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FACTORS AFFECTING EFFICIENCY OF AGRICULTURAL LAND-USE MODEL

Nguyen Bich Ngoc[1,*], Ho Viet Hoang[1], Mai Thi Khanh Van[2], Le Ngoc Phuong Quy[1], Tran Thi Phuong[1,3]

[1] University of Agriculture and Forestry, Hue University, 102 Phung Hung St., Hue, Vietnam
[2] School of Hospitality and Tourism, Hue University, 22 Lam Hoang St., Hue, Vietnam
[3] Centre for Climate Change Study in Central Vietnam, 102 Phung Hung St., Hue, Vietnam

* Correspondence to Nguyen Bich Ngoc <nguyenbichngoc@huaf.edu.vn>
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Abstract. This research identifies and analyzes factors affecting the efficiency of agricultural land-use models in Hai Lang district, Quang Tri province, with logistic regression. The sample size is 98 households applying and not applying sustainable agricultural land-use models in Hai Ba, Hai Duong, and Hai Que communes. The results show that education level and income affect the application of land-use models. Besides, the agricultural land is used relatively reasonably. The land-use models reflect sustainability but are not entirely consistent with theory.

Keywords: agricultural land, land-use model, Quang Tri province

1 Introduction

Vietnam is a marine country with over 3,200 km of coastline. Twenty-eight cities and provinces and 125 districts, with 17.7% of the area and 30% of the population, are located along the coast [5]. Nearly 80% of the population lives in rural areas, and over 70% work in agricultural production; therefore, economic development strategies and agriculture in coastal areas require tremendous attention. The Party and the State of Vietnam have identified these strategies as leading fronts in the country's industrialization and modernization. As a result, Vietnam can keep up with the world, contributing to the country's socio-political stability and economic development [1]. At the 4th Central Conference (Session X), Vietnam's marine economic development strategy was approved, and the coastal area has been considered the driving force for integrated economic development [8].

The sandy coastal area of Quang Tri province plays a vital role in agriculture, forestry, and other fields. However, land use has faced numerous obstacles because of the fragmented topography, low natural fertility, and poor water and nutrient holding capacity, leading to low crop yields [3]. Therefore, this issue must be viewed scientifically based on effective and sustainable land use.

In coastal communes, the supply of organic matter to sandy soil is primarily from plant residues. However, the flora here is impoverished with low biomass, and the volume of organic matter added every year is minimal. The drought, leaching–fading, and the risk of desertification occur widely in bare lands, the irregular farming areas in the sandy area of Quang Tri province [9].

Hai Lang is a district south of Quang Tri province, with a diverse land potential with plains, hills, and sandy coastal areas. This area consists of sandy soil and a humid tropical climate. The district has five coastal communes: Hai Ba, Hai Que, Hai Duong, Hai An, and Hai Khe, with a great potential for agricultural, forestry, and aquaculture production, contributing 30.72% to the economic structure of the district in 2018 [7]. However, the district authorities are willing to increase agricultural production in the region. Therefore, assessing the current situation of applying sustainable agricultural land-use models and analyzing the factors affecting these models are essential.

2 Methods

2.1 Collecting data and documents

Secondary data

We collected data and information via documents, synthesis reports, and land inventory statistics of the district. Besides, information on natural, population, socio-economic and cultural conditions were supplied by the District People's Committee, Department of Natural Resources and Environment, Department of Statistics, and People's Committees of Hai Ba, Hai Duong, and Hai Que communes.

Primary data

Primary data were collected from the interviews on the situation of land use and management and the process of building and developing sustainable agricultural land-use models. Discussions with local professional officials and experienced indigenous people in management and production to assess the development of sustainable agricultural land-use models in the coastal area were also carried out.

The number of interview samples, *n*, (households) was determined from the Slovin formula [2].

$$n = \frac{N}{1 + N \times e^2} \quad (1)$$

where *N* is the total number of households; *e* is the acceptable standard error (*e* = 10%, reliability *p* = 90%). Because the total number of households in the communes is 2060, those participating in

Table 1. Sample size distribution in the research

Research area	Total number of agricultural households	Number of samples (investigation form)	Ratio (%)
Hai Ba	558	18	18.37
Hai Duong	902	51	52.04
Hai Que	600	29	29.59
Total	**2060**	**98**	**100**

the interview are 95.37. To ensure the accuracy of the study, we interviewed 98 households. The interviewees were selected randomly from the lists provided by the communes by using the Random function in Microsoft Excel (Table 1).

2.2 Data analysis and processing

We used descriptive statistics, comparison, and methods of data synthesis and analysis to learn about the data.

2.3 Logistic model for sustainable agricultural land use

Logistic regression analysis is a statistical technique used to examine the relationship between the independent variable (the variable or the categorical variable) and the binary dependent variable. In single linear regression, the dependent variable, Y, and the independent variable, X, are related according to Eq. 2, where α is the constant (also known as the intercept); β is the regression coefficient; ε is the error.

$$Y = \alpha + \beta \times X + \varepsilon \qquad (2)$$

The dependent variable Y has only two states: 1 (applying sustainable land-use model) and 0 (not applying sustainable land-use model) in logistic regression. To convert to a continuous variable, we calculate the probabilities of these two states. Suppose p is the probability that an event will occur (e.g., the model is applied), then $1 - p$ is the probability that the event will not occur (e.g., the model is not applied). The logistic regression equation has the following form.

$$\ln \frac{p}{1-p} = \alpha + \beta \times X + \varepsilon \qquad (3)$$

From this equation, we can calculate the predictive probability of applying the models according to the numerical value of X.

$$\frac{p}{1-p} = e^{\alpha + \beta \times X} \qquad (4)$$

$$p = \frac{e^{\alpha + \beta \times X}}{1 + e^{\alpha + \beta}} \qquad (5)$$

The logistic model uses data on indicators and variables affecting the application of sustainable agricultural land-use models. These indicators usually include age, sex, education level, income, and the number of agricultural workers. From these data, using the logistic regression method, we determine the effects of the factors. It is predicted how the application probability of agricultural land-use models changes when the factors change.

3 Results and discussion

3.1 Overview of agricultural land-use models

The coastal area of Hai Lang is well-known for its nutrient-poor white sand and mobile sandy land. The coastal communes, such as Hai Duong, Hai Ba, Hai An, Hai Que, and Hai Khe, have cultivated land, mainly arid white sand, almost entirely dependent on "water from the sky" or rainfed. Climate change adversely affects agricultural production.

Table 2. Agricultural land-use models in communes in sandy coastal areas of Hai Lang district

No.	The formula of crop rotation		Number of applied households at study communes		
			Hai Ba	**Hai Que**	**Hai Duong**
1	Sustainable formula of crop rotation	Rice (two crops: Winter–Spring and Summer–Autumn crops)	15	24	47
2		Bitter melon (at Winter–Spring crop) – legumes (at Summer–Autumn crop)	3	1	12
3		Chives intercropped with cassava (lasting two crops)	–	–	8
4		Chives intercropped with cassava and legumes	–	–	7
5		Peanuts intercropped with corn (at Winter–Spring crop) – mung beans intercropped with corn (at Summer–Autumn crop)	4	–	1
6		Cassava intercropped with mung beans and melons	–	5	1
7	Unsustainable formula of crop rotation	Chives	3	–	15
8		Cassava	6	11	2
9		Melons	–	7	1
10		Sweet potatoes – sweet potatoes	2	6	1

Source: Summary of survey data in 2020

Therefore, farmers in the sandy coastal areas of the district have faced tremendous difficulties and challenges in their production. Facing this situation, Hai Lang district is developing valuable drought-tolerant production models locally.

Table 2 shows that, in recent years, each commune has developed efficient land-use models suitable for the farming process and ecological conditions. Hai Ba grows several types of plants and applies different sustainable crop rotational models, such as peanuts intercropped with corn (Winter–Spring crop); mung beans intercropped with corn (Summer–Autumn crop). Hai Que practises numerous sustainable agricultural land-use models, such as intercropping cassava, mung beans, and melons. Hai Duong, with a relatively large agricultural land area (1,112.68 ha) [4, 6], effectively applies many models and formulas of crop rotation. Realizing that bitter melon and chives help farmers earn a high income, these communes (under the help of local authorities and scientists) have continued to expand the models. Besides, monoculture, such as melon, chives, cassava, and sweet potatoes, is also traditional crops over the years. Among the studied communes, Hai Duong has the highest number of households applying the crop rotation formula (both sustainable and unsustainable formulas), followed by Hai Que and Hai Duong.

3.2 Situation of applying agricultural land-use models

Sources of information access to sustainable agricultural land-use models

Table 3 shows that farming households mainly get information on farming techniques and land-use patterns from extension workers (16.33%), typical farmers (10.2%), other farmers (14.29%), and radio stations (5.1%). These information sources are very important to farmers because they can grasp cultivation techniques quickly. The information is usually available to farmers and can be updated easily. Besides, a large number of households (41.84%) invent and innovate their cultivation techniques by themselves.

Table 3. Sources for information on cultivation techniques of farming households

STT	Sources	Number (people)	Rate (%)
1	Radio station	5	5.10
2	Agricultural extension officer	16	16.33
3	Farmer Association	8	8.16
4	Friends/Relatives	3	3.06
5	Typical farmers	10	10.20
6	Other farmers	14	14.29
7	Invented/ innovated by themselves	41	41.84
8	Other sources	1	1.02
Total		**98**	**100**

Source: Summary of survey data in 2020

Current production situation of farming households

Because the primary income is from rice production, most farmers in the sandy coastal communes of Hai Lang district use nearly all of their existing productive lands to grow rice. They utilize the rest to grow other annual crops, such as chives, legumes, and cassava. The survey data indicate that the household groups applying the land-use model use 8.51 ha of their total cultivated area (35.37 ha) for the sustainable models (Table 4). The non-applying group has 29.15 ha, of which 5.94 ha is for short crops. The average number of land plots in the applying household group is 3.57, and that of the non-applying group is 3.45. The average cultivated area per household is 0.72 ha, and that under the sustainable models is 0.17 ha. For the second group that does not apply the sustainable model, the average cultivated area is 0.59 ha, and that for vegetables is only 0.12 ha. Most of the land requires renovation for agricultural production.

However, land degradation occurs widely in many localities because farmers use land unreasonably, and the agricultural land area decreases gradually since some farmers use it for non-agricultural purposes.

Situation of farming households applying land-use models

According to the survey results in Table 5, among the sustainable land-use models applied by 49 households, 16 were for bitter melon (Winter–Spring crop) – Legumes (Summer–Autumn crop), which is the most widespread (32.65%). The second most popular is chives intercropped with cassava with eight models (16.33%), followed by chives intercropped with cassava and legumes with seven models (14.29%). Other crops are less applied: five models for peanuts intercropped with corn (Winter–Spring crop) – mung beans intercropped with corn (Summer–Autumn crop); six models for cassava intercropped with mung beans (Winter–Spring crop) – melons (Summer–Autumn crop), and seven models for other crops. The small number of the models applied resulted from more care and watering required.

Table 4. Current production situation of farming households

Criteria	Unit	Applying group		Non-applying group	
		Total	**Average**	**Total**	**Average**
Number of land plots	plot	175	3.57	169	3.45
Total cultivated area	ha	35.37	0.72	29.15	0.59
Area for vegetables	ha	8.51	0.17	5.94	0.12

Source: Summary of survey data in 2020

Table 5. Situation of farming households applying land-use models

Sustainable models	Number of models applied by households	Rate (%)
Bitter melon (Winter–Spring crop) – Legumes (Summer–Autumn crop)	16	32.65
Chives intercropped with cassava	8	16.33
Chives intercropped with cassava and legumes	7	14.29
Peanuts intercropped with corn (Winter–Spring crop) – mung beans intercropped with corn (Summer–Autumn crop)	5	10.20
Cassava intercropped with mung beans (Winter–Spring crop) – melons (Summer–Autumn crop)	6	12.24
Others	7	14.29
Total	**49**	**100**

Source: Summary of survey data in 2020

Table 6. Situation of farming households not applying land-use models

The unsustainable models	Number of models applied by households	Rate (%)
Chives	18	33.33
Melons	8	14.81
Cassava	19	35.19
Sweet potatoes	9	16.67
Total	**54**	**100**

Source: Summary of survey data in 2020

Among the non-sustainable land-use models applied by the other 49 households, 54 cropping models were recorded. This number indicates that some households use two or three models on different plots simultaneously. The model of growing cassava accounts for the largest proportion (35.19%) with 19 households, and the lowest (14.81%) is the model of growing melons with 8 households.

Farmers' awareness of sustainable land-use models

When developing options for using sustainable land-use models in sandy coastal communes to meet local socio-economic development requirements, local people have to participate in and contribute to the construction process. Information on why farmers do not participate in the sustainable land-use models is shown in Table 7.

Nearly one-third (32.65%) of the interviewees claimed that there was a lack of water resources. This shortage is caused by the extreme climate and susceptibility to severe droughts. Up to 22.45% of people said that the application of the model was ineffective because of different subjective and objective reasons. 2.04% of the farmers chose other reasons; they said the plants could only grow one crop per year because of the flood in the rainy season.

The results also show that 10.20% of the respondents indicated a lack of inputs, such as materials, machinery, labour force, and other costs; 10.20% of the interviewees claimed a shortage of knowledge about the model. Additionally, 8.16% answered that it was due to the deficit of labour resources, and the same number indicated that the application was lengthy.

By contrast, the 49 households applying the sustainable agricultural land-use models indicated the advantages (Table 8). Nearly half of them (46.94%) said that the models enabled intercrop and polyculture. Also, the protection/conservation of land and water was preferred by

Table 7. Reasons for not applying the model of sustainable agricultural land use

No.	Answers	Households	Rate (%)
1	Lacking government support (production techniques, product consumption)	3	6.12
2	Lack of inputs	5	10.20
3	Lack of knowledge about the model	5	10.20
4	Lack of water	16	32.65
5	Requiring a lot of labour	4	8.16
6	The time from investment to income was long	4	8.16
7	No land-use rights	0	0.00
8	The model application was ineffective	11	22.45
9	Others	1	2.04
	Total	**49**	**100**

Source: Summary of survey data in 2020

Table 8. Opinions on advantages of sustainable agricultural land-use models

No.	Answers	Households	Rate (%)
1	Being intercrop and polyculture	23	46.94
2	Protecting/ conserving soil and water	5	10.20
3	Managing pest and weed	4	8.16
4	Conserving biodiversity	1	2.04
5	Protecting the environment	2	4.08
6	Limiting to use of chemicals	3	6.12
7	Balancing fertilize	9	18.37
8	Others	2	4.08
	Total	**49**	**100**

Source: Summary of survey data in 2020

10.20%. The rate of farmers identifying other benefits of the models is as follows: pest and weed management (8.16%), biodiversity conservation (2.04%), environmental protection (4.08%), chemical use restriction (6.12%), balanced fertilization (18.37%), and other reasons (4.08%).

However, the applicants of the sustainable agricultural land-use models also face certain challenges (Table 9). Nearly 60% of farmers indicated that they had difficulties in plant care. Two household groups of equal numbers (6) claimed that the farming technique was complex and the input costs were high. The rest two groups with the same number of applicants (4) said the capital recovery was slow, and there were other obstacles.

3.3 Analysis of factors affecting efficiency of agricultural land-use models

To evaluate the effects of the factors on the construction and development of agricultural land-use models, we collected information from 98 households. The information on the logistic regression model is presented in Table 10.

Table 9. Opinions about difficulties in applying sustainable agricultural land-use models

No.	Answers	Amount (people)	Rate (%)
1	Complex technique	6	12.24
2	Slow capital recovery	4	8.16
3	Difficult to take care of plants	29	59.18
4	Large input costs	6	12.24
5	Others	4	8.16
	Total	**49**	**100**

Source: Summary of survey data in 2020

Table 10. Results of regression analysis with binary logistic model

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	Age	0.043	0.045	0.914	1	0.339	1.044	0.956	1.141
	Sex	0.615	0.759	0.657	1	0.418	1.850	0.418	8.184
	Education_level	0.273	0.131	4.313	1	0.038	1.314	1.015	1.700
	Employee_number	0.219	0.233	0.885	1	0.347	1.245	0.789	1.966
	Plot_number	–0.199	0.220	0.822	1	0.365	0.819	0.533	1.260
	Area	0.001	0.001	3.117	1	0.077	1.001	1.000	1.002
	Income	0.255	0.057	19.938	1	0.000	1.290	1.154	1.443
	Constant	–16.574	4.612	12.916	1	0.000	0.000		

Source: Model processing results, 2020

The logistic regression model is written as

$$\ln \frac{p}{1-p} = -16.574 + 0.043 \times X_1 + 0.615 \times X_2 + 0.273 \times X_3 + 0.219 \times X_4 + -0.199 \times X_5 + 0.001 \times X_6 + 0.255 \times X_7$$

or

$$\ln \frac{p}{1-p} = -16.574 + 0.043 \times age + 0.615 \times sex + 0.273 \times education\_level + 0.219 \times employee\_number + -0.199 \times plot\_number + 0.001 \times area + 0.255 \times income$$

or

$$\frac{p}{1-p} = e^{-16.574 + 0.043 \times age + 0.615 \times sex + 0.273 \times education\_level + 0.219 \times employee\_number + -0.199 \times plot\_number + 0.001 \times area + 0.255 \times income}$$

We can summarize the binary logistic model in Table 11.

The Sig. of the age, sex, employee_number, plot_number, and area variables is 0.339, 0.418, 0.347, 0.365, and 0.077, respectively (>0.05); therefore, the correlation between the application of the sustainability model and these variables is not statistically significant. Only education_level and income lead to the application of the land-use model with the *OR* of education_level and income of 1.31 and 1.29.

It is known that $\frac{p}{1-p}$ is *odd*; therefore, it can be written as

$$odd = e^{-16.574 + 0.043 \times age + 0.615 \times sex + 0.273 \times education\_level + 0.219 \times employee\_number + -0.199 \times plot\_number + 0.001 \times area + 0.255 \times income}$$

Let odd_0 be the value of the model when all factors are statistically insignificant; then, $odd_0 = e^{-16.574}$. Let odd_1 be the value of the model when education_level increases by one step; then, $odd_1 = e^{-16.574 + 0.273}$. Similarly, if the income increases by one unit, then $odd_1 = e^{-16.574 + 0.255}$.

Table 11. Summary of regression analysis results using binary logistic model

Factors	Odds ratio (OR)	95% confidence interval	*p*
Age	1.04	0.956–1.141	0.339
Sex	1.85	0.418–8.184	0.418
Education_level	1.31	1.015–1.700	0.038
Employee_number	1.24	0.789–1.966	0.347
Plot_number	0.81	0.533–1.260	0.365
Area	1.00	1.000–1.002	0.077
Income	1.29	1.154–1.443	0.000

Source: Model processing results, 2020

The odd of the education level is $OR_1 = \frac{e^{-16.574+0.273}}{e^{-16.574}} = e^{0.273} = 1.31$.

The odd of income is $OR_1 = \frac{e^{-16.574+0.255}}{e^{-16.574}} = e^{0.255} = 1.29$.

At this time, it can be interpreted that when the education level increases by one level, the ability to apply the model increases by 1.31 times (results exp (B) in the table above when $e^{0.273} = 1.31$). When farmers' income increases by 1 million VND, the ability to apply the model increases by 1.29 times (exp (B) results in the table above when $e^{0.255} = 1.29$). The statistical significance of the variables of education_level and income is less than 5%, with a general confidence level of 95%. Thus, the regression coefficients are statistically meaningful, and the logistic model can be written as

$$\ln \frac{p}{1-p} = -16.574 + 0.273 \times X_3 + 0.255 \times X_7$$

The education level (X_3) and income variables (X_7) are positively related to the dependent variable, indicating that the higher the farmers' education level and income, the higher the possibility that they apply the model. Because of farmers' insufficient qualifications, traditional production, and low investment from the government, the agriculture sector and farmers must focus on more training, assistance, and acquiring knowledge. Land cannot make money, but the farmers who work on that land do it.

Currently, the agricultural sector has two most concerning issues: paddy land decrease and farmers' low income, especially those producing rice. Therefore, they have little incentive to concentrate on production. Income significantly depends on the investment in applying sustainable agricultural land-use models. To have a higher income, they have to invest more capital in production equipment. As a result, low-income households encounter tremendous difficulties in applying the model.

Thus, the education level and income affect farmers' decision to apply the sustainable land-use model. To apply the models, the farmers have to use high technology in production, which, in turn, requires farmers to acquire a higher education level. Besides, state organizations must develop reasonable policies to encourage more farmers to apply the models to bring efficiency.

4 Conclusion

The interviews reveal that peanut intercropped with maize and mung beans intercropped with maize were applied in Hai Ba (three models) and Hai Duong (one model). While melon and cassava intercropped with beans were grown in Hai Que (five models) and Hai Duong (one model). Chives intercropped with cassava model and chives intercropped with cassava and mung beans were planted in Hai Duong (eight and seven models). Bitter melons in the Winter–

Spring season and beans in the Summer–Autumn crop were grown in all three communes with 15 models. Of the studied communes, Hai Duong has the most number of households applying and not applying the crop rotation formula. Regarding the efficiency of production, the farmers' education level and income positively affect the application of sustainable agricultural land-use models.

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