Banggai Yam (*Dioscorea* spp) Farming System and Its Technical Efficiency in Banggai Kepulauan of Central Sulawesi Indonesia

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***Abstract*—The research objective was to determine Banggai yam farming system, its fertility and its technical efficiency in Central Sulawesi of Indonesia. A random sampling method was used to select 130 household farmer respondents living accros 11 villages in South Buko. Data collected included cultivated land area size, seeds, labors, stand number, production and other data such as land selection, clearing techniques, and local wisdom based cultivating practices. Soil samples were taken from a land under Banggai yam cultivation and 1 – 4 year fallowed lands. The Soil were analyzed for pH, carbon organic (SOC), total N, available phosphorous and cation exchangeable capacity (CEC). The technical efficiency was determined using Frontier Production Function analysis. Results showed that the Banggai yam farming system is a shifting cultivation with no external inputs. The soil nutrients tends to increase with increasing fallow periods. The productivity of the farming system cannot be improved with its current technology but with more advanced technology input suitable to the local environment and the local wisdom.**

Keywords—Banggai yam, local wisdom, shifting cultivation, technical efficiency, sustainable agriculture.

I. INTRODUCTION

Yam has been known as one of the main foods for many people in Humid and Sub Humid Tropic [1]. Besides growing easily and its nice taste, yam is also rich in carbohydrate [2,3,4,5]. Banggai yam (*dioscorea sp*) - locally known as baku, tebe or uwi is one of the specific local food commodities in Central Sulawesi of Indonesia, especially in Banggai Kepulauan and Banggai Laut districts. It is the staple food of the native people in those areas. It can therefore be considered a functional and an alternative food to rice.

Based on morphological characters, reference [6] has clustered yam from Banggai Islands into four groups A, B, C and D. Each group consists of 16 accessions, two accessions, 19 accessions, one accession, respectively.

Banggai yam farming system has been long traditionally practiced based on farmer local wisdom in the area. The local wisdom is basically a knowledge obtained by living life in balance with nature. This is important for preserving the sustainability of resources, and socio-economic of local farmer community [7]. Local people have the capacity to develop harmonization with the rural development, to improve their welfare and to sustain the environment [8]. In the last two decades, there has been increasing awareness on the existence and values of the local knowledge, so there is the need to integrate it into agriculture sector development. However, traditional knowledge has limitations as found in scientific knowledge [9].

The development of Banggai yam in Banggai Kepulauan district has been facing some obstacles including limited capital, traditional cropping system, limited market accessibility, limited farmer knowledge and skill, non-existent of the product end value, low yam prices, limited local government supports, and the geographic location of Banggai Kepulauan District which is on the edge of seashores and dominated by dry land. The dry land has charateristics such as: uncertain, undistributed and limited annual rainfall; occurrence of extensive climatic hazards such as drought and flooding; undulating soil terrain; practices of extensive agriculture i.e. prevalence of mono cropping, similarity in types of crops raised by most farmers of a particular region; and very low crop yield [10]. Besides that, the shifting cultivation system of slashing-collecting-burning practiced by farmers so far has made the soil fertility to decrease rapidly [11] and led to low plant production. The production of Banggai yam decreased 54,45% in the year 2009 to 2012 [12]. It shows that the local based farming system of the Banggai yam needs improvement for it to be sustainable.

The development of Banggai yam needs information on its current technology applied by the farmers, the availability of its potential natural resources particularly the soil nutrient

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status of the lands both those under cultivation as well as under fallow, and its technical efficiency rating used as an indicator for the necessity of new technology inputs to improve the traditional cultivation techniques used by the farmers. Therefore, the aims of the research were: (1) to describe Banggai yam farming system, (2) to analyze soil nutrient status under cultivating or fallowing, and (3) to determine the productivity and technical efficiency of Banggai yam farming system in South Buko Sub district, Banggai Kepulauan district of Indonesia..

II. METHODS

A. Research Site

The research was conducted on South Buko sub-district, Banggai Kepulauan district, Central Sulawesi province of Indonesia. The location of the research was on the eastern part of Sulawesi peninsula which lies between 122°45'50" and 122°55'40" east longitude and between 1°24'30" and 1°35'50" south latitude . It is one of the Banggai yam production centers.

B. Respondents

Respondents of the research were 130 households who cultivated Banggai yam in South Buko sub district. They were selected using a random sampling technique from the total population of 1301 farmers lived across 11 villages. The data collected were respondents' characteristics, yam production and its production factor (planted land area size, labors, seeds, stands, fertilizers and pesticides). Other data include the techniques used for land selection and land clearing, and local wisdom based cropping techniques (soil tillage, seed provision, planting, fertilization, harvesting, and ritual activities during plant cultivation).

C. Soil Nutrient Analysis

The lands where the soil samples taken were those under Banggai yam cultivation (after 5 year fallow) and those under fallow for 1-4 years (after Banggai yam cultivation). The soil samples were analyzed for pH using pH meter; soil organic carbon (SOC) using Walkley and Black method; total nitrogen (N-tot) using Kjedahl method; available phosphorous (P-avail.) using Bray 1 method; bases (K,Ca, Mg, Na) and cation exchangeable capacity (CEC) using leaching method (NH_4OAc pH 7.0 extractant).

D. Productivity and Technical Efficiency

The productivity of the Bangai yam farming system was analyzed using Cobb-Douglas production function while the technical efficiency rating (TER) using frontier production function of Farel model [13]. Technical Efficiency is a measure of farming system efficiency managed by farmers calculated using the following equation:

$$TER = \frac{Y_i}{\hat{Y}}$$

where:
Yi = actual production.
$\hat{Y}$ = potential production (*frontier production*).

The actual production is derived from production function by applying the ordinary least square (OLS) method, thus it can generate the average production achieved by farmer in the field. Similarly, the potential production is obtained from the use of Maximum Likelihood Estimation (MLE) method on frontier production to generate the highest yield produced by the farmer in the field.

Technical efficiency measures the amount of production for a set of certain inputs. There are four production factors in the Banggai yam farming system used by the farmers in the research site including land area size (x_1), seeds (x_2), stand (x_3) and labor (x_4).

III. RESULTS AND DISCUSSION

A. Banggai Yam Farming System

Banggai yam farming in South Buko is a monoculture system cultivated in dry lands under dry climate. The system implemented is shifting cultivation with fallow period of 5 – 8 years and a planting period of 8 – 9 months (one season) within one year. The main reason that the fallow period take such a long period is due to its low land productivity to support sequential cropping at the same area. Traditional yam cropping systems (shifting cultivation, slash-and-burn, and short fallow) often result in soil nutrient depletion [14]. Soil fertility dramatically decrease after harvesting [15], thus the soil can no longer provide the amount of nutrients the plants needed and long fallow period is necessary to recover the soil back into its relatively good natural fertility. According to [16] a significant increase in soil organic carbon (SOC) with natural fallow was observed after 2 or 3 years. Fallow with natural vegetation can contribute to the maintenance of fertility and crop production, however, length of fallow period does not need to exceed 2 years. The effect of the duration of previous fallow on yam yield depends on the extent of soil condition degradation [17].

Land reutilization after the fallow period is determined based on the present of vegetation (trees, bushes, and weeds) growing in the land. The vegetation variables considered were population, stem diameter, and height. High tree populations, large stem diameters and high plant height indicate a relatively fertile soil and therefore suitable to be replanted. Similar methods are also used to choose a new land for extension. These methods were also observed by [18] who reported that the selection of land for the farming system is determined by the kind of vegetation whilst that for the soil fertility is by its vegetation biomass. The biomass is an accumulation of dry mass production over soil surface.

Land clearing for shifting cultivation is initiated by weeds clearing using either large knives or a lawn mower followed by slashing trees/bushes. The slashed trees later are collected and eventually burned. Shifting cultivation with its slashing-burning method for the land clearing is a common practice in dry land cultivation. The primary reasons farmers use this method due to the fact that it is quick, easy, and cheap and aimed at improving soil nutrients, controlling weeds, decreasing cost, suppressing pests and diseases and increasing food crop production [15]. Slash and burn lead to increased nutrient availability within a short period [19] by influencing the soil physical and chemical characteristics. Coarse and fine silts are the most affected soil physical characteristics whilst the chemical characteristics were pH, SOC, Ca, Mg, K, Na, CEC, P, and base saturation, although the effects are mostly short-lived [20].

Following the land clearing through slashing-collecting-burning and with no tillage, seeds are sown directly using sticks to make holes. The diameter of the hole is about 3.18 – 3.82cm and the stick is made of wood with a sharp iron cover at the lower tip. The depth of the hole is 20cm with the width of 10cm dependent upon the size of the seeds. The diameter of the holes ranges between 30 – 50cm and 30 – 40cm deep. This practice is implemented to avoid land degradation due to erosion, thus it can be perceived as land conservation practices. The seed holes are relatively shallow due to the presence of a lime sub layer at 20cm deep. Conservation tillage practices improve both psychochemical and microbiological propertis of soil [21].

The source of the seeds (local name *tebe*) is generated from previous harvesting after the plants are 7 – 9 months old and indicated by dried leaves and stems. Good quality seeds are shown by soft skin covering the yum (no lump), not flabby, no damage/wound, not suffering from pest and disease attacks and they have been stored for 2 – 3 months in barn (local name *longgo*). The reasons for the storage are to decrease their water content and to allow dormant period of 50 – 150 days of the seed to end [22]. The time from harvest to sprouting was shorter as harvest was delayed. The period from sowing to sprouting for each clone was similar for tubers harvested from 140 days after planting, but tubers harvested earlier took longer to sprout [23]. The time period from harvest to sprouting, however, was affected by storage period [5]. The seeds planted in one area consist of 4 – 5 varieties. The varieties are selected based on liking/taste, land condition, and production potency. Relatively round seeds are planted in rocky soil, while relatively elongated seeds are planted in deep soil.

The size of the seeds is varied i.e. small, moderate and large with different shapes. Small yam can be directly planted whole, while medium and large potatoes are usually cut 6-8 cm long and 5-7 cm wide. Planting spaces are relatively dependent upon land condition. Under fertile and deep subsoil, the planting space tends to be wider. Under rocky land, the planting space is irregular, but generally the seeds are planted under equilateral triangle pattern with the distance between the plants are 60 – 100cm (11.547 – 32.075 plants per hectare). These are relatively similar to the findings of [24] who stated that the planting spaces for yam are 60cm x 45cm, 60cm x 60cm, or 90cm x 90cm with the best growth and largest yields found in the planting distance of 60 cm x 60 cm.

The Banggai yum cultivation uses no external input neither pesticide nor fertilizer, thus it can be categorized as organic agriculture. Soil fertility improvement is solely dependent upon the natural processes such as decomposition of plant litter by microorganism decomposer, rainfall nutrients, animal dung accumulated during fallow period, ashes from burned plant remains during land clearing done two weeks before planting as well as burned weeds two months after planting.

The harvesting time of the Banggai yum is conducted into two stages. The first stage is prepared either for consumption or selling. The harvesting was done either with an interval period of five days when the plant age between 4 – 7 months or when it is necessary. The second stage is carried out after the yam has been allowed to grow for up to 7– 9 months but mostl are harvested after eight months for seed purposes. The harvesting of plants for consumption or sale is marked by the leaves starting to turn yellow and drying, while for seed purposes it is done when the leaves and stems are dry. Both harvestings are conducted when the land relatively dry.

The source of labor for the Banggai yam farming system is farmer households who work in mutual cooperation and hired labors paid by farmers particularly during land clearing and planting. Some farmers still conducted some rituals both before planting and after harvesting asking God to protect the plants from any constrictions, to generate good production as well as to bless the farmers on their activities.

B. *Soil Nutrient Status*

Soil chemical characteristics such as pH, C-organic (SOC), N-total (N-tot.), available P (P-avail), and cation exchangeable capacity (CEC) are depicted in Table 1.

TABLE I. SOIL NUTRIENTS STATUS

Fallow (year)	pH	SOC (%)	N-tot. (%)	P-avail. (ppm)	CEC (cmol+/kg)
1	6.42(sa)	5.20(vh)	0.37(m)	73.72 (vh)	20.06(m)
2	6.92(n)	6.43(vh)	0.44(m)	39.78(vh)	28.03(h)
3	7.10(n)	6.61(vh)	0.53(h)	42.27(vh)	30.20(h)
4	7.22(n)	7.92(vh)	0.56(h)	43.09(vh)	28.02(h)
5*	6.74(n)	5.33(vh)	0.42(m)	67.17(vh)	17.06(m)

*Observed after the plants have grown for seven months
sa: slightly acid, n: neutral, vh: very high, h: high, m: moderate.

Soil pH appeared to increase with fallow period from between 6.42 (slightly acid) to 7.22 (neutral) but it decrease under planted land. This pH range is still suitable for Banggai yam to grow. Some previous research showed that yam is adaptable to cultivation under different soil condition. Yam (*Dioscorea alata*) can grow in alkaline soil [25] to acid soil [26, 27]. Soil acidity is affected by organic acids and nutrient availabilities influencing the ability of plant root to absorb the nutrients [28].

C-organic content increases with increasing fallow period up to four years but then decrease after the soil was replanted. Increasing SOC comes from in-situ agricultural waste generated by residues of vegetation grown in the fallowed land. Those residues affect soil quality positively for crop production such as increases in soil organic matter (SOM), nutrients, physical structure, water content, and microorganisms, as well as hindering soil loss by wind and water erosion [29]. According to reference [15], land fallowed for more than three years contains C-organic and nitrogen higher than those for two and one year as well as non fallowed land. Sufficient organic matter in soil plays a very important role for plant production in dry land [30], because organic matter is a source of macro and micro nutrients for plants. Lessening C-organic content and nutrients occur due to absorption by Banggai yam as indicated by the soil samples taken after Banggai yam was grown for seven months. The longer the fallow period the higher the nutrient contents, however, under the fallow period of five years the nutrient contents appear to decrease.

P-available status is very high indicating that it is sufficient to support the growth of Banggai yam. The five-year cycle shifting cultivation allows sufficient time for organic matter to decompose well. During the decomposition such nutrients as Na, Ca, Mg, and K are released as free-cation, but Fe and Al are fixed, and N is used by microbes for building their cells [31].

The status of the cation exchangeable capacity (CEC) in the research sites moderate to high. CEC content increases with increasing fallow period time up to four years but decrease after that (five years). The CEC is affected by types and amount of clay as well as organic matter content of the soil. Low CEC soil has low ability to hold nutrients thus less available nutrients. However, if this soil CEC is predominantly occupied by basic cation such Ca, Mg, K and Na (high BS), it can improve soil fertility. On the contrary, poor soil has its CEC dominated by acid catgions such Al and H because the nutrients have been leached [28].

Based on the nutrient status in the research site, it is recommended that the soil fertility where Banggai yam are planted need to be improved through addition of organic fertilizer to support sequential planting and the sustainability of the Banggai yam farming. The most studied systems of organic matter production using legumes are based on herbaceous legumes and woody perennials, besides that application of organic nutrient sources such as cow dung ensures a more balanced nutrition and less probability of the negative effects on tuber quality of yam [32].

C. Production Function

The Production function is a function that describes the physical relationship between output and input variables used. The input variables in this research were those variables affecting the output of Banggai yam production. There were four production factors i.e. land area size (X_1), seeds (X_2), stands (X_3) and labors (X_4). The estimation of production input parameters of the Banggai yam production was done by changing the form of the Cobb-Douglas production function [33, 34] into a multiple linear equation. The estimation of the regression parameters used the ordinary least square (OLS) method which then resulted in the following equation:

$$Y = 0.9999 - 0.09552X_1 + 0.0000026X_2 + 0.0000017X_3 + 0.000146X_4$$

The estimated parameters in the stochastic frontier production function show the value of frontier elasticity production generated from the inputs used. The results of the estimated parameters and the variables affecting on the production of Banggai yam are depicted in detail in Table 2.

The data in Table 1 shows that the four independent variables simultaneously affect the Banggai yam production significantly at α 5% as indicated by the F-counted of 2.616. The determination coefficient (R^2) suggests that the production of the Banggai yam was affected by the independent factors by 77.72% while the remaining 32.28% was affected by other factors not determined in this research. Partially, only two variables i.e. the land area size (X_1) and the labors (X_4) significantly affect the Banggai yam production. The former had a confidence interval of 90% and the later had that of 95%. But for the land area size the direction is negative indicating that the use of land is no longer technically rational because the production margin was negative. Therefore, it is necessary to change the shifting cultivation system to settled cultivation by introducing more advanced technology.

TABLE II. TECHNICAL EFFICIENCY ANALYSIS USING STDLIN MODEL OF THE BANGGAI YAM FARMING SYSTEM IN SOUTH BUKO OF BANGGAI DISTRICT OF CENTRAL SULAWESI PROVINCE

Independent Variables	Regression Coefficients	t Test Values	Probability Values
Land area size (ln X_1)	-0.95525E-01	-2.889*	0.059-0.1
Seeds (ln X_2)	0.25819E-05	0.949ns	0.342-0.0
Stands (ln X_3)	0.17566E-05	1.151ns	0.250-0.1
Labors (ln X_4)	0.14549E-03	2.128**	0.033-0.1
Constants	0.99990	4153	0.000-1
F-counted	ά = 5%	2.616**	
R^2	77.72%		

**Significant at ά=5%, *significant at ά =10%, ns not significant

The coefficient regression for the land area size variable is -0.0955 with t-counted of 2.889 at significance level of 0.059 indicating that for every 1% increase in the land area size will significantly reduce the Banggai yam production by 0.0955%. This analysis shows that the management of the Banggai yam farming system is no longer efficient (optimal). Some factors contribute to this situation include poor cultivation practices, low work ethos of the farmers particularly when their capacity to manage the farming increase.

The coefficient regression for the labor input is 0.000145 with t-counted of 2.128 at significance level of 0.033 indicating that for every 1% increase in the labor number will significantly reduce the Banggai yam production by 0.000145%. This indicates the number of labor play a very important role in increasing the Banggai yam productivity. The labor variable relates to need of intensive maintaining during the growth period of the yam particularly weeding activities to avoid the plant from competing with the weeds for nutrients.

D. Technical Efficiency

Technical efficiency is an index showing the ratio between the actual production and the maximum production [33]. Based on the partial analysis of the use of the production inputs, it is more likely to increasing the technical efficiency with those variables. On the contrary, the existent of non-significant variables hinder an opportunity to increase the technical efficiency through these inputs for improving the productivity of the Banggai yam farming. This fact is supported by the level of technical efficiency which is equal to 1. It indicates that the current technology used by the Banggai yam farming system can no longer able to increase its productivity. The shifting cultivation and with no fertilizer used might be putting the surrounding environment at great risk of being degraded. Increasing the productivity of the Banggai yam farming system in the research location can be done by introducing more advance technology suitable to the local environment and culture. However, individually some households had already achieved the technical efficiency needed as shown by the very small gap between the actual production and its potential production.

There were 40.8% of the Banggai yam farming systems that had the technical efficiency level of larger than 1, whilst 59.2% of the households still below the technical efficiency level of 1.

IV. Conclusions

The farming system of Banggai yam practiced in South Buko sub district is a shifting cultivation with a slashing-collecting-burning land clearing and a fallow period of 5 – 8 years. Cultivation techniques are based on farmer knowledge inherited from generation to generation. The planting pattern is monoculture with 4 – 5 varieties in one cultivated area. The Banggai yam shifting cultivation is an organic farming dependent solely upon natural processes and without external input.

Chemical soil fertility tends to increase with increasing time of the fallow period. The soil fertilty status of all land units range from low to moderate particularly for N-total, K, Mg, Na, CEC, SOC, P and BS are relatively high. Thus, the use of such input as organic fertilizer need to be considered.

The Banggai yam farming system in the research site generally cannot be improved under the current technology of shifting cultivation and without fertilizer addition (TEL = 1). Increasing the Banggai yam farming can be achieved through more advance technology suitable to local environment and local wisdom.

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