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Use of exploratory factor analysis for sustainability determination of fruit tree production: A case study in Hau Giang province, Vietnam

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ABSTRACT

The study aims to estimate components affecting the cultivation practices of fruit trees. The survey was conducted from February to May 2018 using data from 150 households in Hau Giang Province. The fruit trees surveyed included Green peel pomelo (Chau Thanh and Chau Thanh A Districts), Sanh orange (Nga Bay Town), Xoan orange (Phung Hiep District), Sugar mandarin (Phung Hiep and Long My Districts), and Cat Hoa Loc mango (Chau Thanh A District). Results showed that indicators related to soil fertility were still suitable for citrus tree and mango cultivation. The exploratory factor analysis employs five components: Land use, nutrient use, economic efficiency, orchard design, and labor use. Those components are related to three aspects of sustainable development such as ecology/environment (land use, nutrient use, and orchard design), economy (economic efficiency), and society (labor). The two most essential components were land use and nutrient use. Based on the five components explored, the recommendations for improving the effectiveness of fruit tree production toward sustainable cultivation are proposed.

1. INTRODUCTION

Fruit production has encountered several hurdles in recent years, as society wants to boost fruit consumption while increasing safety and lowering the detrimental impacts of intensive farming practices (e.g., pesticides and fertilizers) [1]. With a production of 883 million tons, fruit crops cover 65.29 million ha worldwide and have an average yield of 13.52 tons/ha [2]. According to Milošević *et al.* [3], fruit trees, notably stone fruits, are perennial plants with a deep root system that allows staying in the exact location, that is, soil, for decades. Other fertilizers must replace the soil fertility declines to achieve high and constant yields and good exterior and internal fruit quality. Fruit trees can be grown in various soil types. On the other hand, fruit trees develop on highly fertile soils and provide variable yields and production from year to year. However, controlling trees for good growth are challenging for farmers in the problem soils.

Guong *et al.* [4] reported that the perennial fruit orchards in Hau Giang showed signs of soil degradation, such as reduced organic matter, easily compacted soil, and washed-out topsoil, low-quality pH, and gradually depleted soil. Commercially, many significant fruit trees are planted on acid sulfate soils and are susceptible to Aluminium toxicity. Over the last decade, we have made considerable progress in understanding fruit trees' physiological and molecular responses to Al toxicity [5]. Poor nutrients, fungi, and diseases in the soil cause more damage to fruit trees' growth. The disproportionate long-term application of inorganic fertilizers and little use of organic fertilizers have also adversely affected soil fertility. There are still some shortcomings in mango farming, such as unreasonable garden design, no interest in improving the soil, low flowering and fruiting, and farmers using a lot of chemical fertilizers and less use of organic fertilizers. Based on the above limitations, the study aims to use exploratory factor analysis (EFA) to analyze critical influencing components in the cultivation techniques of fruit trees. The fruits tree selected as Green peel pomelo (*Citrus maxima* (Burm.) Merr.), Sanh orange (*Citrus nobilis var typical* Hassk), Xoan orange (*Citrus sinensis* (L.) Osbeck), Sugar mandarin (*Citrus reticulata* Blanco), and Cat Hoa Loc mango (*Mangifera indica* L.), for sustainability determination. The study was conducted in Hau Giang province, Viet Nam. The recommended measures to support citrus and mango cultivation on the acid sulfate soils toward Sustainability are necessary.

2. MATERIALS AND METHODS

2.1. Study Location and Data Collection

The survey was performed from February 2018 to May 2018 in Hau Giang Province as a case study using stratification and random sampling approaches. The sample size for the survey was 30 according to critical probability and statistical concepts through non-trivial, real-world of Hogg *et al.* [6] for each fruit tree species. The data were collected by direct interviewing farmers using prepared questionnaires. It included citrus trees, such as Sanh orange at Nga

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Bay Town; Xoan orange at Phung Hiep District. Sugar mandarin at Phung Hiep and Long My Districts, Green peel pomelo at Chau Thanh and Chau Thanh A Districts, and Cat Hoa Loc mango at Chau Thanh A District. There were 30 households (or orchards) that were randomly surveyed for each fruit tree species. There were 14 observed variables: number of people per household, an education level (years), tree age (years), tree lifespan (years), age of planting beds (years), tree density (tree/ha), bed width (m), ditch width (m), ditch depth (m), amount of applied N (kg/ha), amount of applied P_2O_5 (kg/ha), amount of applied K_2O (kg/ha), fruit yield (ton/ha), and income (million VND/ha). Soil samples were randomly taken (0-20 cm depth) from five citrus and mango orchards in the survey area and analyzed at the Can Tho University lab. The study location is shown in Figure 1.

2.2. EFA

EFA is a statistical technique used in multivariate statistics to reveal the underlying structure of a comparatively large set of variables. To identify the underlying correlations between measured variables is the main objective of the EFA technique, in other words [7]. When creating a scale, researchers frequently utilize it to identify a set of latent constructs that underlie measured data (collection of questions intended to test a specific study topic) [8]. This strategy should be used when a researcher does not have a significant hypothesis about the components or patterns of observed variables [9]. The factor loadings and specific variances of the model are estimated through fitting techniques. Factor loadings, which evaluate the impact of a common element on a measured variable, are the correlation coefficients between items and components. There are many different kinds of appropriate approaches for factor analysis. However, nothing is known about their advantages and disadvantages, and many do not even have a precise name that is constantly used [7].

In this study, we used the principal component analysis method [10] to find the latent components of farming from many observed variables. The varimax orthogonal rotation method was applied to structure independent elements from observed variables. Kaiser's eigenvalue criterion (>1) was used to select components extracted from observed variables. Factor loading was blocked at a value of 0.5. Cronbach's Alpha reliability coefficient checked the internal consistency of the observed variables. Finally, an analysis of variance is used to compare practical indicators based on the variance homogeneity test [10].

Figure 1: Study location in Hau Gang province, Vietnam.

3. RESULTS

3.1. Soil Properties of the Study Site

According to Mallarino and Sawyer [11], the total amount of N was relatively high (0.10–0.15%), the total phosphorus was rich (>0.1%), and the amount of K exchanged was at the average level (0.4–0.6 meq/100 g). The Cation Exchange Capacity value ranged between 11 and 50, indicating that the soil was rich in clay [Table 1].

3.2. Farming Techniques

3.2.1. Fruit tree age, the lifespan of trees, and age of bed

The age of fruit trees in the survey area was varied. The highest age (value) was observed in Cat Hoa Loc mango), and the relatively low ($P < 0.05$)) in Xoan orange [Table 2]. In general, the age of citrus trees was within a stable fruiting period (5–10 years). Therefore, the average lifespan of citrus trees was lower than that of Cat Hoa Loc mango ($P < 0.05$). On the other hand, the lifespan of Cat Hoa Loc mango was higher than that of citrus trees ($P < 0.05$). Furthermore, the age of the bed (20.3 years of Cat Hoa Loc mango was highest compared to citrus trees (8.1 and 10.3 years) except for Green peel pomelo (17.1 years) at $P < 0.05$.

3.2.2. Size of beds, ditches, and tree density

The bed, dith, and ditch depth were not statistically significant differences between the fruit tree types [Table 3]. The ditch depth was suitable for fruit tree farming in the Mekong delta region. However, the bed width tended to be small (average of 5.6 m) compared to the recommended size (6–8 m). Furthermore, the ditch width was relatively small (2–3 m) compared to the recommended size (3–4 m). Tree density between fruit tree types was significantly different ($P < 0.05$) due to the difference in planting distance. The highest tree density was Sanh orange compared to other citrus trees, because this tree was planted quite dense compared to the recommended length (tree spacing from 2 to 3 m). Xoan Orage and Sugar mandarin were cultivated thicker than recommended distance (tree spacing of 4 m), and similarly for Green peel pomelo (tree spacing from 5 to 6 m). The tree density of Cat Hoa Loc mango is suitable compared to the recommended distance (tree spacing from 6 to 8 m). In general, the survey fruit trees in Hau Giang were found to be densely planted [12].

3.2.3. Fertilizers applied

The amount of inorganic N, P_2O_5, K_2O, and organic fertilizers [Table 4] applied to each hectare of the orchards was not statistically significant. Based on tree density and fertilizer for each tree, the Green peel pomelo, Sanh orange, Xoan orange, and Cat Hoa Loc mango were applied with higher N, P_2O_5, and K_2O fertilizers. Sugar mandarin trees were fertilized with lower amounts of N, but more elevated quantities of P_2O_5 and K_2O were recommended. The amount of organic fertilizer was calculated based on the tree density of the orchards [Table 3]. The difference in tree types was not statistically significant and was lower than the recommended amount (10–20 kg/tree/year) [12].

3.2.4. Farmer information and income

Table 5 showed that the tree area, number of people per household, cultural level, and profit were not statistically significant between types of fruit trees. The average education level of farmers reached

Table 1: Soil properties of different fruit tree raised beds.

No.	Soil properties	Green peel pomelo	Sanh orange	Xoan orange	Sugar mandarin	Cat Hoa Loc mango	Average
1	pH_{H2O}	4.32	4.03	4.19	4.29	4.57	4.28
2	Organic matter (%)	2.41	7.41	5.40	5.29	2.60	4.62
3	N total (% N)	0.154	0.406	0.266	0.291	0.193	0.260
4	P total (% P_2O_5)	0.043	0.162	0.107	0.129	0.081	0.104
5	K exch (meq/100 g)	0.536	0.592	0.124	0.169	0.262	0.337
6	CEC (meq/100 g)	19.6	17.4	17.8	19.5	17.9	18.4
7	Sand (%)	2.42	1.21	4.10	2.11	3.08	2.58
8	Silt (%)	34.19	44.17	44.45	34.52	41.05	39.68
9	Clay (%)	63.39	54.62	51.45	63.37	55.88	57.74

Table 2: Comparison of tree age and tree lifespan (years), and age of planting beds (years) of fruit trees.

No.	Type of tree	Tree age	Tree lifespan	Age of planting bed
1	Green peel pomelo	7.2^{b}	7.9^{b}	17.1^{ab}
2	Sanh orange	6.4b^{c}	8.5^{b}	10.3^{c}
3	Xoan orange	4.3^{c}	5.8^{b}	8.1^{c}
4	Sugar mandarin	7.5^{b}	8.0^{b}	15.9^{b}
5	Cat Hoa Loc mango	16.4^{a}	18.5^{a}	20.3^{a}
	CV (%)	43.6	48.9	37.0

In the same column, the numbers followed by the same letters are not statistically significant differences from Duncan's 5% test. CV: Coefficient of variation

Table 3: Comparison of bed width (m), ditch width, ditch depth (m), and tree density (trees/ha) of fruit trees.

No.	Type of tree	Bed width	Ditch width	Ditch depth	Tree density
1	Green peel pomelo	5.4	2.9	1.3	556^{c}
2	Sanh orange	5.9	2.8	1.3	2.052^{a}
3	Xoan orange	5.9	2.9	1.2	1.107^{b}
4	Sugar mandarin	5.1	2.4	1.2	1.079^{b}
5	Cat Hoa Loc mango	5. 8	2.7	1.3	220^{d}
	CV (%)	27.3	28.2	21.9	38.5

In the same column, the numbers followed by the same letters are not statistically significant differences from Duncan's 5% test. CV: Coefficient of variation

Table 4: Comparison of the amount of N, P_2O_5, K_2O, and organic fertilizers (kg/ha) applied to fruit trees.

No.	Type of tree	N	P_2O_5	K_2O	Organic
1	Green peel pomelo	291.4	319.2	171.0	1,674.7
2	Sanh orange	306.7	297.6	162.8	1,867.6
3	Xoan orange	336.9	334.7	199.2	2,420.5
4	Sugar mandarin	312.3	350.3	217.3	2,283.3
5	Cat Hoa Loc mango	309.7	327.3	201.2	1,790.0
	CV (%)	41.3	37.2	46.2	40.3

CV: Coefficient of variation

level 2 (6–9 school years of 12 years of general education). The yield of fruit trees was significantly different ($P < 0.05$) due to differences in tree type, age, care, etc. The citrus yields in the survey area were low except for Sanh orange. With a tree density of 220 trees/ha [Table 3], the fruit yield of Cat Hoa Loc mango was relatively high in mango farming conditions in the Mekong delta.

Table 5: Comparison of tree area (ha), number of people per household (HH), an education level (year), fruit yield (ton/ha), and income (million VND/ha) of fruit trees.

No.	Type of tree	Tree area	People per HH	Education level	Fruit yield	Income
1	Green peel pomelo	0.510	4.2	7.7	7.4^{c}	210.3
2	Sanh orange	0.672	4.0	6.0	21.7^{a}	205.0
3	Xoan orange	0.539	4.4	7.4	7.7^{c}	157.3
4	Sugar mandarin	0.592	4.6	7.3	14.3^{b}	206.5
5	Cat Hoa Loc mango	0.821	4.7	7.1	9.1^{c}	291.2
	CV (%)	38.2	32.5	37.1	45.8	30.2

In the same column, the numbers followed by the same letters are not statistically significant differences from Duncan's 5% test. CV: Coefficient of variation

3.3. Factor Analysis

3.3.1. Statistical analysis of observed variables

Cronbach's Alpha reliability coefficient analysis resulted in a value of 0.60, suitable for EFA [13]. The value of the Kaiser–Meyer–Olkin test for the common variance is 0.61 (required >0.5). The Bartlett test values [Table 6] on the correlation matrix were different from the homogenous matrix with a statistical significance ($P < 0.05$) that was suitable for extracting components [10].

3.3.2. Extracted components

The EFA results showed that the cumulative rate of the total variance was 65.88%, with five extracted components (eigenvalue >1). Furthermore, the five components explained 65.88% of the total variance.

3.3.3. Farming main improvement recommendations

People increasingly understand that agriculture must have both high-yielding and high economic effects to maintain long-term Sustainability in farming. At a global conference on basic human rights to adequate food, the idea of sustainable food consumption was approved. The Food and Agriculture Organization of the United Nations has defined sustainable diets [14]. As a result, farmers concerned about their crop production systems' environmental Sustainability and rising production costs have started applying enhanced system management that eventually led to the

ultimate vision of sustainable agriculture. According to Wall (2007) [15], conservation agriculture is a set of widely accepted management approaches for assuring more sustainable agricultural production.

4. DISCUSSION

Table 1 showed that the average soil pH of the orchards was <5, which was not suitable for good nutrient uptake. On the other hand, the amount of soil organic matter content was quite good (>4%), exceptionally high in the soil planted with Sanh orange (7.41%). In these orchards, the organic matter can help nutrient and water use of trees, reducing soil compaction, and increasing water infiltration into the soil [16]. Figure 2 showed that the first component (eigenvalue 2,521; 18.01%) was formed from observed variables: age of planting bed, the tree lifespan, tree age, and tree density. The negative loading coefficient of the tree density variable is obtained due to a negative correlation with the other three variables included in the analysis. Because these four variables are related to the growth of fruit trees based on soil, the first component is land use, which is related to the soil's physical, chemical, and biological properties. It, in turn, affects the longevity of trees, planting density as well as the time of land use.

The second component (the eigenvalue 2323, 16.60%) was formed from the observed variables such as the amount of applied N, amount of applied P_2O_5, and amount of applied K_2O. Because these three variables are related to fertilizer application for fruit trees in farming, the second component is nutrient use. Nitrogen, phosphorus, and potassium are the three main nutritional elements commonly applied in fruit cultivation, because they influence tree growth and yield. In Hau Giang, farmers tend to use a lot of nutrients (especially N) to supply fruit trees, which can affect the Sustainability of land use, because it can cause excess nutrients in the soil and impact the environment. These essential components explained 34.61%.

Table 6: Kaiser–Meyer–Olkin test on common variance and Bartlett with correlation matrix.

Kaiser-Meyer-Olkin test	0.61
Bartlett's test	
Chi-squared	396.4
Degree of freedom	91
Level of significance	0.000

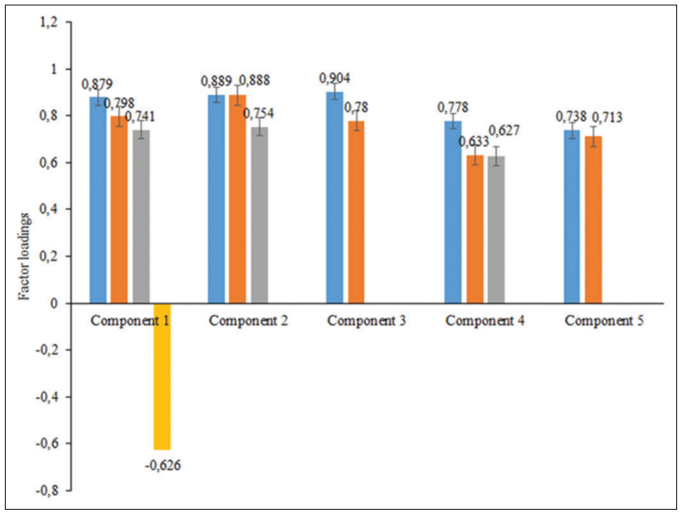

Figure 2: Component loading and extracted components. Factor loading of component 1 were 0.879 (age of planting bed), 0.798 (tree lifespan), 0.741 (tree age), and −0.626 (tree density), Factor loading of components 2 were 0.889 (amount of applied P_2O_5), and 0.754 (amount of applied K_2O). Factor loading of components 3 were 0.904 (fruit yield) and 0.780 (income). Factor loading of components 4 were 0.778 (ditch width), 0.633 (bed width), and 0.627 (depth ditch). Factor loading of component 5 were 0.738 (education level) and 0.713 (number of people per HH).

The third component comes from the observed variables of fruit yield and income. This component is economic efficiency. High yield and increased economic efficiency are the expectations of fruit farmers. However, this is related to applying a good farming technique and the appropriate use of the soil (tillage preparation, nutrient supply, care, pest control, etc.). The fourth component was obtained from the ditch width, bed width, and depth ditch variables. This component is called orchard design. The appropriate orchard design (ditch, bed) is related to planting density, tree life, etc. In the Mekong Delta, the unreasonable design of orchards will lead to the phenomenon of soil being flooded, waterlogging in the rainy season (due to low soil), and causing important diseases (such as root rot) to affect tree growth.

The fifth component is formed from observed variables of education level and the number of people per HH. These two observed variables are related to the demographic named labor use, which affects economic efficiency labor is also a factor affecting fruit cultivation. In general, most young people tend to find jobs in the city instead of supporting farming in the household, so the large size of the household can help the labor force in fruit cultivation. In addition, cultural level is a factor that allows farmers to acquire advanced knowledge about farming to improve farming techniques. It can be seen that these five components were related to three aspects of sustainable development such as ecology/environment (land use, nutrient use, and orchard design), economy (economic efficiency), and society (labor). The contribution of the tree area did not affect the EFA output. The organic fertilizer was also removed from the EFA results. It may be due to a small number of orchards using organic fertilizers (small sample size).

In terms of land use, to maintain long-term fertility, the improvement of the soils should be regularly performed through the stages of cultivation, such as tilling the topsoil, silting, and liming. In addition, it is necessary to design a reasonable spacing and tree density (narrow planting spaces on rows, large planting spaces between rows) following recommendations for increasing land-use efficiency. Furthermore, regarding nutrient use, fertilizing fruit trees in the orchards should be reduced and balanced. Again, compost should be provided annually, at least 10 kg/tree/year, to help maintain soil texture and fertility. Finally, in terms of economic efficiency, increasing the rate of type 1 fruit (size of fruit) for easy consumption and high sale price is necessary.

Regarding orchard design, the bed width should be designed to suit the perennial growing conditions of fruit trees (6–8 m). In addition, one should pay attention to making alum ditches on the beds to drain water and avoid waterlogging. Finally, concerning labor use, the development of a workforce of young farmers with at least a secondary education level to promptly grasp scientific and technological advances applied to fruit cultivation is suggested.

5. CONCLUSIONS

The soil fertility was found to be suitable for fruit tree production. The soil indicators related to soil fertility were still ideal for citrus

tree group and mango cultivation. Among five components, the use of the EFA method explored land use, nutrient use, economic efficiency, orchard design, and labor use. The two most important components were land use and nutrient use, and recommendations to improve the effectiveness of fruit tree production toward sustainable cultivation are proposed. However, the orchard design was not reasonable, because farmers often use thin topsoil and plant citrus trees in high density. In addition, inorganic nitrogen, phosphorus, and potassium fertilizers were highly applied and not balanced, while organic fertilizers were used less than recommended.

6. AUTHORS' CONTRIBUTIONS

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agreed to be accountable for all aspects of the work.

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8. CONFLICTS OF INTEREST

The authors report no financial or any other conflicts of interest in this work.

9. ETHICAL APPROVALS

This study does not involve experiments on animals or human subjects.

10. DATA AVAILABILITY

The datasets generated during and/or analysed during the current study are available from the corresponding author.

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