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Understanding farmer's perspective: A pathway model to comprehend farmer's adaptation strategies to bolster productivity in Mauritius

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ABSTRACT

Meeting the challenges of a sustainable food security has always been the prime concern of every developing country. Agriculture being a major contributor to climate change with a net emission exceeding 17% of green-house gases, the scientific community urges a paradigm shift in the sector to reduce these emissions. However, insufficient attention has been given to the main actors of the sector which are the small scale farmers and their perception in adapting to climatic changes. These small holder farmers are highly vulnerable to changes in climate, as they live on a marginal income, and the crops they depend upon are highly affected by climate. This paper seeks to investigate the impact of climate change on farmers' productivity and their adaptive responses to these impacts. A bottom-up approach was used to identify farmers' perceptions about the impacts of climate change on their crops, and the adaptation measures they are employing to counter these impacts, and to understand their vulnerability to the changing climate. Around 115 small scale farmers were interviewed throughout Mauritius- in the North, South, East, West and Centre. Subjecting the data obtained to the Structural Equation Modeling showed that farmers are already being impacted through the shift in rainfall patterns, quantum of precipitation and increase in pests and diseases, all of which have a direct impact on their usual cultural practices. Increasing fertilizer, watering frequency and pesticide has been the only advice normally given to farmers to bolster their productivity.

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Key words: Agriculture, farmer's perspective, adaptation, modeling.

INTRODUCTION

Several regional and national researches have highlighted the plausible negative impacts of current climate variability and future climate changes on agricultural productivity. Therefore, the necessity to develop adaptation strategies has become crucial. This is particularly applicable to developing countries that are more vulnerable to the impacts of current variability and future changes in climate, due to their high dependency on rain-fed agriculture and the difficulties they have to go through to adapt to variations and changes in climate (Huq et al., 2004; Sivakumar et al., 2005; Kurukulasuriya et al., 2006; Adger et al., 2007; Lobell et al., 2008; Schlenker and Lobell, 2010).

According to Hatfield et al. (2011) and Lal et al. (2011), maintaining a sustainable food security would rely mainly on the reduction of agriculture's vulnerability to the forecasted changes in climate and reduced GHG emissions from a grass-root farmers' level. According to Berry et al. (2006), the success or fall of climate change adaptation and mitigation in agriculture mainly depend on farmers; Howden et al. (2007) argues that it is fundamental to understand farmer's attitudes and perception of climate change. This in turn facilitates actions required in climate change adaptation and mitigation of GHG emissions though this still represent a challenge because farmers' adaptive

measures rely on their long term acquired perceptions and beliefs about climate change. It is crucial therefore to understand the various factors that influence farmer's beliefs and risk perceptions in response to the threats posed by climate change. Their response is very valuable, especially to the predicted vulnerability of sustainable food and energy production to climate change (Dunlap, 2010).

Thwaites et al. (2008) interviewed 36 farmers, and found that 18 of them believed climate change was occurring, while the others were either antagonist about climate change or its associated impacts or were not informed enough to have an opinion about it. In a survey that consisted of 750 farmers, Donnelly et al. (2009) found that only 27**%** believed that climate change was or anthropogenic origin. The term "identity-protective cognition" has been coined to refer to the fact that people acknowledge or deny climate change evidence based on how it fits with their own cultural values and those similar with others (Kahan et al., 2007; Donnelly et al., 2009). This implies that proof of climate change will be rejected if it leads to farmers' cultural values being threatened, or accepted if farmers' cultural values are respected (Cohen et al., 2007; Kahan et al., 2011).

There are several factors that influence farmers' climate change adaptive strategies. These may include abrupt changes in weather conditions, increase in the number of pests, market conditions, soil quality, and water availability (Risbey et al., 1999). According to Misra (1992), the types of management strategies adopted by farmers can be categorized as a day-to-day response, that include tactical responding to short-term signals such as variations in the weather and a strategic response to longer term signals such as changes in the climate, and policies made over the long term and under governments.

Jackson et al. (2010) and O'Connor et al. (1999) found that farmers who trusted governmental institutions readily agreed to apply the different climate change adaptation policies proposed by these entities even though farmers prefer to take those actions that achieve quick and efficient results. Adaptation of agricultural practices pertinent to the fore-casted impacts of changing climate could include manipulation in land management strategies, drainage systems, crop varieties and sowing dates to maintain and bolster yields, and enhance soil fertility.

The role of indigenous knowledge in designing appropriate research, development and extension strategies that are relevant to the local conditions has long been recognized and is well documented (Chambers, 1983; Richards, 1985; Chambers et al., 1989; Agrawal, 1995; Pretty et al., 1999; Carswell and Jones, 2004). Traditional and/or indigenous knowledge can play an important role in developing practical and rational approaches that facilitate small scale producers in adapting to impacts of current and future climates, and several studies have helped to understand and assess farmer perceptions about climate variability and the mechanisms employed to cope with it, across Africa and elsewhere (Nyong et al., 2007; Thomas et al., 2007; Sleggers, 2008; Bryan et al., 2009; Mertz et al., 2009).

In the case of the Republic of Mauritius, a lot of emphasis is being placed on the reduction of GHG emissions in all sectors. Agriculture being one of the largest emitters (17%) of GHG emission (FAO, 2011); it has become a state of urgency to start acting on the local level. Mauritian agriculture is highly dependent on synthetic chemical fertilizers, mostly nitrogen based (ammonium sulphate and urea), for maintaining soil productivity. Farmers use large amounts annually, and its usage is advocated by the extension services. According to the latest statistics, fertilizer consumption has increased from 33.1 tons in 2013 to 35.2 tons in 2017 (Mauritius statistics, 2018). The farmer community in Mauritius has inherited their art of practicing agriculture from their parents and peers. It was only in 1994 that a proper institution was created to support small scale farmers through extension services and training. Therefore, before institutional support was provided, farmers in Mauritius had already established their own cultural practices and mode of adaptation to various challenges based on their perception, and through trial and error. This is why it is imperative to make farmers the main focus of studies on climate change adaptation and mitigation in the agricultural sector, and to *a priori* study and understand their perceptions, beliefs, attitudes and values. Any national strategic and action plans developed to resolve the impacts of climate change that farmers are facing without the active participation of farmers will be an entirely academic one, without much hope of its being accepted and implemented by the farmers.

To comprehend the pathway through which Mauritian farmers are currently adapting to the new challenges that climate change is posing to their productivity, a structural equation modeling (SEM) approach was used to test the following hypotheses:

H_1: Perceiving climate change as a threat will force farmers to adapt their cultural practices accordingly;

H_2: Modification in cultural practices will help farmers to bolster their productivity;

H_3: Training in climate change will impact on the normal cultural practices of farmers.

Each hypothesis proposed aims to understand whether the traditional/inherited way of practice is still feasible in the face of a changing climate and whether the extension services, whose advice and guidance based essentially on modern conventional scientific knowledge, backed by policy makers have been able to change the mindset of farmers in altering their cultural practices sufficiently to enable them to cope adequately with the impacts of climate variability and climate change.

METHODOLOGY

Area of study and data collection

Mauritius is a tropical island with two seasons: a warm humid summer starting from November to April and a relatively cool dry winter from June to September. The months of October and May are mostly known as the transition months with no significant change in temperature. The mean maximum temperature reaches 29.2°C during summer, during which frequency of tropical cyclones is at its peak. The coolest months are July and August where average minimum temperatures can drop to 16.4°C. Rainfall ranges from about 4 000 mm on the Central Plateau to about 800 mm along the coast. Year to year variability can be very high, with annual rainfall ranging from 1 171 to 3 539 mm, respectively across the island (MMS, 2010).

Primary data were collected during the survey through face to face interview with the farmers. The survey covered 115 small farmers across the various zones of Mauritius as follows: North (23), South (23), East (27), West (24) and Centre (18). Each zone is distinct as per its micro climate and farming strategies. A questionnaire was devised for this study and included simple Yes-No questions, as well as, open-ended questions where the respondent could provide information in a totally unbiased way. Previous experience has shown that farmers tend to be hesitant to offer genuine replies to questions if they are in presence of any authority, such as an extension officer or a policy maker) and/or if they feel intimidated by the interviewer. Therefore an approach of empathy, compassion and altruism had to be adopted to first gain the trust of farmers before starting the essential questions in the survey. The interview was conducted in the local language – Creole – after having explained to the farmers the purpose of the interview, and after having assured them of the confidentiality of their responses. Care was taken to avoid the interview lasting more than fifteen minutes.

A pre-testing of 10% of the sample was done, and the questions amended according to the response obtained to make them clearer and remove any possibility of ambiguity or misunderstanding on the part of the farmer.

Data analysis

The data obtained from the survey was extracted and transformed in close ended questions. The close ended questions were loaded into SPSS software (SPSS v20, 2018) and transformed into codes, for example, (1=yes, 2=no). Frequency analysis was conducted for each question.

The Structural Equation Modeling (SEM) was developed using the software AMOS (AMOS v21, 2018) which is an add-on of SPSS, and used to test the hypotheses. Structural equation models are used for defining multivariate relationships based on a versatile class of modeling. SEMs generally blend regression models and factor analysis thus allowing structural relationships between latent variables (Bollen, 1989). Specifically, this model brings forth the connection between latent variables that illustrate a pathway to the adaptation process of local farmers in face of a changing climate from their own perception. This model thus estimates the relationship between the various variables that represent farmer's perspective on the changes in temperature, precipitation, their changes in cultural practices and its final impact on yield.

RESULTS AND DISCUSSION

Profile of farmers

Table 1 shows the profile of the farmers interviewed. Unlike other African countries, the farming community in Mauritius is highly dominated by males which represent 97.4% of the farmers interviewed. The explanation for this dominance is explained by the culture of the country, where the responsibility of women was to manage the household whilst that of the man was to provide food through farming. For this reason, even at present, it is mostly males who are owners of farms rather than females. With respect to age, only 6.1% of farmers interviewed were young people below the age of 30 while a majority >50 years old represent 66.9% of the cases who are on the verge of retirement in the coming years. For a small island as Mauritius, this number is alarming given the large number of farmers that would retire soon and the lack of young ones to replace them. In any given adaptation or mitigation strategy to bolster food production, it is automatically assumed that the farming community will continually replenish with years. A decrease in the number of farmers actually challenges all optics of food production strategies and models (Berry et al., 2006).

Inspite of their age, the respondent farmers nonetheless do have some basic primary education (45.2%) that enables them to learn and adapt quickly. Farmers with tertiary education (7%) are mainly people who have retired from other fields of work and who are practicing agriculture as a side business. A great majority of respondents have over 15 years of experience in farming and were active in this sector on a part time basis since their early childhood. This research also showed that the farming community in Mauritius is very conscious of climate change and are experiencing it to varying degrees.

Climate change as perceived by farmers

Table 2 gives an insight on how they perceive the changes in climate over the years. Farmers who are highly dependent on the variability of climatic conditions are

Table 1: Profile of farmers (n = 115).

Label	Percentage (%) of cases
Gender	Male: 97.4 Female: 2.6
Age	<30: 6.1 31-40: 10.4 41-50: 16.5 51-60: 36.5 >60: 30.4
Education	Primary: 45.2 Secondary: 47.8 Tertiary: 7.0
Years of experience in farming	<1: 1.7 1-5: 7.0 6-10: 19.1 11-15: 6.1 >15: 65.2
Familiar with climate change	Yes: 81.7 No: 18.3

Table 2: Climate change as perceived by farmers (n=115).

Label	Percentage (%) of cases
Rainfall	Increase: 72.2 Decrease: 17.4 Same: 1.7 Do not know: 1.7
Temperature	Increase: 73.9 Decrease: 17.4 Same: 8.7

those that are primarily concerned with abrupt changes (Huq et al., 2004; Sivakumar et al., 2005; Kurukulasuriya et al., 2006; Adger et al., 2007; Lobell et al., 2008; Schlenker and Lobell, 2010). While perception of farmers has often been overlooked because of lack of empirical backing, it is nonetheless at the very base of their adaptation activities and strategies. 72.2% of farmers affirm that the rainfall pattern has increased during the recent decades, while 73.9% of farmers affirm that the temperature has increased during the same period. These affirmations actually corroborate the local meteorological data. Mertz et al. (2009) and Gbetibouo (2009) also reported similar figures from respondents in Eastern Saloum in Senegal and in three regions of Limpopo River Basin of South Africa.

The historical annual rainfall pattern in Mauritius from 1981 to 2017 gives an indication on how the daily rainfall has changed over the decades (Figure 1). This long term pattern suggests that the rainfall has a decreasing trend. The decreasing gradient ($y = -0.0209x + 43.89$) indicates that the rainfall will continually decrease in the coming years. This study however showed that 72.4% of farmers have reported an increase in rainfall, which is in contrast to the official figures from the MMS. This can be explained by the fact that while overall annual precipitation in the country is decreasing, the increasing prevalence of high intensity-long duration rainfall, leading to flash floods (with consequent flooding of fields and destruction of crops) gives the impression that precipitation has increased.

The changing rainfall pattern could prove to be very detrimental to the agricultural sector in Mauritius.

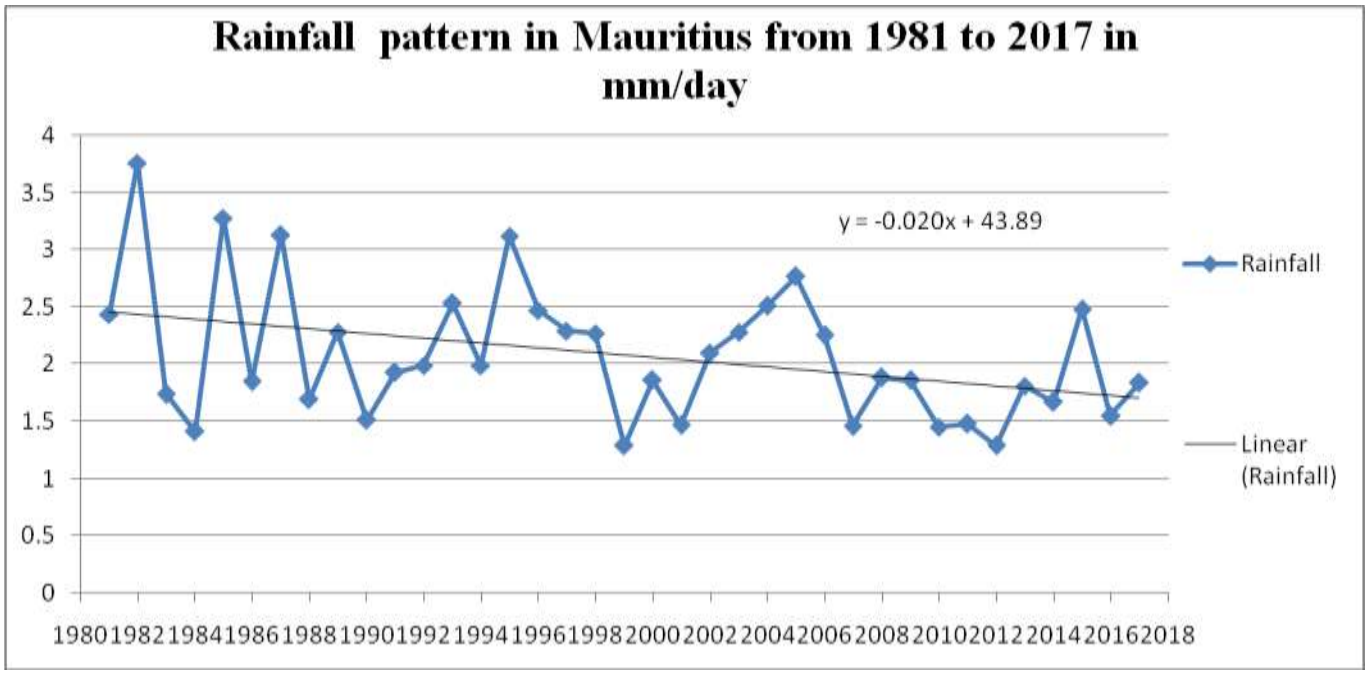

Figure 1: Historical annual rainfall pattern in Mauritius from 1981 to 2017 (Source: NASA Prediction of Worldwide Energy Resources, 2018).

During the recent years, the rainfall intensity and duration has changed, with an increase in high intensity and long duration precipitation events which cause flash floods and other damages to the agricultural system. Rainfall is considered the most crucial factor in sustaining agricultural productivity, however, the quantum and distribution of precipitation within the cropping seasons is more important than just the total annual and or total rainfall within the growing seasons (MacCarthy et al., 2009). This modification in rainfall, evaporation, run-off and moisture storage (Rosenzweig and Hillel, 1995) has also been listed in various parts of tropical and sub-tropical Africa, which have been experiencing droughts since the 1970s (Paehler, 2009; Syrquin, 2008); vegetation stress, rapid plant loss and desertification in certain circumstances (Bachelet et al., 2001). Frequent high intensity-long duration rainfall is more of a threat for agriculture than a boon. Excess of rainfall causes water logging in soils, promotes root rot in plants, and disrupts normal working schedule (planting date, harvest and pesticide application).

Figure 2 shows how the minimum and maximum temperature has evolved since 1981 up to the present. The trend (y = 0.0317x - 38.136) indicates an increasing gradient of the temperature which is one of the most critical factor that has influenced farmer's cultural practices. As the survey has pointed out, 73.9% of the farmers interviewed perceived an increase in temperature, and have adapted accordingly. Incremental variation in temperature may increase agricultural productivity, but it cannot be generalized, because this phenomenon is region specific (Rosenzweig and Hillel, 1995); some regions are likely to benefit from increased agricultural productivity while others may suffer reductions, according to their location and dependence on the agricultural sector (IPCC, 1996b). In Mauritius, these changes are impacting on the pest and disease abundance much more than on plant phenology. Increase in pest and diseases not only affect plant yield but also adds to the cost of production for farmers, due to the increasing amounts of pesticides used by farmers in response to the increased damage to their crops.

Adapting to climate change

Table 3 summarizes the adaptation practices implemented by local farmers, based on their own perceptions and beliefs, in order to adapt to the effect of climatic change. It is worth noting that in this context, local farmers professed not to have received any formal training (72.2%) on how to adapt to the effects of climate change and used their own experience in most cases to decide on a course of action. Gbetibouo (2009) and Deressa et al. (2009) reported similar findings in a study in Limpopo River Basin of South Africa and Ethiopia, respectively. Among the Mauritian respondents, 33.9% have increased their irrigation frequency, being unable to rely on the distribution of rainfall during the cropping season and 43.5% have increased the amount of fertilizer in order to bolster their production, and also started applying organic amendments

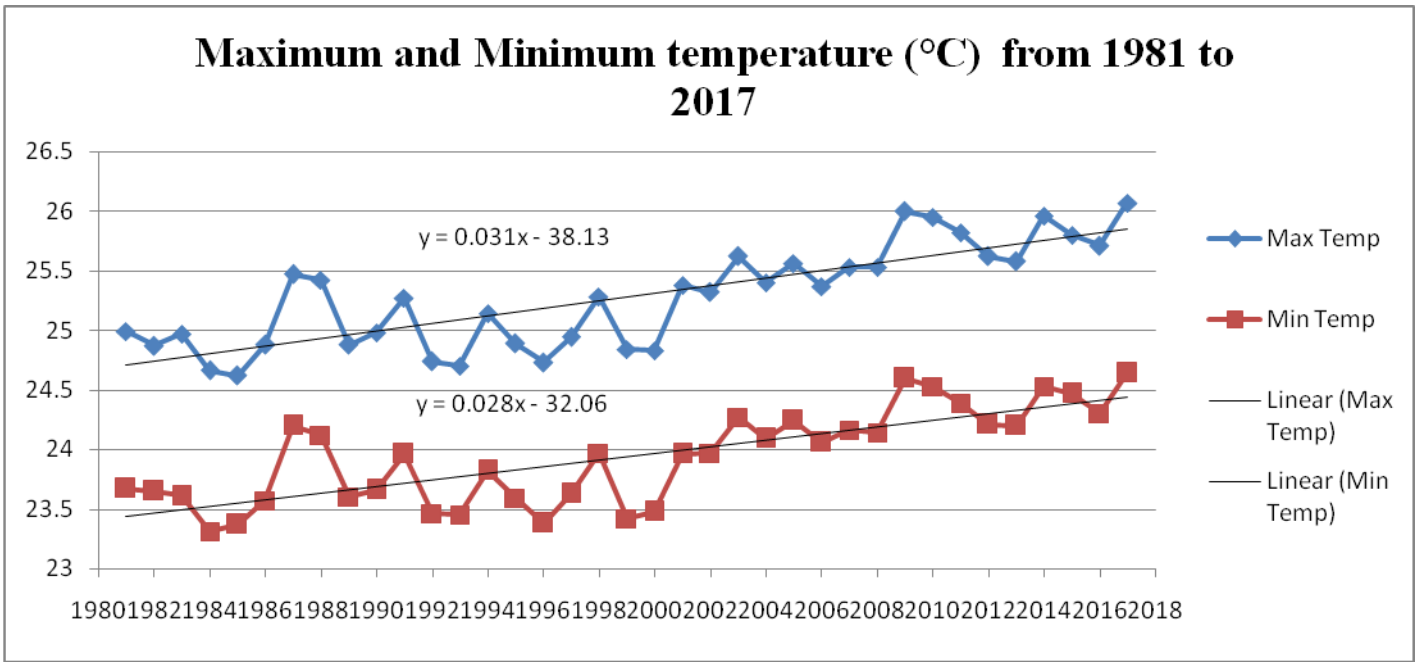

Figure 2: Historical annual minimum and maximum temperature in Mauritius from 1981 to 2017 (Source: NASA Prediction of Worldwide Energy Resources, 2018).

Table 3: Adaptation strategies by farmers to climatic change (n=115).

Label	Percentage (%) of cases
Watering frequency	Increase: 33.9 Decrease: 13.9 Same: 50.4 Do not know: 1.7
Fertilizer application	Increase: 43.5 Decrease: 7 Same: 48.7 Do not know: 3.5
Pesticide application	Increase: 64.3 Decrease: 11.3 Same: 20.9 Do not know: 3.5
Addition of organic amendment	Yes: 97.4 No: 18.3
Use of improved seeds	Yes: 100
Mechanization	Yes: 81.7 No: 18.3
Followed training	Yes: 27.8 No: 72.2

in the form of compost, manure and scum. The most alarming outcome of this study is that 64.3% of growers have increased their amount of pesticides. Most of the farmers interviewed stated that increasing the amount of pesticide was the only way for them to maintain productivity, since the number of pest and diseases has been on the increase in recent years, and that they found it "next to impossible" to grow vegetables without using pesticides. With normal dosages of pesticides, their vegetables were still being affected and they were unable to sell them in the local market. Shortage of agricultural labour has encouraged farmers to invest in machinery, with 81.7% of farmers hiring tractors for land preparation activities. Support for hiring tractors is usually under the aegis of agricultural cooperatives or private entrepreneurs. In the present context, small farmers and cooperatives use mechanization solely for land preparation purposes and it has not yet been extended for harvesting or sowing; only the 4 major sugar estates in Mauritius have these facilities which unfortunately is not accessible to small scale farmers.

The study has also showed that 100% of farmers use new, imported hybrid varieties of seeds for the main crops cultivated in Mauritius. Hybrid seeds have the merit of higher yield capacities, and a much broader range of adaptability to various climates and resilience to extreme conditions. While hybrid seeds are economically feasible, however, they represent a danger to the local varieties in Mauritius which are disappearing at an alarming rate every year. Though local varieties have much lower productivity than hybrids, nevertheless they are much better adapted to the local climate and can be part of a resilience strategic plan in face of the changing climate. Dependence on imported seeds makes the agricultural system of Mauritius vulnerable to any shift in external market prices, availability, transportation and increased pest and disease introduction. Such threats are potentially serious and can drastically affect the agricultural sector in Mauritius, as in other countries in similar situations.

The SEM Model

Absolute fit indices determine how well a model fits the sample data (McDonald and Ho, 2002) and demonstrates which proposed model has the most superior fit. These measures provide the most fundamental indication of how well the proposed theory fits the data (Jöreskog and Sörbom, 1993). Figure 3 shows that, in the present study, the chi-square value was significant ($p = 0.000$), the RMSEA was 0.128, and the GFI was 0.916. A good model fit would provide an insignificant result at a 0.05 threshold (Barrett, 2007) of the chi-square statistics. The Root Mean Square Error of Approximation (RMSEA) is the second fit statistic; RMSEA of between 0.08 to 0.10 provides a mediocre fit and below 0.08 shows a good fit (MacCallum et al., 1996). Finally, the Goodness-of-Fit statistic (GFI) is generally accepted that values of 0.90 or greater indicate well-fitting models (Tabachnick and Fidell, 2007). Therefore the model developed in this study suggests a good fit.

Furthermore, regression coefficient for 'Adaptation in cultural practices' and 'Increasig productivity' was found to be significant. This would imply that through modification of their agronomic practices, farmers have been able to adapt to climate change and maintain their productivity; this structural coefficient supports H_2. A change in the application of pesticide was determinant in farmers in adapting to climate change, while increasing fertilizer and the watering frequency had positive but somewhat weaker relationship. H_1 and H_3 were not accepted because their impact on the adaptation practices was not significant. Even though the relationship between the two coefficients was weak; the theory does not reject that perception on climate change affects cultural practices, because farmers who maintained that temperature was increasing, in fact irrigated their fields more often. An increase in temperature induced an increase in pesticide application, contrary to rainfall, the former having a negative and but strong relationship and the later having a positive but weak relationship.

Farmers having followed formal training on climate change issues did not modify their cultural practices; therefore it can be assumed that farmers rely much more on their perception to adapt to changes rather than on training received. There are several reasons for this, partly because farmers take pride in resolving their problems themselves (Nowak, 2013). This theory is supported by Donnelly et al. (2009), Kahan et al. (2007) and Cohen et al. (2007) who also studied the same phenomena among local farmers. Another reason is that often times the training is too theoretical and generalized, and not tuned to solve individual farmer's specific problems. It was noted that an issue of trust existed between the farmer and the extension officer, some of whom are perceived by the farmers as being too academic and inexperienced.

The introduction of compost in the farmer's cultural practices has been only recent in the fight against climate change through reduction of reliance on synthetic fertilizers. Based on the model, it is understood that a reduction in net yield has been observed, however, it is worth reflecting on the fact that farmers have been relying on synthetic fertilizers for more than 20 years and have been promoting productivity without the addition of any organic amendment. This long term practice had more impact on the productivity observed today rather than the effect of the climate on the later. Without addition of organic matter over long period of time, the organic pool decreases in most soils which causes a disbalance in the soil ecosystem. With loss in soil fertility and decrease in micro-organisms the soil only becomes an inert media that can only rely on fertilizer addition to sustain plant growth (Havlin et al., 2006). In the long term, without a transition in this sector, farmers are going to face more problems in

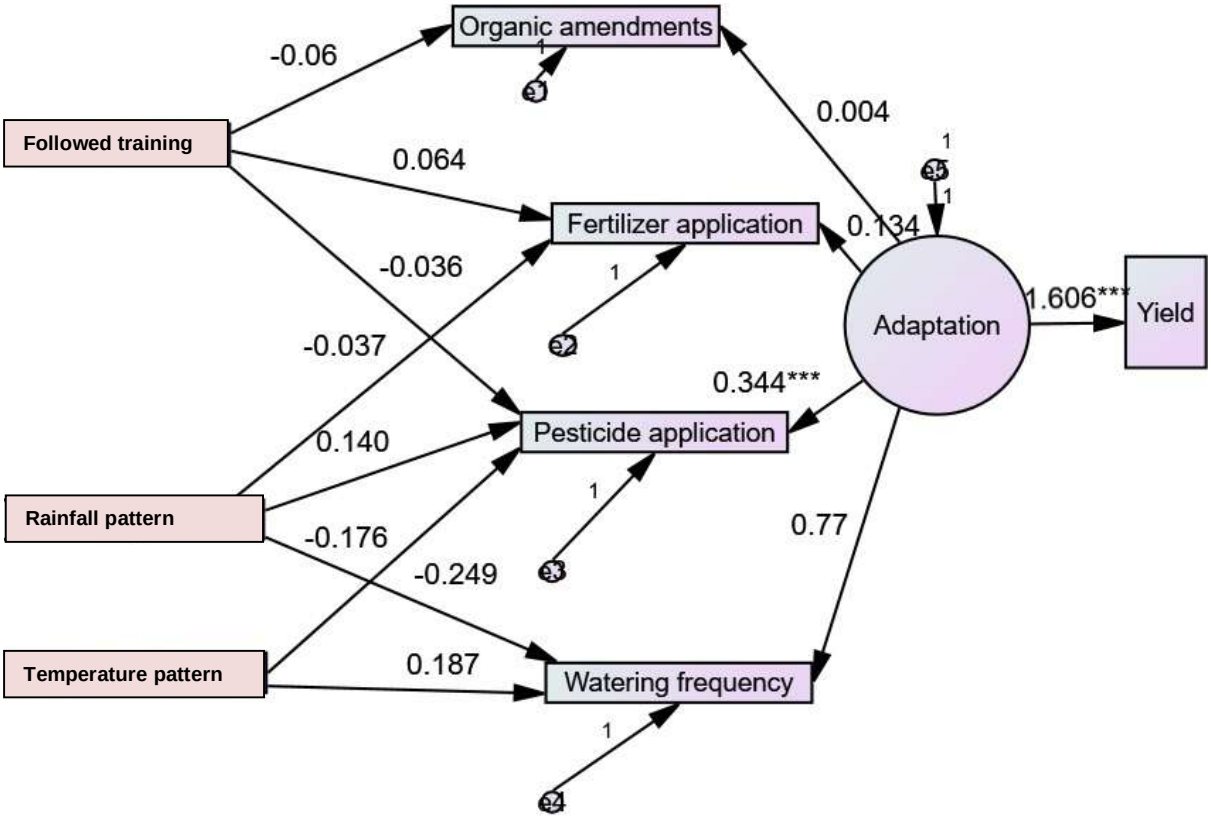

Figure 3: Model of perception to adaptation pathway diagram (*$p < 0.05$. **$p < 0.01$. ***$p < 0.001$).

maintaining their productivity coupled with the effect of climate change, the non -replenishment of new generation of farmers and inadequate support from institutions.

There have been several other studies addressing the latent relationships between perceptions on climate change and behavior or policy supports. Gordon et al. (2015) found that farmers in Iowa were more confident in organizations that promoted an ecology based attitude as sources of information relative to climate change. Dietz et al. (2007) measured how informed respondents were on climate change based on sources that include television, magazines and newspapers but found no connection among exposure to origination of the information or self-aquired knowledge related to climate change and support for climate change policy. O'Connor et al. (1999, 2002) mentioned that any increase in average global temperatures would rise over the next 5 decades based on belief in climate change and the rating of its likelihood. They estimated understanding of causes through the assessment of the discerned role of numerous possible causes of climate change. The study showed that the view that average temperature would rise worldwide over the next 5 decades and comprehension of the impact of global warming to be pragmatic predictors of strategic supports. O'Connor et al. (2002) in his research depicted no relationship among belief in temperature rise and policy support or expressed similarity of involvement in voluntary green-house gas reducing behaviors; a pragmatic relationship was nevertheless found between comprehensions of causes of both of those variables.

Brody et al. (2012) used an index measure based on climate change and its causes to assess whether fossil fuels had an incremental impact on atmospheric concentration of green-house gases, and also whether nitrous-oxides are a green-house gas. The study further included elements regarding scientific certainty about sea-level rise and global rainfall. The study concluded that relationships between belief and support for action are not distinct and found no connection between climate knowledge scale and likelihood to adopt climate change mitigation.

Such studies provide a practical perspective of the role that distinct dimensions of climate change perceptions may play in molding reactions to climate change and provide numerous indications on the perception of farmers on climate change, and their vulnerability. Within these scenarios, the implication of farmers as leading roles is highly solicited in mitigating GHGs emission and changing their current practices for a more ecologically based agriculture.

Conclusion

Farmers in Mauritius rely mostly on their perception to adapt to the changes in climate based on knowledge that has been transmitted from one generation to another;

however, the declining farming community will not be able to sustain the population needs in the coming decades if there is no new generation of farmers to maintain productivity, who represent till date only a small fraction of the farming community. The axis of a long-term climate resilient food system should therefore be the mainstreaming of farming among the younger generation through provision of funding, facilities, training and continuous monitoring of the later. Focus on soil management should be placed in *priori* to increasing yield, without proper training on management of soils ecosystems, reduction in fertility will only negate strategies in building resilience against climate change or imply negative results. There is need for recruitment of more extension officers for adequate extension: the farmer ratio will help reduce the gap between years of experience and productivity.

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