International Journal of Agricultural Economics
2024, Vol. 9, No. 5, pp. 277-286
https://doi.org/10.11648/j.ijae.20240905.15

Research Article

Optimizing Malagasy Agricultural Productivity and Its Contribution to the Growth of Economy

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Abstract

This present article addresses the optimization of agricultural productivity in Madagascar. In accordance and in line with the government's policy for Madagascar Development, the Ministry of Agriculture (GSP: General State Policy) has adopted development project plans focused on improving the standard of living of the rural world and, above all, the economic situation. At present, the rate of agricultural production is steadily declining over time and space, but according to INSTAT (Malagasy Institute of Statistical), 85% of the Malagasy population are farmers. Therefore, in the context of improving Malagasy agriculture, what are the main factors behind this decline? Since Malagasy citizens contribute to the development of the nation, we have chosen as the theme of our research project: The improvement of agricultural products in Madagascar. According to our field results, the structure of the soil's organic elements has been destroyed (soil infertility, favoring and dominance of various defective insects). What are the causes of this destruction? In addition, we found that the overuse of chemical fertilizers and chemical products applied to treat insects is one of the main factors. This research project is divided into three main parts: firstly, a feasibility study. Next, the scientific presentation of the project, and finally, the results and cost estimates.

Keywords

Agricultural, Optimization, Productivity, Madagascar, Nation’s Development

1. Introduction

There is no doubt that the potential of agriculture for Madagascar is enormous. It is one of the sectors that contributes nearly 30% of GDP and involves over 85% of the working population [1].

In many regions, one of the main problems that Malagasy agriculture face, is the use of treated substances, generally chemical, which leads to fertility’s degradation. At the moment, the state of these infrastructures represents a major obstacle to any attempt to develop the country. Looking at the current situation, agricultural development to meet daily needs is the best strategy for fighting against poverty.

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Received: 11 March 2024; **Accepted:** 9 April 2024; **Published:** 31 October 2024

2. Problems and Project Objectives

The first step is the description of disadvantages of chemical use. According to our field surveys, most farmers are victims of chemical use. As stated in their statements, production decreases by approximately 50% per year after 5 years of use, due to the following factors:

1. The soil becomes infertile and rigid;
2. Various destructive insects are favored;
3. The quantity of water is very low;
4. The rainy season is destabilized;

These factors favor the destruction of soil chemical elements, which leads to many disadvantages, such as the outbreak of the various diseases we saw during our field visits. The following figure shows some photos of plants attacked by diseases [2].

Figure 1. *Plants attacked by diseases.*

Based on our analysis, the main factor that influences/causes the destruction of chemical element of the soil is the use of chemical product. In one word, Soil infertility is then the main factor of decline production.

Clearly, soil quality is proportional to the rate of decreased production. So, we are going to formalize the problem in a probabilistic way to have a decision-making aid [3].

For the Malagasy government, the engine of development is based on agricultural activities [4]. Despite this, the land is becoming infertile due to the abusive use of various chemical products, with the following consequences:

1. Ever-diminishing agricultural produce (risk of famine);
2. Food insecurity (risk of various diseases);
3. Destruction of the environment (risk of climate destabilization and destruction of the ozone layer);
4. Instability of monetary value (the economy of the State in general).

All these factors show that our country is in decline, and we need to take action to remedy this situation.

Due to these problems, the main objective of this project then, is the use of natural method but not the chemical product to improve the production rate in order to:

1. Improve the soil quality (organic structure);
2. Improve the farmers' economic standard of living;
3. Enhance the value of the Green Revolution in Madagascar;
4. Improve and protect the environment;
5. Avoid the various diseases caused by the consumption of chemical products.

3. Methods

3.1. Method 01: Determination of Natural Material Utilization

Within the framework of production improvement, our first method is based on the use of natural elements such as natural fertilizers and treatment with biological products (in liquid form).

The advantages obtained after using agricultural methods and techniques are:

1. Reducing the costs for the farmer (no need to buy fertilizers);
2. Improving the soil organic structure (increased production);
3. Eliminating the risk of food insecurity;
4. Protecting the environment.

3.2. Method 02: Using TOROLALANA Book

As part of the process of popularizing our agricultural approaches and techniques, we suggest the use of the book entitled *TOROLALANA* as a second method. This book is not only a training aid to facilitate popularization but also a guide to help farmers. The book contains three important chapters:

1. The processes involved in making natural fertilizers;
2. The processes required to manufacture organic products (in liquid form);
3. The way of using them [5].

3.3. Method 03: Scientific

1. Stochastic process (Markov chain);
2. SCILAB programming language including a specific algorithm.

3.3.1. Stochastic Calculus

A sequence of random variables $X_0, X_1, \dots$ with values in a countable set S is a Markov chain if at any time n, the future states (or values) $X_{n+1}, X_{n+2}, \dots$ depend on the history $X_0, \dots, X_n$ only through the present state X_n. Markov chains are fundamental stochastic processes that have many diverse applications [6].

Definition: The random variable sequence (X_n) is said to be a Markov chain if X_{n+1} depends only on X_n: $P(X_{n+1} \mid X_0, X_1, \dots, X_n) = P(X_{n+1} \setminus X_n)$

Transition matrix: The transition matrix of a Markov chain is defined by: $Q = (Q_{ij})_{i,j=0,\dots,n}$, such that

$$P(X_{n+1} = x_j \setminus X_n = x_i) = Q_{ij}$$

with

$$\sum_{i=0}^{n} Q_{ij} = 1.$$

Transition graph: The transition graph is defined by the following set:

$$G = \cup_{i,j=0}^{n}\{(x_i, Q_{ij})/\ Q_{ij} > 0\}$$

Stationary law: this is the law of convergence of the Q^n matrix when n is large enough [7].

3.3.2. Searching for Optimal Parameter Values in Algorithms

To obtain the best performance in terms of soil quality, a dataset should be processed. Machine Learning and Deep Learning algorithms have been used as part of the search for optimality. Here, the performance of neural networks is taken advantage of. It should be noted that the present case constantly encountering multi-variable or non-variable combinatorial optimization problems. That is, these n variables V_1,..., V_n, belong to the domains D_1,..., D_n, which are subjected to a set of constraints C. Solving the problem boils down to finding the values of $V_i \in D_i$it such that constraints C are respected and minimizing a cost function G [8].

These Algorithms rely on complex parameters that are not always obvious for human beings to determine. They, therefore, depend on the values of the elements and the substances set by the user or possibly by an expert. Hence, the need to find optimum values from field tests. This, calls for a combination of disciplines, combining statistical concepts with powerful computer algorithms (for processing) and modeling of mass data from observation phenomena [9].

Before presenting the algorithm applied in our research, it should be mentioned that the use of a database is essential. Thus, the parameters selected are the following: soil quality, the various destructive elements, the quantity of water, and the season to predict the probability of eventual gain. In order to achieve a good result with no surprises, constraints are also elements not to be neglected. In general, they favor the destruction of the soil's productive elements, and this destruction leads to many possible drawbacks [10].

Optimization algorithm:

1. Y: target variable (gain)
2. X: matrix of explanatory variables (soil quality, various destructive elements, water quantity, season)
3. M: matrix of variables to be predicted
4. use of the optimization module to subdivide the sample into a training and a validation sample
5. data subdivision -
6. import a class for processing //Logistic Regression class
7. create an instance of the class
8. run instance on training data build predictive model
9. value prediction
10. confusion matrix
11. recover test values
12. outputs

The following table shows the evolution of the rate of decline production caused by the use of chemicals:

Table 1. *Evolution of production.*

Year	2015	2018	2020
Rate of decrease in production *	0%	2%	50%

As stated in our hypothesis, the decrease in this rate is proportional to soil quality.

Table 2. *Soil quality.*

Decrease of	Quality of soil
0%	Fertile
50%	moderately fertile
100%	infertile or almost certainly desert

For ease of modeling, let's assume

$state\ (Fertile\ land) = state_0 = 0$

$state\ (medium\_fertile) = state_1 = 1$

$state(infertile) = state_2 = 2$

Then, we can simplify the state of the land by the set $E = \{0, 1, 2\}$

4. Applications and Results

Let's assume that the random variable X_N [11] determines the state of fertility of the land to be cultivated after N years of chemical element use.

For ease of calculation, let $n = N - 5$ and X_n be the random variable that determines the fertility status of the land to be cultivated after n years of use.

The random variable sequence (X_n) is a Markov chain of state space $E = \{0, 1, 2\}$ because next year's fertility state depends only on the current fertility state.

That's mean:

$$P(X_{n+1} = j \setminus X_0, X_1, \dots, X_n = i) = P(X_{n+1} = j \setminus X_n = i) \quad (2)$$

$$(X_{n+1} = 1 \setminus X_n = 0) = \frac{50}{100} = \frac{1}{2}$$

$$P(X_{n+1} = 2 \setminus X_n = 0) = \frac{50}{2*100} = \frac{1}{4}$$

$$P(X_{n+1} = 2 \setminus X_n = 1) = \frac{50}{100} = \frac{1}{2}$$

$$P(X_{n+1} = 1 \setminus X_n = 2) = P(X_{n+1} = 0 \setminus X_n = 1) =$$

$$P(X_{n+1} = 0 \setminus X_n = 2) = 0$$

because the state is irreversible.

From the property $\sum_{i=0}^{n} Q_{ij} = 1$, we easily derive:

$$P(X_{n+1} = 0 \setminus X_n = 0) = 1/4$$

$$P(X_{n+1} = 1 \setminus X_n = 1) = 1/2$$

$$P(X_{n+1} = 2 \setminus X_n = 2) = 1$$

Then the transition matrix of this chain is given by:

$$Q = \begin{pmatrix} 1/4 & 1/2 & 1/4 \\ 0 & 1/2 & 1/2 \\ 0 & 0 & 1 \end{pmatrix}$$

To determine the convergence of this matrix, we used SCILAB as a computational tool. The aim of convergence research is to determine the limiting value of n so that the law of states will be stationary (final state).

According to our SCILAB calculations, for $n \geq 16$

$$Q^{16} = \begin{pmatrix} 0 & 0 & 1 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \end{pmatrix}$$

Therefore, the convergence value of the Q matrix is

$$n_c = 16.$$

Then $N = n_c + 5 = 16 + 5 = 21$ and this is the convergence time (years) that the farmer started using chemicals.

In the five years before, the production decline rate varies very slowly. In fact, we'll take the probabilities linking these stages as approximate values.

5. Discussion

Optimizing agricultural productivity in Madagascar is a plan for achieving higher sustainable yields while maintaining soil fertility [5] (reducing the use of chemical elements, especially fertilizers). Based on the results of our calculations, we have obtained the following graphical illustrations and interpretations:

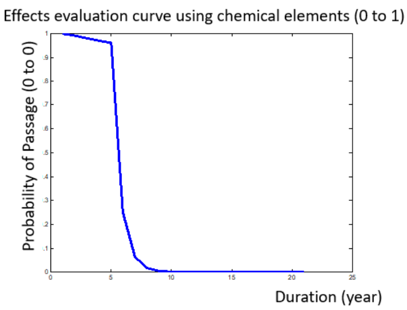

Figure 2. *Effect evaluation curve using chemical elements (0 to 1).*

Initial state: fertile land → Final state: it is impossible to say whether it will still be fertile after 13 years at most: medium-fertile or infertile land after 13 years.

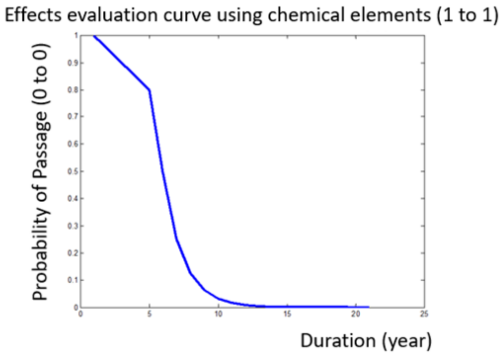

Figure 3. *Effect evaluation curve using chemical elements (1 to 1).*

Initial state: fertile land → Final state: it is impossible to say whether it will still be fertile after 13 years at most: medium-fertile or infertile land after 13 years.

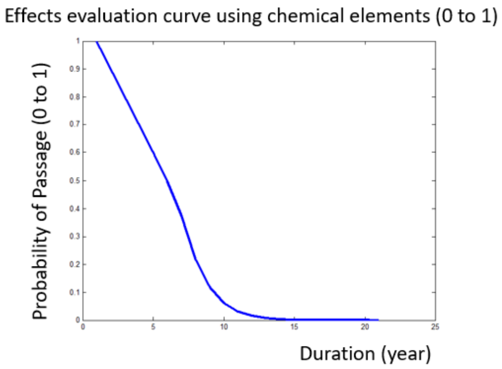

Figure 4. *Effect evaluation curve using chemical elements (0 to 1).*

Initial state: fertile land → Final state: land impossible to say it will be medium-fertile after 21 years at most and that implies finality = infertile state.

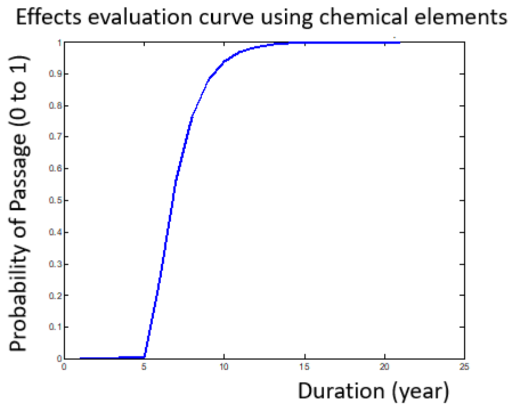

Figure 5. *Effect evaluation curve using chemical elements.*

Initial state: fertile land → Final state: infertile land safe and certain after 21 years.

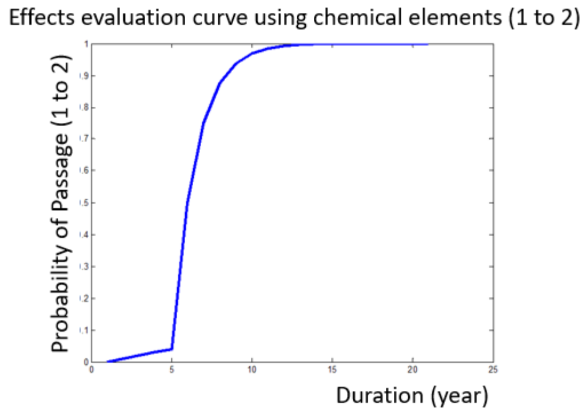

Figure 6. *Effect evaluation curve using chemical elements (1 to 2).*

Initial state: medium-fertile land → Final state: infertile land for sure after 20 years.

Considering all these illustrations, we obtained the following curves:

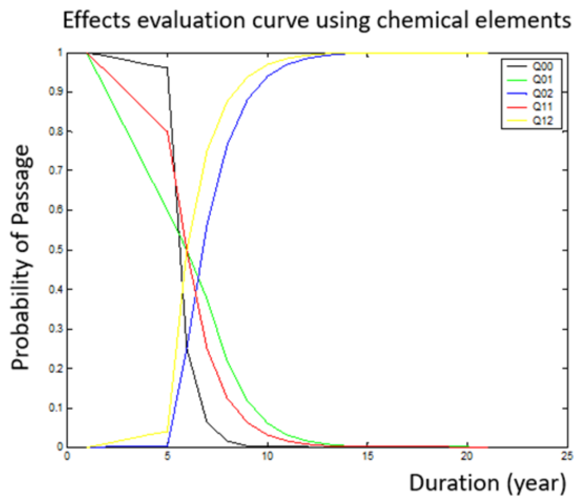

Figure 7. *Effect evaluation curve using chemical elements.*

To sum up, the values of the elements of the convergence matrix and the preceding illustrations and interpretations show us that, whatever the initial state of the land, after 21 years, counting from the time of the first use of chemicals, the probability of having an almost certain desert land is equal to 1, which is equivalent to saying that the rate of production decrease will be 100% after 21 years.

From the curves of Q02 and Q12, we can see that for around 15 years, the soil will definitely become infertile: the decrease in production is almost 100%. In fact, we can determine the expression of the function that determines the evolution of the production decline rate by the non-continuous linear function f defined by:

$$f(x) = \begin{cases} 0 \; if \; x \leq 5 \\ \dfrac{100x}{15} \; if \; 5 < x \leq 14 \\ \dfrac{100x}{15} + 1 \; if \; 14 < x \leq 21 \end{cases}$$

This gives us the following curve for evaluating the production decline rate:

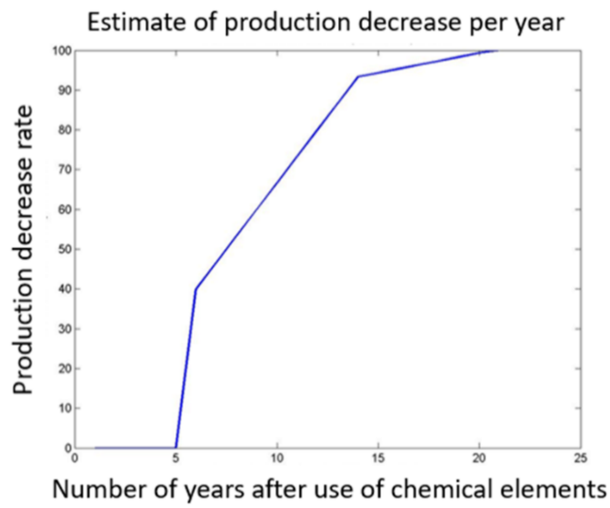

Figure 8. *Estimate of production decrease per year.*

In practical terms, on average in 2005, Malagasy farmers began using chemical fertilizers and chemical liquids [12]. According to our calculations, we can predict the decline in the production rate by the following curve:

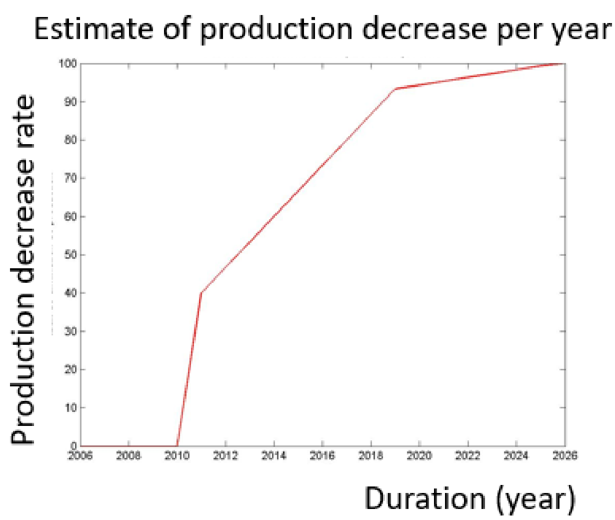

Figure 9. *Estimate of production decrease per year.*

This curve shows that by 2026 at the latest, the production rate will have fallen to 100%.

Design illustration of the effects of chemical use:

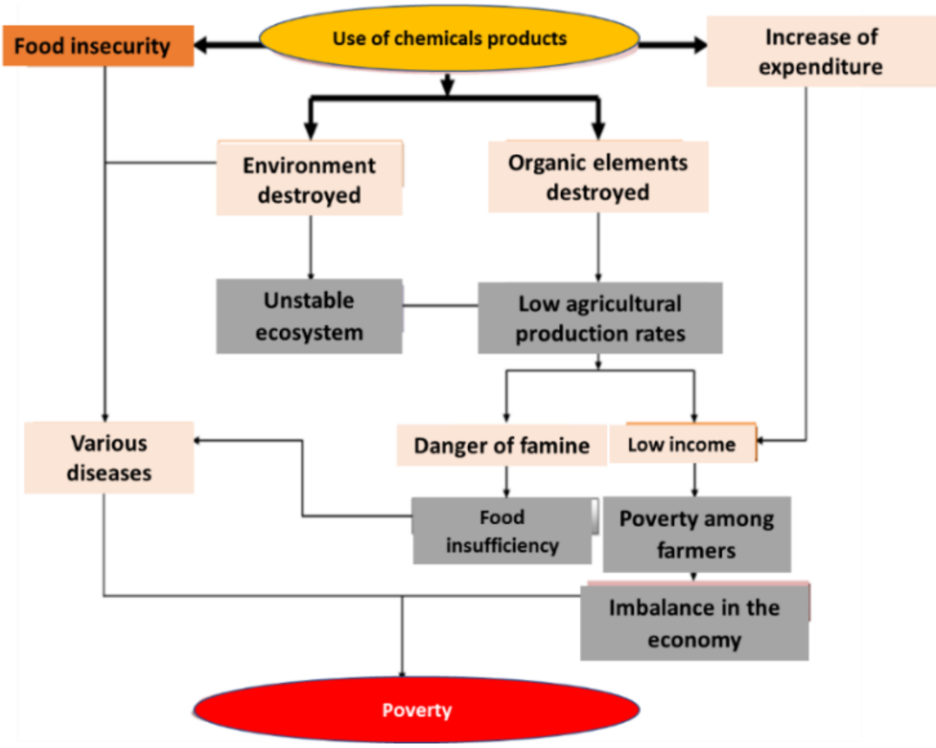

Figure 10. *Illustration of the effects of chemical use.*

This conceptual diagram shows that the use of chemical elements is a major factor contributing to poverty. So, what steps should we adopt to take care of the soil in order to avoid this constant decline? Two methods for improvement will be presented: Natural fertilizers and Natural liquid.

a) Natural fertilizers

The use of natural fertilizers enhances the structure of organic elements in the soil [8]. The photos below show some of the stages in our inventions:

Figure 11. *Natural fertilizers.*

b) Natural liquid

Based on our experience in the field, applying methods and techniques for treating the soil with natural fertilizers will be one of the best option in the future. Malagasy governments and development partners can also promote agricultural productivity growth by recognizing and capitalizing on the contribution for applying this method [13]. The photos below show some of the steps involved in creating a treatment method:

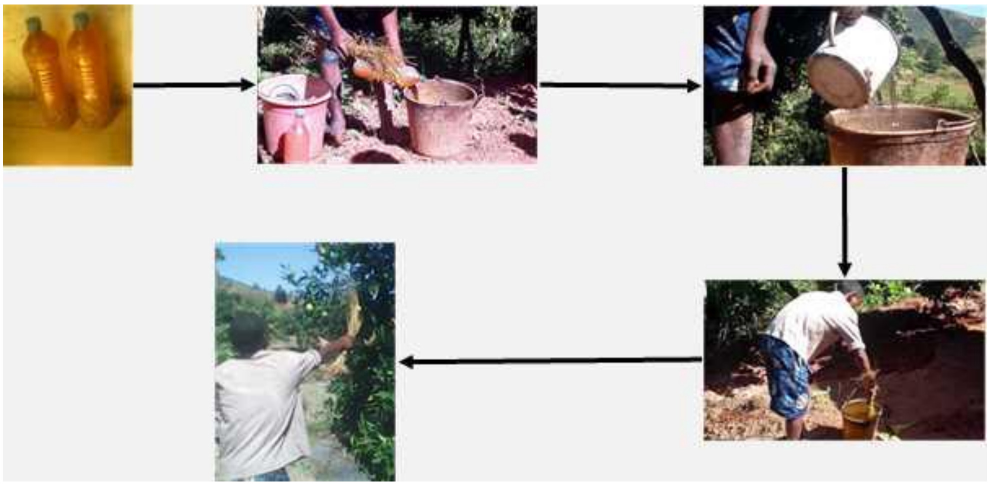

Figure 12. *Natural liquid.*

By way of illustration, the various photos we have taken in the field are evidence of effectiveness of our methods and techniques.

Figure 13. *Good result of our method.*

The rate of increase in production is rising at around 10% per year. So, we can say that the best solution is the use of natural elements but not chemical products. We hope that this rate will increase to 100% after 10 years.

Illustration by design of the Advantages of using natural products:

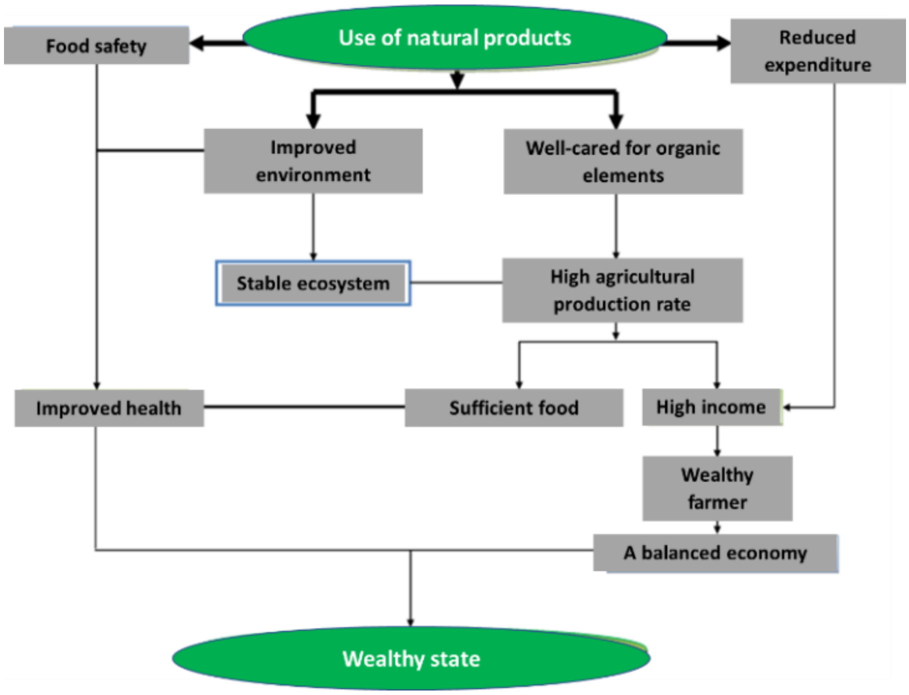

Figure 14. *Advantages of using natural products.*

This conceptual diagram shows that the revalorization of organic soil elements (use of natural elements) brings many advantages.

6. Conclusions

Within the framework of the exploitation of project under the topic which leads to the improvement of the agricultural products in Madagascar, we chose and respected the following steps: research of the topic which corresponds with the sustainable development in agricultural matter, this research report must accompany as of place of study in the 22 regions in general. This involves the fieldwork, the analysis of survey results, the planning and the determining body of the assignment.

During the courtesy visit we made to the 8 regions, we learnt that the use of chemical elements is an exclusive factor in soil destruction and the worst; it is the greatest factor that declines the agricultural production in our country, todays. Nonetheless, a research has been carried out to curb their use. That should be the biggest reason for Malagasy farmers not to use them anymore [14]. They have to replace this method for sustainable economic development and the green revolution in agricultural production.

In the course of studying the environmental and economic impact caused by the use of chemical elements, we can draw up logical frameworks to demonstrate the central problem. Therefore, to be able to carry out our objective in this project, the following stages has been respected: the feasibility study to be able to determine our goal to reach, plan of activity to define this activity envisage, it is about determination materials necessary and finally the study of estimated budget to allow to realize this project.

As key figures, Agricultural products are still Malagasy's main export industry, generating USD 2.5 million, accounting for 70% of total sales in 2020/21 [15, 16]. In 2022, the share of agriculture in Madagascar's GDP was 21.89%. For the next five years, the government of Madagascar intended to invest at least 10% of its budget in the agriculture, livestock and fisheries sector, with the aim of strengthening its management and infrastructure investment capacities. This commitment represents a total of $350 million. The present research looks at the future contribution of various products, such as: 821,600 T of maize (corn) in 2028 (current production: 267,633 T); 50,400 T of soybeans in 2028 (4,620 T in 2022). 25,000 T of groundnuts in 2028 (11,000 T in 2022) [17, 18].

Abbreviations

ARDWE	Agriculture, Rural Development, Water and Environment
DEA	Diplôme d'Etudes Approfondies
ESIIA	Electronics and Artificial Intelligence
ENAM	Ecole Nationale d'Administration de Madagascar
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistical
GDP	Gross Domestic Product
GIS	Geographic Information Systems
GSP	General State Policy
INSTAT	Institut National de la Statistique

SCILAB	Scientific Laboratory
STC	Specialized Technical Committee
TADAT	Tax Administration Diagnostic Assessment Tool
USD	United States Dollar
USGS	U.S. Geological Survey.
WB	World Bank

Author Contributions

Andriamiadanomenjanahary Harivelo Chandellina Camille: Conceptualization, Investigation, Supervision, Data curation, Writing – review & editing.

Randrianasolo Herilalaina Fabien: Conceptualization, Resources, Methodology.

Razafindrazaka Fenolaza Tsiory: Resources, Methodology.

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography

Dr. Andriamiadanomenjanahary Harivelo Chandellina Camille is a professor in the Department of Cognitive Science in ESPA (Polytechnic High School of Antananarivo), where he has been since 2017; is a professor in the Department of Telecommunication in IESAV (High School Institute of Antsirabe), and ENAM (National Administration School of Madagascar) in a various Department. He completed his PhD in Cognitive Sciences from STII University of Antananarivo in Dec 2017. He completed also his Master of Telecommunication from Polytechnic High School of Antananarivo in 2014 and Master of Computer Science Engineer from National Computer School of Fianarantsoa in 2004. Recognized for his exceptional contributions, Dr. Camille His research interests span both Science Cognitive, Data Analysis and Big Data Analysis in local and cloud. Much of his work has been on improving the quality, analysis, and performance of multiple areas, mainly through the application of data science and data scientist and performance evaluation. In the economy research, he has worked on macro and micro economy of Madagascar and also econometric. In addition he has made numerous contributions to IA, has focused on the big data analysis, economy, and optimization of decision making. For his research efforts he was awarded in 2017 during ‘’Doctorial’’by Antananarivo University Research Achievement Award for ‘outstanding research’.

Randrianasolo Herilalaina Fabien is a designer specializing in public finance control at the Ministry of Economy and Finance in Madagascar, part-time lecturer at the Higher Polytechnic School of Antananarivo (ESPA), with a focus on Geographic Information and Territorial Planning. He obtained his PhD in Territorial Planning from the University of Antananarivo in 2023 and his Advanced Studies Diploma in Agro-management from the Higher School of Agronomic Sciences in 2011. Recognized for his outstanding contributions in strategy and organizational management, Dr. Fabien has been awarded an entrepreneurial and leadership certificate from the Ministry of Youth and Sports. Additionally, he holds a diploma in diplomacy from the Center for Diplomatic and Strategic Studies (CEDS) of the Indian Ocean and has undergone training in expertise, specializing in financial administration at the National School of Administration of Madagascar (ENAM). He participated in the Agrobiodiversity Research Forum from November 29 to 30, 2017 in Fianarantsoa.

Razafindrazaka Fenolaza Tsiory is a Tax Inspector with the Ministry of Economy and Finance (MEF), specializing in Geographic Information Systems (GIS) with Madagascar National Parks (MNP) in Madagascar. He obtained his Master's degree in Electronics, Computer Systems and Artificial Intelligence (ESIIA) from the Institut Supérieur Polytechnique de Madagascar (ISPM) in 2002, and the Diplôme d'Etudes Approfondies (DEA) from the Ecole Nationale d'Administration à Madagascar (ENAM) focusing on Information and Communication Technology (ICT) in Public Administration in 2016. He also graduated from the Centre d'Etudes Diplomatiques et Stratégiques (CEDS) in Madagascar in 2017. Following a training course organized by the African Tax Administration Forum (ATAF), the International Monetary Fund (IMF) and the World Bank (WB) in 2021, he was awarded a certificate entitled Tax Administration Diagnostic Assessment Tool (TADAT) in Antananarivo.

Research Field

Andriamiadanomenjanahary Harivelo Chandellina Camille: Artificial Intelligence, Data and Big Data analysis, Economic, Mathematic, Management, Operational Research (optimization), Telecommunication.

Randrianasolo Herilalaina Fabien: management, sociology, agronomy, financial administration, economics, tourism, engineering, territorial planning, legal science, diplomacy.

Razafindrazaka Fenolaza Tsiory: management, public finance, diplomatic, financial administration, diplomacy.