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Indigenous Climate Perception and Agricultural Management: Insights from Local Indicators Functionning in the Rural of Ambovombe-Androy, Southern Madagascar

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Abstract

Climate change is a pressing global challenge that affects communities worldwide, particularly indigenous peoples who have cultivated a deep relationship with their environment over generations. The understanding of climate change is often derived from a rich tapestry of traditional knowledge, local indicators, and lived experiences that shape their agricultural practices. This article explores how indigenous perspectives on climate perception and agriculture management provide valuable insights. It also characterized the perceptions of the inhabitants on climate change impacts through determining the type of local indicators linked on weather forecasting. The ethnographic field study was conducted with 44 respondents who had not left the localities in the past 10 years and were selected by purposive sampling. Data was further analyzed qualitatively by content analysis given the prevalent use of Likert and Osgood type scales analyses, Correspondence Analysis (CA) and Discriminant Analysis (DA). The data were collected on indigenous perceptions and knowledge of climate, types of indicators and their functioning. The findings showed that 93% of the participants perceived the reality of climate variability. This change exposed the farmers to negatives impacts (100%). Local people possessed high level of climate knowledge (61%) from which they identified main 27 local time markers in the zone of Ambovombe-Androy. This diversity implies that the populations rely mainly on the plant, animal and abiotical indicators present in their immediate environment to direct and adapt their agricultural activities/calendars. Moreover, recognizing the indicators of climate change highlighted by indigenous communities can inform scientific research and climate action initiatives. This collaboration can bridge gaps in understanding and leverage combined expertise to create holistic climate solutions.

Keywords: *Weather Forecasting; Livelihoods; Climate Change; Sustainability.*

I. INTRODUCTION

The devastating consequences of climate variability threaten to plunge millions of people in Africa into extreme poverty as seasonal agriculture is strictly associated with the climate of a specific zone and is linked with the annual and transannual climatic variability (Andersson et al., 2020). Adjustments within these multiple perspectives are required in response to actual or expected climate changes by modifying processes, practices, or structures to mitigate damage or exploit opportunities (IPPC, 2024). Thus, with the focus on Indigenous Knowledge (IK), climate change adaptation involves adjusting to the physical environment or human systems in response to potential or anticipated climatic shocks and their impacts (Jiri et al., 2016; Kom et al., 2023; Taylor et al., 2023, Tashi et al., 2024). IK is defined as a collection of knowledge, beliefs, practices, traditions, and customs outlining the relationships between organisms (including humans) and their environments that have evolved through adaptive processes over time and have been passed down through generations via cultural transmission (Dean 2023; Rarai et al., 2022; Li and Han 2022; Maliao et al., 2022; Vargas 2019; Kupika et al., 2019; Mangada 2021). Indigenous practices refer to the application and utilisation of IK in real-world contexts and

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putting into action the skills, beliefs, and cultural practices of indigenous peoples in various areas of life, such as agriculture, medicine, environmental management, education, and community governance. The practices are deeply embedded in the cultural heritage and environmental understanding of Indigenous communities (Hooli 2016; Apraku et al., 2021; de Scally and Doberstein 2022).

Thus, the indigenous farmers have evolved adaption and response practices to the climatic demands. This change may be a global phenomenon, but its effects will not be evenly distributed among the world's population. Climate change is causing significant environmental changes, such as recurrent droughts that accelerate the decline of forests (Olivares and Lopez, 2019; Pitti et al., 2021), but these severe droughts can also lead to primary impacts such as acute food shortages, loss of livestock, as well as malnutrition and other health-related issues (Hales et al., 2014). In addition, this phenomenon has secondary impacts such as migration from rural to urban areas (Eriksen et al., 2005; Dercon and Porter, 2014). Particularly in Androy region, climate variability has a profound influence on the quality of agricultural production and determines livelihoods in terms of food security (Ravohitrarivo et al., 2011). Since 1931, a major drought has been recorded, leading to displacement and loss of life of the population in the sedimentary zone (KIOMBA-MADIO, 1997, Canavesio, 2014). 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 decrease and irregularity of rainfall leads to a variation in climate that forces farmers to restructure their cropping calendars. The latter, less informed about national weather forecasts (Chisadza et al., 2014; Matewos, 2020), mobilize their knowledge and skills as well as available resources to adapt to climate variability (Retnowati et al., 2014; Clifford et al., 2020). The IPCC (2014) defines local knowledge as “indigenous, local and traditional knowledge systems and practices, including indigenous peoples' holistic views of their communities and environment”. The knowledge and experience of the Ntandroy (the inhabitants of Androy region) 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. They thus constitute benchmarks of primary importance used to adapt to climate change (Son et al., 2019). Indigenous people predict weather with signs of warning of impending disasters using social, bio-physical and ecological indicators (Apraku et al., 2021; Granderson 2017; Hiwasaki et al., 2015). They pay attention to behaviour and appearance of various environmental entities like insects, plants, birds and animals (Inaotombi and Mahanta 2018; Launio et al., 2020; Chaudhary et al., 2021; Filho et al., 2022; Ingty 2017); moon-star alignment (Filho et al., 2022); animal intestine interpretation (Filho et al., 2022); and tide flow, snowdrifts, and direction of currents (Shaffril et al., 2020) and more. Such knowledge is often used to develop the traditional seasonal calendars, which consist of complex, locale-specific environmental observations. These calendars guide Indigenous people in their activities, dictate social events like ceremonies and weddings, and help predict seasons, floods, storms, big waves, and droughts (Hiwasaki et al., 2015). Numerous scientific studies are helping to identify, document and analyze ethnoclimatic knowledge for integration with national weather data (Cornell et al., 2019; Andersson et al., 2020; Falconer et al., 2020; Rasmus et al., 2020). The phenological stage of certain plant species, the observation of the abundance of certain types of animals (marine and terrestrial) at a certain time of the year, as well as the change in wind direction, the appearances and shapes of celestial body elements constitute crucial information that indigenous populations use to monitor, direct and adapt their agricultural activities (Mhita, 2006; Udmale et al., 2014).Various studies have also focused on the local perception of the natural disasters. Furthermore, adaptation strategies based on traditional knowledge have been identified by various authors for preventing floods and droughts (Masinde 2015, Paredes-Trejo and Olivares, 2018; Cortez et al., 2018). The perception of indicators is part of an adaptive management logic that allows farmers to manage agricultural seasons (Gyampoh et al., 2009; Sánchez-Cortés & Chavero, 2011). Through their practice, the knowledge they create, share and maintain, strengthens their climate resilience and offers a window into how communities conceptualize their own vulnerability (Hiwasaki et al. 2014).

Androy region is characterized by high climatic variability and is one of the driest regions in Madagascar. It is prone to severe and cyclic droughts and experiences high intra-seasonal variability during the rainy season. Nevertheless, research on this topic remains very little investigated in Madagascar, especially in the Androy region, despite its importance for the indigenous populations, who are generally vulnerable, and the climatic emergency. This study proposes to analyze and valorize local knowledge on bio-temporal indicators used in the Androy zone. Specifically, it will: inventory the biophysical indicators used in decision making on the agricultural activities /calendars; characterize the perceptions of the inhabitants on climate change through determining the plant, animal species and the positions and appearances of atmospheric elements common in human activities, particularly in the rural villages of Beaniky and Antseky surveyed.

- *Presentation of the Study Area*

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) (Monography, 2013). 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.

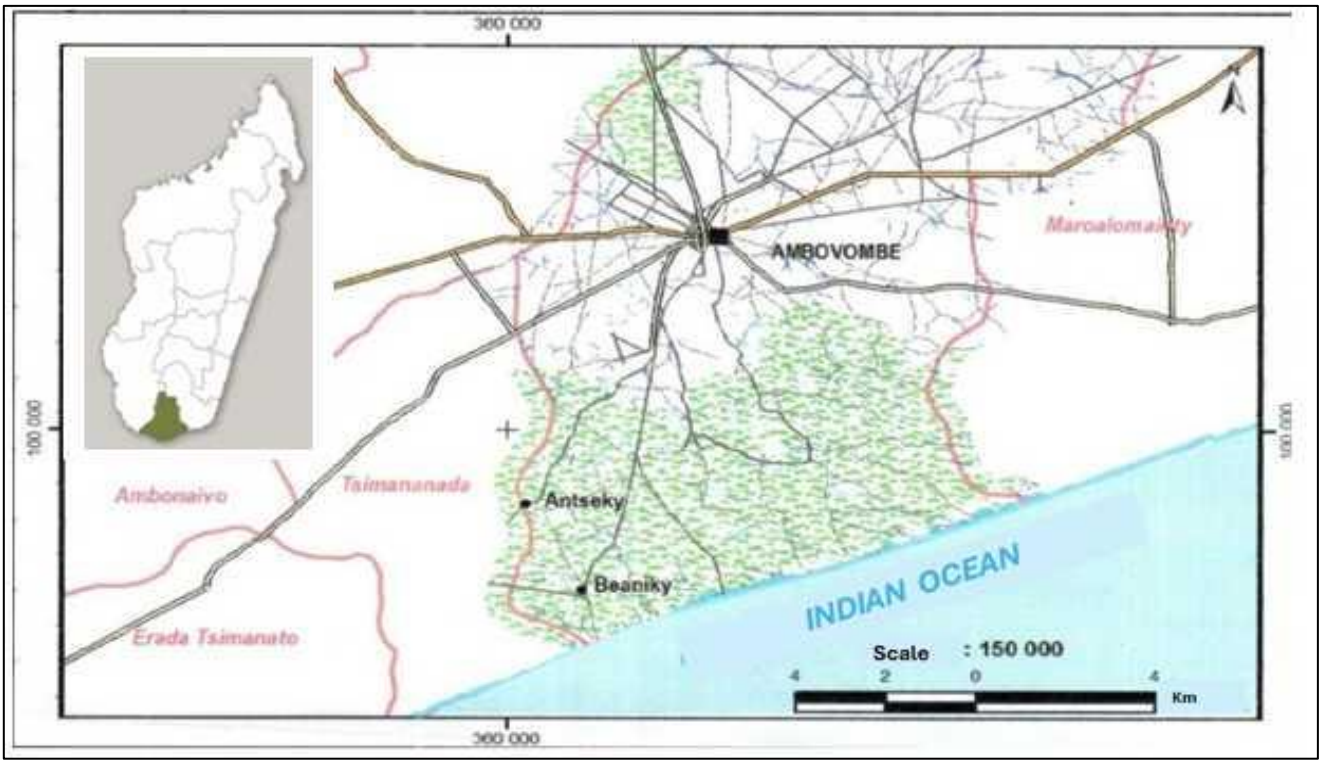

Fig 1 Study Sites Location
(Source: FTM, 2021)

➢ *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, grayish 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 (Monography, 2013). 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 favorable. 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 (Monography, 2013). 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. Fisheries and marine resources have been exploited for only a few decades in Ntandroy territory after having long suffered from the impacts of climate change for about 90's.

II. METHODS

➢ *Participant Typology and Selection Criteria*

This research chose the qualitative and indigenous methodological framework to investigate research questions centered on indigenous knowledge (Kovach. M, 2012; 2006), encompassing a worldview of relational and tribal knowledge. The recognition of indigenous research work conducted by indigenous research methodologists such as Wilson (2008), Smith (2012), Denzin, Lincoln and Smith (2008). Kovach (2010), and Chilisa (2012), who resisted the colonial research approaches, are highly acknowledged. The study considered indigenous research methodologies because it advocated for an anti-colonial discourse. Qualitative research seemed to be the best research methodology to relate to farmers' livelihoods and cultural meanings in relation to weather and climate predictions. The study is exploratory in nature since it assesses indigenous adaptations to climate variability. Qualitatively, information from farmers pertaining to

adaptations of rain-fed agricultural systems was obtained using a closed-ended questionnaire, focus group discussions, expert interviews in key sectors involved in climate and agriculture. The questionnaire used a five-point Likert scale (Likert, 1932; Joshi et al., 2015) to assess farmers' indigenous climate knowledge (very high, high, very low, low, and unknown). In addition, Osgood's differential semantic scales (Osgood et al., 1957) that allow for the analysis of both the content and the intensity of respondents' attitudes towards the concept of indigenous climate knowledge. This common body of reference is composed of the main dimension: evaluation (good-bad). 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 (10) 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. Furthermore, 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 analyze the level of transmission and perspectives of indigenous 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 local 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.

➢ *Experiment*

- *Analysis of Perceptions of Trends in Significant Climate Parameters*

The concept of "perception" falls within the field of psychology. Its relative nature stems from the fact that a judgment of perception results from comparing farmers' subjective experiences with a standard of comparison based on their knowledge of the past. The objective was to gain a deeper understanding of perceptions regarding the influence of climate variability on community subsistence activities. The approach involved asking an open-ended question. The Likert and Osgood scales were used to gauge the intensity of respondents' agreement by presenting them with statements pre-incorporated into a scale and asking participants binary-response questions (Yes, No); the responses were then recorded and transcribed. Correspondence Factor Analysis (CFA) and Pivot Table (PT) were used to identify the most recurrent climate variations based on perceptions of trends in significant climate parameters over the past few years. The qualitative variables studied are the significant climate parameters mentioned in the participants' discourse analysis.

- *Assessment of Perceptions and Impacts of Climate Change Conditions*

The assessment of perceptions was conducted using a "semantic" scale among individuals whose families had lived in the area for more than ten years. Among them, participants were asked for their views on climate change in their local environment specifically, how they felt, feel, and think about climate change. They were asked to assess how they have experienced the effects of climate change in recent days and over the past 10–15 years. The objective was to understand perceptions of the impacts of climate variability on the communities' sustainable livelihoods. CFA and PT were used to highlight the impacts of climate change conditions as perceived by the community over the past few years. The variables highlighted were perceptions of changes related to the age of the farming populations.

- *Identification of the Level of Indigenous Climate Knowledge*

The concept of local knowledge was clarified during interviews conducted using individual questionnaires and focus groups. Participants' lived experiences were therefore examined in the analysis of perceptions regarding the effects of climate change on the activities of local farmers. The objective was to determine whether local populations are able to predict the quality of upcoming growing seasons by providing binary responses

(Yes, No). This allowed participants to express their agreement or disagreement based on their knowledge and experiences, using a 5-point Likert scale to evaluate the proposed strategies. Analysis of farmers' climate forecasting ability identified the following variables: the age of the populations and their respective levels of climate knowledge.

- *Identification of Types of Local Climate Forecasting Indicators and How They Work*

The goal is to determine whether there are direct ways to predict the climate at the local level. Sources of indigenous knowledge, the process of their development, and the mechanisms of exchange and transmission within communities were identified through household surveys. Climate phenomena are perceived through sensory and psychological means. The occurrence of climate phenomena is signaled by indicators that exist in the environment and that shape people's perception of the state of the climate. Discourse analysis was employed. CFA was used to highlight the typology of local climate prediction indicators and their corresponding functions. Analysis of participants' statements made it possible to distinguish the main groups of indicators, their predictive effects, and the corresponding quality of the predicted season.

➢ *Data Analysis and Processing*

- *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. Farmers' perceptions and experiences of the impacts of climate variability were reported qualitatively and analyzed 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.

- *Data Preparation and Processing*

Data analysis was conducted using multidimensional methods with XLSTAT 2016 software: Correspondence Analysis (CA) and Discriminant Analysis (DA). The purpose of this method is to characterize the available thermo-climatic trends in order to compare them with community perceptions. Using XLSTAT 2016 software, the processing of this secondary data allows for the creation of a CFA plot showing the degree of disagreement or agreement between perceptions and significant climate parameters. In addition, the Likert and Osgood scales are used to assess perceptions and the impacts of climate change conditions. As for the Discriminant Factor Analysis (DFA), its objective is to identify the sources of indigenous knowledge that farmers relied on to better understand and, to the extent possible, respond to environmental changes, as well as to forecast, manage, and adapt their activities and cropping calendars appropriately. Local climate forecasting methods were identified and presented in tabular form.

The qualitative data collected from direct interviews were entered and cleaned in Excel by removing missing values or those that appeared to be outliers. Qualitative variables take the value 0 or 1. All quantitative variables were transformed into Reduced Centered Variables (RCVs) using the formula :

$$RCV = (xi - x) / \sigma$$

Where

X = The original raw value
$\boldsymbol{\mu}$ = The arithmetic mean of the population or sample
$\boldsymbol{\sigma}$ = The standard deviation, which measures the dispersion of the data.

It transforms different datasets to a standard normal distribution (mean = 0; SD =1) for comparison

III. RESULTS

➢ *Socio-Economic Profiles of the Participants*

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. Rain-fed 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	37
Gender	Female	17	39
	Male	27	61

Education level	Illiterate Literate (Primary school level)	33 11	75 25
Subsistence activity	Fishing Agriculture	3 41	7 93
Religion	Traditional Christian	12 32	27 73

Source: Fieldwork, November 2020

➢ *Local Perception on the Climate Change*

The phenomenon of Climate Change is widely known by its name in a local language: *Hamotson-taogne / Taom-polake*. The study revealed also that the majority (93%) of participants perceived an effect of climate change on their daily activities, while 7% were uncertain. Fig. 2., presents the perceptions of local communities on the reality of climate change.

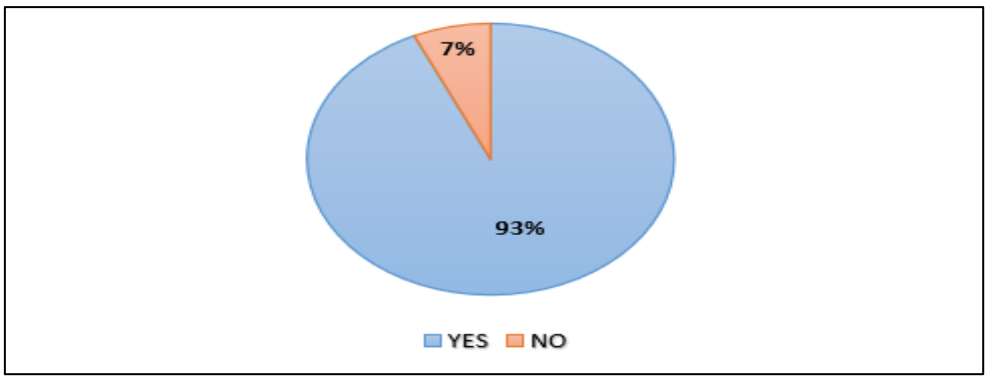

Fig 2 Local Perception on Climate Change
Source: Fieldwork, 2020

➢ *Community's Perception on the Climate Change and its Impacts*

- *Perception of Significant Climate Trends*

Rural communities have close ties with their surrounding environment. The most significant changes affecting people's livelihoods relate in particular to the decline in rainfall and its unpredictability, variations in wind intensity and direction, and an increase in perceived temperatures. According to Correspondence Analysis (CA), the population has three (03) types of perceptions of climate change (Fig. 3) : 'Very Bad', 'Bad' and 'Constant'. The first corresponds predominantly to the permanent effect of the Easterly Wind (W_E), whilst the second is linked to Precipitation (P°). The 'Constant' perception, meanwhile, corresponds to Temperature (T°). The community perceptions 'Very Bad' and 'Bad' are variables that correlate with the two climatic parameters W_E and P°, given that the angle between F1 and F2 is less than 90°. This means that the negative impact of climate change experienced by farmers is linked as much to the level of precipitation as to the dominance of the East Wind. The pressures exerted by these two climatic parameters are highlighted as being highly significant. Nevertheless, the heatwave exerts an opposing influence (the angle between F1 and F2 is greater than 90°) on two other parameters. The lack of rain, exacerbated by persistent strong winds, is drying out the ecosystem. Even when there is heavy rain, and easterly winds prevail as a result, the communities fear crop failure.

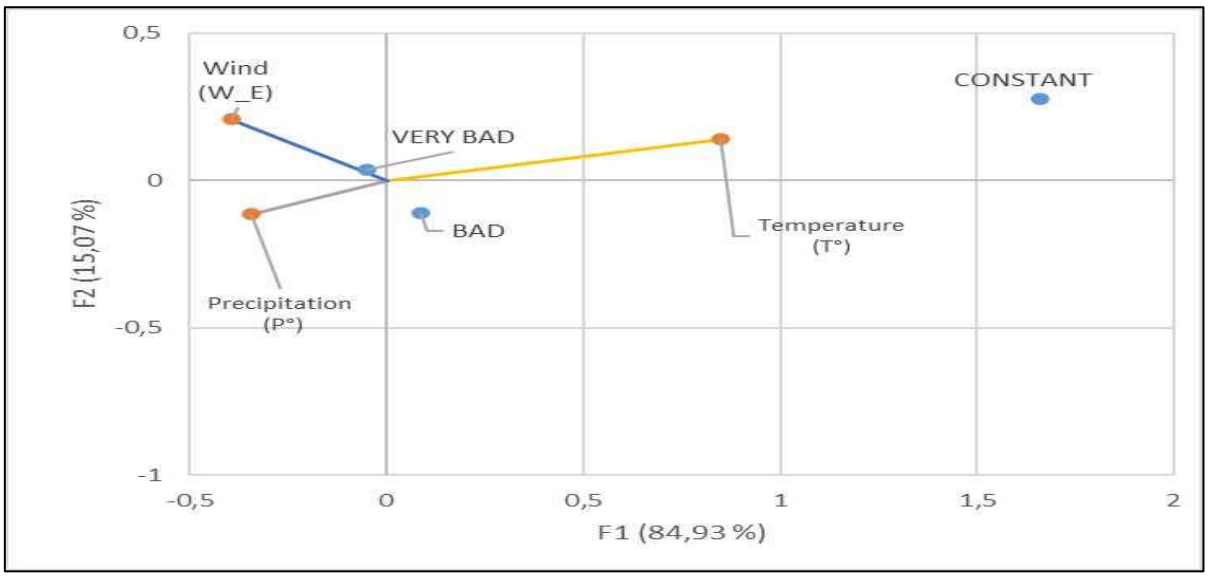

Fig 3 Correspondence between Climate Parameters and Local Perceptions

- *Climate Parameters Trend in Androy Area*

In Androy, the most important climatic factors for rain-fed agriculture are rainfall, temperature and wind. Thus, in the framework of our study, the climate factors that were analyzed are: rainfall (number of rainy days and rainfall amounts), temperatures (minimum and maximum) and winds (seasonal dominance, direction and speed). Data collected over 38 years (1981–2019) of rainfall records in Ambovombe show a downward trend in annual precipitation of 175 mm. Since 1981, annual precipitation has ranged from 575 mm to 400 mm. Average annual rainfall of 400 mm or less corresponds to years of famine (Kere), which result from food shortages leading to Sorondrano ritual practices. The climatological record for Ambovombe Androy has documented eight (08) instances of food crises in which annual rainfall was less than 400 mm. These low rainfall levels significantly reduce crop production and have severe and prolonged impacts on food security. In the eight observed cases of extreme drought, the sharp decline in rainfall coincided with rising temperatures. These quantitative findings were compared with the socio-psycho-anthropological perceptions of the stakeholders regarding their memories of overall vulnerability, as reflected in the vernacular terms used to describe periods of food scarcity.

The last climatic parameters, changes have been felt by the local population, from the 90s, concerning the winds. They concern both their intensity, their direction and the periods of occurrence. Other than the decrease in rainfall and the overwhelmingly dry warming, the easterly winds are the most formidable in Androy. The entire population (100%) recognizes this great change that has not been experienced as before. This easterly wind is dangerous for livelihoods and community activities in Androy. In general, however, the windy periods are more numerous, violent and longer. The average hourly wind speed in Ambovombe is higher at 19.1 kilometers per hour. The windiest period of the year lasts 3.2 months, from 31 December to 6 April. Throughout March 2019 in Ambovombe, for example, the scientific information on the average hourly wind direction, in order of prevalence, comes from the east (74%), south (16%), north (6%) and west (4%). For Ambovombe, the average annual wind speed with a normal value (1980-2009) is 3.64m/s at 10m from the ground, with a maximum of 4.65m/s in February and a minimum of 2.58m/s in June (NASA, 2010)

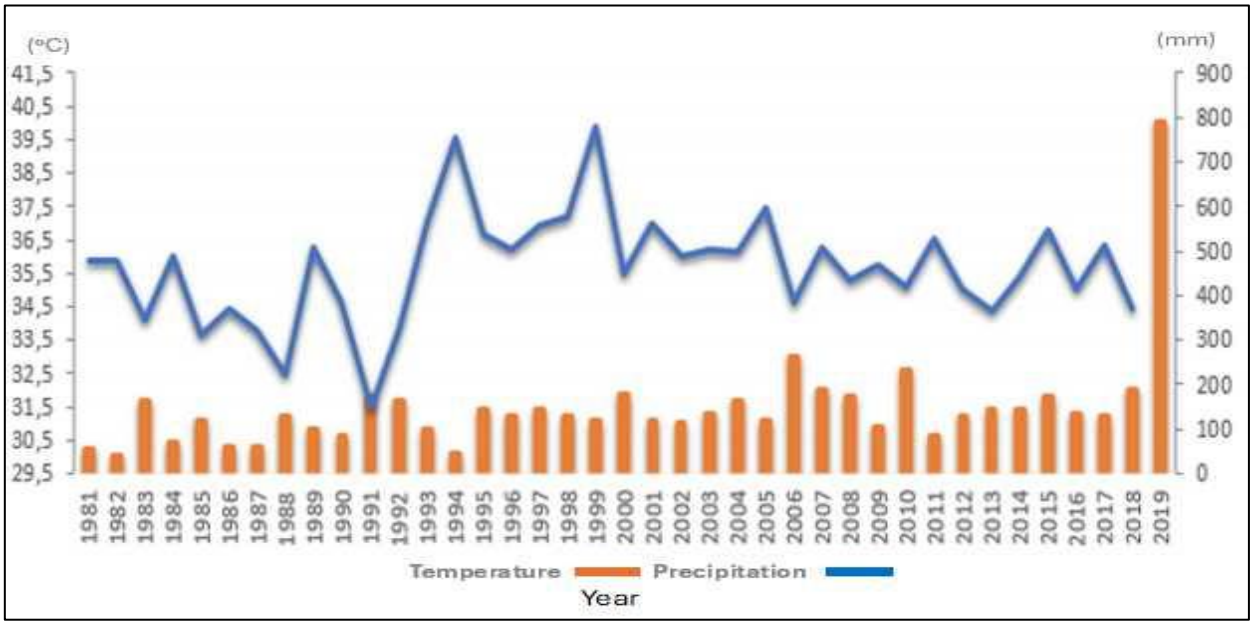

Fig 4 Trends in Climate Parameters in Androy (DGM, 2020)

- *Climate Change's Perception on Community Well-Being*

Ethnographic surveys have shown that participants recognise the reality of climate variability, which is described using various concepts in the local dialect that explain it. The majority of participants nearly 98 per cent of those interviewed state that climate variability is not conducive to subsistence activities and that these uncertainties have a negative impact on community survival (Fig.5). Three types of perception have been identified by the DFA. Of these, the 'Bad' and 'Very Bad' perceptions are linked to older participants (aged 45 and over). The younger the participants (aged 25–45), the more their awareness of the phenomenon is 'Constant'. The younger generations' sense of indifference reflects the fact that their judgement lacks a solid frame of reference, given that the effects of climate change are only perceptible over the course of decades. Conversely, older people (aged 45 and over) are more sensitive and perceive climate change as 'Very Bad'. These perceptions regarding older and elderly people mean that they have been able to compare successive decades with one another and have deduced that there has been a noticeable negative change. Furthermore, the high level of sensitivity among older people reveals their degree of vulnerability. Their comparison of the past with the present leads to a feeling of insecurity.

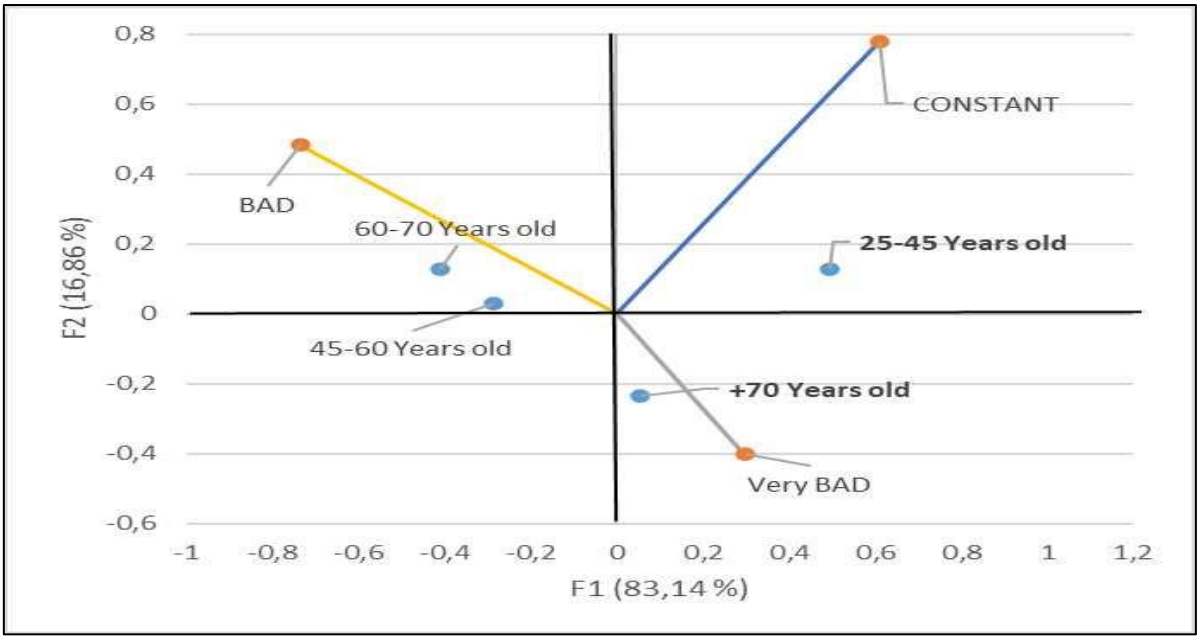

Fig 5 CC Impacts on Local People Well-Being

➢ *Level and Sources of Local Meteorological Knowledge*

- *Level of Meteorological Knowledge*

The community's knowledge of weather forecasts is an important element of the concept of ethno-meteorology. The interview revealed that they possess a high level of local ecological knowledge. Three levels of knowledge were identified (Fig.6): 'Very high', 'High' and 'Average'. The age of the participant determines the community's level of ecological knowledge. Younger people have less knowledge (average level) in this area compared with older participants. The 'Very high' and 'High' levels are attributed to farmers aged 45 and over. The older the farmers are, the greater their level of ecological knowledge, as this is based on continuous, multi-generational experience. Moreover, the phenomenon of climate change can only be observed locally over a period of several decades. The level of local meteorological knowledge is correlated with the age of participants.

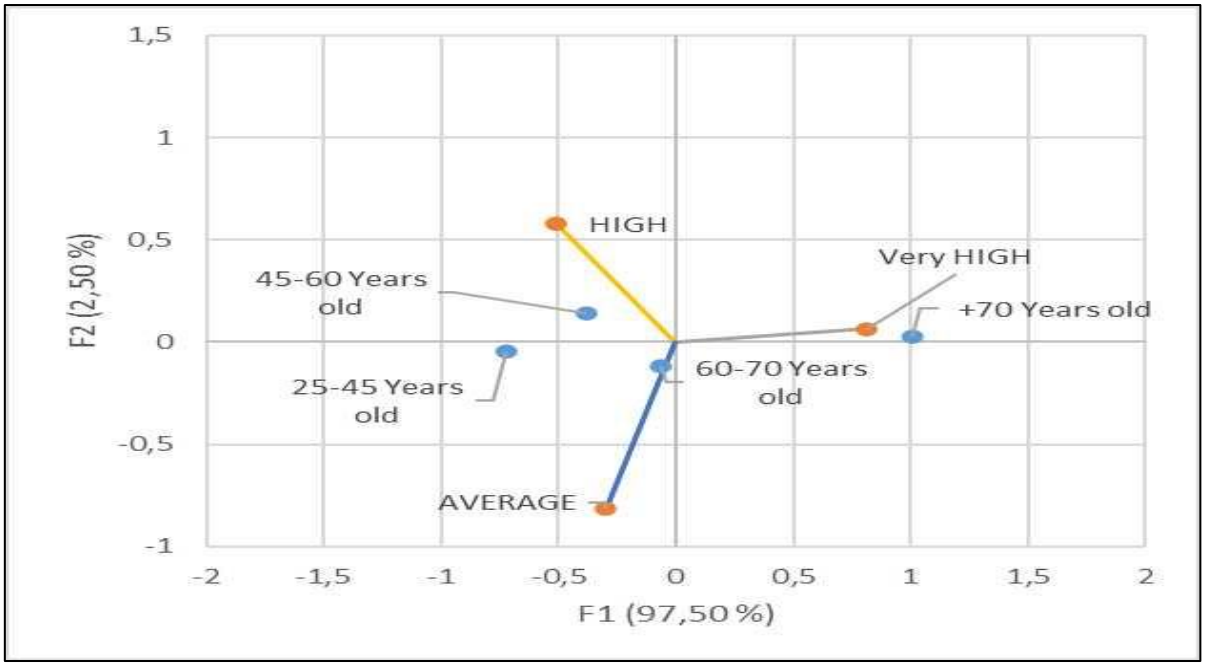

Fig 6 Local Knowledge Level Correlation with the Age of Participants

- *Local Climate Indicators and How They Work*

Discriminant Factor Analysis (DFA) has made it possible to identify three main groups of indicators: animal-related indicators, plant-related indicators and abiotic indicators. Indigenous peoples possess a moderately high level of climate knowledge, which they use to observe and interpret the main local indicators (Fig.7)

Abiotic-atmospheric indicators are located at the top and to the right of the axis, reflecting its dominant patterns, which are highly revealing and provide immediate insights for climate forecasting on a daily, monthly, seasonal and

annual basis. These observations are directly linked to changes in atmospheric conditions affecting the appearance of the sky, as well as the type, intensity and direction of the winds. These changes are clearly visible and perceptible to local populations, for whom they serve as clear indicators.

Indicators of animal origin, meanwhile, are ranked second, whether they are marine or terrestrial animals. These various species have been identified, and the levels of prediction they provide can be divided into three categories: immediate, short-term, and medium- to long-term impacts. The local people interviewed mentioned both terrestrial and marine animal species. The behaviour and movements of these species indicate a forecast of rainfall in the immediate future, within the coming month or in the coming seasons. Wild and domestic animals are used to predict changes in the weather. They are generally found near homes, which facilitates their continuous observation and the recording of their characteristics, such as those of cattle and goats.

Wild and cultivated plants are the third most commonly used method for climate forecasting in Androy. They are mainly observed and analysed during the dry season (May–December) and whilst agricultural activities are taking place, from January to August. These plants are commonly found throughout the landscape, both within and around agricultural plots, and form part of the agroforestry systems in the Androy region. These plant species were mentioned during the interviews. The analysis carried out by local communities focuses in particular on two distinct phenomena: fruiting and flowering whether these are abundant or scarce on the one hand, or early or late on the other.

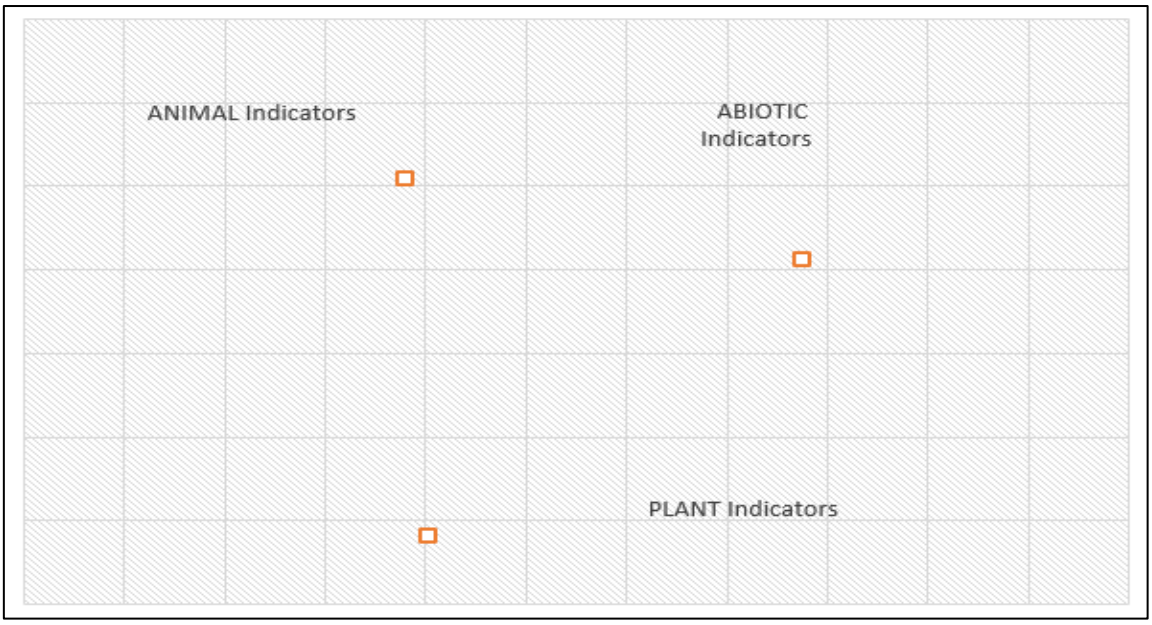

Fig 7 Correspondence and Dominance of the Three Local Climate Indicator Groups

- *Indigenous Indicators Used by Farmers for Weather Prediction*

Communities evaluate local weather and climate change based on their experiences through their interaction with the environment. The study found that indigenous knowledge exists in the communities and farmers use local indicators to forecast weather and forthcoming seasons in a given year. The farmers in Beaniky and Antseky villages were found to use plant phenology and fructification, animal's behaviour, the solar system and the wind in forecasting weather (Tab. 2).

Atmospheric and astronomical indicators (Abiotic 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.

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.

Wild and cultivated plants are used for climate prediction in Androy at 34%, and are mainly observed and analyzed 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.

Table 2 Local Indicators and its Functioning on Weather Forecast

Type of Indicator		Description/ Event	Seasonal Quality		Period of Occurrence
			P	G	
I-Atmospheric and Astronomical Indicators (AAI)					
Medium And long term effect	The Moon *(Volañe)*	Red fire color	**x**		December
		Concave	**x**		
		Tilted		**x**	
	Cloud *(Rahoñe)*)	Direction/Formation from North to South		**x**	October-November
	Wind *(Tioke)*	Direction East to West	**x**		December-February
		Direction South/North/West		**x**	
	Lightning/Thunder	Night blow from the Ocean		**x**	October- November
	Fog *(Zono)*	Making the landscape wet every morning		**x**	September-October
II-Animal Indicators (AnI)					
With immediate effect	Termite *(Renembotre)*	emerging from its termite mounds		**x**	In all seasons
	Chameleon *(Tañe)*	Opening its mouth towardsthe sky.	**x**		December-January
	Sea Grasshopper *(Valalandriake)*	jumping and swimming towards the West against the wind		**x**	In 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 *(Boleake)*	Are found dead in the seashore	x		July/September
	Whale (*Trozoñe*)	Bathe their babies in the surface of the sea		**X**	November - December
	Sardine (*Sohely*)	Abundant appearing in the oceanic zone	**x**		In all seasons
	Bee *(Tantele)*	Massive hive abandonment	**X**		August-September
		Flock to and enter caves and tree trunks		**x**	
	Locust *(Valala kijeja)*	Spread in swarms	x		April-July
	Thunder Grasshopper *(Valalanampy)*	Breed abundantly in all landscapes		x	January-February
	Bird *(Taontaonkafa)*	Move far to coastal areas singing		x	December-January
	Wild parrot *(Vazañe)*	Moves from north to south to peck sorghum cobs	x		April-July
	Sheep *(Añondry)*	Shakes its furs every morning		x	Not specified
	Cattle *(Añombe)*	Crunches bones/remains of cloths and human excrement	x		Not specified
	Cow *(Añombe vave)*	Sprays her urine to humans from her tail		x	
III-Plant Indicators (PI)					
Medium and Long-term effect	Tamarind *(Kile)*	Abundant fructification	x		June – September
	Lamoty	Abundant fruiting	x		August-October
	Sike Herambazaha	Early flowering		x	November - December
		Late flowering	X		
	Fengoke	Abundant flowering		x	Idem
		Rare flowering	X		
	Voandelake	Early flowering/ abundant		x	November-December,
	Prickly pear	Abundant fruiting		x	October-December

Source: Fieldwork, 27-30 November 2020 Where P: Poor; G: Good

IV. 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. Research to date suggests that these changes exceed the threshold of human perception over a lifetime (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). 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 populations (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. The analysis of the climate stations close to Ambovombe –Androy showed possible trends in changes in micro regional climate variability. Changes related to an increase in temperature, decreases in rainfall and speed/dominance of East wind are particularly evident. These trends are consistent with the perceptions expressed by the inhabitants of Beaniky and Antseky who stated a decrease or even a virtual absence of annual rainfall.

"*According to our older informants, the rainy season has become random for the past 40 years. In the past, the rainy season used to last from October to March, but now it only starts in December/January and ends in February, with mostly light and intermittent rains. The first rains can no longer be predicted today".*

The major threats of changing climate are erratic rainfall and rising air temperature. The intensity of rainfall has reduced, and the number of rainy days has declined leading to a decline in crop production and offsets in other ecological systems. In rural areas, farmers must sow seeds in advance. Since the crops' growth period is shortened. Farmers can no longer follow their tradition to plant and harvest crops like before, according to our informants. Other than the decrease in rainfall and the oppressive and dry warming, the easterly winds are the most formidable in Androy. The entire population recognizes this great change that has not been experienced in the past. This easterly wind is dangerous for livelihood and community activities. The statements of local people are unanimous on this, saying:

"*Our life, with our agro-pastoral activities are uncertain since the domination of this easterly wind. Sometimes it rains moderately and can ensure our livelihood activities but the warming is exacerbated by the intensity of the winds tearing up and causing siltation of arable soils as well as young crop plants by its intensity*."

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 theorized as local cosmologies, local classification systems or ontological regimes (Orlove and Roncoli, 2010). 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).

The ethno-climatological surveys carried out in the two villages of Beaniky and Antseky on temporal markers show that the appearance of certain animals (terrestrial and marine), the song and behavior of birds, as well as abiotic observations of a climatic and astronomical nature based on clouds, winds and the moon are indicators that enable farmers to anticipate the time and thus better manage their agricultural calendars. These results are similar to those obtained by Agbodan K.M.L., Akpavi S., Amegnaglo K.B. et al. (2020), in Togo, and Audefroy & Sánchez (2017) in Mexico, where these indicators not only guide decision-making on cropping itineraries, but also predict the risk of extreme events such as natural disasters like floods, earthquakes, and long dry periods. The 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), Elia et al. (2014) 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.

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. Fisheries and marine resources have only been exploited without social restrictions for a few decades in the Ntandroy region. Rural coastal communities have been turning to fishing as an alternative subsistence activity since the major climate crisis of 1990–1992. However, for ages, the communities' familiarity with marine climate indicators has not been limited by this sociocultural constraint except in terms of their exploitation. In any case, seafood is not considered taboo.

The indicators used by farmers, herders and fishermen to predict the quality of the rainy season is thus available throughout the year. Indicators that farmers rely on further include fruit production and tree phenology, animal behavior, 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. The main threats affecting plants and terrestrial wildlife are primarily deforestation, wildfires, habitat destruction, the expansion of agricultural areas or grazing lands, as well as illegal hunting and exploitation for food or commercial purposes. It refers to human activities that influence the physical composition of a system, such as farming practices, water management, resource use, and population pressure. When Ms Harena and Hovosie stated 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. Additionally, the climatological and meteorological perception has great strength, due to its deep roots in the experiences and personal experiences of agricultural communities (Olivares, 2012; Olivares et al., 2015; Montenegro et al., 2021). This knowledge constitutes indigenous people's own knowledge and enables them to understand local weather and climate conditions before making decisions about crops and agricultural practices (Anandaraja et al., 2008; Kalanda-Joshua et al., 2011; Rautela and Karki, 2015). In general, the producers express certain conclusions about the evolution of the weather experienced, as indicated by the studies by Olivares (2014a); Olivares et al. (2017); Camacho et al. (2018). Seen in this way, the foregoing allows us to infer that the recognition of the knowledge, beliefs and practices that rural agricultural communities have with respect to these factors, contribute to providing very valuable information complementary to scientific information, for the construction of policies associated with the development of mitigation and adaptation alternatives.

V. CONCLUSIONS

The study assessed the relevance of IK 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; Granderson, 2017). 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 programs in small-scale societies wherever they are located. 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. It was learned that many of the local farmers, and mostly elders, possess IK on weather prediction. The findings from this study lead to the conclusion that traditional knowledge systems regarding climate and the environment provide their users with the tools necessary to respond both *proactively* and *reactively* to the specific characteristics of a given environment. Traditional climate knowledge remains a largely unexplored field of study in Madagascar, despite its influence on the development and dynamics of its indigenous peoples. This study demonstrates the importance of this knowledge for those who engage in agricultural activities in the study area. Traditional ecological knowledge is part of the "toolkit" that farmers use to carry out agricultural practices, and further in-depth studies could open up new avenues for decision-making in light of ongoing processes of climate change and climate variability at the local level. indicate that the farmers have recently perceived the reliability and accuracy of the local indicators to have been reduced by climate change and variability because of changes in the environment. In this regard, to assist the local farmers, timely and accurate weather forecast information is needed.

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- *Author's Contribution*

The first author collected, processed and drafted this article. The other authors read and corrected the manuscript. All the authors read and approved the final manuscript.

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