Hue University Journal of Science: Agriculture and Rural Development
pISSN: 2588-1191; eISSN: 2615-9708
Vol. 131, No. 3C, 2022, P. 27–38, DOI: 10.26459/hueunijard.v131i3C.6761

EFFICIENCY OF ARABLE LAND USE IN BINH SON DISTRICT, QUANG NGAI PROVINCE

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(*Received: April 8, 2022; Accepted: May 6, 2022*)

Abstract. When agricultural land gradually decreases, assessing the efficiency of arable land use has scientific and practical significance. It provides information and data for regional planning. The land fund of Binh Son district, Quang Ngai province, is almost thoroughly exploited. Unused land occupies just 0.6% of the total area (46,685.24 ha). Research on thirteen major crops in Binh Son district indicates that chilli, squash, and watermelon have the highest economic efficiency with a profit (VA) of 126.7, 90.1, and 87 million VND/ha/crop, respectively. Their profit is 9.0, 6.5, and 6.3 times that of rice. Also, their capital efficiency is relatively high at 1.35–1.45. However, watermelon is subjected to more risks than chilli and squash because of market instability. Cucumbers, melon, red pumpkin, corn, peanuts, green beans, sugarcane, and cassava have medium to low economic efficiency (18.2 to 41.1 million VND/ha/crop). The lowest economic efficiency is found with rice (11.6 million VND/ha/crop). Generally, farmers apply fertilizers unreasonably and out of balance. Applying a low quantity of organic fertilizers and a high amount of inorganic fertilizers (especially nitrogen fertilizer) causes soil degradation. Therefore, local authorities should encourage farmers to adjust their fertilizer application to prevent soil degradation and health risks.

Keywords: arable land, crops, efficiency, Quang Ngai

1 Introduction

With the current rapid urbanization and industrial development in Vietnam, the agricultural land fund is narrowing dramatically by transferring to non-agricultural purposes [1, 2]. A strong downward trend is predicted in the future. According to the year 2030’s land-use plan, agricultural land is 27.73 million hectares, decreasing by 251,220 hectares compared with the year 2020 by transferring to non-agricultural land [3]. More importantly, the quality of arable land is decreasing, resulting from improper crop distribution, overexploitation, and a lack of reclamation and restoration [4, 5]. The prevailing abuse of agrochemicals (inorganic fertilizers, pesticides, and herbicides) in farming is one of the main reasons for health risks to soil and people [6, 7]. Besides, population growth can put pressure on the agricultural system soon while the national land fund is unchanged [8]. For solving this issue, two solutions should be carried out simultaneously: a thorough exploitation of unused land and agricultural policies toward efficient and sustainable development [8]. Developing land-use types with high economic and environmental efficiency, combined with proper agricultural practices, is a long-term strategic orientation [9, 10].

Binh Son is a coastal plain district in the northeastern Quang Ngai province. It converges favourable conditions and opportunities to exchange and access scientific and technical achievements. It is becoming an attractive area for foreign and domestic investment through key projects, such as ports and oil refineries, that are contributing substantially to the province's economy. Statistic data in 2021 show that the total area of Binh Son district is 46,685.24 ha, making up one-tenth of that of the province. Although agricultural land occupies 78.19% of the total area, the share of agricultural-forestry-fishery production is only 20%. Evaluating the potential and land-use efficiency is a scientific basis for managers to issue sustainable agricultural development policies. Therefore, this research aims to evaluate the economic, social, and environmental efficiency of the main crops in Binh Son district, Quang Ngai province. It provides the local governments with the status of the arable land use; thereby, they can give proper agricultural development orientation to achieve high economic efficiency and improve soil qualities toward sustainable agricultural development.

2 Methods

2.1 Study area

The study was conducted in Binh Son, a district in northeast Quang Ngai province. The district's area is 46,685.24 ha, with 22 communes and one town. The area has characteristics of coastal plain with low-hill and dune terrain (slope of 3–20°). There are two distinct seasons in the district: the dry season (February to July) and the rainy season (August to January). The average temperature is 25.7 °C; the number of sunshine hours is 260–270 a month, and the annual precipitation is relatively high at 2,301 mm; it rains primarily in October and November. The district often suffers from storms that severely affect the crops.

2.2 Data collection and processing

Secondary data, including land statistics and inventory and land-related documents in Binh Son district, were collected from the Binh Son People's Committee, the Department of Natural Resources and Environment, and the Land Fund Development Centre. The land-use data were evaluated for the years 2009, 2014, and 2021.

Primary data, including land-use types, the yield of major crops, farming practices, and fertilizer use, were obtained by interviewing 60 households practising agriculture with questionnaires. The households were chosen randomly in each of the nine following communes: Binh Hai, Binh Tri, Binh Phu, Binh My, Binh Chuong, Binh Trung, Binh An, Binh Khuong, and Binh Minh. The data were aggregated and processed on the R-studio software.

2.3 Arable land use efficiency

The arable land-use efficiency in this study was investigated regarding economy, society, and environment for each land-use type. To evaluate whether a land-use type is sustainable, we need to consider the economic profit, job availability, and a safe agricultural environment.

Economic efficiency is related to Gross output (GO), Intermediate cost (IC), Added value (VA), and Capital efficiency (CE). Gross output is the total economic value of agricultural production in an accounting period and a unit area: $GO = total\ products \times product\ value$. Intermediate cost is the total cost used to pay for materials and services during agricultural production. Added value is the difference between the gross output and intermediate cost or the profit of a crop: $VA = GO - IC$. Capital efficiency is the profitability of a capital: $CE = VA/IC$.

The social efficiency of land-use types can be assessed according to the following indicators: employment opportunities, infrastructure, social welfare, and farmer health care. However, in this study, we only analyze the employment opportunities and the value of working days (VL). The VL is calculated as follows: $VL = VA/working\ days$.

The environmental efficiency was evaluated through the amount of inorganic and organic fertilizers applied compared with recommended doses. The inorganic fertilizers were superphosphate, KCl, and nitrogen converted to urea.

3 Results and discussion

3.1 Land potential

In 2021, the total area of Binh Son district was 46,685.24 ha, of which agricultural land, non-agricultural land, and unused land accounted for 36,504.16 (78.19%), 9,902.44 (21.21%), and 278.20 ha (0.6%), respectively [11] (Fig. 1). The land data statistics from 2015 to 2021 [11] indicated that 629.8 ha of agricultural land and 528.6 ha of unused land were transferred to non-agricultural land for projects, facilities and infrastructure, transportation, and other socio-economic development activities. The structure of land use in Binh Son district is shown in Table 1.

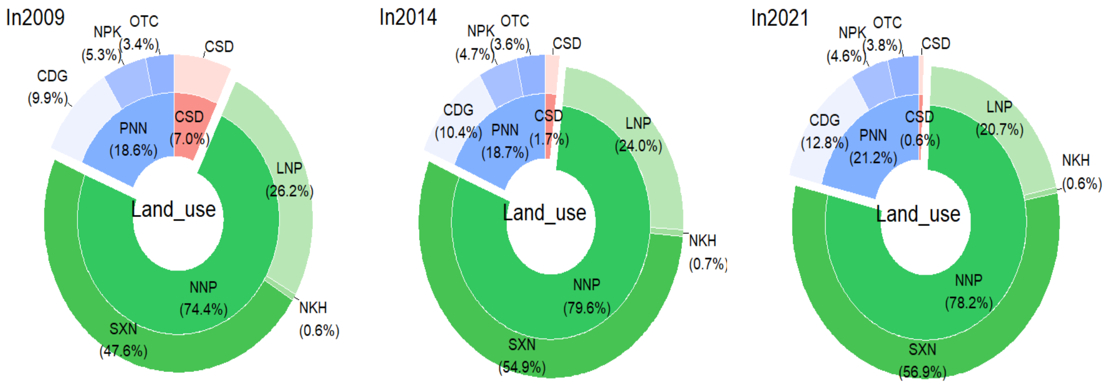

Fig. 1. Land-use structure of Binh Son district in 2009, 2014, 2021 [11]

Notes: NNP: Agricultural land, SXN: arable land, NKH: other agricultural land types; PNN: non-agricultural land, OTC: residential land, CDG: dedicated land, NPK: other non-agricultural land types; CSD: unused land.

Binh Son district exploited its unused land relatively thoroughly. Above 90% of unused land, corresponding to 2,978 ha, was exploited for agricultural and non-agricultural purposes over the 10 years. Therefore, the solutions for satisfying future food security needs should focus on maximizing the productivity of existing farmland within its functional limits. To optimize crop productivity and support sustainable development, it is necessary to meet two basic requirements relating to inherent and dynamic soil properties. First, land use should be appropriate for regional soil, climate, and water conditions. Secondly, the supplication of essential nutrients should be based on inherent soil properties.

3.2 Arable land-use efficiency

Economic efficiency

Efficiency of main crops

The economic efficiency of the major crop was recapitulated in Table 1. The cropping system in this area is relatively diversified with an intermediate cost for seeds, fertilizers, pesticides and herbicides, hired labour, and other costs during the farming period. Although the IC values are notably different among crops, there is no significant variation in the IC value of a crop among households. Agricultural product prices vary but are relatively even across the region because of the similar product quality.

Table 1. Economic efficiency of main crops (ha/crop)

No.	Crop	GO (1,000 VND)	IC (1,000 VND)	VA (1,000 VND)	Days	VL (1,000 VND)	CE	CE/day
1	Rice	31,603	20,021	11,582	120	97	0.58	0.005
2	Corn	63,980	34,857	29,123	80	364	0.84	0.010
3	Peanuts	86,833	45,687	41,147	115	358	0.90	0.008
4	Green bean	38,500	20,305	18,195	55	331	0.90	0.016
5	Sesame	39,750	20,500	19,250	75	257	0.94	0.013
6	Squash	155,000	64,950	90,050	95	948	1.39	0.015
7	Red pumpkin	65,570	30,680	34,890	90	388	1.14	0.013
8	Cucumber	72,760	32,570	40,190	60	670	1.23	0.021
9	Chilli	215,000	88,300	126,700	120	1,056	1.43	0.012
10	melon	63,000	25,700	37,300	90	414	1.45	0.016
11	Watermelon	151,267	64,233	87,033	65	1,339	1.35	0.021
12	Sugarcane	85,000	52,500	32,500	190	171	0.62	0.003
13	Cassava	55,800	17,600	38,200	270	141	2.17	0.008

Notes: GO is the Gross output; IC is the Intermediate cost; VA is the Added value; CE is the Capital efficiency; and VL is the value of a working day.

Among the 13 studied crops, chilli, squash, and watermelon gave the best economic efficiency. The gross output of these plants is 215, 155, and 151.3 million VND/ha, respectively. For each crop, the added value of chilli, squash, and watermelon is 126.7, 90.1, and 87 million VND/ha, respectively. Their production profit is, in turn, 9, 6.5, and 6.3 times that of rice and 3–4 times that of other crops. However, they also require high farming investment: 88.3 million VND/ha/crop for chilli and 64 million VND/ha/crop for squash and watermelon. The working day's value is 1.339 thousand VND for watermelon, 1.056 for chilli, and 948 for squash. The prices of chilli and squash are relatively stable; therefore, the income is also constant. Although watermelon has high economic efficiency, its production suffers from risk because the market is heavily dependent on Chinese traders. Its selling price fluctuates substantially from several hundred to 7 thousand VND/kg. Therefore, some households growing watermelons want to change to Japanese cantaloupe.

The economic efficiency of cucumber, melon, red pumpkin, corn, peanuts, green beans, and sesame is low. Their gross output fluctuates from 38.5 to 86.8 million VND/ha, and their profit attains 18.2–41.1 million VND/ha with a working value of 257–670 thousand VND/day.

Sugarcane, cassava, and rice have low economic efficiency, with rice being the lowest (31.6 million VND/crop/ha for GO and 11.58 million VND/crop/ha for AV), considerably lower than for other crops. These products have a working day's value of 171, 141, and 97 thousand VND, respectively. Meanwhile, rice requires careful cultivation and strict irrigation. In general, rice cultivation is more challenging than others, while the profit is negligible. These results are similar to those of Le et al. [12] when they studied the crop production at the coastal communes in Quang Dien district, Thua Thien Hue province.

Capital efficiency is the most suitable for economic efficiency evaluation if the farming time is similar. Meanwhile, some plants are short-term crops, and others are annual. Hence, in this study, we focus on capital efficiency for a working day. Our results indicate that vegetables generally provide relatively high working-day efficiency, between 0.010 and 0.021. Cassava, peanuts, rice, and sugarcane have efficiency below 0.008. Although cassava has the highest CE, its working-day efficiency is low. This low cassava working-day income is more consistent for assessing economic efficiency.

Efficiency of land-use types

Five land-use types were evaluated, namely rice monoculture, 2-rice-1-vegetable, 1-rice-2 vegetables, vegetable monoculture, and annual plants. The economic efficiency of these land-use types is shown in Fig. 2. The vegetable-monoculture type has the highest economic efficiency with an annual GO of 166.5–302.1 million VND. After deducting intermediate costs, the profit of this type is 76.4–157.3 million VND. Similarly, Do & Nguyen reported the notable economic efficiency of this land-use type when they studied the production in An Thi district, Hung Yen province [13].

The next high economic efficiency is the 1-rice-2-vegetables type, with a 58.7–142 million VND profit. In particular, pumpkin-rice-squash and squash-rice-cucumber types have a high

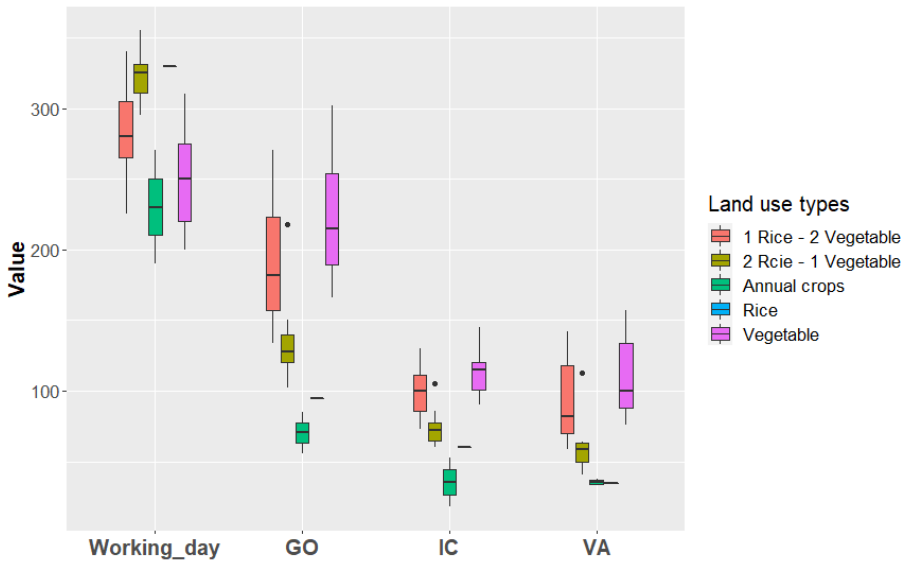

Fig. 2. Economic efficiency of land-use types (Working-day in days; GO, IC, and VA in million VND)

profit of 136.7 and 142 million VND. In contrast, the rice monoculture and annual crop types have the lowest economic efficiency. Their profit is 35.2 million VND on average.

Social efficiency

Social efficiency was assessed through the number and value of working days for the land-use types. As the primarily cultivated crops plants required different plant growth stages, their number of working days is different. The annual crop does not need special care for 190–270 days, and their working-day value is relatively low (141–171 thousand VND). With this crop, farmers have much idle time, and they could do other agricultural activities or part-time jobs for the rest of the year to increase income. However, industrial activities and services in the location are less available; therefore, farmers are redundant in the idle time. Oppositely, rice-monoculture and 2-rice-1-vegetable types occupied most of farmers' working time, and the income is as low as 109–338 thousand VND/day. Hence, developing diversified agriculture that combines seasonal farming activities and high-value livestock husbandry is an efficient solution for these three land-use types. This solution helps farmers to improve their income.

The vegetable-monoculture and 1-rice-2-vegetables land-use types have a similar working time of 200–340 days. The value of a working day is the highest for the vegetable monoculture, ranging from 353 to 672 thousand VND, especially for the watermelon-peanut-corn, watermelon-corn-sesame, and watermelon-corn-green beans types. The 1-rice-2-vegetables land-use type has a slightly lower working-day value at 222–536 thousand VND. Farmers can have this daily income if they have sufficient arable land.

Environmental efficiency

The survey data on fertilizer quantities for primary crops are shown in Table 2. The combination of inorganic and organic fertilizers helps improve soil fertility and nutrient-holding ability. Adding manure could increase soil organic matter and reduce pollution in husbandry areas. However, the results indicate that the farmers used few organic fertilizers (mainly manure) for crops, averaging only 1/10 of the recommended quantity.

In contrast, widespread overuse of inorganic fertilizers occurred in the study area. Seven of the thirteen major plants, namely peanuts, green beans, sesame, squash, red pumpkin, chilli, and sugarcane, were administered with an exceeding urea quantity (three times that of the recommended dosage). Besides, farmers applied a large quantity of KCl for rice, green bean, sesame, squash, watermelon, and sugarcane. They also used a relatively high dose of superphosphate for sugarcanes.

Farmers in this region use fertilizer according to their farming experience. Whenever the yield of a previous crop is low, they gradually increase the fertilizer dose in the following crops. At first, increasing the fertilizer dose is quite effective, improving crop yields. Then, the increase in fertilizer application does not change the crop yield further, so the fertilizer dose is kept constant. However, the fertilizer quantities applied are usually over the recommended dosage. This could cause further soil degradation and decrease crop yields at present and in the future.

Soil degradation due to agrochemicals abuse (inorganic fertilizer, pesticides, and herbicides) has been one of the most critical problems for agriculture these days [6]. The overuse of inorganic fertilizers leads to the competition between macronutrients and micronutrients during nutrient transportation to plants. The plant, therefore, can be deficient in micronutrients and become underdeveloped even when macronutrients are fully applied. Also, the fertilizer imbalance is a favourable condition for pest and disease development. Overusing fertilizers also causes environmental pollution and affects human health. Generally, farmers underestimate the role of organic fertilizers regarding soil fertility and crop yields. If they do not change their farming practices, soil quality and crop productivity will continue to decrease considerably, and it will be challenging to renovate in the future.

Table 2. Fertilizer application and the recommended dosage for main crops

No.	Main crops	Amount of fertilizers ha/crop								References
		Urea (kg)		Superphosphate (kg)		KCl (kg)		Organic fertilizer (tons)		
		App.	Rec.	App.	Rec.	App.	Rec.	App.	Rec.	
1	Rice	260	195–260	298	303–424	162	67–100	0.75	5–6	[14, 15]
2	Corn	283	474–608	351	485–582	144	187–240	0.62	5–10	[16]
3	Peanuts	217	54–87	177	303–485	147	100–150	0.63	4–5	[17]
4	Green bean	463	87	281	364	217	100	0.52	5–10	[18]
5	Sesame	450	100–120	175	400–500	200	100–120	0.40	1–1.5	[19]
6	Squash	340	222–278	220	417–556	120	12–13	0.30	11–14	[20]
7	Red pumpkin	300	150–200	200	364–485	120	200–217	0.30	1–1.5	[21]
8	Cucumber	400	304–477	190	909–1091	90	200–251	0.50	20–25	[22]
9	Chilli	1000	634–808	1200	1712–2197	300	367–434	0.60	6–10	[23]
10	Melon	270	460	200	1454	100	180	0.30	18–20	[25]
11	Watermelon	725	723–868	800	2020–2424	800	557–668	1.20	1	[14]
12	Sugarcane	700	326–543	980	364–727	400	251–367	0.80	10–20	[26]
13	Cassava	295	130–350	260	200–500	60	130–260	1.50	5–10	[2]

Notes: App.: Applied fertilizer, Rec.: Recommended fertilizer; "Light yellow": application below the recommended dosage; "Orange": application above the recommended dosage; "Green": application within the recommended dosage.

4 Conclusions

Binh Son district exploited the land fund well by using 90% of the unused land over 10 years. The agricultural land occupies the majority of the area with 13 major crops and 5 land-use types. Chilli, squash, and watermelon were the three plants providing the highest economic efficiency. Their profit reached 126.7, 90.1, and 87 million VND/crop, respectively. Chilli and squash had a more stable economic efficiency than watermelon. In addition, peanuts, cucumber, cassava, melons, red pumpkins, and sugarcane obtained a moderate profit ranging from 32.5 to 41.1 million VND/crop. Watermelon, chilli, and squash had the highest working-day value of 1,339–948 thousand VND. The capital efficiency of vegetables ranged from 0.010 to 0.021. Rice, sugarcane, and cassava brought the lowest economic efficiency, with a profit of 11.582 million VND/ha/crop, and the value of a working day was 97 thousand VND. Concerning the land-use types, watermelon-peanut-corn, watermelon-corn-sesame, and watermelon-corn-green bean brought the highest economic efficiency. Their profit was 157.3, 135.4, and 134.3 million VND/year.

There was an imbalance in the dose and types of applied fertilizers. Farmers often overused inorganic fertilizers while underestimating organic fertilizers to only 1/10 of the recommended quantities. It could lead to soil degradation and a decrease in crop yields. Furthermore, it might decrease food quality and cause a health risk. Thus, it is necessary to balance inorganic and organic fertilizer applications to develop sustainable agriculture.

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