Traditional predication of drought under weather and climate uncertainty: analyzing the challenges and opportunities for small-scale farmers in Gaza province, southern region of Mozambique

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Traditional prediction of drought under weather and climate uncertainty: analyzing the challenges and opportunities for small-scale farmers in Gaza province, southern region of Mozambique

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Abstract
This paper explores the traditional indicators that small-scale farmers in Gaza province in southern Mozambique use to predict drought events on their rain-fed farms. It analyzes the contextual situation regarding the accuracy and reliability of the traditional prediction methods under the current weather and conditions of climate uncertainty and variability, and the opportunities that their prediction methods can bring to reduce their current and future exposure and vulnerabilities to drought. Farmers use a total of 11 traditional environmental indicators to predict drought, either individually or combined, as required to increase their prediction certainty. However, the farmers perceive that current unpredictability, variability, and changes in weather and climate have negatively affected the interpretation, accuracy, and reliability of most of their prediction indicators, and thus their farming activities and their ability to predict and respond to drought. This, associated with the reduced number of elders in the community, is causing a decline in the diversity, and complexity of interpretation of indicators. Nonetheless, these difficulties have not impeded farmers from continuing to use their preferred prediction methods, as on some occasions they continue to be useful for their farming-related decisions and are also the main, or sometimes only, source of forecast. Considering the role these methods play in farmers' activities, and the limited access to meteorological forecasts in most rural areas of Mozambique, and the fact that the weather and climate is expected to continually change, this paper concludes that it is important to enhance the use of traditional prediction methods. However, the increase of the accuracy and reliability, and continued existence of the methods depends on the farmers' own abilities to enhance, preserve, and validate them by tailoring the traditional methods used to work with the new environmental, weather, and climatic conditions, or through the development of new methods.

Keywords Drought · Traditional prediction · Local knowledge · Adaptation · Weather uncertainty · Climate uncertainty

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1 Introduction

Over the generations, small-scale farmers whose livelihoods depend on rainfall have developed a detailed system for gathering and interpreting signs from the weather, the climate, and the environment in order to predict rain, to interpret its implications, and to make farm-related decisions (IPCC 2007; Speranza et al. 2010). This intricate system has enabled them to become familiarized with and to recognize changes in their surrounding environment and climate (Hyland et al. 2016; Tschakert 2007). They do so without a detailed understanding of the scientific factors that drive the changes or the use of recorded data for understanding weather patterns (Ramnath 1988). The term 'traditional prediction' refers to environmental indicators that are locally used to read its signs and to then interpret the expected weather or climate conditions (Zuma-Netshiukhwi et al. 2013). This paper seeks to develop a comprehensive understanding of traditional methods used by farmers to predict drought, the dynamics of the methods under the current weather and conditions of climate uncertainty and variability, and the opportunities the methods can bring to reduce farmers' current and future exposure and vulnerabilities to drought.

In recent years there has occurred a resurgent interest in traditional prediction methods in relation to disaster risk reduction due to the increased number of natural hazards transforming into disasters because of current climate change. Natural hazards turn into disasters when they destroy people's lives and livelihoods (WMO 2018). On one hand, some scholars feel skeptical about the accuracy and reliability of traditional prediction methods under current weather and climate change and variability (Chinlampianga 2011; Kempton 1997, King et al. 2008). On the other hand, various scholars have acknowledged and emphasized the importance and use of local knowledge for weather and climate prediction (Chand et al. 2014; Roncoli et al. 2002; Speranza et al. 2010), decision making, climate change adaptation (Anik and Khan 2012; Ishaya and Abaje 2008; Leonard et al. 2013) and to complement scientific information (Green et al. 2010; Huntington et al. 2004; King et al. 2008). More recently, scholars have also stressed the need to go beyond that and to acknowledge the importance of validating and documenting this knowledge to enable it to continually exert its multiple use and benefits over generations to come (Chang'a et al. 2010; Kijazi et al. 2013; Lebel 2013).

While these scholars praise the numerous advantages of local knowledge for weather and climate prediction, on the whole they do not see local knowledge as a valid system in its own right. Rather, they concentrate on highlighting it as a tool for documentation, and as a source of input to improve and validate science, which is considered the benchmark of all types of knowledge systems (Agrawal 2002; Klenk et al. 2017; Kronik and Verner 2010, p. 145). However, Huntington (2000) and Naess (2013) argue that this trivializes and diminishes local knowledge, resulting in the loss of its dynamism and obscuration of its contribution. What is more, to date these studies have mostly analyzed the role of traditional prediction methods from one angle, i.e., the studies looked at the benefits or challenges of the methods without combining them in a context-specific perspective. As the role of the methods may differ from place to place according to socioeconomic and biophysical characteristics (Klenk et al. 2017), thus, such analysis may not reveal the real picture of the traditional prediction methods, thereby obstructing the broad understanding of the methods and leading to misinterpretation of their context-specific role. Drawing on this, this paper aims to analyze both challenges and opportunities of farmers' traditional prediction methods, taking as an example small-scale farmers' living in remote areas in the southern province of Gaza in Mozambique.

To do so, the paper starts by first unpacking farmers' definitions of drought in order to obtain a clear understanding of what farmers are predicting. It shows how farmers' conceptualization of drought is driven by the impacts on their activities and well-being, and how such conceptualization differs from the one used by the National Institute for Disaster Management (INGC), and how the timing of occurrence of drought relative to farmers' activities influences their perception of drought risks. Second, it explores the diverse (traditional and meteorological) forecast methods used by farmers. Then, the paper focuses on traditional prediction methods to discuss the contextual situation regarding the accuracy and reliability of the methods under the current scenario of weather and climate variability. Here the paper shows through farmers' perceptions and viewpoints the links between the current changes in the weather, climate, and environment, and the methods their use to predict drought, and the consequences of that. It also shows how independently of the outcomes, farmers value their traditional forecast methods and use them as their primary forecast for farm-related decision making, even when they are provided with seasonal meteorological forecasts.

Following that, the paper discusses the contextual importance of enhancing, safeguarding, and validating traditional drought prediction methods for the less privileged groups of farmers who live in places where there is no location-specific meteorological station to timely monitor and communicate drought, or who have limited access to scientific forecasts, as is the case for most rural farmers in Mozambique. Although the paper recognizes the high importance of traditional prediction methods in such places for the timely prediction of drought, and other natural hazards, it also acknowledges the role of meteorological forecasting in farmers' decision making and responses to drought. Thus, combining both scientific and traditional methods would be crucial to strengthen the success of the forecast, and thus to reduce farmers' vulnerability. However, the paper reinforces that a successful combination of forecast methods imply first the understanding of the nature of farmers' traditional methods as this will further facilitate the communication of scientific forecasts to farmers in a way that is meaningful and relevant to their decision-making.

1.1 Perspectives on traditional prediction methods

Traditional prediction methods are important to farming communities around the world that lack, or have limited access to, scientific forecasts. Such communities commonly use a combination of biological, celestial, and climatic indicators to predict the weather and climate, including the behavior of plants and animals; the strength and directions of winds; the color of the sky; and the appearance of the clouds, the sun, and the stars (Chang'a et al. 2010; Green et al. 2010; Lefale 2010). However, the way communities observe, read, and interpret the indicators may vary according to their culture and the surrounding environment. For instance, while Mengistu (2011) found that farmers in Adiha, Ethiopia, interpret winds blowing in one direction close to the time of land preparation as a sign of drought, Santha et al. (2010) found that farmers in India consider windy periods which occur near to the agricultural season as a sign of good rains coming. Moreover, farmers in Tlaxcala, Mexico, reported that the inclined angle of the moon is an indication that rain will fall within 5 days (Eakin 1999), while Tanzanian farmers view this as a sign of erratic rainfall to come (Chang'a et al. 2010). All of these are examples of farmers relying on single indicators. Yet, communities' abilities to combine multiple types of indicators are also considered valuable as the practice is believed to increase confidence in the accuracy of their predictions, and to reduce their vulnerability to weather and long-term climate change (Garay-Barayazarra and Puri 2011; Huntington et al. 2004).

Nonetheless, despite their abilities, nowadays, farmers worldwide are increasingly exposed to unpredictable and more frequent, severe and lengthier drought events that are impacting their yields, production, food security, and livelihoods. This is the result of several interlinked climatic and non-climatic factors, such as extreme weather and climate variability, and soil type or management (IPCC 2007; Mishra and Desai 2006). As a result, farmers have been conducting their prediction activities in increasingly unpredictable and challenging conditions, which has affected the performance of some of the indicators routinely used to predict the weather and climate, and causing adverse consequences to farmers who are unprepared for an incorrect prediction. For this reason, the accuracy of farmers' traditional prediction methods has been questioned by some scholars (e.g., Ayal et al. 2015; Chinlampianga 2011; Egeru 2012; King et al. 2008; Orlove et al. 2010). For instance, Ayal et al. (2015) and Egeru (2012) argue that the accelerated weather and climate change and variability are causing a change in the usual behavior and the disappearance of some plants and animals used to predict the weather. They gave examples of acacia trees and hartebeest, which are disappearing, and African teak trees, a yielding timber scientifically known as *Milicia excels,* changing their shading patterns, i.e., dropping off and growing new leaves in unusual periods of the year, and hornets nesting at the ground level instead of hollow trees. Adding to that, Lebel (2013) found that the traditional prediction knowledge holders in India claimed a reduction of 25–40% of the accuracy of a set of bio-indicators they have monitored. Egeru (2012) also reported Eastern Uganda farmers' perceptions of changes in wind direction and intensity as a result of climate change.

Because of this decline in the accuracy and reliability of some indicators, it is argued that farmers are no longer able to predict when the rain is going to start and when they will be able to start planting their crops, or if the rain will be good enough for the forthcoming agricultural season. Consequently, some farmers who prepare their land and plant their crops based on traditional prediction techniques are forced to replant them due to an unexpected dry spell after the early rains (Egeru 2012; Tambo and Abdoulaye 2012). In most cases, farmers are forced to reschedule their activities (Chand et al. 2014; Chinlampianga 2011) or choose to plant short-circle varieties to reduce the risks (Ishaya and Abaje 2008; Orlove et al. 2010). Regardless of that, farmers still use and rely on their methods as, for them, the challenges they face do not mean, under the current circumstances, that their predictions are not always going to be reliable and accurate (Eakin 1999). Indeed, even science has issues to accurately predict some parameters, such as the duration and coverage of drought (Roncoli et al. 2009), which in some places is aggravated by the fact that the forecasts are not location-specific (Kogan 1997). As both traditional prediction and scientific forecast methods have uncertainties of their own, Eakin (1999) and Ebhuoma and Simatele (2017) suggest that it may lead farmers not to trust and have the willingness to use the scientific forecasts. While Roncoli et al. (2002) and Speranza et al. (2010) contend that it may, in fact, create an environment for farmers to be interested in and accept scientific forecasts to increase the confidence of the forecasts, thus reinforcing the need and importance of making scientific forecasting information accessible to farmers to minimize risks and agricultural losses.

Conversely, some studies have registered a decline in the use of traditional prediction methods due to an increase in modernization and cultural homogenization, a reduction in the number of elders using such techniques, and a lack, or poor documentation of them (Boven and Morohashi 2002; Chang'a et al. 2010; Muyambo et al. 2017). Additionally, some researchers have registered a decline in the richness of, and some contradiction in, the interpretation of diverse traditional indicators by farmers (Manyanhaire 2015; Mengistu 2011; Santha et al. 2010). Notwithstanding this, Ziervogel (2001) argued that as the interpretation of environmental indicators is a part of personal knowledge and experience, inconsistencies are expected, even within the same community. This stresses the urgent need to safeguard traditional knowledge which, despite the current challenges faced, continues to be the primary source of farmers' forecasts for farm-related decisions, especially considering that access to, and utilization of, scientific forecasting remains very limited in most rural areas (Chisadza et al. 2013). Thus, although several factors might increase farmers' vulnerability to drought, Wongbusarakum and Loper (2011) contend that the lack of drought-related information and early warning systems are making farmers more vulnerable to its impact.

Therefore, there is growing recognition among researchers (e.g., Green et al. 2010; Kalanda-Joshua et al. 2011; Mahoo et al. 2015; Manyanhaire 2015) of the importance of making forecasts as location-specific as possible, and some scholars have suggested combining traditional prediction and scientific forecast methods with the aim of increasing their accuracy and reliability, and thereby reducing farmers' vulnerability to weather and climate change. These scholars argue that traditional knowledge may provide an informal record of communities' observations of local changes in the environment and climate over time, thus offering useful insights to fill the paucity of scientific data about changing trends and patterns of local seasons and weather, and other phenological observations made over several generations. These local measurements will aid historical climate reconstructions that will be useful to analyze and understand the weather and climate trends, and so further increase the confidence and accuracy in the projection of possible future scenarios. Many studies explored this and found good agreement on some aspects and poor agreement on others such as rainfall trends. For instance, Ayal et al. (2015), Huntington et al. (2004) and Roncoli et al. (2002) agree that the local measurement may aid in the location-specific historical analysis of the trends in onset, duration, and distribution of seasonal rainfall or environmental changes. While Lebel (2013), Mackinson (2001) and Speranza et al. (2010) contend that because local measurement focuses on timing, not the quantity of rainfall, it may fail in aiding the analysis of the quantification of trends in rainfall. Additionally, they argued that because local measurement uses different parameters and scales, it may be incompatible with science, thereby would make the analysis challenging. The following section builds on this discussion by exploring the relevance of traditional prediction methods in the context of Mozambique.

2 Study setting and methods

Mozambique provides a highly relevant context to explore the use and importance of traditional drought prediction methods by small-scale farmers in rain-fed areas. Agriculture remains the primary economic activity of the country, practiced by approximately 80% of the population, of which 95% practice the activity under rain-fed conditions. The majority of these farmers practicing rain-fed agriculture live in rural areas (Uaiene 2008), which continue to have limited, or no, access to scientific forecasts. Due to several years of independence (1964–1974) and civil war (1977–1992), Mozambique continues to have a highly reduced number of functional meteorological stations, so that most rural communities, including the study sites, do not have one. The country has only 27 synoptic weather stations, each station providing coverage for 29,000 km^2; thus, there are significant amounts of missing data (INGC 2009). Moreover, the Mozambican National Meteorological Institute (INAM) is limited in its capacity to adequately monitor, forecast, and communicate the current weather and climate, or to analyze the past and present trends to help predict future drought situation, location, extent, or magnitude (INGC 2009). The country also lacks a comprehensive system to adequately manage drought (Muller 2014). The fact that the country is one of the most vulnerable in the world to natural disasters and climate change, ranking third among the African countries, adds extra weight to the problem (Venton et al. 2013; World Bank 2014). Thus, traditional methods to predict rainfall and timely make farm-related decisions are highly relevant and continue to be the most widely used methods in most rural communities. The selected study site, Gaza, is one of the provinces with significant geographical gaps in meteorological station coverage and is one of the most affected by drought, which occurs in seven out of every 10 years (Uaiene 2008).

Within Gaza province, the specific study locations were the districts of Chibuto (Gomba and Magondzwene communities) and Guija (Mbala-Vala and Chimbembe communities), both located in the south-west. As in the rest of the country, small-scale rain-fed agriculture is the primary economic activity in Gaza, practiced in an average area of around 1 ha. Women constitute the majority of farmers and inhabitants of the province (around 60%). The province also registers a low number of people who are over 45 years old (less than 20%) (MAE 2005). For instance, in Gomba, Chibuto, where I had access to a more detailed list of the inhabitants, which included age, people over 45 years old constituted only 1.63% of them. These demographics are attributed to several reasons, such as labor migration to South Africa, or to other locations within the country, and early death of men between 15 and 49 years old due to HIV–Aids, and tuberculosis (Gawaya 2008). Agriculture is also characterized by the use of traditional cultivation techniques, such as hoe (100%), animal traction (38.2%), and low-level use of chemical fertilizers (1.6%) and pesticides (1.4%) (MINAG 2012). The main cultivated crops are cassava, maize, and beans (butter and cowpea). Although there is considerable variation in level and distribution between and throughout the years, two typical seasons characterize the climate of the districts, regions and the country in general: a cool and dry 'winter' season from May to September (average temperatures of around 20 °C); and a warm and rainy 'summer' season from October or November to April, with December and January being the hottest months (with average temperatures exceeding 28–30 °C), and February the rainiest (Hulme et al. 2001).

However, rainfall is very low, varying between 400 and 600 mm per annum, and normally occurring on a series of isolated rain days and locations, barely exceeding 50 rain days per year. A mid-season dry spell often occurs during the rainy period, causing significant effects on crop yields. Therefore, agricultural activities start in November and are divided into four periods: early rains (November–January); rains, which can be used for a second planting (February–April); harvest of the first planting (May–July); and harvest of the second planting (August–October) (Cunguara et al. 2011). Livestock rearing is also commonly undertaken in both districts, the main livestock being cattle and goats, followed by sheep, pigs, and poultry (chicken and ducks). Livestock is rarely used for commercial purposes unless there is a major financial need. Cattle ownership is prestigious, and some animals are used as traction or drought for farming activities, while others are consumed on special occasions, such as family visits. The main off-farm activities are the production and commercialization of wood, charcoal, traditional alcoholic drink, and artisanal fishing (GDG 2012).

The study was conducted between April and September 2017, the first 3 months of which were spent in Chibuto and the remaining months in Guija. A total of 25 focus group discussions (FGDs) were conducted to explore participants' conceptualizations of drought, their memories of past drought events and why those events were memorable to them, the diverse traditional methods they use to predict drought, access to other sources of forecasting, and viewpoints of the reliability and accuracy of all forecast types accessed and used. Each FGD comprised six to eight participants and were organized according to participants' gender and age group (three age groups per gender: 16–24; 25–44; and over 45 years old). Participants were randomly selected based on a list of habitants of the communities supplied by the leaders. A snowball sampling was also used to replace the absent participants selected randomly. These groupings were intended to make the participants feel more comfortable with one another and therefore more likely to express their knowledge and viewpoints in front of each other. The FGDs were useful as they facilitated comparison between respondents of the amount and type of knowledge they have of traditional prediction methods.

Twelve interviews with key informants (community leaders, governmental bodies, and NGOs) were also conducted to explore the kinds of drought-related information that they provide to farmers and to investigate the nature of drought adaptation strategies being carried out at the study sites and their outcomes. Additionally, the study made use of official documents and reports from the government and Non-Governmental Organizations (NGOs), journal articles, online newspapers, handbooks, and field reports related to the areas under study. All the interviews were audio recorded to ensure a complete transcript as possible of each discussion could be produced. Photographs and field notes of participants' behaviors, activities, interactions, and settings complemented the data collection by allowing a more rigorous capture and subsequent description of the context of the study sites. NVivo was used to analyze the data, collected and organized through a coding scheme, to establish similarities and differences in group responses.

3 Results

Before this section explores how farmers in the study site traditionally predict the occurrence of drought events, the current contextual situation, and relevance of their traditional prediction methods in terms of the accuracy and reliability, it is essential to understand what farmers identify or define as drought to further have a better understanding of what farmers are predicting. In this section, the paper draws on the empirical data to demonstrate how farmers conceptualize drought and compare it with the concept of agricultural drought, which is adopted by the INGC. It then explores the diverse methods farmers use to forecast drought based or not on their definition, and how farmers perceive the links between the current changes in the weather, climate, and environment, and the methods their use to predict drought.

3.1 Farmers' conceptualization of drought

Results show that farmers define drought based on its negative impacts on their farming activities and livelihoods. Similar findings among Tanzanian and Spanish farmers were reported by Slegers (2008) and Urquijo and De Stefano (2016), respectively. Based on the most cited definitions of drought by participants, the information was combined to conceptualize drought as a lack of rain that makes rain-fed crop production difficult or impossible, dries up water sources and grass, causes thirst and hunger for people and livestock, and results in livestock death. Livestock, especially cattle, were always mentioned by farmers because of the crucial social and economic role these animals play in their lives. Clearly, what farmers actually consider drought is the lack of rain. However, the concept of agricultural drought accounts for a shortfall in rainfall over an extended period that leads to suboptimal availability of water and soil moisture for their adequate farming activities (Wilhite et al. 2014). Therefore, some farmers argued that they feel affected by drought when it happens before planting and not after, since following planting they can always get some production for household consumption, such as 'green leaves' from a plant known as cacana (*Momordica balsamina*). Slegers (2008) also noted similar perception among Tanzanian farmers who perceive drought as complete crop failure, not a reduced crop production due to rainfall deficiency; thus, they believe have never experienced a drought.

3.2 Farmers' methods used to predict drought

3.2.1 Access to meteorological forecasts

Only regarding the recent drought occurring in the country, have 62.5% of farmers in the study site begun to gain access to seasonal meteorological drought forecasts, although this is not location specific. Their main sources of information are through local authorities (57.6%), radio (32%), and family and friends (10.4%). The information provided concerns the possibility of drought occurrence during the season and advice about what to do to make timely preparations for the upcoming event to reduce its negative impacts. Such preparations include: storing seeds for planting when the rain starts; selling livestock; or finding other sources of income (e.g., production and sale of traditional mats, charcoal, or wood) to provide money for food. Most participants stated that they use the seasonal meteorological drought forecast because their personal experiences of diverse hazards, such as floods and strong winds, meant they could confirm that the information provided was accurate. Additionally, they perceive local authorities as reliable because they are seen to be at the top of the hierarchy of the social structure, and thus respected and their advice followed. In fact, in their framework to diagnose barriers to adapt to the changing climate, Moser and Ekstrom (2010) argue that people give enormous consideration to the source of information provided. The perception, or evidence, that they have not been wrong in the past constitutes the basis on which to build trust, although this is something that can easily be undermined (Patt and Gwata 2002). Therefore, although some farmers have argued to the contrary, most consider the meteorological information useful for them to make timely preparations for the expected adversity.

3.2.2 Traditional prediction methods

All farmers in FGDs reported that their main sources of the seasonal drought forecast for farm-related decisions are their traditional prediction methods. A total of 11 traditional prediction methods were identified in the study sites (see Table 1) and grouped into four categories of indicators: celestial bodies (3); weather and climate (5); physical environmental (2); and biological (1). As shown in Table 1, the indicators serve to predict, near the rainy season, the imminent possibility of no rain during the following day or night. However, when these indicators become recurrent for long periods of time, then they become signs of possible drought for upcoming agricultural season.

The celestial body indicators farmers have been observing around the rainy season to predict drought include the moon's appearance and position (92% of the FGDs), the

Table 1 Small-scale farmers' short-term traditional drought prediction indicators ($n = 25$ FGD)

Category of the indicator	Type of indicator	Description of the interpretation of the indicator	Community which uses the indicator[a]	Number of references[b]
Celestial bodies	Moon appearance and position	When the moon rises clear, i.e., without a circle with rain or heavy cloud appearance inside it	Gomba, Mbala-Vala, Chimbembe	9
		When the moon rises the other way around, i.e., turned to the top with its back turned to the earth	Gomba, Magondzwene Mbala-Vala, Chimbembe	8
		When the full moon rises in a perpendicular or inclined position	Gomba, Magondzwene	4
		When the moon gives signs of rain, but it does not rain	Magondzwene	1
		When the moon is not surrounded by clouds during the night	Mbala-Vala	1
	Sun	When the sun is clearly visible, without clouds around or a circle that looks to have water on it	Mbala-Vala, Chimbembe	2
	Star quantity and appearance	When the stars are clear, without any cloud shadows around	Gomba	3
		When there are numerous numbers of stars in the sky	Gomba, Chimbembe	3
		When the stars are constantly moving from one place to another, are radiant, and brighten up the earth	Mbala-Vala, Chimbembe	3
		When the stars are not concentrated in the sky but dispersed	Magondzwene	1

Table 1 (continued)

Category of the indicator	Type of indicator	Description of the interpretation of the indicator	Community which uses the indicator[a]	Number of references[b]
Weather and climate	Air temperature	When it is very hot throughout the year	Magondzwene	4
	Clouds	When there are no clouds, or the clouds are clear and dispersed in the sky during an extended period in a year, or during the season considered as rainy	Gomba, Magondzwene Mbala-Vala, Chimbembe	21
		When during the morning the clouds are dark, showing signs of rain but then they start clearing up through the day and become clear and it does not rain	Magondzwene, Mbala-Vala	2
	Wind direction	When the wind blows in only one direction (e.g., West) without response (blowing) from the opposite direction (e.g., east)	Gomba, Magondzwene Mbala-Vala, Chimbembe	9
		When the wind blows in two opposite directions as if one direction was responding to the other (e.g., West and East directions)	Mbala-Vala, Chimbembe	5
		When it is windy because there is no rain with wind	Magondzwene	2
		When the wind blows in one direction and is not accompanied by thunder	Magondzwene	1
		When there is no wind	Gomba	1
		When the wind starts blowing and suddenly stops	Mbala-Vala	1
		When there is a whirlwind during the morning period	Chimbembe	1
	Thunder	When there is thunder but no rain	Magondzwene	1
	Lightning	When there is lightning but no rain	Magondzwene	1
		Where there is lightning coming from only one direction and not from two opposite directions	Magondzwene	1

Table 1 (continued)

Category of the indicator	Type of indicator	Description of the interpretation of the indicator	Community which uses the indicator[a]	Number of references[b]
Physical environmental	Dew	When there is no dew in the field early in the morning	Magondzwene	1
	Fog	When the fog disappears by 7 am and not by 10 am as happens during the rainy season	Magondzwene	1
Biological	Animal behavior	When the animals are quiet, not running and playing a lot as usual	Gomba	1

[a]Gomba and Magonzwene are communities from Chibuto district, while Mbala-Vala and Chimbembe are from Guija district

[b]Number of FGDs which have given the response

sun's appearance (8% of the FGDs) and the stars' appearance and quantity (44% of the FGDs). According to these farmers, the main signs from the moon of upcoming drought are: when it rises 'the other way around,' i.e., turned to the top with its back turned to earth; when it rises in a perpendicular or inclined position; or, when it is clear, without a circle which gives the appearance of rain or heavy clouds. Similar findings were reported by Eakin (1999) in relation to the moon's appearance and backward position, but not concerning the inclined position. Also, signs of no rain soon include when the sun is clearly visible, without clouds around or a circle that looks to have water on it; or when the stars are numerous and radiant in the sky and brighten up the earth, or when the stars are dispersed in the sky.

Regarding weather and climate, despite farmers having mentioned using indicators such as very hot temperatures throughout the year, and the occurrence of thunder and lightning without rain, to predict drought, signs from wind (72% of the FGDs) and clouds (88% of the FGDs) were the most cited. According to these farmers, the main signs of forthcoming drought are: when there are no clouds; or when the clouds are clear and dispersed in the sky during the rainy season; or when they have been showing this behavior over a long period during the year; or when during the morning the clouds are dark and showing signs of rain, but then they start to clear during the day until the sky becomes completely clear and no rain falls. The appearance of the clouds was also reported as being used in different parts of the world as a short-time predictor of rainfall, such as in India and Mexico (Eakin 1999; Santha et al. 2010).

However, the farmers' interpretation of the signs of drought from the wind around the rainy season were contradictory within the communities. Even though, in both study locations, 36% of the FGDs argued that it is a sign of drought when the wind blows in one direction only (e.g., from the West), 20% of farmers in FGDs in Guija district argued to the contrary. These farmers contended that the wind blowing in two opposite directions is a sign of drought. However, in Chibuto, 12% of the groups rejected both views with the justification that, independent of the direction, the fact that it is windy means drought will occur because there is no rain with wind. Nonetheless, even in other parts of the world, the interpretation of the wind is still quite diverse. Some examples are the similar findings from Mengistu (2011) of the interpretation of the wind blowing in one direction as a sign of drought, and the opposing findings from Santha et al. (2010). Nonetheless, much of this confusion related to the interpretation of the direction, presence, or absence of the wind as a sign of drought came from those under 45 years old.

The use of physical environmental indicators such as dew and fog to predict drought was only reported in Magondzwene community in Chibuto. According to farmers, signs of upcoming drought occur when there is no dew on the field early in the morning, or when the fog disappears by around 7 a.m., rather than persisting until around 10 a.m. as is usual when the rainy season is approaching or underway. In fact, several times during the fieldwork I faced intense fog on the morning trips to the communities in Chibuto, and indeed it disappeared before 8 a.m. with the intensity of the sun. Despite animal behavior being frequently reported as a biological indicator to predict the weather in different parts of Africa (e.g., Ayal et al. 2015; Chang'a et al. 2010; Speranza et al. 2010), it was not so common in the study sites, even though livestock rearing is commonplace. Only one group discussion of males over 45 years old in Gomba, Chibuto, mentioned this, explaining that they predict drought when their animals change their behavior, becoming quieter and not running or playing as much as usual.

3.3 Perceptions of changes affecting drought indicators

Farmers have recognized diverse changes in their surrounding environment (trees, grass, fog, water levels, and soil) and in the weather and climate (wind, temperature, and rainfall) over the years. They also recognized that some of these changes have affected the accuracy and reliability of their predictions. For instance, 52% of the FGDs in both study locations noticed a significant reduction in the quantity of stars compared to the past and stated that this has affected their interpretation of the signs from this indicator. In the past, a reduced number of stars meant rainfall would come in a few hours, but now such a sign is almost meaningless.

A similar decline in the use of fog and dew as a sign of drought was also registered as farmers noticed that now fog does not last as long as it used to, and often it has already disappeared when they wake up due to intense heat, even during the winter. The intense heat during the evening also affected the formation of dew, as it is now barely seen in the morning and its absence is felt by the crops. Additionally, the intense heat throughout the year that has been verified in the country over the past decades has affected farmers' interpretation of hot temperatures which endure for extended periods in a year as a sign of drought. Farmers have explained that now summer periods are warmer and longer, and winters are much shorter and not so cold. Indeed, records show that since 1960 the temperature in the country has increased between 1 and 1.6 °C, which was accompanied by an increase in the number of hot days (INAM 2013). Lastly, farmers have lost confidence in the use of the start of the rainfall as an indicator of drought as they have noticed that, nowadays, it starts late and is irregular, thus while in the past they would plant from September to December, now they no longer know the exact months they will plant. Some farmers even contend that they no longer plant during the summer season. In fact, records also indicate a later start of the rainfall season since the 60s (INGC 2009), and inter-annual variability regarding rainfall beginning and cessation, which makes it challenging to determine the official start of the agricultural season (MICOA 2013).

I witnessed some other reliability issues related to the clouds, during the fieldwork since there were some days that the sky was cloudy as described by participants as indicating rain in the past, but it did not rain. There were also some days where there were no signals from any traditional indicators, but it rained. However, on these occasions, the rain was of such light intensity that participants considered it only useful to dampen the dust on the roads and in their yards, not for planting. Similar reliability issues, but with the moon's position, were also found by Eakin (1999) when interviewing farmers in Tlaxcala, Mexico. Therefore, in cases when farmers fail to predict the occurrence of drought, they start observing visible signs that drought is already occurring through plant behavior (52% of the FGDs); delays in rainfall beginning (12% of the FGDs) or reduction in water levels in the lake (8% of the FGDs). They explained that they can observe the occurrence of drought when the trees, crops, woods, and grasses start to dry up, they look brown as if they have been burned, and they lose their leaves. They can also notice that drought is already happening when they observe the stunted development of their crops and the dryness of the soils (Fig. 1) and perceive delays in rainfall beginning (not raining between September and December).

Notwithstanding, farmers' difficulties with their prediction indicators have not impeded them from using their methods to make farm-related decisions since there are also occasions when the methods still appear to be useful to them. Even when they are

Fig. 1 The stunted development of maize crops as a result of the occurrence of dry spell. The photograph in the left side is from Chibuto district and in the right side is from Guija district

provided with meteorological forecasts, and despite the trust they have in this source of information, farmers continue to value traditional prediction methods and always make use of them for confirmation of other sources. They ask the elders to use their knowledge, wisdom, complexity and diversity of forecast methods to traditionally predict the weather and to certify or deny the scientific forecasts given by the local authorities to the community. The elders' predictions are then what primarily influences farmers' motivations to use the scientific forecasts or not. One such example was found during this study when farmers explained that, although the last drought has ended recently, they became aware, through the local authorities and radio, of the possibility of occurrence of another drought in the upcoming season, and they believed in the information, and have been preparing for the event because the elders followed-up and positively confirmed it.

4 Discussion and conclusion

This paper uses a case study of small-scale farmers in rain-fed areas in Gaza province in southern Mozambique to understand how farmers predict drought and the contextual situation regarding the accuracy and reliability of the traditional prediction methods under the current weather and conditions of climate uncertainty and variability. The paper also assesses the opportunities that farmers' predictions may bring to their activities and daily lives. Due to their dependence on the natural environment for their livelihood activities, farmers often observe, monitor and use traditional indicators to predict the weather and climate. These methods have acted as important tools to help them analyze the implications of the prediction and make farm-related decisions, such as the type of crops to plant each season, when to start planting and precautionary measures to take to avoid losses or prevent hardship (Chand et al. 2014, Green et al. 2010). The methods have been fundamental in helping farmers to reduce their exposure and vulnerability to weather and environmental changes (Nyong et al. 2007; Roncoli et al. 2009).

Farmers have been using a total of 11 traditional drought prediction indicators, either individually or combined, as required to increase their prediction certainty. However, results show that the most used indicators are the moon's appearance and position (92% of the FGDs), clouds' appearance (88%), wind direction (72% of the FGDs), star quantity and appearance (44% of the FGDs) and plant behavior (40% of the FGDs). They not only use their traditional prediction methods because of being poor and highly illiterate, as stated by Muyambo et al. (2017), but also because it is part of their cultural knowledge and inheritance which they believe should be passed from generation to generation. They have learned these methods from their grandparents and parents during their story-telling moments around the fire, and they also transmit them on to their descendants. Additionally, due to the very sparse or non–existent weather stations in most rural areas in the country, which makes drought monitoring and early warning a daunting task, on many occasions, farmers' traditional drought prediction methods are the main, or only, source of information for them.

Despite increased efforts by government to diffuse the regional seasonal meteorological forecasts through the local authorities or radio, farmers do not always have access to the forecasts, for which there are several reasons. Some examples are: non–participation in their community meetings, lack of radio ownership, or in other cases, the information is simply not transmitted to farmers. Even though radio constitutes the only medium through which farmers have access to information due to the lack of electrification, less than 3% of the farmers owned one. Moreover, despite the presence of NGOs in the study sites, and the existence of the INGC in the country, farmers reported they did not receive drought forecasts from them, but only information related to predictions of cyclones, floods, strong winds, and storms. They explained that the Red Cross and INGC have even formed a committee of those specially trained to disseminate these kinds of forecasts through the use of flags, where, for instance, a blue flag means to prepare for the occurrence of heavy winds within 24 or 48 h, a red flag means the wind will come within a few hours or is already blowing, or a yellow flag indicates heavy winds and rainfall within 24 h. These are the same colors used by INAM as part of their cyclone alert system. Nonetheless, lessons could be taken from these mechanisms of communications to incorporate in early warning systems for drought.

Nevertheless, results show that farmers are aware of, and acknowledge that, the current unpredictability, variability, and changes in weather and climate negatively affect the reading, interpretation, accuracy, and reliability of most of their prediction indicators, and thus their farming activities. Thus, like other findings (Chinlampianga 2011; Kempton 1997; King et al. 2008; Tambo and Abdoulaye 2012), farmers now face some difficulties in their ability to predict when the rain will start, so they can start to plant their crops, or if the rain will be good enough for their agricultural season, as they did in the past. As a result of the difficulties with the predictions, on some occasions, farmers do not obtain the expected yields as unexpected dry spells occur during plant development. What is more, because of their difficulties in predicting drought, farmers explained that nowadays every raindrop represents an opportunity to plant their crops that cannot be missed, as they cannot be sure that rain will come again at another time in the year. This is the reason farmers have started planting during the winter season (April–August), not a traditional practice in their communities since by doing so they can guarantee their harvest and their families' subsistence.

Adding to that, although farmers have not recognized that some other changes in their indicators affect their prediction methods, the fact that only one FGD of over 45 years old mentioned the use of some traditional prediction indicators, such as animal behavior and dew, suggests a decline in the use of these methods when compared to other indicators, which were mentioned by people from different age groups. However, it is not clear whether or not this reduction in the use of such indicators, and in their interpretations, were caused by the reduction of their accuracy or availability as, for instance, farmers continue to own livestock, although in much reduced quantities when compared to the past. On the other hand, even though the few existing elders continue to transmit their prediction knowledge to their descendants, similar to findings from Kalanda-Joshua et al. (2011), a decrease was also registered in the diversity and complexity of traditional prediction methods among younger people. According to Chang'a et al. (2010), traditionally it has been the elderly who have the local knowledge and who subsequently pass this knowledge on to the next generations. Thus, results showed that while people older than 45 years old would give more diverse and detailed information about their reading and interpretation of signs from the celestial bodies, weather and climate, younger people's (from 16 to 24 years old) knowledge of those signs was shown to be much reduced. This latter group mostly gave examples of biological and physical environmental indicators, which were not predictions but visible signs that drought was already occurring, such as when the crops and grasses start drying up, or when water levels in the lake reduce.

The reduced number of elders and reduced knowledge and recognition of local prediction methods is threatening not only the richness and complexity but also the endurance of those methods and farmers' ability to make a timely response to drought. Ensor and Berger (2009) argue that the fact that education has become more available to younger people means that they learn what is taught at school, and their unique community knowledge is not transmitted to them. In addition, it is argued that as the younger generation spend less time in direct contact with the environment and, as agriculture is no longer their only livelihood activity, they gain a little experience in reading and interpreting drought indicators through long-term observation of their environment and climate (Speranza et al. 2010). In fact, most of the younger participants in the study, mainly males, had more than one livelihood activity, and they often referred to off-farm activities as their main ones, as their wives were responsible for the on-farm activities.

Notwithstanding, as the natural climate variability associated with climate change is expected to lead to never before experienced extreme weather and climate events (IPCC 2012), and specifically with the expected stronger influence of future El Niño events, and the increase in frequency of extreme drought in Mozambique by 2060 (INAM 2012), farmers will increasingly require timely drought forecasts for their farming-related decisions. Since the climatic projections and early warning systems to provide better information to vulnerable people in the country are still non–satisfactory (Governo de Mocambique 2017), farmers will continue to rely on their traditional prediction as their main, or some cases only, methods to predict drought. The fact that farmers have themselves made their own judgement about the accuracy and reliability of certain methods they use, made them more aware of the risks they may face and which type of methods they can partially or entirely rely on, such as the moon's appearance and position. Nevertheless, as the moon is only visible for part of the month this may force the farmers to revert to the use of the others available indicators, which were reported to have become less reliable. Tailored and robust traditional prediction methods would be of great benefit to farmers and for scientific research into drought adaptation.

The future of traditional prediction methods and the potential increase in their accuracy and reliability depends on the farmers' own abilities to enhance, preserve, and validate the methods by tailoring them to fit the new environmental, weather, and climatic conditions, or by the development of new methods based on that. This is because most of the traditional prediction methods they use were created by continually observing the indicators in different environmental, weather, and climatic conditions as registered today; as they have changed over years, so have the indicators (Ayal et al. 2015; Egeru 2012; Speranza et al. 2010). Thus, the indicators should not be interpreted in the same way as they were in the past. Since farmers have a long history of adaptation to the changing environment through adjustments to their farming practices (Adger et al. 2013; Lebel 2013; Nyong et al. 2007), their traditional prediction methods should also be part of the process to endure. Indeed, Speranza et al. (2010) contend that with the gradual changes that are occurring, local knowledge may not remain static as local communities may progressively identify new indicators. However, the paper acknowledges that it will take time for people to identify and share the new indicators that work under the changing conditions.

The paper emphasizes that the adjustments in the farmers' prediction methods must be accompanied by the transmission of this knowledge to the younger generations. Even though the younger generation currently has more access to education, there are off-school opportunities to transmit the knowledge to them. However, as the younger generation is more interested in the scientific forecasts (Ayal et al. 2015), to ensure that the taught knowledge will be put into practice, the teaching should be accompanied by efforts to revitalize their interest in their traditional prediction methods as well as increase awareness of the importance of the methods. Thus, there is a need for communities to find locally appropriate mechanisms in order to achieve the above revitalization. This will help to safeguard the continued existence of their local knowledge, as this is, and will continue to be, their main source of forecast information, as well as a powerful tool for their farm-related decisions and adaptation to drought. For example, as the younger generation enjoys socializing with friends after school, perhaps gathering them together as a group for collective learning can, to some extent, be attractive to them and create a 'positive competitive and cooperative learning environment' during and after the sessions that will contribute to maximizing their learning. This strategy may result in them frequently observing their environment and climate in order to read and interpret signs and exhibit their skills to each other. The strategy might also provide opportunities to transmit the knowledge to more people, including those who do not have elders in their families.

On the other hand, despite not location-specific, the paper also recognizes the role of meteorological forecasting in farmers' decision making and adaptation to drought, and believes that the short-term meteorological forecasting in poor countries such as Mozambique will improve with time with the creation of more observation sites and better tools to predict and monitor the weather. Since farmers showed trust and acceptance of meteorological forecasts and taking into consideration the nonsatisfactory early warning systems that predominate in most rural communities in Mozambique, combining both scientific and traditional methods would also be crucial to strengthen the success of the forecast, and thus to reduce farmers' vulnerability. One potential way of combining these methods could be through Participatory Scenario Planning (PSP) for seasonal climate forecasts and decision making, which has been increasingly researched and implemented in parts of the world such as sub-Saharan Africa. During PSP both traditional and scientific climate forecasts are shared and interpreted by community members and the relevant governmental and development bodies. Such an approach can also constitute a powerful way to revitalize the value of the traditional prediction methods among the community members as well as among the governmental and development bodies.

PSP would enhance the governmental and development actors' awareness of the methods and the unique roles the methods have played, currently play, and will continue to play in helping farmers to make timely predictions of drought, and other natural hazards, and reduce their vulnerability to these events, in spite of the current difficulties faced. As supported by Kalanda-Joshua et al. (2011), the awareness and understanding of the nature of traditional prediction methods will further facilitate the communication of scientific forecasts in a way that is meaningful and relevant to farmers' decision-making. This may facilitate the interpretation of the forecasts and the successful combination of both forecast methods, as well as the development of context-specific and feasible strategies for timely responses to drought. This may represent a win–win opportunity for the farmers, the government and their development partners, as by reducing farmers' vulnerability to drought it may also reduce their dependence on food aid.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interests.

Ethical approval An ethical clearance of the study was requested from and granted by the University Research Ethics Committee. I also confirm that the selected people voluntarily participated in the study, they were aware that they could discontinue their participation from the research at any time if they wish so, and that the study was not using information in a way that could directly or indirectly affect them adversely. Moreover, all participants were informed that their participation was anonymous, and to further maintain their privacy and anonymity, the filled forms and results would be coded rather than named, unless they agreed to be identified.

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