Original Research Article

Climate variability: perception and observation of local indicators as a guide for weather forecasting and farmer decision making (Case: Inhabitants of Beaniky and Antseky Ambovombe –Androy MADAGASCAR)

Abstract

Showing the reality of climate change at the spatiotemporal scale and understanding its meanings based on readings of local indicators is fundamental knowledge for developing various adaptation strategies. The ethnographic field study was conducted with 44 heads of targeted agricultural and fishing households who had not left the localities in the past 10 years. Data was collected on indigenous perceptions and knowledge of climate, types of indicators and their functioning. The surveys showed that 93% of the participants perceive the reality of climate variability. Local people have a high level of climate knowledge (61%) from which they observed animal (marine and terrestrial) climate indicators, plant indicators and atmospheric indicators. The combination of indigenous ecological knowledge with modern science should be implemented to collaborate on accurate weather forecasting.

INTRODUCTION

The devastating consequences of climate variability threaten to plunge millions of people in Africa into extreme poverty due to over-reliance on rain-fed production through agriculture to eliminate hunger and reduce poverty (Thornton et al, 2011; Phiiri et al, 2016). This change may be a global phenomenon, but its effects will not be evenly distributed among the world's population. Many indigenous communities are beginning to feel the effects of climate change (IPCC 2001a, 2001b, 2007). Climate change is causing significant environmental changes, such as recurrent droughts that accelerate the decline of forests (Belem et al., 2017; Ouédraogo and Thiombiano, 2012; Higgins et al., 1999; Grouzis and Albergel, 1989), reduce vegetation cover and agricultural yields, and promote the expansion of bare areas (Bambara et al., 2013). In Madagascar in general and in Androy in particular, climate variability has a profound influence on the quality of agricultural production and determines livelihoods in terms of food (in)security. Since 1931, a major drought has been recorded, leading to displacement and loss of life of the population in the sedimentary zone. The recurrent drought situation has reduced the availability of water for life of the inhabitants of the region, for agriculture and livestock contributing to a situation of vulnerability. The results of assessments conducted in February 2016 concluded that a total of 1,140,000 people were food insecure due to an overall crop loss of about 80%. Deficiencies related to climate variability thus diminish the capacity of the Androy to produce food qualitatively and quantitatively for the population and call for proactive and reactive measures at more local levels. The knowledge and experience of the Ntandroy have enabled specific actions for an adaptive response to drought based on their perception of the changing environment and socio-cultural practices related to climate, particularly rainfall. Traditional ecological knowledge can play an important role in short- and medium-term weather forecasting (Parrotta and Agnoletti 2012). They are also "an invaluable basis for developing adaptation and natural resource management strategies in response to environmental and other changes" (Raygorodetsky 2011). The recent emergence of environmental humanities as a distinct field focused on the meaning of environmental experience in a highly degraded environment (Morton 2009) has thus attracted the interest of environmental anthropologists. Through their practice, the knowledge they create, share and maintain, strengthens their climate resilience and offers a window into how communities conceptualise their own vulnerability (Hiwasaki et al. 2015). This knowledge, based on the cultivation of worldviews, shapes their perception of who or what is causing climate change and how best to respond? Based on traditional Ntandroy ecological knowledge, how can people perceive and understand climate change in their terroir? This paper aims to understand the meanings of change based on the interpretation of local indicators used as a guide to farmer climate prediction. Farmers can predict rainfall availability and scarcity by observing the behaviour of animal and plant species and the position and appearance of atmospheric elements at scales relevant to human activity, particularly in Beaniky and Antseky d'Ambovombe Androy (Madagascar).

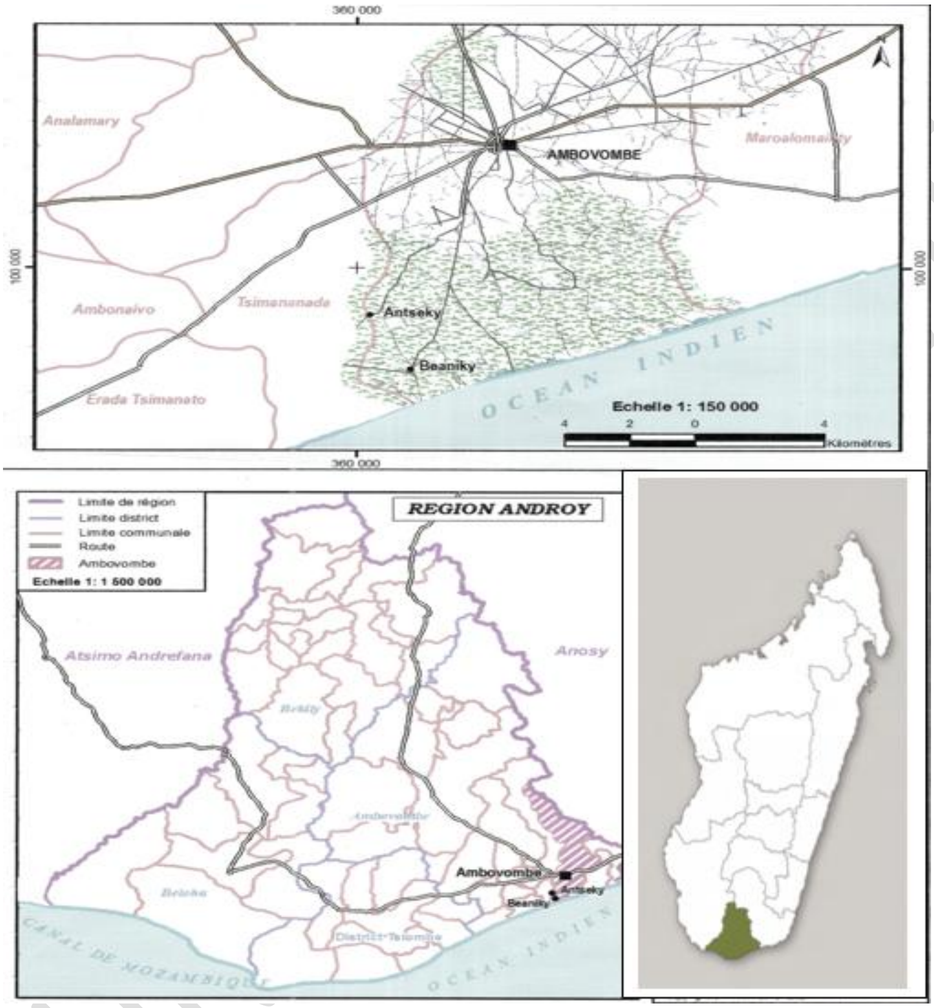
PRESENTATION OF THE STUDY AREA

Geographical location

The villages of Beaniky and Antseky are located in the coastal zone, to the south, around ten kilometers from Ambovombe-Androy: Beaniky (25° 16' S - 46° 4' E) and Antseky (25° 13' S - 46° 2' E). The sites were selected for their vulnerability to the effects of climate variability given the high levels of environmental degradation prevalent in the region, with a deforestation rate increasing from 1.16% between 2005-2010 to 1.49% between the years

2010-2013 and low rainfall. The area is humanized. However, the ecological balance of the area is strongly threatened by an invasive species of cactus, the so-called "*raketa mena*" (red cactus). The study focused on the District of Ambovombe, (in particular its two rural villages) a town that has become a symbol of the effects of climate change in the local, national and global imagination.

Map 1: Geographical location of Beaniky and Antseky in Ambovombe (Madagascar)



(Source:FTM, 2021)

Physical and climatic characteristics

This area is generally desert; in the south of Androy, a relatively fertile and populated limestone strip, but without water. It is calcareous and sandy. The characteristics of the soil do not lend themselves well to the characteristics of the soil do not lend themselves well to cultivation, but the vegetation adapts to the difficult conditions; from a thorny, greyish bush, trees emerge, without shadows, bristling with prickles. The corresponding crops are grasses and tubers. The average rainfall in our villages is less than 350 mm/year, with a water deficit on a national scale. The study area has no rivers or ponds to draw water from. At the same time, the temperature is high, between 29°C and 42°C. The Androy has two seasons (dry and wet). The dry season lasts eight months (March/April - October) while the rainy season lasts four months (November - March). There is a general decrease in rainfall during the dry season, resulting in a shortage of water. The drought is thus always favourable. The vastness of the area, with its grasslands growing on limestone soil, makes it a setting that facilitates extensive livestock farming; in the coastal area, in contact with the sea (in the case of the village of Beaniky), on the other hand, the primary productive activity is not fishing. The economic characteristics of the communities are dominated by agriculture. The main feature of the relief is a plateau with peaks that rarely reach 250 meters and is connected to the sea by a gentle slope. This plateau then degrades into increasingly sandy soils. On these areas, violent seasonal winds cause the silting up of arable land, making it difficult for people to farm. The Beaniky and Antseky area is dominated by three types of wind in intermittence, namely the white wind (Tiopoty), the east wind, which dries out, and the red wind (Tiomena). Agriculture and breeding are the main activities of the inhabitants of the region. Fishing is a marginal activity that only interests a minority of the inhabitants of the coastal zone, such as the village of Beaniky, which has two fishermen's associations.

Socio-economic characteristics

Because of the chronic rainfall deficit, agriculture in the area is very uncertain. When the year is good, there is a surplus of crops, when it is bad, there is a shortage. But since bad years are more numerous than normal years, food insecurity reigns in the region. In addition to the rainfall deficit, agriculture also has other problems: the progressive impoverishment of the soil due to wind erosion and cultivation practices (non-use of fertilizers,), the lack of agricultural equipment (ploughs, etc.) and the existence of harmful insects, and the persistence of traditional production systems, etc. Poverty indicators confirm that a large majority, 94.4%, of the region's population is classified as poor in 2010, for example. These are those who have a level of aggregate consumption (food and non-food) below the national poverty line of 468,800 Ar/person/year ( ). This incidence of poverty is the same in both urban and rural areas. As for the intensity of poverty, which measures the average percentage difference between the consumption of the poor and the poverty line ( ), the level in Androy was 60.9% in 2010. It is 21.3% in urban areas and 38.3% in rural areas. Compared to the national situation, the incidence and intensity of poverty are more severe.

METHODS

Participant typology and selection criteria

This research chose the qualitative and indigenous methodological framework to investigate research questions centered on indigenous knowledge (Kovach, 2009), encompassing a worldview of relational and tribal knowledge. Qualitative research seemed to be the best research methodology to relate to farmers' livelihoods and cultural meanings in relation to weather and climate predictions. During the ethnographic fieldwork, the study sought to identify the first key subjects, those considered to be "experts" with traditional knowledge about the climate. The first step was to contact the local authorities to obtain information and, above all, to identify the heads of households (men and women) who had lived in the area for more than ten years and who must be over 50 years old. Informants who have resided in the area for a longer period will tend to have more reliable perceptions of the climate. This age criterion is explained by the fact that climate change is very slow and it is adults who may have experienced it. It is also assumed that at the age of 10, an individual is able to memorize certain key facts about the evolution of the climate and changes in the natural environment over the last few decades and to reveal them. These people are also expected to have knowledge of local indicators related to primary sector activities. Similarly, they could have the capacity to interpret local indicators that facilitate their climate forecasting, crop decision making and possible types of adaptation.

In addition, the category of subjects aged between 25 and 50 years, who are a young generation practicing agriculture and fishing as an activity. This age group was selected to identify and analyzes the level of transmission and perspectives of indigenous Ntandroy ecological knowledge in the rural world. These young generations were approached just to identify trends and perspectives of traditional knowledge on weather and climate under the effect of rural exodus and especially the disappearance of animal and plant species playing as climate indicators in Androy.

Sample and sampling technique

In order to be able to study the life context of the inhabitants of Beaniky and Antseky in depth, the sample size was aimed at information from key informants rather than in width. The qualitative surveys thus employed small samples with a relatively small number of people, studied in their life context of ecological knowledge. The sample size was determined by purposive sampling strategies to collect data on, among other things, local perceptions of climate change and endogenous adaptive measures based on traditional ecological knowledge. Data was collected from 44 targeted male and female household heads, farmers and fishermen, combined with historical climate data to assess participants' perceptions of climate change and variability, and to compare perceptions with historical trends from weather data. Meteorological data was collected from the Ministry's Meteorological Services available in the study area. Two types of data were used in this study: primary and secondary data. The secondary data were described and summarized quantitatively collected from the National Meteorological Service. The available historical climate data on rainfall and temperature for Ambovombe Androy covers a period of 38 years (1981 to 2019). In addition, community socio-demographic data were collected from local authorities for use in the descriptive statistics. Primary data was, in turn, collected from key informant interviews and interviews using semi-structured questionnaires with each participant. The questionnaire was structured in three distinct parts including (i) the assessment of indigenous climate perception and knowledge, (ii) the identification of local climate indicators; and (iii) the functioning of these local indicators.

Data analysis

Qualitative techniques of data analysis were used to analyze data collected from the field. Data collected from both primary sources and secondary sources were analyzed leading to the identification of aspects relevant to the informants in Beaniky and Antseky d' Ambovombe-Androy.Farmers' perceptions and experiences of the impacts of climate variability were reported qualitatively and analysed using simple descriptive statistics. The information obtained on weather and climate forecasting strategies through observation and indigenous interpretation of local indicators that are used for farmer decisions in managing the impact of recurrent climate shock was described using descriptive statistics. Finally, the role of traditional ecological knowledge from the indigenous perception of climate change and variability, the categories and varieties of local indicators and their functioning in relation to cropping calendars were presented in tabular form with comments. Thanks to such an analysis, it is possible to systematize and interpret the meanings attributed by local populations to environmental phenomena in order to be able to use them in risk management linked to climatic variability in the Ntandroy country in the search for food self-sufficiency.

RESULT

Socio-demographic characteristics of households

The characteristics of the participants are given in Table 1. The majority of participants were people over 50 years of age. Women accounted for approximately two fifths. Only one third of the heads of households were literate. Rainfed agriculture is the main economic activity of the majority of households in the area. Annual incomes are modest. Approximately three-quarters of the participants are Christians.

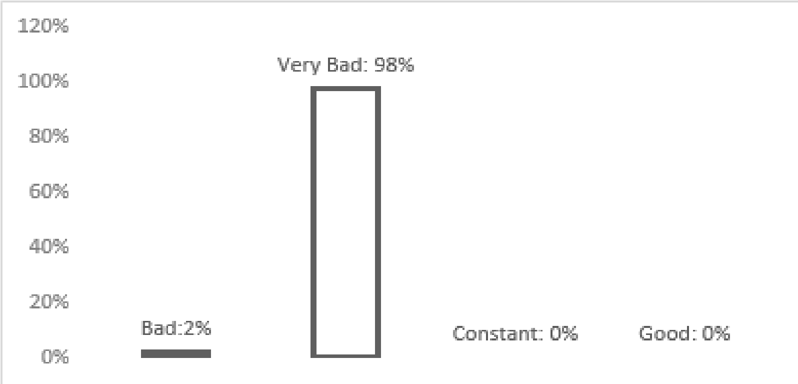
Table 1: Socio-economic characteristics of households

Characteristic (N=44)		Numbers	% of total
Age	25-50	20	45
	50-65	08	18
	>65	16	36
Gender	Female	17	39
	Male	27	61
Education level	Illiterate	33	75
	Literate (Primary level)	11	25
Subsistence activity	Fishing	3	7
	Agriculture	21	93
Religion	Traditional	12	27
	Christian	32	73

1-Peasant perceptions of climate variability in Beaniky and Antseky

The ethnographic surveys showed that the majority of participants (93%) perceive the reality of climate change (*Hamotson-taogne* / *Taom-polake*) by affirmation (Yes). Nearly 98% of the interviewees affirmed that climate variability is not favourable to agro-pastoral activities and that these hazards have negative impacts on community survival at a very bad level.

Figure 1: Perceived impacts of climate change on community well-being



Source: Fieldwork, 27-29 November 2020

Significant climate change

Climatic variability and disturbances have been noticeable in Ntandroy for several decades. The most significant changes in terms of the population's livelihoods are the decrease and unpredictability of rainfall, variations in the intensity and direction of winds, and the increase in temperatures. According to the information provided by the populations, these changes were observed around the 1970s but have intensified in the last decade or so. The older informants all mentioned that the change was felt "*since then sorghum cultivation has not been practicable in the coastal areas*". For the populations of these two study villages, times are no longer as they were before. Table 2 presents the perceptions of local communities on the effects of climate change.

Table 2: Summary of farmers' perceptions of climate change.

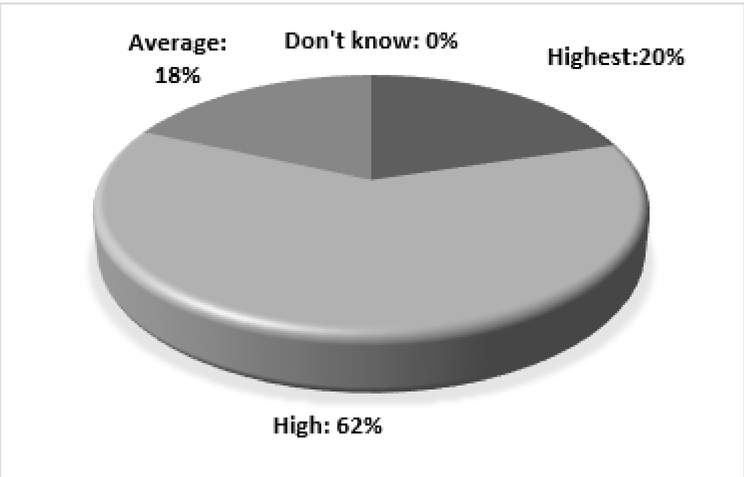
Climate parameters	Indicators of change
Rainfall	-Decreasing and almost absent rainfall -Early cessation of rains -Delayed rains -Rainy season duration shortened -Drought prolonged, severe and cyclical
Temperature	- Increasingly hot temperatures - Scorching heat
Wind speed (easterly)	-Increasingly strong winds - Frequency of dust fog -Permanence of easterly winds -Silting up of crop plots -Drying up of young and cultivated plants

Source: Fieldwork, 27-29 November 2020

2-Level of indigenous knowledge about climate

Community knowledge of weather forecasting is an important element of the ethno meteorology concept. It is based on traditional ecological knowledge passed down from generation to generation. Based on the continuous and multi-generational experiences of the farmers in Beaniky and Antseky, the interviewed populations responded positively with 100% yes to the perception of variability of local crop seasons. The interview showed that they possess local ecological knowledge such as: highest (20%) and high (62%) and 0% have no knowledge.

Figure 2: Level of indigenous knowledge about climate



Source: Fieldwork, 27-29 November 2020

3- Local indicators and their functioning

Indigenous peoples have a high level of climate knowledge (62%) from which they observe and interpret the main local indicators in three categories by priority: abiotic and astronomical indicators, animal indicators and plant indicators.

1-Atmospheric and astronomical indicators

Atmospheric and astronomical indicators are mentioned by 68% of the indigenous peoples. A total of 05 groups of atmospheric and astronomical events were specified during the interviews. The local people's observation and interpretation of this type of indicator is directly related to changes in atmospheric conditions affecting the appearance of the sky and the type, intensity and direction of the winds. These changes are clearly visible and perceptible to the local people, and they are clear signs of this.

Table 3: Local weather forecast indicators of atmospheric types

Type of indicator		**Description/ Event**	**Seasonal quality**		**Month of occurrence**
			P	G	
I-ATMOSPHERIC AND ASTRONOMICAL INDICATORS					
Medium and long term effect	The Moon *(Volañe)*	Red fire color	x		December *(Safary)*
		Concave	x		
		Tilted		x	
	Cloud *(Rahoñe)*)	Direction/Formation from North to South		x	October-November *(Saramañitse - Vatravatra)*
	Wind *(Tioke)*	Direction East to West	x		December-February *(Safary-Hatsiha-Valasira)*
		Direction South/North/West		x	
	Lightning and Thunder *(Hotroke - Varatse)*	Night blow from the Ocean		x	October – November *(Saramañitse - Vatravatra)*
	Fog *(Zono)*	Making the landscape wet every morning		x	September-October *(Saramanty-Saramañitse)*

Where P: Poor; G: Good

2- Animal indicators

Predictors of animal origin were the most numerous and specific signs mentioned in relation to weather conditions, whether terrestrial or aquatic (marine) at 53%. In total, 19 different species were identified, whose prediction levels can be divided into three: immediate, short-term and medium to long-term impacts. Wild and domestic animals are used to predict weather variations. They are usually found close to houses, which facilitates their continuous observation and inventory of their characteristics, e.g. cattle and goat species.

Table 4: Local climate prediction indicators of animal species

Type of indicator		Description/ Event	Seasonalquality P	Seasonalquality G	Month of occurrence
		II-ANIMAL INDICATORS			
With immediate effect	Termite *(Vacambaxo)*	emerging from its termite mounds		x	In all seasons
	Chameleon *(Taña)*	Opening its mouth towards the sky.	x		December-January*(Safary -Hatsiha)*
	Sea Grasshopper*(Valalandriake)*	swimming towards the West against the wind		x	All seasons
	Sea-Pig *(Lambondriake)*	Moving westward against the wind		x	idem
	Swallow *(Tsikiriokirioke)*	They play and fly high in the sky		X	Idem
Medium and Long Term	Squid *(Bolaoka)*	Are found dead in the seashore	x		July - September*(Sakavey -Saramanty)*
	Trozoñe *(Whale)*	Bathe their babies in the surface of the sea		X	November - December *(Vatravatra-Safary)*
	Sardine *(Sokeky)*	Appears abundantly in the oceanic zone	x		In all seasons
	Bee *(Tantely)*	Massive hiveabandonement	x		August-September *(Volambita-Saramanty)*
		Flock to and enter caves and tree trunks		x	
	Locust *(Valalabijaja)*	Spread in swarms	x		April-July *(Asotry)*
	Thunder Grasshopper *(Valalanamy)*	Breed abundantly in all landscapes		x	January-February*(Hatsiha - Volasira)*
	Taotaonkafa	Move far to coastal areas singing its song		x	December-January *(Safary - Hatsiha)*
	Wild parrot *(Vazaña)*	Moves from north to south to peck sorghum cobs	x		April-July *(Asotry)*
	Sheep *(Añondry)*	Shakes its furs every morning		x	*Not precise*
	Cattle *(Añombe)*	Crunches bones, remains of cloths and human excrement	x		*Not specified*
	Cow *(Añombevavy)*	Sprays her urine to humans from her tail		x	

Where P: Poor; G: Good

3- Plant indicators

Wild and cultivated plants are used for climate prediction in Androy at 34%. Their observation and analysis are mainly done during the dry season (May-December), and during agricultural activities, from January to August. These plants are commonly found throughout the landscape, in or around agricultural plots (Teteke or Tonda) and are part of the agro-forestry systems of the Androy region. A total of 06 plant species were mentioned during the interviews. The analysis of local populations is linked to two distinct phenomena, namely fruiting and flowering, whether they are abundant or scarce on the one hand, or early or late on the other.

Table N° 5: Indicators of local climatic forecast of plant species

Type of indicator		**Description/ Event**	**Seasonal quality**		**Month of occurrence**
			P	G	
III-PLANT INDICATORS					
Medium and Long-term effect	Tamarind *(Kile)*	Fruits abundantly in all landscapes	x		June - September *(Asotry-Faosa)*
	Lamoty	Abundant fruiting	x		August-October *(Faosa)*
	Sike(Herambazaha)	Early flowering		x	November-December *(Vatravatra-Safary)*
		Late flowering			
	Fengoke	Abundant flowering		x	idem
		Rare flowering			
	Voandelake	Early flowering/ abundant		x	November-December, *(Vatravatra-Safary)*
	Prickly pear (Raketa)	Abundant fruiting		x	October-December *(Faosa-Safary)*

Where P: Poor; G: Good

DISCUSSION

To our knowledge, this study is the first small-scale qualitative attempt to assess the knowledge and perceptions of vulnerable communities in the two rural villages of Ambovombe-Androy about climate variability. The results provide important information on what people think, believe, observe and know from their local experience about the impact of climate change on livelihood activities and especially the ways in which people manage it. Most of the participants interviewed were men (heads of households) for specific reasons. The community studied is 'patriarchal' in character, yet a quarter of the population was female. The majority of participants were relatively poor and had no formal education, with livelihoods based on agriculture and livestock. Fishing is marginal, despite the fact that our study sites are all on the edge of the Indian Ocean, due to the ancestral restriction that this sector does not go hand in hand with pastoral activity. Nevertheless, they have a clear perception of climate change and variability through the practice of these three subsistence activities promoting contact with the multidimensional environment.

An important personal variable studied was the participants' perception of the reality of climate change and variability. It is surprising how many articles in the wider global climate change literature do not address local perceptions at all. Research to date suggests that these changes exceed the threshold of human perception over a lifetime (Mormont and Dasnoy 1995, Doyle 2009, Spence et al.2011, Rudiak-Gould 2013). Others argue that the effects of change are visible to the naked eye (Riedlinger and Berkes 2001, Green et al.2010). Among farmers in coastal regions of Bangladesh, household size significantly influences the perception of climate change (Uddin et al. 2017). The perception of a change in rainfall pattern increases with the level of education of the producer in the locality of Yanfolila in southern Mali (Sanogo et al. 2016). However, the results of our study dispute the influence of the population's level of education on its perception. The majority of our population (75%) were all illiterate yet their perception of "yes" to local climate change was 93%. The study could conclude that people's education level is not always correlated with perception. Furthermore, differences between the gender and age groups of respondents do not affect the perception of climate change, only that it is related to responsibility as head of household (regardless of age and gender).

Another variable is knowledge of climate variability. In line with Ogunlade et al. (2014) and Al Buloshi and Ramadan (2015), more than half of the respondents had an excellent level of knowledge. In Rodriguez-Franco and Haan (2015), more than 90% of respondents were well informed about climate change. But in contrast to our finding, for example, Kabir et al. (2016) found that education level was significantly associated with knowledge about climate change. Our result showed that about 80% of the respondents have in-depth (higher and high level) knowledge of climate change yet the study was conducted on predominantly illiterate (75%) and primary school educated (25%) populations. One could conclude that the high level of climate knowledge of the respondents in this study was not due to their certain level of education. Our finding could further conclude that the level of climate knowledge is not correlated with the level of education of the person. It is acquired through contact and interaction with the environment. Therefore, the way in which people perceive and experience environmental change is very likely to be shaped at least in part by existing vernacular conceptions of the environment, whether they are referred to or theorised as local cosmologies, local classification systems or ontological regimes (Orlove et al. 2002, Descola 2005). Traditional ecological knowledge can inform various aspects of climate change assessments (Parrotta and Agnoletti 2012). Traditional ecological knowledge is based on the accumulation of long-term, land-based wisdom gained from experiences with organisms, habitats, ecosystems and ecological processes. Therefore, this way of knowing allows for the comparison of historical landscape conditions with current conditions (Parrotta and Agnoletti 2012).

Climate indicators

There is a growing number of studies on local weather forecasting in different parts of Africa and the world. It is worth noting that many of these have been conducted in land-based areas focusing on farmers' knowledge. For example, a study by Chang'a et al (2010) revealed how farmers in the highlands of southwestern Tanzania predict rainfall using local environmental indicators and astronomical factors. Kijazi et al. (2013) reported on the role of farmers' and herders' indigenous knowledge in weather and climate prediction in Mahenge and Ismani wards in Morogoro and Iringa regions, respectively, for example. Few studies have focused on marine areas. However, Tobisson et al (1998) conducted a study to try to understand how fishing communities in Zanzibar make the best use of local knowledge about tides and monsoons in their fishing activities. Unfortunately, this study did not explicitly state how fishermen's knowledge is used to predict different weather parameters. The choice of our study site was motivated by the geographical position (coastal), where mixed subsistence activities (agriculture and fishing) are practiced. Our study therefore helps to fill this gap as all respondents are aware of and have mentioned marine predictors for weather forecasting through their contact with the sea. Moreover, livestock activities (cattle and goats) are mostly developed by drinking half-salted water at the sea (rano hoba) every three days. The indicators used by farmers, herders and fishermen to predict the quality of the rainy season are thus available throughout the year. Indicators that farmers rely on further include fruit production and tree phenology, animal behaviour (land and sea), wind and weather phenomena and manifestations in the form of divinations, visions and dreams for local diviners. Our findings show that abiotic predictors significantly predominate (68%) over animal and plant predictors due to environmental deterioration. When Ms Harena and Hovosie state that: "Often we are lost, and can't even figure out what climate prediction we can expect because of the huge variability. These young female participants mentioned that there are some people in the villages and groups who have a higher level of commentary and reading of local indicators associated with the quality of the coming seasons. This result reflects, therefore, that comments on local indicators are generally more specific and based on the older male gender than the women.

CONCLUSIONS

The study assessed the relevance of indigenous knowledge of the villagers of Beaniky and Antseky, Ambovombe-Androy Madagascar. The results showed that the local indicators commonly used for weather and climate forecasting fall into three categories, namely plant, animal and abiotic indicators. Their views illustrate the multifaceted nature of traditional knowledge and its role in weather and climate forecasting for planning and management of agricultural activities of farmers and fishermen in the context of climate variability. Traditional weather and climate observation systems and the management of variability and hazards have been the predominant focus in the context of climate change (e.g. Salick and Ross 2009; Green et al. 2010; Lefale 2010). Climate change and its risks are a global concern (Al Buloshi and Ramadan, 2015) but due to the different social context, the way communities and individuals perceive it, the level of knowledge and the way they behave in the face of this phenomenon are different. In this regard, Niles et al (2016) stated: "The way individuals perceive climate change is very personal, grounded and influenced by a number of factors". Local perceptions are thus essential for designing successful and sustainable natural resource management programmes in small-scale societies wherever they are located (Oldekop et al. 2012). They need to be understood as part of larger knowledge systems that have been developed locally, through repeated interactions with the environment, and passed down through generations.

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