THE ECONOMIC AND ENVIRONMENTAL PERFORMANCES OF AGROFORESTRY LAND-USE MODELS IN DAK NONG PROVINCE

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SUMMARY

We studied the economic and environmental performance of different types of land-use models inside and outside forestland in the Central Highlands of Vietnam. We used a semi-structured interview method, descriptive statistical methods, a structural model, and a matching method to obtain and analyze data from 414 plots at 31 communes in Dak Nong province. Six agroforestry land-use models were investigated at the study site, including pure industrial crops (coffee), pure fruit trees (*Passiflora edulis*), pure plantation forests (*Acacia Mangium*), intercropping of industrial plants and fruit trees, intercropping of industrial and forestry trees, and short-term crops (*Cassava*). On forestland, the agroforestry land-use models yield fewer economic and environmental outcomes than those on agricultural land. The pure industrial tree becomes the most popular agroforestry land-use model, yet it produces fewer outcomes in relation to the remaining models. The top three land-use models are (1) pure fruit tree, (2) intercropping of industrial plants and fruit trees, and (3) intercropping of industrial and forestry trees. The empirical findings illustrate some policy implications for achieving further sustainable development associated with the effective agroforestry land-use models in Dak Nong province.

Keywords: Economic and environmental impacts, forest land, land-use models, rural livelihood.

1. INTRODUCTION

The Central Highlands is an important region for Vietnam's socio-economic development and national security, encompassing five provinces: Kon Tum, Gia Lai, Dak Lak, Dak Nong, and Lam Dong (Dinh et al., 2019). This region has been facing deforestation and forest degradation, land degradation, land conflicts (Khuc et al., 2018; Meyfroidt et al., 2013; To et al., 2013). Further, the poverty rate of the region is relatively high compared to other regions of the country (Nguyen et al., 2009; Nguyen, 2015). In this context, adopting and developing agroforestry production activities is considered as a good way to help eradicate hunger, alleviate poverty, and improve rural livelihoods (Prime, 2012). A better understanding of agroforestry land-use models would help farmers and policy-makers improve livelihood strategies and future policies. Many empirical studies have been done in the Central Highlands (Cramb et al., 2004; Dang and Shively, 2008; Dinh et al., 2019; Meyfroidt et al., 2013; Sikor and Ngoc, 2007), yet there have been few comprehensive studies assessing the economic and environmental impacts of agroforestry land-use models in the Central Highlands. In this study, we aim (1) to characterize the agroforestry land-use models in Dak Nong province; (2) to assess the economic and environmental impacts of land-use models inside and outside forestry land; (3) to identify the factors of economic and environmental performance; and (4) to recommend land-use policies to facilitate sustainable development associated with appropriate land-use models for the Central Highlands.

2. RESEARCH MOTHODOLOGY

2.1. Study area

The area for this study is in eight upland districts in Dak Nong province (Figure 1). Most study sites are located in the districts of Tuy Duc, Dak Song, and Dak Gllong. The targeted study area generally presents a typical feature in terms of socio-economic-ecological characteristics of Dak Nong. For example, the poverty rate is still relatively high, and people’s livelihood is highly associated with agroforestry production activities. Agroforestry land is gradually degrading due to deforestation and mining. Severalagroforestry production models have been adopted and practiced by the farmers (landowners) in the study sites in the past years, including six models: (1) Short-term agricultural crops (assava, maize and beans); (2) Pure fruit tree (Avocado, Jackfruit, Durian, Orange, Tangerine…); (3) Pure industrial tree (Coffee, Pepper, Cashew…); (4) Pure forest tree (Acacia, Senna siamea, Pine…); (5) Intercropping of industrial plants and fruit trees (Avocado + Jack + Cashew; Coffee + Cashew + Avocado; Coffee + Pepper + Avocado; Article + Avocado; Pepper + Avocado…); (6) Intercropping of industrial and forestry trees (Senna siamea + Coffee; Macadamia + Coffee; Article + Avocado + Rubber…).

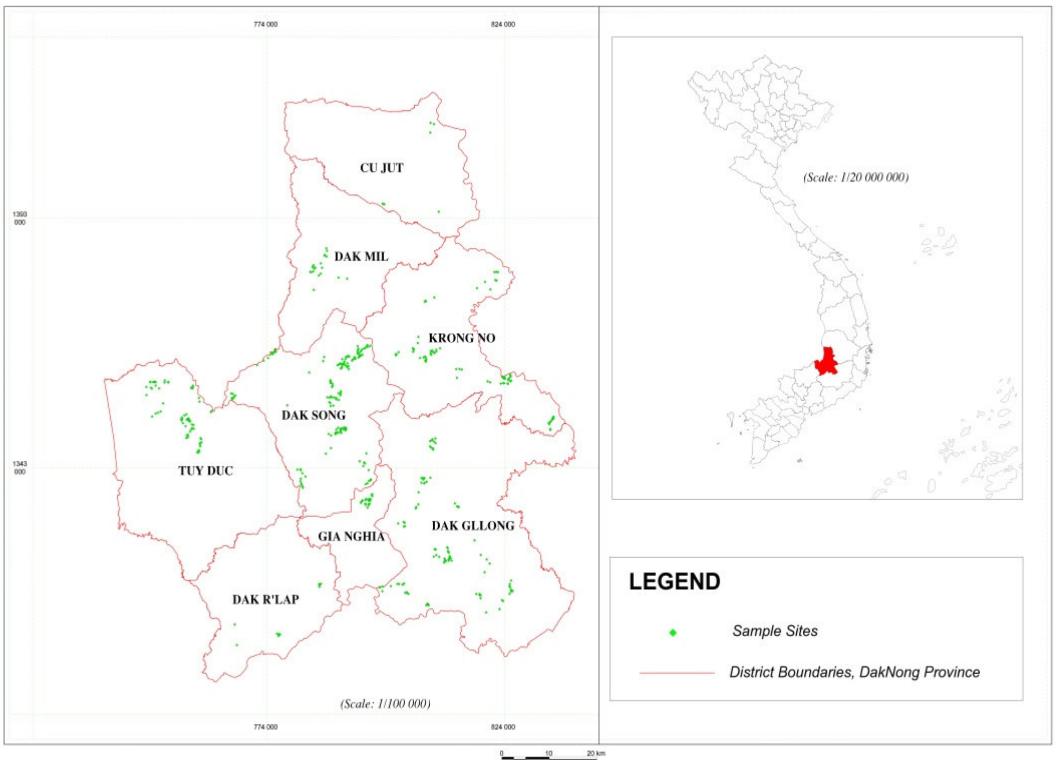

Figure 1. Map of study site in Dak Nong province

2.2. Data collection

We used a set of questionnaires to collect relevant information on agroforestry land-use models. A focus group was used to test and improve these questionnaires before a field survey was conducted. The data were obtained from 414 plots from landowners at 31 communes in Dak Nong. Three information groups were collected during the field survey in 2018, including land-use models and economic and environmental outcomes. For land-use models, we learned the land status (inside forestland, outside forestland), kinds of crops/plants (short crops, industrial trees, etc.). For economic data, we collected all relevant information for each land-use model such as revenue, cost (seed cost, labor cost, etc.). For environmental data, we collected information about many dimensions such as vegetation structure, canopy, soil composition, soil tightness, soil thickness, and land-use model. Given the actual status of the plots, we assigned a point to every dimension. We measured the environmental outcome of the agroforestry land-use model by calculating the total environment point for the respective plots.

2.3. Data analysis

We used several methods to empirically analyze data. First, a descriptive statistics method was used to present the features of the agroforestry land-use model, while a nonparametric test was employed to compare the economic and environmental impacts of those targeted models. A Wilcoxson test was used to deal with non-normally distributed data. Second, we used a matching method to quantify the economic and environmental impacts of agroforestry land-use models. The purpose of propensity score matching is to determine the average treatment effect (ATT) of each agroforestry land-use model so we took every available land-use model into consideration. Model 1 was automatically excluded by propensity score matching due to data limitation. For running propensity score matching, we only retained those key covariates that are relevant to outcomes of land-use models. The specific procedure of the matching method in this study specifically followed the study of Magliocca et al. (2019). Third, we used a regression model to identify the factors influencing the economic and environmental outcomes of land-use models. We chose the structural model because it has proved to be a good one for unraveling complex land-use systems (Khuc et al., 2018). After initial data processing, we kept 214 observations for building up the models. After iterative testing, a final structural model was formed. The two dependent variables are revenue and total environment points of the agroforestry land-use model. The independent variables included LANDST, models M2, M4, M5, M6, ELEV, SLOPE, LAND, INVEST1, and INVEST2 (see Table 1 for the details).

Table 1. Definition of variables included in the structural model

Variables	Justification	Sign expected		Sources
		Economic	Environment	
LANDST	Land status. Binary variable. 1 = forestland; 0 = outside forestland (agricultural land)	-	-	Field survey
M2	Binary variable. 1 = pure fruit tree; Otherwise takes 0	+	-	Field survey
M4	Binary variable; 1 = Pure forest tree; 0 = otherwise	+	-	Field survey
M5	Binary variable. 1 = Intercropping of industrial plants and fruit trees; 0 = otherwise	+	+	Field survey
M6	Binary variable. 1 = Intercropping of industrial and forestry trees; 0 = otherwise	+	+	Field survey
ELEV	Elevation (meter)	+/-	+/-	Field survey
SLOPE	degree	-	-	Field survey
LAND (ln)	Natural logarithm of land area	+	+	Field survey
ENVI	Total environment points within a 100-point scale	+		Field survey
INVEST1 (ln)	Initial investment (million Vietnam Dong)	+	+	Field survey
INVEST2 (ln)	Investment when land-use model begins to have products (million Vietnam Dong)	+	+	Field survey

Sources: Data were collected in Dak Nong during 2019; personal calculation.

3. RESULTS

3.1. The agroforestry land-use models

The first objective of the study was to understand the current agroforestry models. As presented in Table 2, there are six agroforestry land-use models covering over 525 ha across

31 communes in eight districts in Dak Nong province. M3 is the most popular model (272 plots), followed by M1 (38 plots), M2 (33 plots), M6 (32 plots), and M5 (10 plots). This evidence in part illustrates the landowners' (farmers') preference for the type of agroforestry production and/or also may reflect the outcome of a set of agroforestry policies that have been implemented in the last decade.

Table 2. Features of land-use models in study sites

Land-use models	Sign	N	No of crops	Districts	Communes	Area (ha)
Short-term crops	M1	38	11	6	14	54
Pure fruit tree	M2	33	8	6	14	46
Pure industrial tree	M3	272	6	8	26	331
Pure forest tree	M4	29	14	8	14	44
Intercropping of industrial plants and fruit trees	M5	10	3	5	8	12
Intercropping of industrial and forestry trees	M6	32	10	6	13	38
Total	**6**	**414**	**38**	**8**	**31**	**525**

Sources: Data were collected in Dak Nong during 2019; personal calculation.

The more specific characteristics of the agroforestry land-use models are presented in Table 3. A majority of the studied area falls under forestland type (94.1%). Although model M3 has the largest area (320 ha), model M4 has the largest land per plot (1.52 ha/plot). Unlike models M1, M2, M3, and M4, the percentage of forestland of total land for models M5 and M6 is only 75% and 71.05%, respectively. Model M1 has no agricultural land, yet its area per plot is relatively high (1.42 ha/plot) compared to that of other models.

Table 3. Features of land-use models by forestland in study site

Models	Inside forestland			Outside forestland			Total		
	N (plot)	Area (ha)	Average (ha/plot)	N (plot)	Area (ha)	Average (ha/plot)	N (plot)	Area (ha)	Average (ha/plot)
M1	38	54	1.42	0	0	0	38	54	1.42
%	100	100	-	-	-	-	100	100	-
%	9.67	10.93	-	-	-	-	9.18	10.29	-
M2	31	42	1.35	2	4	2	33	46	1.39
%	93.94	91.3	-	6.06	8.7	-	100	100	-
%	7.89	8.5	-	9.52	12.9	-	7.97	8.76	-
M3	265	320	1.21	7	11	1.57	272	331	1.22
%	97.43	96.68	-	2.57	3.32	-	100	100	-
%	67.43	64.78	-	33.33	35.48	-	65.7	63.05	-
M4	27	42	1.56	2	2	1	29	44	1.52
%	93.1	95.45	-	6.9	4.55	-	100	100	-
%	6.87	8.5	-	9.52	6.45	-	7	8.38	-
M5	8	9	1.13	2	3	1.5	10	12	1.2
%	80	75	-	20	25	-	100	100	-
%	2.04	1.82	-	9.52	9.68	-	2.42	2.29	-
M6	24	27	1.13	8	11	1.38	32	38	1.19
%	75	71.05	-	25	28.95	-	100	100	-
%	6.11	5.47	-	38.1	35.48	-	7.73	7.24	-
Total	393	494	1.26	21	31	1.48	414	525	1.27
%	94.93	94.1	-	5.07	5.9	-	100	100	-
%	100	100	-	100	100	-	100	100	-

Sources: Data were collected in Dak Nong during 2019; personal calculation.

3.2. The economic and environmental impacts of land-use models

The second objective of this study was to quantify the impacts of land-use models on economic and environmental outcomes across forestland and agricultural land. The results of propensity score matching (PSM) for the economic outcomes of five land-use models are presented in table 4. Model M2 yields the highest impact when compared with the other models. For example, after matching, models M2 and M5 have a positive difference but only model M2 has a high T-stat value (2.49). This means that the economic impact of model M2 is statistically different and higher than that of the remaining models. The absolute value of T-stat is relatively small (1.19, 0.82, 0.36, and 1.32 for models M3, M4, M5, and M6, respectively), which indicates that there is no statistically significant difference in economic impacts for those models between land types.

Table 4. The economic impacts of land-use models in the study site

Unit: Million VND/ha

Models	Sample	Treated	Controls	Difference	S.E.	T-stat
M2	Unmatched	183.86	88.50	95.36	22.93	4.16
	ATT	183.86	66.77	117.08	47.03	2.49
M3	Unmatched	82.12	144.06	-61.94	15.00	-4.13
	ATT	82.12	122.42	-40.30	33.83	-1.19
M4	Unmatched	18.55	98.98	-80.44	36.26	-2.22
	ATT	18.55	102.36	-83.82	101.72	-0.82
M5	Unmatched	178.75	93.87	84.88	37.97	2.24
	ATT	178.75	135.50	43.25	119.68	0.36
M6	Unmatched	141.28	92.17	49.10	22.98	2.14
	ATT	141.28	182.79	-41.52	31.42	-1.32

Sources: Data were collected in Dak Nong during 2019; personal calculation.

Table 5 shows the results of environmental outcomes of five land-use models. After matching, models M4, M5, and M6 have a positive difference but both models M5 and M6 have a high T-stat value (2.29, 7.70). This means that the environmental impact of models M5 and M6 is statistically different and higher than that of the remaining models. In other words, model M6 yields the highest environmental impact (27.17 points), followed by model 5 (12.5 points), when compared with the other models. For model M2, the absolute value of T-stat is relatively small (0.66), which indicates that there is no statistically significant difference in economic impact for this model inside and outside forestland. The negative difference in treated and controls (-16.79) associated with T-stat (-4.92) means that model M3 has a significant negative impact on the environment.

Table 5. The environmental impacts of land-use models in the study site.

Unit: environment point.

Models	Sample	Treated	Controls	Difference	S.E.	T-stat
M2	Unmatched	52.00	50.76	1.24	2.78	0.44
	ATT	52.00	54.50	-2.50	3.78	-0.66
M3	Unmatched	46.72	64.74	-18.03	1.53	-11.76
	ATT	46.72	63.51	-16.79	3.41	-4.92
M4	Unmatched	50.64	50.87	-0.24	4.32	-0.05
	ATT	50.64	45.00	5.64	4.65	1.21
M5	Unmatched	64.50	50.45	14.05	4.46	3.15
	ATT	64.50	52.00	12.50	5.47	2.29
M6	Unmatched	82.48	47.91	34.58	1.99	17.38
	ATT	82.48	55.31	27.17	3.53	7.70

Sources: Data were collected in Dak Nong during 2019; personal calculation;

The results of the environmental outcomes of five land-use models across forestland and non-forestland are presented in Table 6. We take cases I and II into consideration. The first refers to all plots and the latter refers to the plots with revenue only. Environmental and economic outcomes of the land-use model of non-forestland are statically different and higher than those of forestland regardless of dimension.

Table 6. The comparison of the land-use model by economic and environmental outcomes.

Dimensions	N	Inside forest land	Outside forest land	Wilcoxon test
Case I	414	-	-	-
Economics	393	70.56	235.24	Prob > |z| = 0.0000
Environment	21	49.26	69.05	Prob > |z| = 0.0000
Case II	214	-	-	-
Economics	195	142.21	260.01	Prob > |z| = 0.0165
Environment	19	50.35	71.00	Prob > |z| = 0.0000

Sources: Data were collected in Dak Nong during 2019; personal calculation.

3.3. Determinants of the outcomes of agroforestry land-use model

The third objective of this study was to identify the factors influencing the outcome of the land-use models. The empirical results of a structural model are presented in table 6 - 7. The P-value of < 0.05 in all following models indicated that these models were statistically significant in explaining variation in the dependent variable.

The results for income are mostly as expected (Table 7). The variables of M2, M4, ENVI, and INVEST1 had significant positive effects on the revenue of the land-use model. Variable LANDST had a statistically significant and negative correlation with the environmental outcome of the land-use model (model 3). If the land-use model was practiced on forestland, the revenue decreased by 24.1%. The next two variables, M2 and M4, had a statistically significant and positive correlation with the economic outcome of the land-use model (model 1). This means that if M2 and M4 are present, revenue of the model increased by around 73.1% and 82.9%, respectively. This means that the replication of models M2 and M4 would help significantly increase revenue for landowners. The variable environment was positively and significantly correlated to the revenue. If the environmental score increased by 1 point, then revenue increased by almost 0.8%. This evidence means that the factor of environment plays a crucial role in increasing outcome for the agroforestry land-use model. The variable INVEST1 was positively and significantly correlated to the revenue. If the landowner increased his/her investment by 1 million Vietnam Dong, the revenue of the agroforestry land-use model increased by almost 0.39%. This evidence illustrates that the expansion of investment could help improve outcome in the study region.

For the environmental dimension, all variables in the food equation had the expected effects; variables of M2, M5, and M6 had significant positive effects on the environment. Variable LANDST had a statistically significant and negative correlation with the environmental outcome of the land-use model. If the land-use model was practiced on forestland, the environmental points decreased by 10.8%. As expected, variable M2 had a statistically significant and negative correlation with the environmental outcome of the land-use model. In the opposite case, variable M5, M6 had a statistically significant and positive correlation with the environmental outcome of the land-use model. This evidence means that the expansion of the land-use model of M5, M6 could help improve the environment in the study region.

Table 7. Results of the structural model of agroforestry land-use model outcomes

Variables	Mean	S.D.	Full model		Restricted model	
			Economic	Environment	Economic	Environment
			(1)	(2)	(3)	(4)
LANDST	0.91	0.29	-0.152	-0.108	-0.241	-0.106
			(1.32)	(3.27)***	(1.72)*	(3.20)***
M2	0.07	0.25	0.731	0.067	1.093	0.055
			(5.75)***	(1.78)*	(7.31)***	(1.53)
M4	0.01	0.10	0.829	-0.024	0.123	-0.001
			(2.62)***	(0.25)	(0.32)	(0.01)
M5	0.02	0.15	0.347	0.315	0.862	0.300
			(1.59)	(5.26)***	(3.32)***	(5.12)***
M6	0.11	0.31	0.023	0.457	0.042	0.459
			(0.15)	(15.14)***	(0.22)	(15.24)***
ELEV	730	139	-0.000	0.000	0.001	0.000
			(0.61)	(0.80)	(3.58)***	(0.34)
SLOPE	5.72	5.05	-0.007	-0.029	-0.022	-0.028
			(0.83)	(15.82)***	(2.33)**	(15.83)***
LAND (ln)	9.32	0.58	0.067	0.030	0.083	0.030
			(1.33)	(2.05)**	(1.35)	(2.02)**
ENVI	52.19	15.14	0.008		0.004	
			(1.94)*		(0.86)	
INVEST1 (ln)	16.67	0.97	0.394	-0.013		
			(10.35)***	(1.13)		
INVEST2 (ln)	17.15	0.58	0.085	-0.013	0.160	-0.015
			(1.56)	(0.80)	(2.42)**	(0.96)
Constant			9.779	4.228	14.411	4.085
			(8.34)***	(12.50)***	(10.86)***	(12.98)***
Observations			214	214	214	214
R^2			0.60	0.78	0.40	0.78
Chi2			321.13	748.27	142.70	742.58
P-value			<0.001	<0.001	<0.001	<0.001

*Sources: Data were collected in Dak Nong during 2019; personal calculation; Absolute value of z statistics in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%.*

4. CONCLUSIONS

This study explored agroforestry land-use models, particularly focusing on assessing their economic and environmental impacts, in 414 plots in Dak Nong province. The empirical findings suggested several key policies would help promote sustainable development for agriculture, rural areas, and farmers.

First, many high-outcome agroforestry land-use models were investigated in the study area, which in part illustrate the effectiveness of agroforestry development policies in recent years, especially policies regarding the development of planted forests and industrial crops. The model of pure fruit tree is the highest economic impact when compared with the other models. There is no statistically significant difference in economic impacts for those models between land types. The model of intercropping of industrial and forestry trees yield the highest environmental impact, followed by the model of intercropping of industrial plants and fruit trees, the model of pure forest tree has a significant negative impact on the environment.

Second, many factors affect the revenue of the agroforestry land-use model, including environmental factors. Hence, the models of pure fruit tree and intercropping of industrial plants and fruit trees, as well as intercropping of industrial and forestry trees, are highly recommended for replication to achieve further long-term sustainable development. Third, the features of the land are highly related to the level of investment by land users, which has strongly influenced the outcomes of the agroforestry land-use models. It is important to have a suite of appropriate policies to not only reconcile possible land conflicts but also incentivize landowners to invest their capital in agroforestry practices to earn higher income in the future.

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HIỆU QUẢ KINH TẾ VÀ MÔI TRƯỜNG CỦA MÔ HÌNH SỬ DỤNG ĐẤT NÔNG LÂM KẾT HỢP Ở TỈNH ĐẮC NÔNG

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TÓM TẮT

Bài báo nghiên cứu hiệu quả kinh tế và môi trường của các loại mô hình sử dụng đất khác nhau trong và ngoài đất lâm nghiệp ở Tây Nguyên, Việt Nam. Chúng tôi đã sử dụng phương pháp phỏng vấn bán cấu trúc, phương pháp thống kê mô tả, mô hình cấu trúc và phương pháp so sánh để thu thập và phân tích dữ liệu từ 414 lô tại 31 xã, tỉnh Đăk Nông. Sáu mô hình sử dụng đất nông lâm kết hợp đã được nghiên cứu tại địa điểm nghiên cứu, bao gồm đất trồng cây công nghiệp thuần túy (cây cà phê), đất trồng cây ăn quả thuần túy (chanh leo), rừng trồng thuần loài (Keo tai tượng), đất trồng xen các loại cây công nghiệp và cây ăn quả, trồng xen công nghiệp và cây lâm nghiệp và đất trồng cây ngắn hạn (Sắn). Trên đất lâm nghiệp, các mô hình sử dụng đất nông lâm kết hợp mang lại hiệu quả kinh tế và môi trường hơn thấp so với trên đất nông nghiệp. Trồng cây công nghiệp thuần túy là mô hình sử dụng đất nông lâm kết hợp phổ biến nhất, nhưng có hiệu quả thấp hơn so với các mô hình còn lại. Ba mô hình sử dụng đất có hiệu quả cao nhất là (1) trồng cây ăn quả thuần túy, (2) trồng xen các cây công nghiệp và cây ăn quả, và (3) trồng xen cây công nghiệp và lâm nghiệp. Kết quả nghiên cứu cũng đưa ra một số gợi ý về chính sách để các mô hình sử dụng đất nông lâm kết hợp ở tỉnh Đăk Nông được sự phát triển bền vững hơn nữa.

Từ khóa: Đất lâm nghiệp, mô hình sử dụng đất, sinh kế nông thôn, tác động kinh tế và môi trường.

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