Analysis of farming efficiency and smart farming system development in supporting garlic self-sufficiency: A concept

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Abstract. In Indonesia, the agricultural sector has a strategic role in sustaining the national economy. Various policies have been made with the aim of increasing the strategic role, both in the form of policies to achieve food self-sufficiency, reduce imports and even policies to encourage exports. One of the important commodities in the agricultural sector is garlic. This commodity is the government's priority to be managed and targeted for self-sufficiency by 2021. This paper tries to trace the success of garlic farming through data studies and related literature. The review of existing data shows that over the past four years (2014 to 2017) the ratio of garlic production to imports was very small just only 4.15%, indicating that Indonesia still depends on imported garlic. Amount of imported garlic grew 5.09% per year, but on the other hand, domestic production grew negatively -1.73%, meaning that domestic production is still not enough for domestic consumption. As a discouraging form towards the achievement of self-sufficiency, this paper also reviewed the literature on the efficiency concept of garlic farming at the farm level through the approach of econometric models, as well as the concept of developing smart farming systems used for product tracking functions to the consumer level, on the contrary can be traced back to products produced by farmers. Through the offering of these two thought concepts, it is expected to contribute in supporting the government program to achieve garlic self-sufficiency.

Keywords: garlic self-sufficiency, farming efficiency, smart farming system

1. Introduction

Indonesian government has made a policy to achieve garlic self-sufficiency in 2021, with the aim to reduce imports which tend to increase. This step is very important because the average ratio between garlic production and imports from 2014 to 2017 just only 4.15%. This shows that the dependence on imported garlic is still high. The Ministry of Agriculture estimates the land which is needed for garlic planting to achieve the self-sufficiency covering 65 thousand hectares, while for the seedling land it takes 14 thousand hectares [24]. The land needs are very large because in 2017 there was only 2,146 hectares of the harvested land. Therefore, an additional 60 thousand is needed to met the land needs [23].

Regarding land availability [7], stated that the garlic-producing land in Indonesia is concentrated in the highland with altitude from 600 metres to 1,100 metres above sea level (asl), with cool and dry air. In lowland areas where the availability of land is still wide, it is rare to find garlic-producing areas. Therefore, from the needs of a large area to achieve self-sufficiency, a suitable location needs to be chosen by considering the ability of farmers as managers of garlic farming.
Farmers' cultivation techniques which has an important part of the garlic farming system have not been efficient. The use of production inputs such as land, seeds, and fertilizers are technically not yet efficient. Seedlings are one of the main factors that technically lead to low farm efficiency [16]. The decline in garlic productivity from year to year was caused by tuber seeds that were suspected of carrying the disease [13]. In addition, a number of local seeds are more widely available for highland such as Lumbu Hijau and Lumbu Kuning, only Lumbu Putih varieties are available for lowland [20]. Highland garlic varieties are not good if planted in the lowland.

Local garlic produced by farmers is often less competitive with imported garlic in terms of size and price. This makes the numbers of imported garlic. On the contrary, garlic planted by farmers decrease. On the other hand, domestic consumption is increasing along with the increase in population. The increase in imports actually began since Indonesia signed Punta del Este as the GATT system in 1986 [17]. The system requires each country to change non-tariff barriers to tariffs and reduce domestic and export subsidies for agricultural commodities.

Although there are many obstacles to achieving garlic self-sufficiency in the future, it is not necessary to think backward. The challenges ahead will be more complex, the agricultural sector is faced with global demands which are often known as the “Industrial Revolution 4.0”. [22] Expressed their opinions about the challenge, that the Industrial Revolution 4.0 is a form of response to the rapid development of sensor technology, interconnection, and data analysis integrated into various industrial fields, including the agricultural industry. The challenge also affects the government's desire to achieve garlic self-sufficiency. It is not only government obligation to think about it, but also for the academics and practitioners.

By looking at wide-range obstacles and challenges to achieve garlic self-sufficiency, this article examines the aspects of garlic farming on a micro-scale based on technology. This is a form of contribution from practitioners to realizing self-sufficiency in garlic, reducing imports, and it can even be found that the concept of smart farming can meet the demands of the industrial revolution 4.0. The approach method used is a literature study of various garlic farming and trading policies, also exploring the facts of local wisdom, the concept of quantitative analysis on farming aspects and the study of the Industrial Revolution 4.0.

2. Import, production management and land availability

In 2017, Indonesia's imported garlic about 559.73 thousand tons, while production was only 19.16 thousand tons (figure 1). During the period 2014 to 2017, imported garlic grew by an average of 5.09%, whereas production in the same period decreased by 1.73%. The main import of Indonesian garlic comes from China. Indonesia is the largest garlic importer from China with a contribution of 17.9% of China's total exports, above Vietnam with 6.2% and Malaysia with 5.6%. In 2017, China's garlic stock reached a record of 3.2 million tons high, rose 1.05 million tons from the previous year [25]. Seeing the high amount of garlic imports in Indonesia, the estimated of land needs for planting to support self-sufficiency in the area of 65 thousand hectares becomes a tough job. One other way that can be done is to increase the productivity of garlic.
The productivity of garlic produced by Indonesian farmers was not optimal, the reason is the application of technical cultivation that is not in accordance with the SOP (Standard Operational Procedure), also the use of low-quality seeds [11]. In addition, diseases also affect tuber size, resulting in low productivity. This condition triggers an increase in import volume. In 1983, the import of garlic only reached 9.92 thousand tons, but in 2017 the number reached 559.73 thousand tons. Efforts to increase garlic productivity through the use of good seeds is believed to have a significant effect in increasing production, so that import can be reduced [9, 15]. The problem faced so far is the conventional seed production techniques which have not produced high-quality seeds, one of which is due to viruses that are always carried on the seed bulbs. Seed production through tissue culture techniques can be implemented as an alternative method. Tissue culture methods could create new plants that are virus free from plants that were originally infected [18].

To increase garlic production in the future, it is not only depending on the seed’s quality, the management of irrigation and fertilization of garlic plants are also a determinant of production. Surface irrigation management combined with fertilization in production input management system can actually increase 19% of garlic production [19]. Surface drip irrigation has a noticeable effect on garlic yields than other types of irrigation. Drip irrigation technology combined with fertilization can be considered as a breakthrough than previous irrigation methods which use water flooding on garlic land.

By looking at the constraints of using garlic cultivation technology, especially the use of production inputs such as seed, irrigation, and fertilization, it is necessary to breakthrough to obtain an efficient garlic farming system. The step that needs to be done is to develop the concept of efficiency farming on new land by considering various factors. The concept of practical development and research needs to be carried out simultaneously because time to achieve the garlic self-sufficiency target in 2021 is getting closer. Therefore, the selection of development sites is a determining factor. Parigi Moutong Regency in Central Sulawesi is one of the areas which has a large potential of land, there is a land that has an altitude above 600 meters and land under 600 meters. However, agricultural land in Parigi has limitations in terms of water availability [5].

This paper describes the concept of efficient garlic farming development combined with the application of smart farming in Parigi Moutong Regency, Central Sulawesi. This region chosen with the consideration of the ease in integrating various technologies, scientific studies, and management of its implementation. Various parties such as business people, government and farmers in Parigi Moutong District have been willing to become new development areas. If this implementation is considered successful in terms of various aspects, then replication is carried out on a wide scale in other locations.
3. Efficiency concept on garlic farming

The efficiency of the farming system is basically in the concept that is intended for producers/farmers to be able to manage their farms well and ultimately increase production and profits. A rational farmer will use optimal production input as long as the added value produced is equal to or greater than the additional cost of adding the input. Efficiency is a comparison of output with inputs used in a production process [8].

The concept of efficiency into three parts, namely: 1) Technical Efficiency, 2) Price Efficiency, and 3) Economic Efficiency [2]. Technical efficiency measures production performance at certain levels of input use. Price efficiency or allocative efficiency measures the level of success of farmers in their farming to achieve maximum profit. Maximum profit can be achieved when the marginal productivity value (MP) of each given factor of production equals with the marginal cost. Economic efficiency is a combination between technical efficiency and price efficiency.

The concept of technical efficiency can be explained in terms of input use [1, 10] and is assumed to be in the Constant Return to Scale condition. figure 2 shows the concept of technical efficiency, where the horizontal axis represents the use of input X_2 and the vertical axis describes the use of input X_1. The SS curve is *isoquant* which represents various combinations of inputs (X_1 and X_2) which are used to produce a certain number of outputs (Y). All points on the *isoquant* reflect technical efficient production.

An effort can be made to measure the efficiency of the farming system, which operates at point P. At this point (P), the on-farm is assumed to produce the same level of output (Y) as it is produced on the *isoquant / SS’*. To determine the technical efficiency of the farming system, a line can be drawn from the origin (0) to the point P. The line crosses the *isoquant* at point Q. In the case of a technically efficient farm, the total output (Y) produced by using input X_1 and X_2 are defined by input point Q. At the point P, input X_1 and X_2 are not used efficiently by farmers. So, the observed technical efficiency (TE) of a farmer is defined as the OQ / OP ratio, which shows the proportion where the combination of P inputs can be reduced.

Related to figure 2, if input prices are available, allocative efficiency (AE) or according to [1] also called price efficiency can be determined. The *isocost* line (AA’) is described as offending SS’ *isoquant*
and cuts the OP line at point R. Point R shows the optimum input-output ratio which minimizes production costs at a certain level of output because the isoquant slope is the same as the isocost line. Point Q is technically efficient, but is allocatively inefficient because of production at point Q costs higher than point Q'. The OR-OQ distance shows a decrease in production costs if production occurs at point Q' (efficient on TE and AE). If TE and AE can be calculated, then economic efficiency (EE) can be calculated by multiplying TE and AE values.

3.1. Stochastic frontier production function and efficiency calculation

The equation of the stochastic frontier production function in summary as follows [4]:

\[ Y_i = x_i \beta + (V_i - U_i), \quad i=1,2,3,\ldots,n \]  

where:
\( Y_i \) = production produced by the i-th farmer
\( x_i \) = input factor used by the i-th farmer
\( \beta \) = parameter vector that will be estimated
\( V_i \) = random variables related to external factors, dispersed
\( \left( V_i \approx N(0, \sigma^2_V) \right) \)

\( U_i \) = non negative random variables, assumed to affect the level of technical inefficiency and related to internal factors, dispersed
\( \left( U_i \approx N(0, \sigma^2_U) \right) \)

The stochastic frontier production function equation has been used for two decades and experienced development by accommodating various things, including: assuming a general distribution for \( U_i \) such as truncated normal distribution, considering panel data and time, variations in technical efficiency, development of methodology for cost function and also estimation of the existing equation system [4]. Parameter estimation of the stochastic frontier production function can be completed using the Frontier 4.1 software program.

In the stochastic frontier production function, the components of model error consist of \( V_i \) and \( U_i \), as shown in equation (2). Particularly for the \( U_i \) component which describes the effects of technical inefficiency can be modeled through the following equations [3]:

\[ U_i = z_i \delta + W_i \]  

\( W_i \) is assumed truncated normal dispersed with mean 0 and variety \( \sigma^2 \).

3.2. Technical Efficiency and Economic Efficiency

Frontier 4.1. Software can be used to estimate the production function with a variety of options, namely: 1) presume the production function model with panel data that is not balance and have a truncated normal distribution, 2) a two-stage regression function by calculating the estimation of production functions and efficiency, then the predicted inefficiency effects value of specific variables (such as: managerial, producer characteristics, etc.) and 3) estimation of cost functions and efficiency predictions for both technical efficiency and cost function efficiency [4]. In terms of efficiency calculations [3], make general equations for technical efficiency, as follows:

\[ ET_i = \exp(-U_i) = \exp(-z_i \delta - W_i) \]  

where the value of \( ET_i \) between 0 and 1 or \( 0 \leq ET_i \leq 1 \).

Assuming that the on-farm is intended to achieve profits, then it must allocate the minimum cost from the existing inputs, or the on-farm achieve allocative efficiency (AE). Allocative efficiency can be
calculated by dividing the value of Economic Efficiency (EE) with ET. For this reason, the EE value must be calculated first. Before calculating the EE value, from the stochastic frontier regression function, the dual frontier cost function must be derived with the following equation:

$$\hat{C}_i = C(y_i, p_i, \beta_i) + u_i$$

where:

- $C_i$ = cost production
- $y_i$ = numbers of output
- $p_i$ = input price
- $\beta_i$ = parameter coefficient
- $u_i$ = error term (cost inefficiency effect)

Economic efficiency can be calculated based on the ratio of the total observed minimum production costs ($C^*$) to the total actual production costs ($C$), as follows [6]:

$$EE_i = \frac{C_i^*}{C_i} = \frac{E(C_i \mid u_i = 0, y_i, p_i)}{E(C_i \mid u_i, y_i, p_i)}$$  \hspace{1cm} (5)

4. Smart farming concept

The concept of smart farming in this paper emphasizes the garlic business process carried out by anticipating the phenomenon of Industrial Revolution 4.0. Indonesia as part of a global system that is moving towards digital business must adapt quickly. Attempt to increase garlic production is not enough. Farmers and stakeholders together with government and business people must create an integrated smart farming concept, one of which is through the application of Cyber Physical System (CPS) integrated with the Internet of Things and Services (IoT and IoS) into the industrial process [12]. CPS technology is chosen because it has a concept that combines the real world with cyberspace. This merger can be realized through the integration between physical processes and computation in a closed manner (figure 3).

[22] Concluded that the application of Industrial Revolution 4.0 provides high benefits for business processes and also the perpetrators, the benefits in are:

- Development in product is faster, flexible and efficient in utilizing resources;
- Improved productivity and increased income, increased demand for labor skilled and increased investment;
- Data utilization from each of existing production process;
- Fulfill the individual needs, more dynamic processes and optimal decision making; and
- Manifest the efficient and smart production process according to consumer needs at a reasonable cost.

Industry 4.0 focuses on making intelligent products, procedures and processes. Producers in industry 4.0 are described as ‘Smart Factory’ who are able to manage complexity, resistant to interference and able to produce goods more efficiently. Activities that occur in smart factories involve humans, machines, and resources that communicate with each other naturally as in social networks [12].

Similar with the Industrial Revolution 4.0, the term of Agriculture 4.0 is also known in the agricultural sector, namely the agricultural revolution in the future and must be green, approached with science and technology. Agriculture 4.0 in its application consider the demand and supply chain, uses technology not only for the sake of innovation but also to improve and handle actual consumer needs. The future will use advanced technologies such as robots, temperature and humidity sensors, aerial
images, and GPS. This progress enables businesses to be better, more efficient, safer, and environmentally friendly [21].

Furthermore [21], describes the use of new technology and new solutions in Agriculture 4.0 could giving hope to the problem of food scarcity. Through the application of Agriculture 4.0, it is expected to produce different products using new technology, bringing food production that has been produced to consumers and increasing efficiency in the food chain by utilizing cross-industry technologies and applications. The world challenge in producing food will be greater, the world must produce 70% more food by 2050, use less energy, fertilizer, and pesticides. On the other hand, it also important to reduce the level of greenhouse gas emissions and overcome climate change effects. Old technology must be maximized, and new ones must be produced.

5. Discussion and solutions

The study of the Indonesian garlic farming system in this paper has revealed several obstacles to future development, such as the availability of land which is ready for planting, the readiness of local varieties suitable for both highland and lowland, efficient cultivation technology, even the marketing aspects of garlic products that must be ready to compete with imported products, are some of the tasks of many obstacles that must be found a solution. Especially if it is related to the Agriculture 4.0 concept as described previously, the effort to achieve garlic self-sufficiency must be well designed.

There are two questions related to the development of garlic, i.e. how to increase garlic production so that it can help the achievement of self-sufficiency in 2021? and how to answer the challenge of the garlic industry facing the Agriculture 4.0 era so that production can compete with imported garlic? The second question is not an easy job in its implementation because careful planning is needed. Therefore, through this paper the concept of "Analysis of Farming Efficiency and Development of Smart Garlic Agriculture" was presented. The concept approach is both presented in figure 3.

Figure 3. The Concept of Smart Farming on Garlic Farming
There are five design elements in the concept of smart farming on garlic farming and each other is interrelated. The function of the five elements can be explained as follows:

- **Element 1 - Field Activities**
  In the field activities, there are many activities that must be carried out, starting from land preparation, preparing the cultivation model, monitoring the use of production inputs, observing climate and monitoring the activities of agricultural machinery used during the production process. In this field activity, farmers are required to work together in one or more groups. Each group is guided by field experts. Activities carried out by farmers are monitored every day using manual worksheets. Farmers are asked to fill their daily activities during the cultivation process of garlic. All data is inputted into the computer system and stored on the local server. The data collected in this field activity is analyzed periodically to see the level of efficiency of garlic farming from each farmer using an econometric approach referring to equation (1) to equation (5). The indicators that are monitored include Technical Efficiency (TE), Economic Efficiency (EE), and in the long run followed by Environmental Efficiency analysis (EEnv). In addition, another analysis is carried out such as aspects of farming inefficiency or often called the analysis of managerial abilities of each farmer. The results of the analysis that have been tested, then made a model with computer that can be used as a monitoring activity periodically.

- **Element 2 - Processing Activities**
  Processing is the second stage activity after the farmer completes field activities. Activities in this phase include grading, processing, packaging and storage facilities. In Agriculture 4.0 implementation, this stage is a determining factor that bridges products from farmers to the market. Farmer products are usually diverse, so that with the construction of processing elements can be obtained a homogeneous and well-classified product. In conventional market systems, processing activities usually involve many stakeholders such as collectors, sub-district traders, wholesalers and so on. A breakthrough is also made through this stage so that farmers' products can be managed properly. For example, if production is abundant it must be carried out by storage to maintain the price effects that usually fall when the product is abundant. Storage facilities function is important to be held. All activities on the processing element are made by computer applications that are integrated in the server, so that it can be traced back to the products sent by farmers. In the long run, the grading, processing and packaging process is carried out by farmers through coordination in the respective farmer groups according to agreed quality. The processing system detects special codes from the products produced by each farmer. All farmers' products must meet agreed standards, then managed to be distributed according to market needs.

- **Element 3 - Trade/Market Activities**
  The marketing of garlic products from farmers is done by e-commerce approach, meaning that customers are given information, promotion and education to be able to access products produced by farmers online. However, before e-commerce is run, the preparation of standardization and product quality must be well developed, as well as the stock management must have been managed properly. In addition to marketing through the e-commerce system, products produced by farmers are also marketed through conventional mechanisms by selectively marketing consumers. At this stage, an application was also built that contained information on the origin of the product, when it was produced, product standards, and the application of complaints from consumers to the products purchased through application installed on the handphone. Thus, it is expected that all complaints or entries are recorded in the computer system and become evaluation material for improvement.

- **Element 4 - Data Management in the Development Area (Local Server)**
  In each development area, an operational sub-system is built where all activities are recorded on a local server. Not only data on production process activities are recorded on the local server, but all
other supporting activities such as climate data, observations of plant pests and diseases, farmer group activities, and other supporting data. All data is managed properly and correctly and is integrated with the central server.

- **Element 5 – Data Management in the Center (Central Server)**
  At the central level where the main analysts, planners and policy makers have activities supported by adequate facilities, including human resources who have various skills, real time data stored in the central server. Through these facilities various activities such as overall activity management, data analysis, complaint handling, policy recommendations and continuous improvement are formulated comprehensively. The server at the center is also designed to function as a data warehouse for other activities in the future.

The design and development of an efficient garlic farming system is still a concept and must be prepared comprehensively. Especially if it is associated with the Agriculture 4.0 phenomenon, it is necessary to take various follow-up steps in the development plan area of Parigi Moutong Regency, Central Sulawesi, including:

- Feasibility study
- Market survey
- Trial
- Socialization to farmers and interested farmers
- Development research in collaboration with academics / universities
- Study of product marketing

Agriculture 4.0 which is used as a reference in this paper is expected to provide benefits for the welfare of society in the future. On the other hand, it is also necessary to think about other impacts such as the emergence of resistance to changes in demography and social aspects, uncertainty in political conditions, limited resources, the risk of natural disasters and the demands for the application which have environmentally friendly technologies. But the real event hasn't happened yet and is still in the form of ideas [14].

### 6. Conclusion

Based on the results of reviews from various literature, the concept of garlic farming efficiency and management has been obtained comprehensively towards smart farming based on Agriculture 4.0 approach. Furthermore, the concept can be tested in areas that have been selected with various improvements. Thus, it is expected that improvements in concepts that have been tested to be replicated in other regions are expected to support the achievement of garlic self-sufficiency in 2021.

Agriculture 4.0, which has been echoed at the international level, has not yet occurred. Besides giving positive benefits, it is estimated that it can also have other social, political and natural disaster risks. So that scientific studies need to be carried out by collaborating with various parties including academics from universities.

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