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METHODOLOGY FOR UNDERUTILIZED CROPS IN ORDER TO INCREASE RURAL ECONOMIC GROWTH THRU ECONOMIC VALUE CHAIN PREDICTION

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Abstract

The methodology deals with creating a model to describe the effects of renewable energy, broadband technology and precision agriculture on rural GDP growing underutilised crops such as the Bambara ground nut. The hypothesis is that by using free energy and cutting out the middle man using broadband, we are able to improve the cost structure for alternative crops to have a lower selling price as compared to an "equivalent conventional crop" which has a mature supply chain and mature planting and production technologies run by traditional energy sources such as diesel generators. The substitution of conventional cash crops with the alternative underutilised crop can only be successful if the cost per nutrition is lower for the underutilised crop. One main result of this effort, which may be of interest to governments, is a reduction in the rate of migration of young people to towns and cities. However, the prediction of success before implementation may be a little complicated. This is because data may not be readily available and in enough volume to use simple machine learning techniques. Hence it is proposed that accurate prediction can be accomplished by training the SVM (Support Vector Machine) to recognise successful villages through only a few significant variables that improve local economic growth. All in all, this framework will be used to aid underutilised crop production by learning from existing crop models through exploring and understanding interactions between crops productions and marketing and then transferring this knowledge to underutilised crops.

Keywords—underutilized crop; economic modeling; rural economic growth; Support Vector Machines (SVM)

Introduction

Importance of Underutilized Crops

According to studies, 95% of the world's food is provided by only 30 species of plants. 3 major crops which are maize, wheat and rice already made up more than 50% of global consumption [1]. With the economic benefits provided by these major crops, it is believed that these three crops (maize, wheat and rice) will be increasingly dominating the market and consumption.

However, wheat is extremely heat sensitive, and rice is vulnerable to heat stress, rising seawater and flooding. Dependance on major crops has inherent agronomic, ecological, nutritional and economic risk that is unsustainable in the long run, especially facing the problem of global climate changes and global warming. It is believed that this will threaten the yield and crop sustainability of major staple crops directly affecting the food security around the world if alternatives are not considered [2].

This is one of the roles that underutilized crops play in ensuring food security. Many of these underutilized species are able to cope with very harsh and difficult environments as some of them are grown wildly in less favorable environments. As mentioned earlier, climate changes and global warming have led us to opt for underutilized crops to ensure food security.

In this project, our concern is to generate income for poor people. Underutilized crops are normally planted by local people in rural areas. Multiple uses offer greater opportunities to raise the income of these local people by diversifying plant products. This will contribute to improvement in the well being of these people in rural areas. As a result, it reduces the rate of migration of young people to towns and cities.

Promoting Cultivation of Underutilized Crops

For the past few years, cultivating and trading underutilized crops contributed to food security and food diversification. Selling underutilized crops also has been recognized as a potential income source for poor communities in rural areas in developing countries as different kinds of policies and frameworks are proposed to be adapted on underutilized crops to improve the supply and demand of these crops. In a study carried out by Horna et al. [3] that discussed on identifying things that determine the success of market chains on the underutilized crops in Ghana. The crop that is adapted in the paper is garden eggs in Ghana. The marketing chain of underutilized crops in Ghana is analyzed and specific policy is suggested to overcome each of the market constraints that are identified for better exploitation of the economic potential of the underutilized crop [3].

In another study conducted by Gotor et al. [4], an analysis was done on the impact of interventions on the conservation and adaptation of underutilized plant species on livelihoods of people from rural communities. The interventions including collaboration between farmers and experts to enhance the varieties of the underutilized crops and introduce value added technologies to the rural community are implemented in Yemen. Seed Supply System was developed and fertilization trials were carried out as well. The results show that these interventions are positive correlated to increase in yield of underutilized crop and hence generate more income to the farmers in this rural area [4]. This paper shows that with proper intervention such as implementing precision agriculture and value added technologies, for example broadband technology, to rural farming methods could bring more income to local farmers.

The paper discussed by Ravi et al. on mobilizing underutilized crops in India by initiated from a bench mark survey was used to study the socio-economic-technological status of the poor community. Based on that, a series of agronomic interventions to promote the cultivation of underutilized crops and generate income through the use of genetic diversity, improved agronomic practices and marketing are suggested [5].

Most of the frameworks in cultivating and marketing underutilized crops species involve human experts to carry out surveys and studies on the plants with minimal adaption of technologies. Their marketing strategy is to diversify the varieties of crop products. They aimed to increase the yield of underutilized crops in order to increase income of rural poor. However, in this project, technologies such as precision agriculture are adapted to study the crops to optimize the yields, broadband service to improve marketing strategy while at the same time implementing renewable energy system to cut cost on the process of cultivating underutilized crop. Hence, increased yield and reduced cost generates more income for rural communities.

In the paper by Guillaume et al. [3], the underutilized crops are defined based on the three characteristics which are: the crop is locally produced in a certain or numerous of restricted rural area, lacking of scientific knowledge on the crop (only practical knowledge is known by local farmers), and current economic value of these crops is relatively low compared to their potential economic value. Successful commercialisation is defined by two characteristics in this paper [3]. The first characteristic is that distribution of profits should be sufficient for the primary producers to continuously produce the crops. The second characteristic is the sustainability of the market overtime in terms of price and profit margin as demand increases. Based on the economic factors identified, the conditions that affect successful commercialisation of underutilised crops for people in rural area are identified as demand expansion, increase in efficiency of supply and supply control mechanism.

Reviews

Reviews on Implementing Technologies for Economic Growth in Rural Areas

Broadband Technology

In order to counter the economic factors as identified in the paper by Guillaume et al, three technologies are proposed to be implemented in the rural area to overcome the economic constraints of marketing underutilised crops which are renewable energy system, broadband technology and precision agriculture. Economic growth in rural areas after implementation of these technologies is governed by the increase in economic value of underutilised crops. Gross Domestic Product (GDP) is the market value of all the goods and services produced over a given period of time. GDP is the primary indicator to gauge the economic growth of certain areas, in this project particularly, the rural area. However, GDP growth is highly dependent on the two main aspects which are aggregate demand and aggregate supply according to Pettinger. Aggregate demand includes consumer spending, investment levels, government spending and trading, while aggregate supply includes productive capacity, efficiency of economy and labour productivity [6]. In order to achieve growth in aggregate demand, growth in a productive capacity must be achieved. One of the reasons productive capacity can occur as stated by Pettinger is the improvement of technology which enables higher labour productivity, for example, development of computers enables greater productivity. A study carried out by Stenberg et al. examines the contribution of broadband in rural America found that the rural areas with early access to broadband had higher levels of growth in wage and salary jobs, non-farm proprietors and private earnings [7]. The paper also summarised ways that rural area communities and businesses can potentially benefit from broadband. Kuttner investigated that the broadband telecommunication capabilities will be a limiting factor to enhance the productivity of agricultural activity which has been the most important contributor to economic growth [8].

Through the use of broadband technology, farmers are able to directly communicate with consumers and eliminate the needs of middlemen. This can solve the economic constraint of lacking transparency in the process of marketing underutilised crops. The profits obtained from selling the crops are also directly payable to farmers without going through a third party which will improve the economic growth in the village. Middlemen charge a high mark up price on consumers which will reduce the demand. By eliminating them, the price of the crops is reasonable enough to drive the demand up and profit margin is optimised. Law of Demand states that as the price of a good rises, the quantity demanded will decline and vice versa. For underutilised crops to be economically competitive to major crops is no longer a mission impossible. Implementation of broadband services can also overcome the problem of lacking practical knowledge and information on consuming underutilised plants by a distant user. This can be done by uploading information to the internet to share with every user around the world to promote the use of underutilised crops. At the same time, sharing scientific knowledge over the internet on underutilised crops that are collected from farm field through precision agriculture with farmers from different corners of the globe aids the farming process of these crops. With broadband service, challenges from the demand side could largely be reduced when users can easily obtain knowledge on consuming underutilised crops including the way to deal with the crops and crop products, nutritional values provided by the crops and so on. Increase in demand usually implies increase in profit selling the crops which then relates to increase in GDP of farmers in rural area by growing and selling underutilised crops.

Precision Agriculture

Precision agriculture optimises agricultural activities in terms of crop science, environmental protection and economics. Precision agriculture matches farming activities more closely with the needs of the crop (water and fertiliser inputs), while at the same time reducing the environmental footprint produced during farming (limiting leaching of nitrogen). This will largely boost the competitiveness of the crop economically due to proper management of fertiliser usage and other inputs based on crop needs. Diagram 2.3 shows the basic process on precision agriculture. Through precision agriculture, the record of the underutilised crops can be stored in data base server for future decision making and recording of scientific knowledge on process of growing these underutilised crops. This could solve the problem of incomplete scientific knowledge on underutilised crops and increase the yield of crops without the needs of intensive labour intervention. Precision agriculture would bring benefits to the supply side of underutilised crops production.

In Bangladesh, a dynamic multi-layered Geographical Information Systems (GIS) database to model wide range of dynamic situations allows the system to be adapted in Bangladesh as the climates and hydrologic conditions vary in the country. GIS collects, stores and analyses spatial data in precision farming. The Government intends not only to increase the agricultural production but also to create a sustainable rural economy with agriculture as its core through the implementation of precision agriculture [9]. In a theoretical example conducted by Gred et al., the results shows that the economical advantages for applying precision agriculture to efficiency related input such as labour, time and mechanical operation is more significant as compared to material inputs such as fertiliser because the amount of fertiliser saved is small compared to total fertiliser used for small scale farm. However, precision agriculture is economically feasible by evaluating the amount of water guaranteed to be safe for a long period and lower cost by reducing nitrate leaching to ground water [10]. Mayes et al. suggested that application of precision agriculture on underutilised crops may be one of the way to optimise crop agronomy as for most of the underutilised crops, the agronomy have not been optimised [11].

Internet is essential to transmit data and store data regarding the crops such as crop agronomy for future use. Hence, broadband technology is necessary to complement the adaptation of precision agriculture on the farm field. In this project, precision agriculture such as wireless sensors is to be implemented with the use of renewable energy and broadband technology to collect data and optimise input on underutilised crops, for example water level, fertiliser amount, soil moisture level, chemical properties, temperature and so on. From the information obtained and proper inputs management, yield of underutilised crops can be maximised and supply to the market increases with economically competitive price.

Renewable Energy System

Study shows that 1.6 billion people, a quarter of humanity, live live without electricity. Lack of electricity in rural areas worsens the situation of people living in this area. Grid extension to supply power to serve these rural areas is not economically feasible due to the high cost of distribution and also due to transmission loss. This happens especially in the area are mostly covered by mountainous and thick jungle. They rely on diesel generators as their main source of power. However, the cost of electricity using a diesel generator is high due to the difficulty of fuel transportation to these areas. A cost effective framework for sustainable and reliable source of energy may be achieved through adaptation of renewable energy system to provide off grid electricity to rural areas in order for people in the areas carry out daily and economic activities.

Tambwe stated that access to energy is essential to promote economic growth in rural areas as agricultural improvement, communication technologies and industrialisation require abundant, reliable and cost-effective energy access. This can be achieved through implementing renewable energy [12]. Richard et al. discussed the economic analysis and environmental impacts of integrating a Hybrid Renewable energy system for a remote village in Alaska stating that transporting fuel for diesel electric generators which is currently widely used is expensive due to the remoteness of the site. Adapting a Hybrid Renewable energy system reduces the cost of fuel consumed by the diesel generators which implies GDP may grow [13]. Many plant species that can be cultivated as food have often been underutilised even when they play essential roles in food security, nutrition and income generation for poor communities in rural areas [14]. In a study carried out by Global Forum on Agricultural Research found that some underutilised species with multiple uses offer great opportunities to raise income of the rural poor by diversifying plant products indicates possible economic growth through cultivation of underutilised crop [15].

Setting up a Renewable Energy System with a mini-grid for electricity distribution allows basic usage of electricity in rural areas for lighting, refrigeration, education, and communication which benefits from the process of cultivating and marketing of underutilised crop, thereby increasing economic productivity and creating new income generation opportunities for the rural communities [16].

Despite the advantages, Renewable Energy Systems are often considered the high cost option especially with the high capital costs of implementation. Khatib et al. performed a comparison of cost, and Hybrid PV/ diesel generator system is proved to be more feasible as compared to a standalone PV system and a standalone diesel generator by optimising the hybrid renewable energy system for zero load rejection. Hence, low operation cost and maintenance cost with non-existent fuel expenses and an increase in reliability and life span of Renewable Energy systems enables an offset of high capital cost especially in remote rural areas. Furthermore, environmental cost associated with the replacement of a conventional energy system with renewable energy systems should be taken into account as well in order to cultivate high nutritious underutilised crops [16].

Proposed Methodology

The model is divided into three stages. The first part is the Rural Area GDP Model where the technologies are defined as features that affect economic activities of the rural area in this project. For this part of the project, a prototype rural village model will be developed to collect data associated with the features and economic activities. The relationship between the features and economic activity is to be explored to see if it can produce the equations that described the relationships.

Based on the relationship derived, system dynamic model can be built, and the variables can be manipulated to observe the change in output GDP. This is the second stage. The output GDP is compared to a threshold GDP of a successful village that could be found in the real world. GDP greater than threshold GDP is classified as 1 (Potentially successful village) and lower than threshold is classified as 0 (Potentially unsuccessful village). This economic model generates the labelled data for training data set that will be the input of SVM in the third stage.

In the third stage of this project, SVM is to be developed to produce the output based on the training data set generated from the Rural GDP model. Given the testing data set of villages, output of SVM predicts the final and accurate GDP value of these villages and classifies the village as potentially successful or unsuccessful.

The reason to have the SVM to do the prediction even though a model will be built is because the model is built based on assumptions and not accuracies. On the other hand, SVM works on historical data. However, for this project, historical data is not able to retrieve because a village that has already cultivated underutilised crops while also implementing a renewable energy system, precision agriculture, and broadband technology does not exist yet. Hence, model is required to generate labelled data to train the SVM.

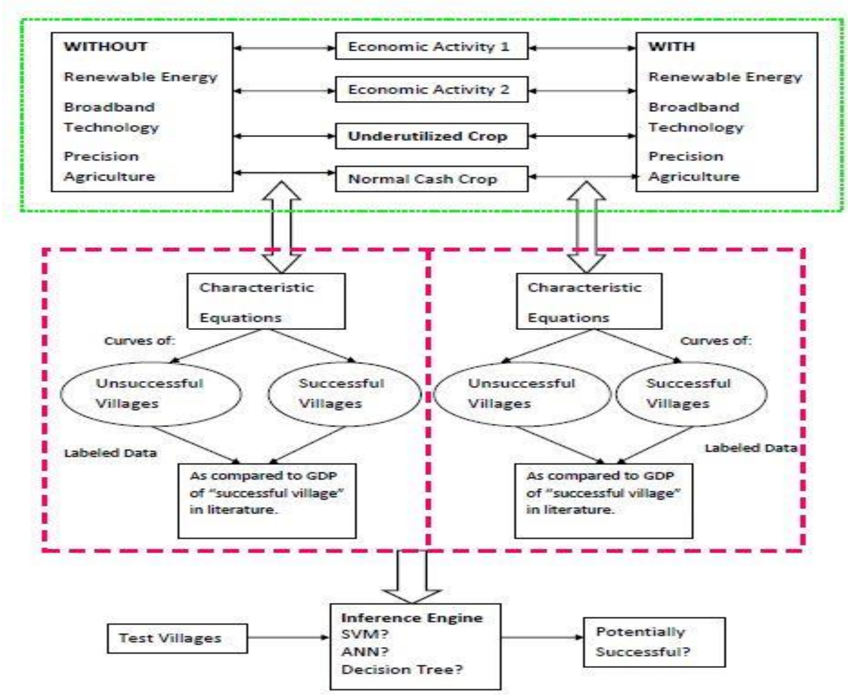

Figure 1: System Architecture

The proposed system consists of a Renewable Energy system that is able to provide low cost and sustainable energy to a remote location; broadband technology which allows farmers in the rural area to directly communicate with consumers and upload information to database through internet; precision agriculture to optimise the inputs to cultivate underutilised crops and increase yields. These technologies are proposed to be implemented to promote successful marketing strategy by increasing the supply and demand of underutilised crops. Figure 3.1 shows the structure of this proposed system.

As can be seen from the system architecture, this system is divided into three stages. At the first stage, characteristics of a village are to be identified such as the economic activities (farming of normal cash crops, fishing, hunting and so forth) that are carried out and sources of energy (diesel generator) in the village before underutilised crop and technologies are brought into the area. The relationship between these characteristics are then examined and defined to build up a model that explains the connection. The relationships will be built based on data collected from visits to farm fields. Subsequently, another set of relationships is defined by replacing the existing energy sources with renewable energy systems and then adding in the cultivation of underutilised crops as new economic activity along with the other two technologies (broadband service and precision agriculture) to form another model to show the difference between output GDP with and without implementation of proposed technologies. These variables can be manipulated with different combinations to obtain training data for SVM.

Initially, the model will be built from a simple relationship based on theories and assumptions. Relationship between the economic activities and technologies will then be further developed from a desktop village that is scaled down from a real village to reflect more of real life. The model can be verified by conducting field trips to rural areas to collect the data to prove that the relationship is approximately correct.

At the second stage, relationships between economic activities and technologies that are derived earlier in first stage form characteristic equations that can be represented by each multidimensional curve that defines characteristics of successful and unsuccessful villages based on the GDP that is generated by these villages by comparing to threshold GDP of successful village that can be found on literature. The curve with GDP greater than threshold GDP is classified as 1 (Potentially successful village) and lower than threshold GDP is classified as 0 (Potentially unsuccessful village). This will generate labelled data to train the classifiers at the next stage.

Given the testing data set of villages at the third stage, a classifier that is chosen after evaluating the performance will classify successfulness of test villages based on the GDP generated by these villages with different characteristics. Hypothetically, Support Vector Machine is used as the baseline classifier due to the robustness of the SVM applying on complex real world situation. However, other classifiers for example decision trees and artificial neural networks will be tested and evaluate the performance towards this application.

In order to make sure that market-driven price of underutilised crops can be achieved when technologies (renewable energy system, precision agriculture and broadband technology) are implemented in the rural area to aid in cultivating and marketing underutilised crops, techno economic modelling could be adapted. 7 steps are involved in techno economic modelling where the first step is to identify financial constraints, goals and potential market of underutilised crops which includes profit margin, initial facility capital loan, transportation and storage cost, potential market size and etc. This is followed by defining physical constraints and goals which are farming area, soil properties, weather, rain fall, irrigation and so on. The third step is to model an existing process of cultivating and marketing cash crops which approximate the requirements by underutilised crops. Cost targets (expected yield and profit) that are to be achieved are then identified. The model is then incorporated with the technologies to achieve the targets. A more complex model is developed at the next step by taking into account dynamic elements that more closely reflect the real world. This model will be tested and validated by collecting real data from farm field and implement on the model.

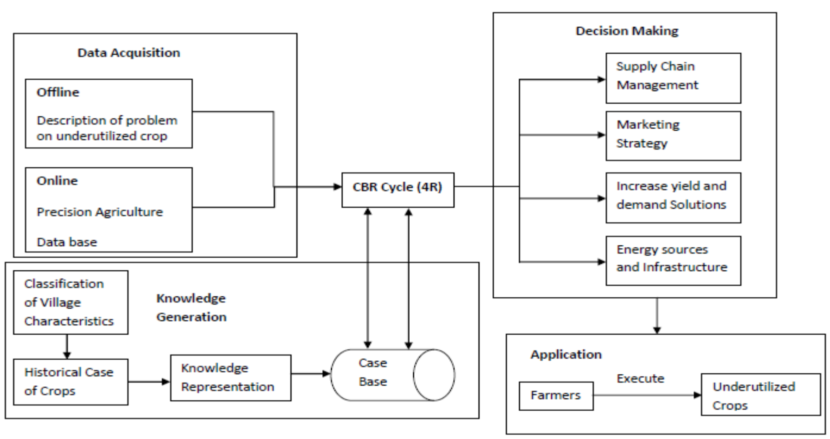

Figure 2: Decision Support System

Figure 2 shows the decision support system. The decision support system is built up by three main components. The first component is data acquisition where problems regarding underutilised crops are identified and addressed. These problems will be input to Case Based Reasoning Cycle. When a problem is addressed, a solution is retrieved from Case Base that is formed in the Knowledge Generation component. In this component, classification of village characteristics such as demographic, infrastructure, technologies and so on that influence successfulness of cash crops generate a domain of knowledge that forms historical case of crops. These different cases are represented in various forms depending on information available on the case.

After the problem goes through Case Based Reasoning Cycle (Retrieve, Reuse, Revise and Retain), output of the cycle is a solution of similar cash crop problem applies to problem arises by underutilised crop which then forms the decision making platform. This component solves the problem related to underutilised crops let it be the supply chain management, marketing strategy, solutions to increase demand and yield, energy sources and infrastructure and so on which is finally applicable to underutilised crops.

Conclusion

The proposed methodology is aimed to solve the constraints faced when marketing underutilised crops in order to improve income and economic growth in rural areas. By proposing this hybrid-case based reasoning and crop-based modelling, this study aims to assess and optimise the economic value of underutilised crops to be economically comparative with the cash crops that already achieved economic success. It is found that the four main economic factors that caused the underutilised crop to be neglected which are the difference between current economic value and potential economic value of underutilised crops, absence of market for underutilised crops, market imperfections and market failures.

Hence, the proposed technologies play the roles to optimise the economic value of underutilised crops, and the proposed model aims to assess economic value of the crops in order for neglected crops to be as competitive and successful as cash crops that are widely available on the market. This is done by implementing Renewable Energy Systems, Precision Agriculture, and Broadband Technology to create more supply and demand of underutilised crops while also lowering the price of underutilised crops in order to be able to compete economically with normal cash crops and balance off the economic potential value and current value of underutilised crops. However, implementing these technologies in the real world directly could be costly especially if the system failed to achieve initial intention. Hence, economic model is proposed to be built to observe relationship between the technologies and economic activities (including underutilised crop) and collect associate data. Inaccuracy of the model can be solved by implementing machine learning techniques. In this project, Support Vector Machines will be used due to suitability and robustness of the classifier. Support Vector Machines classify test data of a real village to be potentially successful or unsuccessful based on training data generated from economic model. Other classifiers such as Decision Trees and Artificial Neural Network will be tested as well to compare performance with Support Vector Machines. These data is then store in the database to form knowledge based system that aids underutilised crop production by learning from existing crop models through the process of Retrieve, Reuse, Revise and Retain of Case Based Reasoning. The system is targeted to be used by farmers that are cultivating and planned to cultivate underutilised crops as well as users who are interested to obtain data and knowledge on underutilised crops.

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