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Contribution to the Promotion of Innovative and Climate-Smart Agroecology: Application to Agriculture and Livestock in the Haute Matsiatra Region, Madagascar

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Abstract:

Climate change (CC) is having negative impacts on agricultural production at global, national, and local scales. Climate risks to agriculture, livestock, and fisheries are expected to increase in the coming decades, particularly in low-income countries with low adaptive capacity such as those in Africa and Madagascar. In most African countries, agriculture must undergo a profound transformation to address the many challenges of CC, food insecurity, malnutrition, poverty, and environmental degradation. This "Climate Smart Agriculture (CSA)" or e-agriculture is an integrated approach to address the interrelated challenges of food security and climate change in order to achieve the objectives of adaptation or mitigation of climate change risks. Support for building resilience, support for community-based environmental projects, and promotion of climate-smart agricultural practices are among the approaches of the AIC. These climate-smart agricultural practices need to be aligned with and supported by national policy and a legal and regulatory framework. Policy and legislation can either slow down or accelerate the adoption of climate-smart agriculture. Promoting innovation requires effective partnerships with the government, the private sector, and universities. The case studies clearly show that there is a need for simultaneous action at the local and international levels on multiple challenges related to climate change. Climate change (CC) has negative impacts on agricultural production globally, nationally, and locally. Climate risks to agriculture, livestock, and fisheries are expected to increase over the coming decades.

Keywords:

climate change; prediction tools; climate smart agriculture; sustainable development; Africa; Mdagascar

I. Introduction

Climate change is a major cause of the degradation of agricultural and livestock production in rural areas. Indeed, seasonal irregularities, excess heat, and changes in rainfall patterns reduce yields, increase the likelihood of crop failure, and lead to an increase in crop and livestock pests and diseases. While, agricultural activity generates a significant income

(Ranaivoson and al., 2023). It employs 80% of the active population and is an essential component of the Malagasy economy, contributing 30% to GDP (43% if agribusiness is included) (Launay, 2019). Rural populations practice essential subsistence agriculture where rice plays a predominant role.

It is important to know how to improve agricultural production while taking into account climate change and the progressive degradation of biodiversity. The objective is to contribute to the promotion of innovative agro-ecology so that the farmers of the RDAL (Regional Directorate of Agriculture and Livestock) can determine the period of production, improve their yield and promote it in a different way in this region of Haute Matsiatra in Madagascar. We chose the region of Haute Matsiatra as our study area because it is our hometown. We want to bring our contribution to the promotion of agroecology in this region.

The interest of this study is obvious, as agriculture represents the primary income-generating activity for farmers in the Haute Matsiatra region. A large number of these farmers also practice arboriculture, an activity that is complementary to agriculture. At the end of this work, we will be able to evaluate the consequences of climate change and predict future yields of each production by taking into account climate change and the progressive degradation of biodiversity (Sultan, 2011).

II. Review of Literature

2.1 Data Collection

To obtain the essential data for our study, we began with a bibliography and webography (Maton, 2000; Graux, 2011; Razafindrazanakolona and al., 2023). The information obtained was then supplemented by surveys of members of the rural population, agricultural agents in Fianarantsoa, and officials of the state services concerned, including the head of the RDALF (Regional Directorate of Agriculture, Livestock and Fisheries) and the General Manager of the GDM (General Direction of Meteorology) Haute Matsiatra. Field observations were also of great help.

The comparison of data from the literature and those collected in the field allows us to highlight the consequences of climate change on agriculture and livestock (Martin and Vaitkeviciute, 2019).

2.2 Identification of the Strengths and Weaknesses of the Main Prediction Tools Used

We listed the three main prediction tools used in the study area. We then compared their strengths and weaknesses. The knowledge of their limitations and strengths allowed us to develop our algorithm to take charge of the agricultural data for a better prediction of their yield.

2.3 Validation of the Efficiency of Our Algorithm

We chose a year for which the cultivated area and the yield were known. We then tried to predict the yield over a few years. The comparison of the results obtained using each management tool used in the field. The one whose results are closest to the truth is the best yield prediction tool (Buisson, 2009).

III. Results and Discussion

3.1 Distribution of cultivated Areas by Type of Crop

Generally, on the high plateaus, almost all of the valleys are exploited, and the slopes with irrigation possibilities are occupied by rice fields in tiers. Other food crops (cassava, sweet potatoes, beans, corn, etc.), mainly for self-consumption, are grown using appropriate techniques.

In addition, we can notice the affluence of market gardening and fruit growing (especially citrus), and wine growing.

The eastern part of the Region is devoted to cash crops such as Arabica coffee. In the South, tobacco is more prosperous. In the mid-west, cassava, peanuts, and corn are planted in abundance, in addition to rice.

Table 1. Distribution of Cultivated Areas by Type of Speculation (2019) in ha

Districts	Total cultivated area (km^2)	Food crops	Cash crops
Fianarantsoa I	2194	1097	125
Fianarantsoa II	98932	43936	3245
Ambalavao	30323	11456	5496
Ambohimahasoa	32787	12171	1336
Ikalamavony	18202	4285	3190
Haute Matsiatra	184438	72945	13392

Les cultures vivrières et de rente de la région Haute MATSIATRA sont le riz, le maïs, le haricot, l'arachide.

3.2 Comparison of Data Handling Technologies for Prediction

Different models have been proposed and studied by many researchers, whether in terms of algorithms, statistics, or neural networks (Fujihara and *al.*, 2010).

The most commonly used methods are statistical methods such as Principal Component Analysis (PCA). Tools such as PaSim have also been developed as well as more recent methods such as neural networks which are currently being used.

However, each model has its limitations.

Table 2. Comparison of Various Approaches with Relevant Criteria

Model	**Strengths**	**Weaknesses**
PCA	Accuracy on prediction	Parameterization Implementation Expensive hardware to perform the calculation
PaSim dedicated tool	Well detailed	Too many settings Clean training for the use of the

		tool
Deep learning	In vogue, much more efficient than the other two	Expensive hardware to perform the calculation Difficult to implement Requires a lot of data

Based on these limitations, we have developed a simple algorithm based on data collected from the Agriculture and Livestock officials in Fianarantsoa. To predict the future possibilities of yields or productions in agriculture and breeding.

3.3 Development of the Yield Prediction Algorithm

Our research leads us to the exploitation of the data according to the proportionality between the yield and the climate.

Here we focused on prediction based on the proportionality between yield and climate. We did not take into account deep learning techniques.

Knowing the yield data for a production year X (as well as data for 5-6 years depending on the data arrangement) and having the temperature T and climate characteristics of Region R during the same year.

We calculated the prediction for the next year X_{n+1} by making the proportionality between temperature T_n and yield X_n for Region R.

$X_{n+1} = X_n/T_n$ with T_n, min °C < T_n < max °C of which min and max are adequate parameters for the production and according to the type of production. The more T_n tends to max, the more X_n tends to be underperforming.

And conversely, the more T_n tends towards the middle of min and max the more X_n tends towards a sufficient yield.

3.4 Validation of the Model or Solution

To validate our model, Table 3 below illustrates the results according to the data provided by the agents in Fianarantsoa by applying these data to our model and some tools and models cited in related works.

Thus the approach is to take the data of the year 2016-2017 and we predicted from these data the year 2018 the one that is closest to the data provided by the agents of agriculture and livestock of Fianarantsoa is considered the most suitable for the prediction.

The data used are shown in Table 3:

Table 3. Yields in the Haute Matsiatra Region in 2018

Yields in the Haute Matsiatra region in 2018			
Cultivated product	**Production (t)**	**Yield**	**Area (ha)**
Rice	145 775.00	2.90	50 300.00
Beans	4 445.00	0.85	5 100.00
Peanut	5 000.00	0,90	5 530.00

Cassava	47 500.00	5 100.00	
Corn	1 700.00	3 500.00	

Table 4. History of the Evolution of Production from 2011 to 2017

History of the evolution of production from 2011 to 2017							
Cultivated product	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Rice	392 575	331 300	352 300	400 280	400 360	342 970	45 585
Beans	5 925	6 060	5 250	4 205	4 550	2 195	3 575
Peanut	4 590	4 460	4 850	5 475	5 485	5 575	1 160
Cassava	189 760	206 000	205 000	184 910	201 200	60 785	52 000
Corn	4 680	6 360	6 300	6 740	6 700	6 365	5 000

In the following table, we will show the comparison between the two models with our model. In the PCA-based models, we have subdivided the year X into X_m months. A month X_m has a yield $X_{m, r}$ so the matrix M will have an element of type $X_{m, r}$.

The PaSim tool, model is already more advanced but has limitations that we have identified in the related work.

3.5 Comparative Table of Existing Solutions

Table 5 describes the comparison of existing solutions.

Table 5. Comparison of the solutions

Comparison of the solutions used in the study area with our algorithm			
Models	Data	Accuracy	Lost value
Our model	Region HM 2017	95.712 %	4.288 %
ACP-based model--	Region HM 2017	95.2 %	4.8 %
PaSim	Region HM 2017	95.675 %	4.325 %

Accuracy = 2018 Value - Predicted Value

<u>For example</u>:

45 (value given by the agent of agriculture and breeding in FIANARANTSOA)

44 (Model performance)

Lost value = 45 - 44 = 1 (lost value)

$Lv = 45 \longrightarrow 100\ \%$

$44 \longrightarrow ?$

$$Lv = 100\ \% * \frac{44}{45} = 98\ \%$$

$\boxed{Lv = 98\ \%}$

According to this table, these models are all similar despite the slight advantage of our model. A future comparison with tests performed with other tools such as the neural network is to be scheduled.

3.6 Discussion

Research on climate change has made major advances in recent years, both at the international, national, and local levels. However, considering the current threats, efforts should be increased, both in the design of monitoring and surveillance actions of climate and its impacts in all sectors and in the contribution to the acceleration of adaptation measures to climate change (Jordy, 2017).

The search for solutions for sustainable development combining the fight against poverty, preservation of the environment, and taking into account climate change, should be at the center of concerns.

Scientific research must accompany the policies, in the actions allowing reducing the impacts of human activities, at the origin of a great part of global warming (Dalmedico and Guillemot, 2006). Resilient agricultural or industrial practices, the use of clean energy, and the reduction of risks and natural disasters... are now priority research areas.

Researchers from various disciplines have their part to play in this objective: climatologists, ecologists, economists, sociologists, geographers, physicists, energy specialists, etc. They are all involved in helping to make decisions and implement policies to limit greenhouse gas emissions and prevent and adapt to climate change.

IV. Conclusion

Madagascar's objectives for 2020, then 2030, as specified in this CPDN concern GHG (greenhouse gas) mitigation measures in all sectors of the national economy and actions identified in the sectors deemed most vulnerable to climate change impacts. It is a general mobilization, in which scientific research has certainly contributed, through the work that has already started and through new initiatives, in consultation with the actors of economic and social development.

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