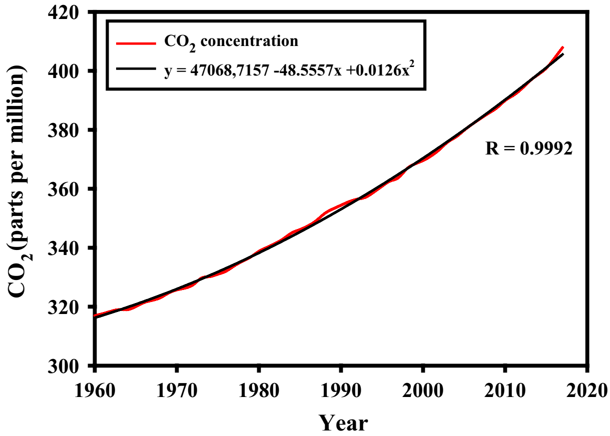

Fig. 1 CO_2 concentration in the atmosphere (1960–2017). *Source*: Based on NASA data

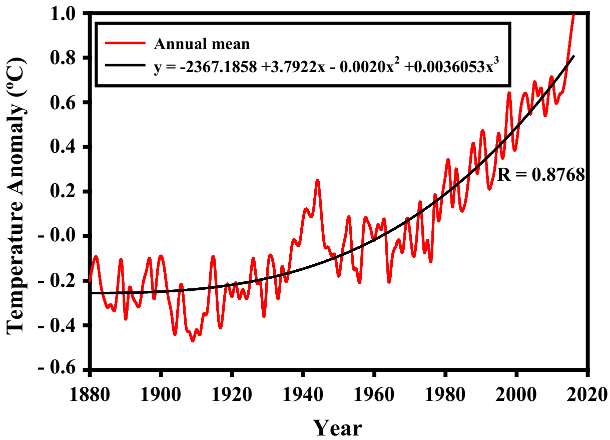

Fig. 2 Global surface temperature (1880–2017). *Source*: Based on NASA data

negatively impact agricultural productivity, especially if they coincide with major developmental stages (Lobell and Field 2007). For example, only a few days of extreme temperatures, in the flowering phase, can drastically reduce the productivity of certain crops (Wheeler et al. 2000). In addition, extreme weather events such as drought periods also negatively affect food production (Lesk et al. 2016). Consequently, the occurrence of extreme weather events has the greatest adverse impact on food insecurity and socioeconomic damages in general (Yuan et al. 2016; Abas et al. 2017; Lewis 2017).

3 Research methodology

3.1 Theoretical and conceptual foundations

As mentioned earlier, EUT and availability heuristic can contribute to explain why divergence occurs between farmers' perception and meteorological records. EUT is an economic approach that can contribute to explaining farmers' perception. EUT was first proposed in the eighteenth century by Bernoulli (1738). This approach can be considered the core of economic theory under uncertainty, conquering adherents in a number of areas including mathematics, administration, psychology and political science (Cusinato 2003). EUT predicts that the decision maker is risk averse (von Neumann and Morgenstern 1947), and has the objective to increase the expected utility. An increase in an individual's utility refers not only to profit maximization, but also to a number of events, such as a pay rise, the purchase of a new stereo, an improvement in health or an improvement in local biodiversity (Edwards-Jones 2006). In this study, EUT refers to an expected change in the well-being of the farmer being that farmers' perception on climate change is linked to the utilitarian aspect (Meze-Hausken 2004). For instance, farmers that have suffered productive losses from droughts may be more likely to perceive a decreasing rainfall, even if this change does not occur (Meze-Hausken 2004). Therefore, this approach has the potential to explain possible divergences between what farmers' perceive and meteorological records.

Availability heuristic was proposed after the second half of the twentieth century by Tversky and Kahneman (1973, 1974). Recently, availability heuristic was widely discussed by Kahneman (2011) in the book *Thinking, Fast and Slow*, where the author provides a number of examples of this cognitive bias. The concept of availability heuristic demonstrates how vivid and salient a certain risk issue is and how quickly one can think of an example that occurred recently (Kahneman 2011). This means that when the individual has determined the level of familiarity regarding determined event, this event may be easily remembered and will appear more frequent (Tversky and Kahneman 1974; Kahneman 2011). For instance, the individual tends to remember events considered as striking (such as an air disaster) or remember events with which they are more accustomed, and thus, these become more vivid in their memories (Ciarelli and Ávila 2009). In the context of climate change, individual experience of extreme weather events can contribute to availability heuristic (Diggs 1991).

3.2 Selection of the reviewed studies

In this paper, we search peer-reviewed studies published from 2000 onwards about farmers' perception[2] regarding climate change in Africa and Asia. A comprehensive search was conducted in September 2017 using Google Scholar, Scopus and Web of Science databases. Similarly the review written by Ford et al. (2015) on the situation of climate change adaptation, also in Africa and Asia, the following keywords were used: climate change, perception, agric*, farm*, livestock, meteorological and variability. All these keywords were used with the keyword farmer*.

Our search focus was studies written in English conducted through farmers' surveys in countries of Africa and Asia that provide quantitative and historical information about meteorological indicators. There are several meteorological indicators to analyze significant changes in climate. Here, we analyzed only studies that provide information on temperature and rainfall data, because both indicators are widely used in studies that also analyze farmers' perceptions. Thus, in this work, climate change refers to a variation in temperature and rainfall records, occurring for decades or longer (IPCC 2014). The reviewed studies comprise the different seasons of the year not influencing the results found. Additionally, the papers should present comparisons between the data obtained by

[2] Generally, farmers' perception was obtained by questionnaires, interviews or farmers focal groups.

the survey and the methodological records. Based on these procedures, 37 pre-candidate studies were identified. However, after reading them in full, the aims of the majority of these papers were not in our interest. Only 18 studies were identified to be closely related to the subject proposed by this review.

Following the selection of studies for review, we constructed two databases. One was for convergent studies (Table 1), and the other was for divergent studies (Table 2). When meteorological records showed, for instance, an increase or decrease in the amount of rainfall over the past few decades and most farmers do not perceive it, there is a divergence between meteorological records and farmers' perception, and then, the study was considered as divergent. On the other hand, if most farmers' perceptions align with meteorological records, the study was considered as convergent. Therefore, we noticed that most studies presented convergence regarding the rise in temperature over the past few years. Thus, the division between convergent and divergent studies was made by analyzing only rainfall records.

The group of convergent studies was formed by eight studies: Hageback et al. (2005), Dang et al. (2014), Yu et al. (2014), Baul and McDonald (2015), Traore et al. (2015), Ayanlade et al. (2016), Alam et al. (2017) and Zoundji et al. (2017). The group of divergent studies was formed by ten studies: Meze-Hausken (2004), Osbahr et al. (2011), Simelton et al. (2013), Zampaligré et al. (2014), Gichangi et al. (2015), Chen and Whalen (2016), Mulenga et al. (2016), Ochieng et al. (2016), Panda (2016) and Ayal and Leal Filho (2017).

4 Results and discussion

4.1 Convergent and divergent studies

As mentioned, the studies were divided into convergent and divergent. In convergent studies (Table 1), in general, most of the respondents perceived an increase in temperature in the last few years. With regard to it, some empirical evidences were provided. For example, some farmers that live in Ansai district, China, analyzed by Hageback et al. (2005) highlighted that they used to dress in thick woolen clothes when they were young, but nowadays, they only wear thin cotton clothes. Thus, for these farmers, climate change (increase in temperature) is more evident in winter (Hageback et al. 2005). Analyzing indigenous farmers in the watershed of Pokhare Khola, Nepal, Baul and McDonald (2015) obtained similar results regarding the perception of occurrence of warmer winters in the recent years. In addition, the temperature increase is also reported by Benin's farmers as follows: "even under trees the heat is unbearable" and "we could work under the sun before, but now it is not possible anymore" (Zoundji et al. 2017).

Unlike temperature, rainfall presents trends of decrease or increase, according to analyzed regions. Thus, despite these rainfall variations in some studies such as Hageback et al. (2005), Yu et al. (2014), Baul and McDonald (2015) and Ayanlade et al. (2016), farmers' perceptions align with meteorological data regarding the rainfall reduction in recent years.

In divergent studies (Table 2), the perception of most samples analyzed does not align with rainfall records. A situation like this is presented by Osbahr et al. (2011) (applied in southwest Uganda), where while farmers perceived changes in rainfall (e.g., intensity, amount, frequency), only the temperature records had a clear signal of change. In addition, in the study of Panda (2016) (search carried out in two districts

Table 1 Details of convergent studies

References	Country	Data[1]	Period[2]	General findings
Alam et al. (2017)	Bangladesh	R and T	1980–2015	Results reveal that all of the households perceive changes in the climate and extreme events, particularly abnormal rainfall with regard to timing and distribution, which has serious consequences for production plans. Meteorological data also support household perceptions of climate change and variability that demonstrate increasing temperature
Zoundji et al. (2017)	Benin	R and T	1966–2015	Farmer's perception appears to be in line with meteorological record data
Ayanlade et al. (2016)	Nigeria	R and T	1982–2014	Perceptions of rural farmers on climate change and variability are consistent with the climatic trend analysis
Traore et al. (2015)	Mali	R and T	1965–2005	Farmers perceived an increase in annual rainfall variability, an increase in the occurrence of dry spells during the rainy season and an increase in temperature. Overall, this is in line with the observed meteorological data
Baul and McDonald (2015)	Nepal	R and T	1982–2007	Analyses of both indigenous farmers' perceptions and meteorological data showed an increase in temperature with longer summers and warmer and shorter winter during the period of 1982–2007
Yu et al. (2014)	China	R and T	1980–2009	The results proved that local farmers' perceptions of major climate variables are generally correct
Dang et al. (2014)	Vietnam	R and T	1978–2011	What farmers perceived was basically consistent with agricultural officers' opinions and recorded weather data
Hageback et al. (2005)	China	R and T	1970–2001	Farmers' perception of climatic variability corresponds with the climatic data records

[1]Information presented: Rainfall (R). Temperature (T)

[2]Historical periods of the meteorological records presented in studies. Some of them do not have the same historical periods among analyzed regions or between temperature and rainfall. Thus, we provide in this table the oldest and most recent meteorological record

Table 2 Details of divergent studies

References	Country	Data[1]	Period[2]	General findings
Ayal and Leal Filho (2017)	Ethiopia	R and T	1982–2012	Farmers' perceptions of change in temperature are cognate with meteorological data analysis. However, their perceptions were found to be in disagreement with meteorological rainfall trends
Panda (2016)	India	R	1951–2015	When compared with the trend in actual rainfall data, perceptions on rainfall are found to more closely align with the results from the nearest station as compared to the station farther from it
Ochieng et al. (2016)	Kenya	R and T	1980–2010	Except in low potential zones, farmers' perceptions of climatic variability are in line with climatic data records
Mulenga et al. (2016)	Zambia	R and T	1950–2011	Data analyzed do not support the perception that the rainy season used to begin earlier, and generally do not detect a reported increase in the frequency of dry spells
Chen and Whalen (2016)	China	R and T	1980–2014	There are no significant changes in mean annual rainfall, but farmers perceive decreasing rainfall during this period studied
Gichangi et al. (2015)	Kenya	R and T	1961–2011	No discernible increasing or decreasing trend in the long seasonal rainfall was observed. However, most farmers reported a decrease in rainfall amount over the period they could recall
Zampaligré et al. (2014)	Burkina Faso	R and T	1988–2008	Farmers were partly aware of climate change, particularly of changes in temperature and rainfall patterns, but their perception did not match well with the recorded annual rainfall data in the southern Sahelian and Sudanian zones
Simelton et al. (2013)	Botswana and Malawi	R	1961–2009	Most farmers perceived that the rains used to start earlier and end later. Meteorological data provided no evidence to support farmer perceptions
Osbahr et al. (2011)	Uganda	R and T	1960–2009	While farmers perceived change in seasonality, distribution, amount, intensity and temperature, only temperature had a clear signal in the climate record
Meze-Hausken (2004)	Ethiopia	R	1953–2002	Statistical analysis of rainfall chronologies was performed and contrasted with qualitative data collected through a survey and questionnaires

[1]Information presented: Rainfall (R). Temperature (T)

[2] Historical periods of the meteorological records presented in studies. Some of them do not have the same historical periods among analyzed regions or between temperature and rainfall. Thus, we provide in this table the oldest and most recent meteorological record

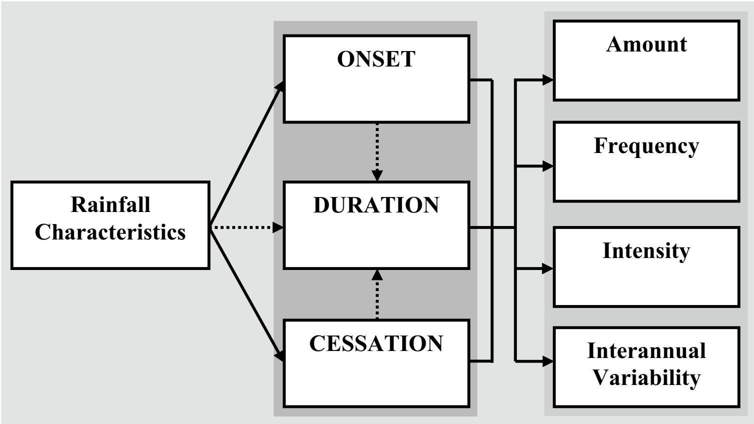

Fig. 3 Analytical flowchart on changes in rainfall. *Source*: Simelton et al. (2013)

in Odisha, India) while most of the farmers perceived that rainfall was decreasing, in some regions there was no statistically significant decreasing trend. A similar situation was found by Ochieng et al. (2016) analyzing eight agro-regional zones (divided into high and low potential zones) in Kenya. In general, the study shows that except in low potential zones, farmers' perceptions regarding climatic changes are in line with meteorological records.

Divergences regarding rainfall changes involve a set of factors, according to the analytical flowchart developed by Simelton et al. (2013) (Fig. 3). In this flowchart, onset and cessation (rainfall duration) refer to *what* has changed, and the frequency, amount, intensity and interannual variability refer to *how* rainfall has changed. Based on this, analyzing regions of Malawi and Botswana, Simelton et al. (2013) sought to answer the following question: "is rainfall really changing?" Among the results found, the authors point out the existence of divergences regarding onset and end of rainfall periods between farmers' perception and meteorological records.

Regarding *how* rainfall has changed, in some studies (see Meze-Hausken 2004; Gichangi et al. 2015; Chen and Whalen 2016; Panda 2016) farmers' perception of a decrease in rainfall amounts does not align with rainfall records. With regard to rainfall frequency, while farmers observed that the number of rainy days had decreased, there is no statistical significance about this trend (Panda 2016). Similarly, analyzing Zambia farmers' perceptions, Mulenga et al. (2016) highlight that often farmers report an increase (frequency or duration) in dry spells in the growing season. However, meteorological records do not show significant trend in rain stress. In addition, another example of divergence is provided by Ayal and Leal Filho (2017) in a study carried out in regions of Ethiopia. In broad terms, the authors point out that unlike farmers' perception, meteorological analysis proves the absence of rainfall amount reduction.

Taking into account the context of divergences between farmers' perceptions and meteorological records, it can be assumed that there are factors that are influencing farmers' perception regarding climate change. Although gradual changes in climate may be almost impossible for people to perceive (Diggs 1991), as mentioned earlier, the divergences presented here can be explained by economic and psychological issues.

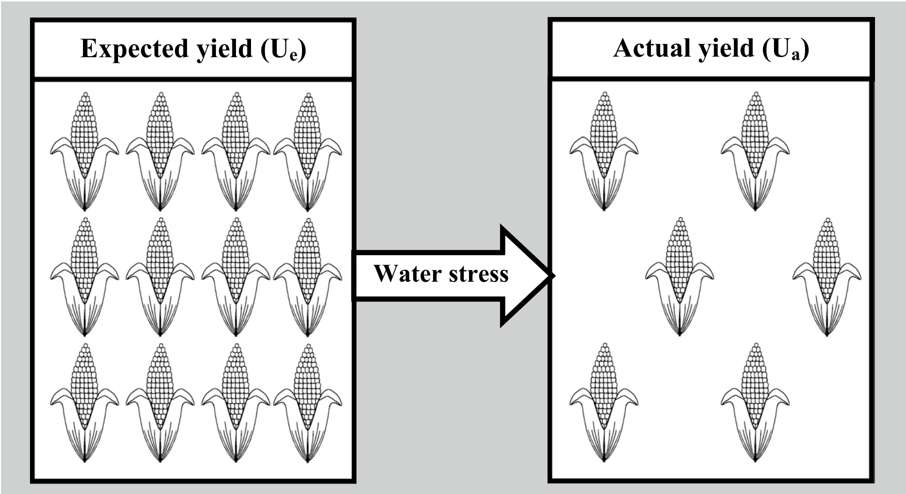

Fig. 4 Example of expected and actual crop yield. *Source*: authors (2017)

4.2 Factors that influence farmers' perception regarding climate change: EUT and availability heuristic

Divergences between farmers' perception and climate change (rainfall decrease in this case) may be in relation to an increase in droughts' frequency and severity. Drought affects the environment in a number of ways. The drying of water sources, loss of livestock, poor health of animals, reduction in household income, malnutrition and crop failures are examples of it (Udmale et al. 2014). Consequently, it also affects the expected change in farmers' utility and it can contribute to the perception of rainfall decrease, even if the meteorological records do not show this trend.

Factors that result in water stress such as water availability increase with temperature, and evapotranspiration can affect negatively agricultural production (Osbahr et al. 2011; Ayal and Leal Filho 2017). For instance, during the growing season of a certain crop, the farmer estimates that he/she will harvest *n* product units (expected yield, U_e). However, with the occurrence of water stress after harvest the actual yield (U_a) is lower than expected ($U_a < U_e$) (Fig. 4). Reducing the production and farm income, farmers' well-being will also be affected through feelings of sadness and worry, as well as uncertainties about the future (Favero and Sarriera 2012), resulting in perceptions of rainfall decrease (Osbhar et al. 2011; Gichangi et al. 2015). In other words, farmers may be more interested in weather records which are more relevant for their activities (Amadou et al. 2015). In turn, this gives a strong indication that farmers' perceptions are linked to the utilitarian aspect.

As it has been known that, agricultural production depends on soil–plant–atmosphere relation, such as water availability and its use by plants (Wagner et al. 2013). Soil properties and plant activities influence the rainfall partitioning by evapotranspiration in the flow and infiltration, impacting water balance on a regional scale. In addition, transpiration is linked to the carbon cycle through simultaneous exchanges of CO_2 and water (Pimentel 2011). Regarding temperature, this factor affects the growth and development of plants. Variations in the intensity, duration and interval of temperature can result in cell damage and, ultimately, the death of the plant (Silva et al. 2009). Through the improvement, some agricultural plants acquired protection mechanisms which made them liable to survive in some unfavorable climate conditions. Even so, unfavorable conditions can affect the yield of agricultural crops. Thus, water deficit and unfavorable temperature conditions interfere negatively in the full development of agricultural plants (Guarienti et al. 2004), decreasing agricultural production.

The accelerated growth of population in developing countries also can influence the perception of rainfall decrease. Meze-Hausken (2004) point out that in Ethiopia population has grown nearly threefold between 1960 and 2000, and then "while the supply of rainfall has been stable during recent decades, demand for it has increased" (Meze-Hausken 2004). A similar situation occurred in other African and Asian countries. Consequently, as expected, the food demand also increased in these regions. With regard to it, "the dependency on sufficient spring and summer rains to meet a household's demand for food means that any negative rainfall anomaly in either season will result in a lower-than-expected supply" (Meze-Hausken 2004).

The psychological issue refers to availability heuristic, i.e., divergences regarding climate change can be influenced by recent extreme weather events that in turn, lead farmers to have mistaken judgment. As a result, farmers generally over-estimate the frequency of such events. Analyzing droughts, it can be true according to Meze-Hausken (2004). For this author, extreme droughts have a central position in peoples' memory when referring to important past events. Some divergent studies reviewed here provide information of recent and recurrent extreme droughts. The study of Meze-Hausken (2004), for instance, that was carried out in some regions in northern Ethiopia (Bahar Dar, Gonder, Combolcha and Mekelle) highlights a number of impacts caused by the severe drought in 2002, affecting levels of water and food availability. According to many farmers of these regions, the drought of 2002 was considered the worst ever recorded,[3] resulting in several losses and adversities for agricultural activities (Meze-Hausken 2004). A recent study that analyzed rainfall tendencies in Ethiopia also highlighted that the year of 2002 was one of the driest years from 1972 to 2011 (Viste et al. 2013).

Analyzing Kenya, based on information about the great droughts that occurred in this country, Gichangi et al. (2015) note that although drought periods are recurrent in the semiarid regions, three of the largest droughts recorded in the last 100 years have occurred in the last decade. Another example of drought frequency increase over the last few years was presented in Osbahr et al.'s (2011) study. Exploring regions of southwestern Uganda based on meteorological information, the authors point out the occurrence of a number of drought periods after the 1990s.

In addition to the studies found in our search, the literature provides other evidences that support the influence of extreme events in farmers' perception (see Moyo et al. 2012; Bryan et al. 2013; Marchildon et al. 2016). For instance, in Zimbabwe, Moyo et al. (2012) argue that a year with poor rainfall (droughts) distribution has an indelible effect in farmers' memories, and it contributes to perception of rainfall decreasing. The authors also conclude that farmers have a good memory of recent events. It is evident in Ayal and Leal Filho (2017), where, despite farmers' perception divergences regarding rainfall records, in recent years farmers' perceptions are in line with these records.

[3] Throughout the last decades, several droughts affected regions of Ethiopia, and many droughts, the whole country Meze-Hausken (2000). According to Degefu (1987), since meteorological recording began, the year of 1972 registered the most devastating drought in Ethiopia. The drought of 2002 mentioned by Meze-Hausken (2004) was considered through farmers' perceptions as the worst.

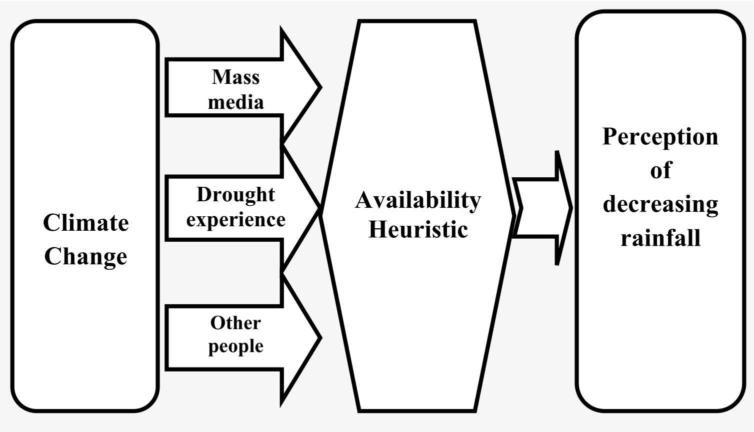

Fig. 5 Influence of availability heuristic regarding perception of decreasing rainfall. *Source*: Based on Clayton et al. (2015) and Hitayezu et al. (2017)

The information presented above contributes to evidence of the occurrence of cognitive biases influenced by drought experience. It corroborates with the idea postulated by Diggs (1991) where "a farmer that had recently experienced one moderate drought would be less likely to believe that drought frequency is increasing, than a farmer that had recently endured two major droughts." Analyzing US regions, the author provides empirical results about the influence of drought experience regarding farmers' perception. In this context, the perception of extreme events may be more available from memory if they are associated with a stronger negative affect (Taylor et al. 2014). In addition, mass media, other people and extension workers also may affect the available memory of farmers (Clayton et al. 2015; Hitayezu et al. 2017) (Fig. 5).

It is important to highlight that farm and farmer characteristics are variables that influence both expected utility and availability heuristic regarding climate change (in this case, perception of a decrease in rainfall). For example, a farmer who has irrigated land areas may not have the same perception regarding a rainfall decrease compared with a farmer that does not have an irrigation system. Another example refers to farmers' age and experience. Compared with younger farmers, older farmers with lengthy experience in agricultural activities may have observed more changes in rainfall during their lifetimes. Understanding these and other particularities is vital to identify and develop mitigation and/or adaptation practices (Hyland et al. 2016), i.e., regional and socioeconomic particularities cannot be neglected by researchers and extension workers. In addition, although changes in climate may affect the whole country, the distribution of those changes may vary among regions (Below et al. 2010). In this context, the effective implementation of mitigation and adaptation practices depends on policies and cooperation at regional scales. Innovation and investments in environmentally sound technologies, including agroforestry, mulching, crop rotation, irrigation, planting high yielding varieties, as well as a change in lifestyle choices, are examples of these practices (Below et al. 2010; IPCC 2014; Mkonda and He 2017).

5 General conclusions and recommendations

Climate change poses a major challenge for the next decades. Due to the greater vulnerability of developing countries, studies have been developed in African and Asian regions seeking to understand what farmers have perceived about these changes. Farmers are not only victims of climate variability and extremes, but, in turn, also active observers (Ayal and Leal Filho 2017). However, in most cases, their perception does not reflect what really has been occurring, presenting unconsciousness regarding rainfall variability. This imprecision in the farmers' perception may be the result of a number of factors. Here, we try to present two of them (expected utility and availability heuristic). The findings of this paper evidenced that analysis of farmers' perceptions regarding climate change should be cautious, because sometimes these results may be misleading or imprecise. Therefore, it is also important to take into account meteorological records, to obtain more accurate results.

In most divergent cases analyzed in this work, farmers' perception is not aligned mainly with rainfall records. Generally, farmers perceive a decrease in rainfall amount while it not occurs. The negative impacts in farm production (i.e., failure in expected utility) caused by droughts and/or when they remember events considered as striking (availability heuristic), including recent extreme droughts, for instance, can contribute to this divergence between farmer's perception and meteorological records regarding climate change. Based on the findings of this study, the following recommendations are provided to future researchers and to improve farmers' resilience:

1. Future studies may analyze simultaneously farmers with and without drought experience in order to check possible similarities/differences between farmers' expected utility and availability heuristic.
2. An analysis comparing farmers with different socioeconomic characteristics and their pro-environmental behavior also may be carried out regarding climate change.
3. Policy and programs should promote micro-practices (farm or regional level)of mitigation and/or adaptation strategies regarding climate change.

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