

Suitability evaluation of circular economic models for sweet potato production in Binh Tan district, Vinh Long province, Viet Nam

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Abstract: The study was conducted to assess the current production status and natural land potential for the development of circular sweet potato plants in Binh Tan district, Vinh Long province, to propose solutions to increase the economic, social, and environmental value of sweet potatoes. The following methods carry it out: collecting primary and secondary data; synthetic, descriptive statistics; analysis of variance, T-test; adaptive assessment; and proposed methods. According to research findings, the varieties of purple, white, yellow, orange, and red-fleshed sweet potatoes are distributed throughout most study areas. The low economic efficiency due to the complicated situation of the epidemic in the past year caused the price of sweet potatoes to drop significantly. The export of sweet potatoes to foreign countries was limited. Meanwhile, the district has suitable adaptive conditions for sweet potato plants, such as texture, pH, humidity, rainfall, irrigation capacity, etc. The recommended models increase income from growing sweet potatoes and raising livestock, bringing higher economic efficiency to people, more labor needed for people to have jobs, and making full use of agricultural and livestock by-products (unused animal manure, leaves, stems, and roots of sweet potato plants), which limiting environmental pollution when handling improper waste products. The study has proposed solutions to increase the circulation of products, thereby increasing the efficiency of sweet potato production. However, people need to learn the proper use and handling of plant by-products.

Keywords: sweet potato, develop, potential, cyclical

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1 Introduction

One of the most significant, adaptable, and underappreciated food crops worldwide is the sweet potato (*Ipomoea batatas* L.), mainly cultivated for its storage roots (Tortoe et al., 2010). Sweet potatoes are

among the top five foods essential for developing nations and help ensure food security (Oke and Seyoum Workneh, 2013). Tuber crops have an essential role in food security as these crops meet local food preferences and provide more edible energy per hectare per day than other crops. Tuber

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crops require sweet potatoes (*Ipomoea batatas L.*) because of their quick growth and large output. The functional food sector is an excellent source of naturally occurring components that promote health, like β -carotene and anthocyanins (Mohanraj and Sivasankar, 2014). It is a shallow-rooted crop (Kumar et al., 2013) and produces more dry matter/unit area and time than most cereals and legumes. Besides, it is highly resource-intensive (Govindakrishnan et al., 2011), and its nutrient requirement, particularly nitrogen, is high. Governments worldwide explore their nations' economic potential to improve their citizens' living standards (Felix et al., 2020). Sweet potato assumes special significance among the tuber crops because of its acceptability as food, feed, and fodder crops (Nedunchezhiyan and Reddy, 2002).

Sweet potatoes are frequently farmed in Vietnam due to their adaptability and ease of growth. The most incredible sweet potato-growing region in the Mekong Delta is the Binh Tan district in Vinh Long province. It is where some famous sweet potato varieties are grown, including orange-fleshed, milky white, Japanese purple, and others. Sweet potatoes are the main export item in the Binh Tan district. However, according to the People's Committee of Vinh Long Province (2021), the production of sweet potatoes is facing many difficulties due to the COVID-19 epidemic, which makes the price unstable,

and traders constantly press the price. So many farmers switched to growing rice and fruit trees. With a large sweet potato growing area, the by-products from growing sweet potatoes are abundant, such as sweet potato leaves, sweet potato strings, and sweet potato roots. However, in the Binh Tan district, farmers need to learn how to use this source of by-products, leading to waste and low economic efficiency.

Currently, the rational and practical use of land resources is one of the issues of particular concern to the Mekong Delta region, including Vinh Long province. It is necessary to research land potential evaluation while accomplishing socio-economic development goals to increase the potential for the prudent use of land resources and protect the environment in the future (Ministry of Natural Resources and Environment, 2018).

From the above situation, the study was carried out to bring into full play the available potential of the land and make full use of natural resources—by-products, improving the efficiency of the sweet potato production model in Binh Tan district, Vinh Long province.

2 Methods

The study was carried out from 2020 to 2022, according to the following scheme (Figure 1), including the following steps.

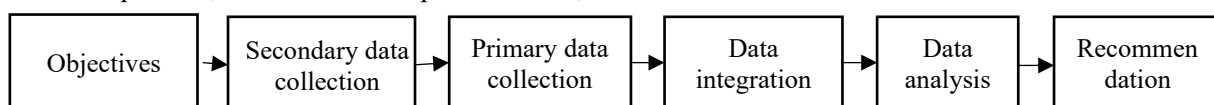


Figure 1 Diagram of the implementation steps

2.1 Secondary data collection

The relevant secondary collection was obtained from the Office of Natural Resources and Environment, Office of Agriculture and Rural Development in Binh Tan District, Vinh Long Province. The reported, published study results from 2020 to 2022 were collected to learn about the current situation and updated information on sweet potato production in the study area.

2.2 Primary data collection

Developing questionnaires and interviewing farmers who are sweet potato growing households in the Binh Tan district, Vinh Long province. Determine the number of people to be surveyed, adopted from Yamane (1967), by determining the sample size of the population of unknown cases:

$$n = Z^2 \times \frac{P(1-P)}{e^2} \quad (1)$$

Where,

n : Sample size;

Z : Z-distribution table lookup value based on

selection reliability;

P: The success rate of sample size estimation *n*;

e: The acceptable error.

Apply the formula with 90% confidence, corresponding to $Z = 1.645$, and an acceptable error rate of $e = 10\%$. Thus, the minimum number of interviews is 68.

2.3 Data analysis

Excel software synthesized and processed the collected data for analysis and evaluation.

Descriptive statistics were analyzed (maximum value, minimum value, mean value, total value, standard deviation) to describe general characteristics such as the number of demographics, the number of central employees, the sweet potato growing area, production, total expenditure, revenue, and profit of the sweet potato production model.

A T-test variance analysis is used to test whether the mean value of the original hypothesis is accepted or rejected. This method is used in the study to test the average value of total production cost, total revenue, and profit of potato production at the significance level of 10% and $\alpha = 0.1$.

2.4 Suitability evaluation

A Framework for Land Evaluation (FAO, 1976) was applied to evaluate sweet potato plants' factors and adaptation requirements (conditions for sweet

potatoes to achieve the highest yield). From there, hierarchical adaptation factors (S_1 : highly suitable, S_2 : moderately suitable, S_3 : marginally suitable, N: Unsuitable) are used to assess the degree of adaptation to the requirements of district sweet potato plants.

Based on the analysis and assessment of the current status of sweet potato production and the basis for evaluating the cyclicity of products from sweet potato plants in the study area, we are proposing solutions to stabilize the circularity of the economy, society, and environment for farmers.

3 Results and discussion

3.1 Current status of sweet potato processing in the study area

To survey the results of 70 households growing sweet potatoes in the Binh Tan district. Sweet potato plants' products include tubers, stems, leaves, and roots. Specifically:

Sweet potato tubers: commonly used raw (baked, fried, boiled/steamed) and processed (starch, alcohol, drinks, dried products, etc.) (Figure 2).

Sweet potato leaves can be used as food (boiled, fried), composted to fertilize crops, or as feed for livestock (goats, cows) (Figure 3).



Figure 2 Ways to process sweet potatoes to produce other products

Sweet potato stems and roots, like leaves, stems, and roots, can compost organic matter and feed livestock (cows, goats) (Figure 4).

3.2 The actual situation of sweet potato processing in Binh Tan district

The study area's total vegetable area in 2022 was

16,523 hectares, of which the sweet potato area was about 746 hectares (4.51% of the total vegetable area) (Department of Agriculture and Rural Development, 2022). The sweet potato production is distributed mainly in Thanh Trung communes (217 ha, accounting for 29.00%), Tan Thanh (156 ha,

accounting for 20.91%), and Tan Hung (113 ha, accounting for 15.14%) (Figure 5). However, in the first 9 months of 2024, the whole district planted 813 hectares of sweet potatoes, a decrease of 220 hectares

over the same period, of which purple sweet potatoes were 330 hectares (Department of Agriculture and Rural Development of Binh Tan district, 2024).

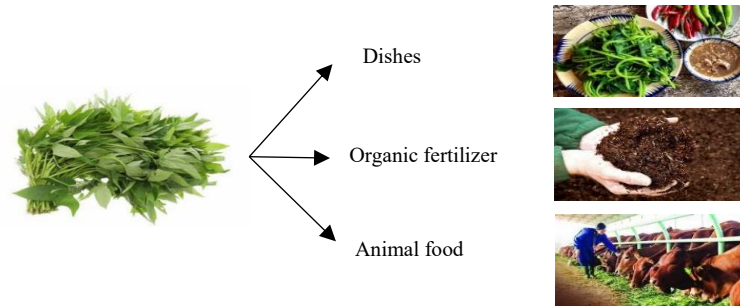


Figure 3 Ways to use sweet potato leaves

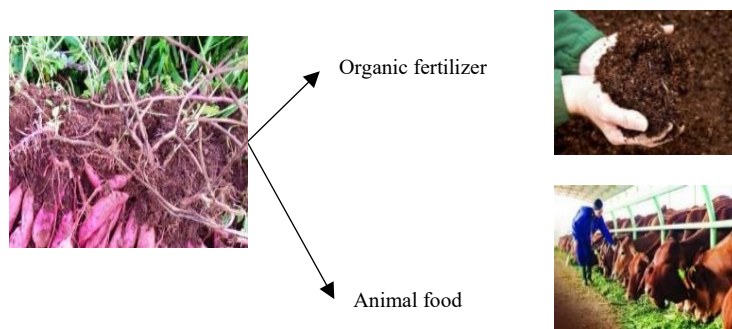
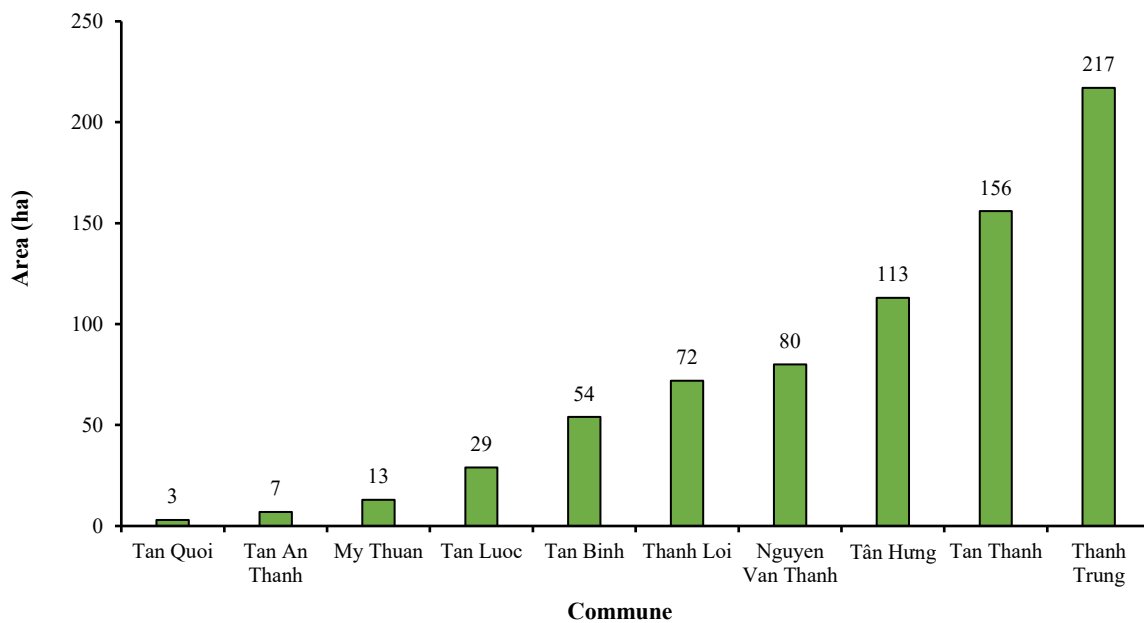


Figure 4 Ways to use sweet potato stems and roots



Source: Department of Agriculture and Rural Development of Binh Tan District (2024)

Figure 5 Area of sweet potato plants in 2022 by administrative units in Binh Tan district

The household survey results identified that the sweet potato varieties grown in Binh Tan include milky white sweet potatoes (18.57%), white-fleshed sweet potatoes (17.14%), and red-fleshed sweet potatoes (14.29%) of the total number of

questionnaires. Three seasons for sweet potato cultivation include Winter-Spring (December-May), Summer-Autumn (May-September), and Autumn-Winter (July-November).

3.3 Economic efficiency of sweet potato

Through analysis of the variance T-test, the average value of economic indicators (total revenue, total expenditure, and profit) of surveyed households has a statistical significance of 90%. It represents all households producing sweet potatoes in the study

area. Specifically, the investment capital for 01 ha of sweet potato cultivation has an observed significance level of 0.837, total revenue is 0.991, and profit is 0.981, which is larger than the expected significance level of $\alpha = 0.1$.

Table 1 Results of analysis and evaluation of economic indicators of sweet potato plants

Unit: VND ha⁻¹ crop⁻¹

	Smallest	Highest	Average
Total expenditure	150,000,000	200,000,000	172,285,714
Total revenue	39,000,000	240,000,000	101,594,285
Profit	-159,500,000	60,000,000	-70,691,428
Effectiveness of capital (B/C)	-1.06	0.3 0	-0.41

Table 1 shows that the average value of total expenditure is 172,000,000 VND ha⁻¹ crop⁻¹. Meanwhile, the total revenue is 101,000,000 VND ha⁻¹ crop⁻¹, resulting in a negative profit of -70,000,000 VND ha⁻¹ crop⁻¹, equivalent to the current capital value of -0.41. From there, it shows that the income from sweet potato production is low, most of which is a capital loss.

3.4 Suitability evaluation of sweet potatoes

Table 2 Land use requirements for sweet potato plants

Factors	Land use requirements	
Soil	Soil texture	The soil texture is silty and porous, the topsoil is deep and airy, and the sandy soil has a high percentage of humus.
	pH	5.6 - 6.6
Water	Rainfall	750 – 1,000 (mm year ⁻¹)
	Humidity	70% - 80%
Irrigation ability	Active watering	
Economy	Profits from roots	> 30 (million VND ha ⁻¹ crop ⁻¹)
	Profit from by-products	> 8 (million VND ha ⁻¹ crop ⁻¹)
	Capital efficiency	> 1
Society	Create jobs for people.	
Environment	Do not pollute the environment.	

Based on the suitability requirements (Table 2), the study conducted a hierarchy of suitability factors for sweet potato plants in the study area. Through survey results, collecting conditions for sweet potato production, the results of synthesizing documents on the suitability factors of sweet potatoes by Hung et al. (2010), and documents on the classification of

According to Hung et al. (2010) and field surveys and households interviewed, the factors (soil, water, irrigation capacity, economy, society, and environment) in the current conditions of Binh Tan district for the cultivation of sweet potatoes, the following requirements were recommended: Conditions for yielding sweet potato plants achieve the best; Conditions where productivity is not optimal but acceptable; unsatisfactory conditions.

potential suitability capacity by FAO (1976), a hierarchy of suitability factors for sweet potato plants in Binh Tan district was developed (Table 3).

From the suitability factors of sweet potato plants in the study area (soil, water, irrigation capacity, economy, society, environment), the suitability factors for sweet potato are developed with four

levels: highly suitable (S1); moderately suitable (S2); marginal suitable (S3), and unsuitable (N). Sweet

potato plants are highly suitable (S1) for the socio-economic conditions in most of the study area.

Table 3 Hierarchy of suitability factors for sweet potato plants

Factors	Hierarchy of Suitability Classes				
	S1	S2	S3	N	
Soil	Texture	Silty and sandy	Heavy soil	Clay _	Heavy clay
	pH	4.5 – 7.5	-	-	>7.5 and <4.5
Water	Rainfall	750 – 1,000	> 1,000	<750	-
	Humidity	70 – 80	60 - 70	50 - 60	< 50 and > 80
	Irrigation ability	Active	Half Active	-	-
	Profits from the root	> 50	50 - 30	30 - 0	< 0
Economy	Profit from by-products	>8	8 - 4	4 – 0	< 0
	Capital efficiency	> 1	1 – 0.3	0.3 – 0	< 0
	Society	Create jobs for many people	-	-	Do not create jobs for people.
	Environment	Do not pollute the environment.	-	-	Polluting the environment

Table 4 Potential levels of different soil types

Soil type	Symbol	Area (ha)	Potential level	
			High	Medium
Depth potential acid sulfate soils	Sp2	9,109.6	8,830.3	279.3
Moderate active acid sulfate soils	Sj1	81.1	81.1	-
Deep active acid sulfate soils	Sj2	241.2	241.2	-
Alluvial soil and less acidic.	Pbe	646.9	646.9	-
Gleyic alluvial soil	Pg	270.6	270.6	-
Alluvial soils with yellow layers without red mottle	Pf1	173.6	173.6	-
Alluvial soil with red and yellow mottle layers	Pf2	109.8	109.8	-
Raised bed soils	N	3,487.9	675.8	2,812.1

Source: Department of Natural Resources and Environment of Vinh Long Province (2022).

According to the Department of Natural Resources and Environment of Vinh Long Province (2022), the potential suitability of different soil types for sweet potato development in the study area is shown in Table 4. It shows that the potential by soil type for sweet potatoes in the study area has 11,029.3 ha of high potential and 3,091.4 ha of medium potential. Most are deep potential acid soils, with 9,109.6 ha, and the least are shallow active acid sulfate soils, with 81.1 ha.

3.5 Advantages, disadvantages, and proposed solutions to growing sweet potato plants

The farmer's survey results of sweet potatoes in Binh Tan district show there are advantages to growing sweet potatoes, such as for farmers with many years of experience cultivating sweet potatoes. Farmers learn from previous growers through training sessions and seminars. Varieties were obtained from selected sweet potato tubers and

vines of the previous crop for propagation. Reputable and quality seedling shops provide varieties. Sweet potato plants are easy to grow and are not picky about soil. Agriculture has certified and encouraged the VietGAP model of sweet potato to implement projects to grow sweet potatoes.

However, many difficulties in sweet potato production in Binh Tan district still need solutions to develop the model presented in Table 5. The training for farmers on circular economic production needs to be mentioned, and more processing factories need to be developed.

3.6 Evaluation of cyclicity for sweet potato products

Through the survey results of sweet potato farmers in the study area, the consumption patterns of sweet potato products by farmers are as follows:

Tubers: Semi-raw accounts for the highest

percentage (100%) because the processing method is still strange to farmers, and there are few processing and manufacturing factories in the study area (Figure 6).

Leaves: are primarily sold raw at wholesale markets and vegetable-purchasing establishments. When sweet potato leaves are not used for sale, fertilizer, or animal feed, they will become garbage

(Figure 7).

Stems and roots are primarily unused or used as fertilizer and animal feed (Figure 8).

The periodic assessment results show that the primary way of consumption is semi-raw, fertilized, or discarded, which has not yet exploited the processing potential of sweet potato products.

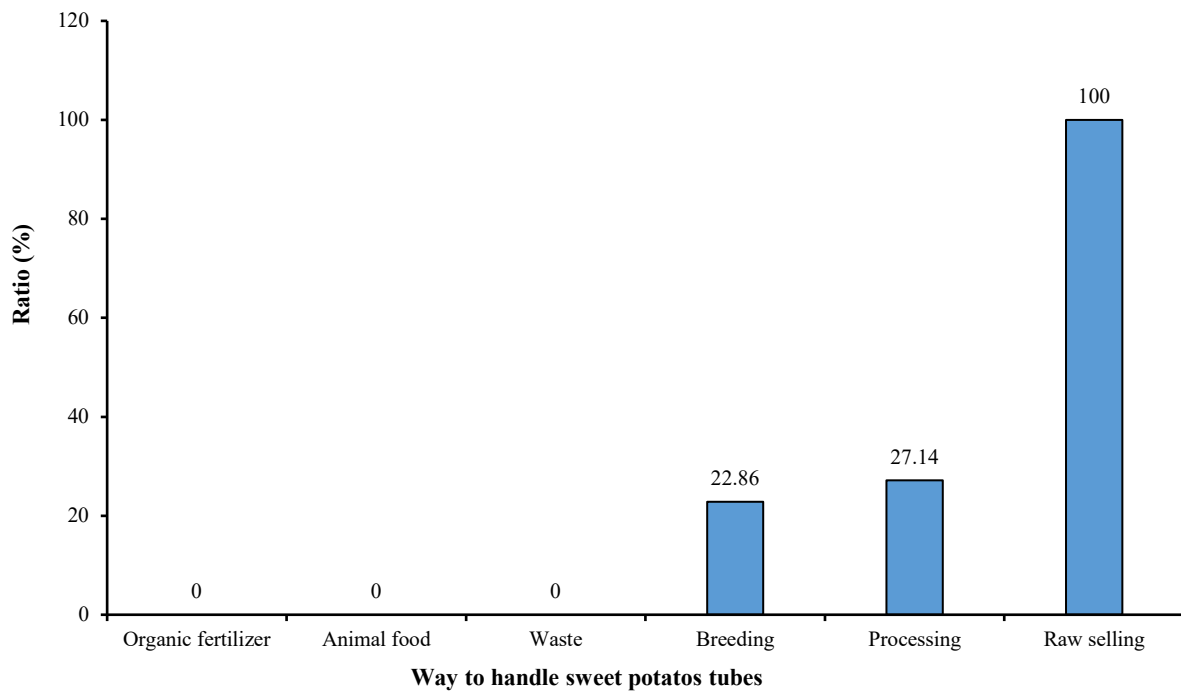


Figure 6 Ways to handle sweet potato tubers

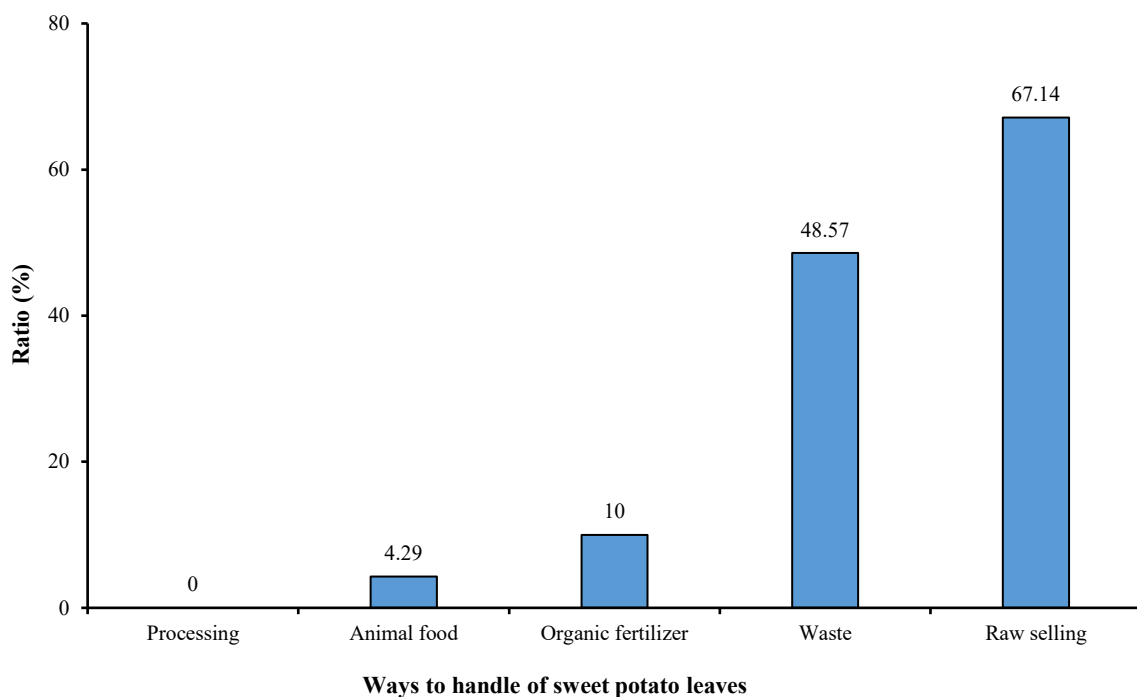


Figure 7 Way to handle sweet potato leaves

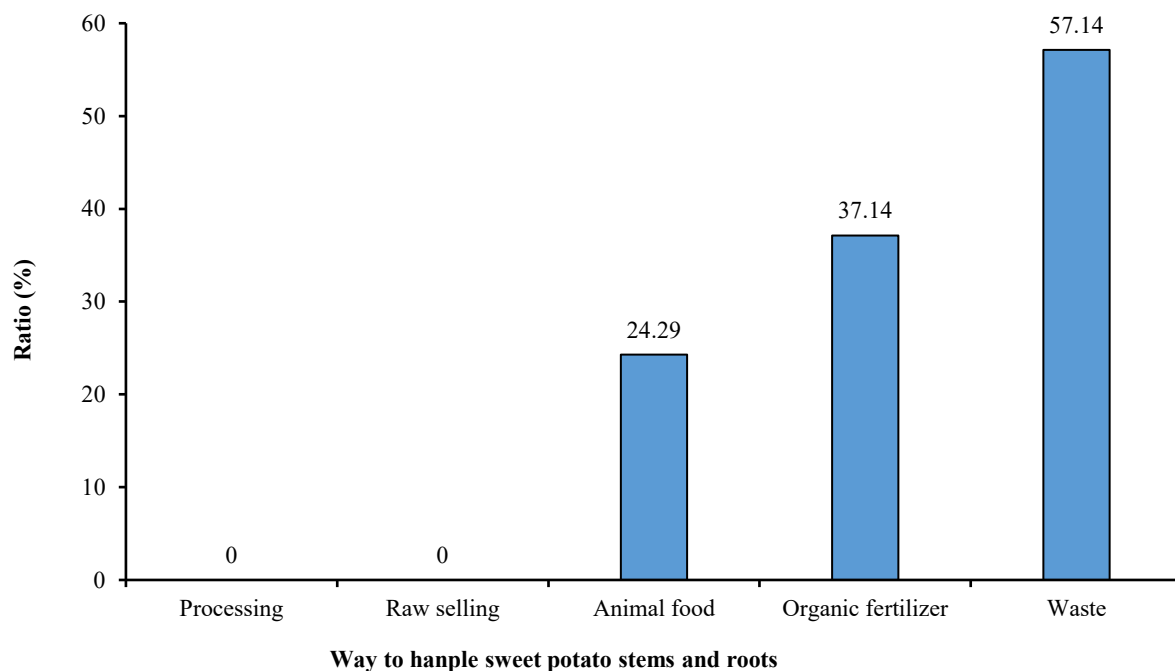


Figure 8 Way to handle sweet potato stems and roots

3.7 Recommendation of circular economics for sweet potato production

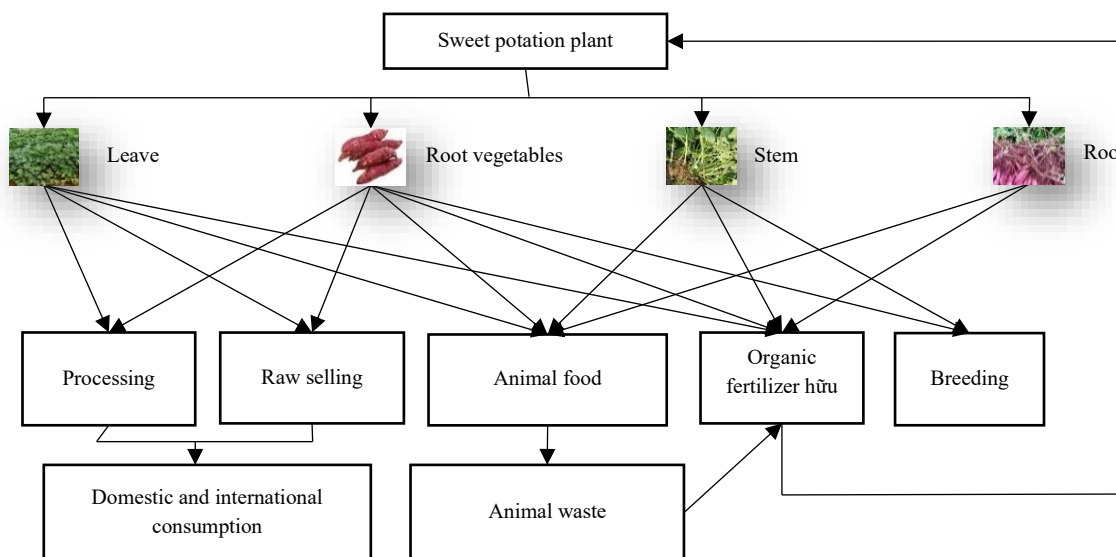


Figure 9 Circular production diagram for sweet potato products

Table 5 Difficulties and solutions for sweet potato production

Difficulties	Solutions
Sweet potato prices have been low since the beginning of the year. To export sweet potatoes to foreign countries.	They are building more factories to produce and process agricultural products to stabilize consumption and market prices. Process sweet potatoes into other products such as starch, alcohol, drinks, snacks, etc., from which the products will be easier to consume.
Sweet potatoes' stems, roots, leaves, and tubers are improperly treated, leading to organic poisoning for crops and soil, water, and air pollution.	Open training courses and instruct farmers on properly handling sweet potato by-products.
Many pests and diseases appear due to the influence of climate change; erratic weather makes	It is necessary to have a mechanism to manage the market for fertilizers and pesticides to ensure the right quality and a suitable price.

According to Hoanh (2021), the sweet potato's leaves and stems ratio ranges from 11% to 14%, while the root is 20% to 25% dry matter content.

Based on production status, advantages and disadvantages, and a potential model, the study proposes a model combining sweet potato cultivation

with livestock (buffalo, cow, and goat) to help improve model efficiency; periodicity is recommended (Figure 9). Some benefits of the model combining sweet potato farming with livestock (buffalo, cow, goat) in the study area include:

Economic: Increase income from growing sweet potatoes and raising livestock, bringing higher economic efficiency to people. When farmers combine sweet potato cultivation with livestock production, they can increase economic efficiency for their families and use by-products of sweet potato plants (unused leaves, stems, and roots) to make food for buffaloes, cows, and cattle. Partially reducing the cost of crop fertilizer and animal feed when using sweet potato by-products as feed for cows and goats; using livestock waste to compost as organic fertilizer for plants.

Social: When combining the sweet potato farming model with raising buffaloes, cows, and cattle, more labor will be needed, creating conditions for people to have jobs.

Environment: Make full use of agricultural and livestock by-products (unused animal manure, leaves, stems, and roots of sweet potato plants), limiting environmental pollution when handling improper waste products. It helps to treat waste by composting (the primary use of plant waste and animal manure through direct or indirect action). It increases the quality of products, creating nutrient-rich organic fertilizer. Compost contains humus, which makes the soil loose, increases the capacity of plants to absorb minerals, and has a good effect on the beneficial microorganisms in the soil. Compost also has a good effect on the soil's physical, chemical, and biological properties, does not adversely affect humans or animals, and solves the problem of ecological pollution.

4 Conclusions

The study assessed the land potential and circularity of sweet potato production in the study area. The results showed that cultivated varieties include purple, white, milk, and red sweet potato.

Still, people are unaware of correctly using and processing crop by-products and their environmental impact. Only a few farmers use the by-products as organic fertilizers and animal feed; the rest are given to neighbors when needed (for cattle and goats), and the rest are thrown away. In addition, the economic efficiency of sweet potato production at this time of year is low, and most of it is lost. The household survey results showed that, in addition to the main product of sweet potato, the tuber, sweet potato by-products such as leaves, stems, and roots can be used in agriculture and daily life. Some circular models have been proposed to increase sweet potato production efficiency in the study area, such as using fresh tubers to process into dishes, such as baking, frying, boiling, and steaming, to increase flavor and nutrition. In addition, sweet potato tubers can also be processed into high-value products such as starch, wine, soft drinks, etc. In addition, sweet potato leaves can be used as food (boiled, stir-fried, cooked in soup) or composted as fertilizer for crops or as feed for livestock (goats, cows). These models can increase income from sweet potato cultivation and livestock farming, increase economic efficiency, provide jobs, make full use of agricultural and livestock by-products, and limit environmental pollution. Sweet potatoes have the potential to adapt and are highly suitable for the socio-economic and environmental conditions of the district. However, people must learn how to use and handle by-products properly.

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