

AGRO-ECOLOGICAL ZONING AND LAND ADAPTATION ASSESSMENT FOR SUSTAINABLE FARMING IN THE BUFFER ZONE OF TA DUNG NATIONAL PARK

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ABSTRACT

Based on the criteria of agricultural ecological partitions, the research used agricultural ecological partition methods in the buffer zones of Ta Dung National Park. Besides, combine the GIS tool (Geographic Information System) to digitize, update information, overlap, zoning, build ecological partition maps, and adapt land units and partitions. Natural adaptive evaluation results and economic partitions for land adaptation for economic efficiency models are combined. Research results show that the buffer zone of Ta Dung National Park is divided into three different agricultural ecological areas including afforestation, perennial industrial crop, and fruit trees. In addition, from agricultural ecological partitions, three promising agricultural farming models are coffee, macadamia, and durian fruit specialized farming models. The research provides scientific data sources for conservation management models for other reserves based on the local community.

Keywords: *Ecological zoning, land, cultivation, National Park, Ta Dung.*

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1. INTRODUCTION

Ta Dung National Park in Dak Nong province is strategically located in economic, environmental, and national security position. Ta Dung National Park plays an important role in watershed protection, upstream of the two large rivers, Krong No - Serepok and Dong Nai river, which protects and maintains the ecological environment balance for the entire region [1], [2]. However, Ta Dung National Park is currently under significant pressure from the buffer zone's population through invasion activities, wood exploitation, and forest products, as well as hunting wildlife...[3], [4]. The effects of livelihoods on forest and environmental resources in the buffer zone have been pressuring the management of Ta Dung National Park [5], [6].

Therefore, the agricultural ecological partition and land adaptation evaluation in the buffer zone of Ta Dung National Park is necessary to establish a scientific foundation for applying conservation management models to other conservation areas based on the local community [7]. Research results can be applied to implement agriculture, protection of natural resources, and environment to ensure sustainable livelihoods for the population of the buffer zone in general and Ta Dung National Park in particular.

2. RESEARCH METHODS

- Information collection method: collection and synthesis of information on natural conditions, socio-economic, industry, and labor from annual reports of province, district, and commune levels (Dak Som commune of Dak G'long district in Dak Nong province, two communes of Phi Lieng and Da K'Nang of Dam Rong district in Lam Dong province, the data from the Ta Dung National Park management board, the report of transfer of Ta Dung National Park in 2018).

- Interview survey method: investigate three buffer zone communes, including Phi Lieng, Da K'Nang, and Dak Som with 120

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households/commune on livelihood resources [3] and the agricultural farming situation of the community in the research field [4]. Results of surveys on livelihood resources and factors influencing the agricultural farming model of the buffer zone of Ta Dung National Park have been presented in the research results of the authors according to the reference [3], [4].

- Geographic information system (GIS) and remote sensing (RS) method: this method is used to build land adaptation in five steps, which are as follows:

Step 1: Gather information about land use and natural conditions in the research area.

Step 2: Choose a background map, shape the image, and digitize it.

Step 3: Use GIS software to build monomer layers of soil, steep slope, irrigation, and the mechanical composition of the soil.

Step 4: Create a map of the land unit (LMU) using single layers.

Step 5: Develop land adaptation maps based on analytical tools in GIS software. From the land use requirements of the types of land use, based on the quality of the land of LMU, comparison to identify the appropriate types of the land of LMU.

- Agricultural ecological partitioning method: agricultural ecological partitioning plays a critical role in natural geography and environmental space, determining the specific ecological laws of each region and sub-region. Since then, the

agricultural ecological map has been digitized, overlapped, and partitioned. Each ecological region has different soil and water properties, as well as different types of farming.

- Assessing land adaptation method: researching land properties and creating a land unit map. Investigate and assess the current state of land use, then select the land use type (LUT) for evaluation and determination of land use requirements. Decentralization (AHP) evaluates the land units' suitability for the selected land-use types. Connect via GIS through IDRISI software, MapInfo to display the distribution of evaluation results following adaptive partitioning.

3. RESEARCH RESULTS

3.1. Agricultural ecological partition of the buffer zone of Ta Dung National Park

The research area is comprised of six major soil types, with the red-yellow soil group accounting for the majority of the buffer area. The distribution of this soil group is as follows: the largest area is 17,353.77 ha of yellow-red soil on clay rock (Fs) (accounting for 65.5 percent), followed by red-yellow soil on magmatic acid rock (Fa) with an area of 4,438.94 ha (accounting for 16.8 percent), and the rest are yellow- brown soil on base and neutral magma (Fu) with an area of 1,153.28 ha (accounting for 4.4 percent) and yellow-brown soil on magmatic base and neutral rock (Fq) with an area of 1,342.79 ha (accounting for 5.1 percent).

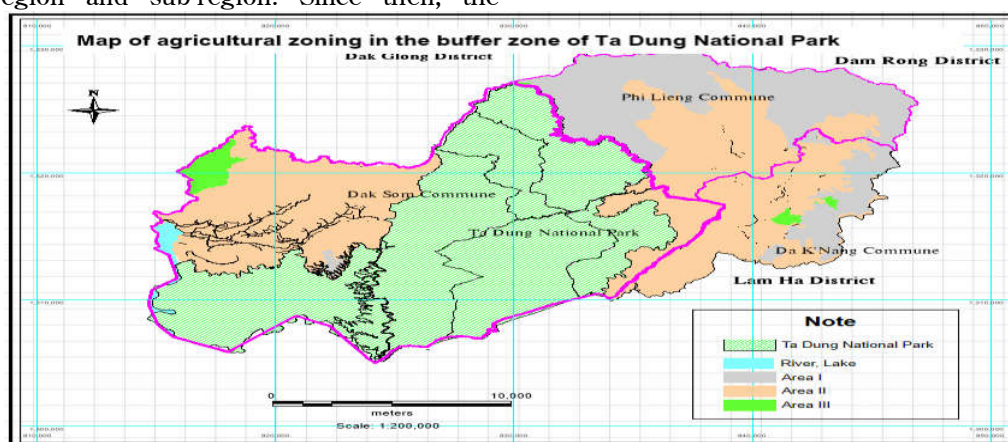


Figure 1. Map of agricultural zoning in the buffer zone of Ta Dung National Park

Red-yellow humus group in the mountain (distributed at belt-high $\geq 900 - 1,800$ m) presents with red-yellow humus on clay rock (Hs) with an area of 1,407.23 ha (accounting for 5.3 percent). The valley soil group has an area of 314,43 ha due to the sloping product (D) accounting for 3.0 percent.

The natural land area in three buffer areas is 47,754.24 ha, accounting for 46.34% of the total buffer area. Agricultural farming is the main economic sector in the communes of the buffer zone of Ta Dung National Park. The production of industrial crops is considered a solution to poverty reduction for people living in the National Park buffer zone with agriculture revenue (mainly from coffee harvesting, high-yielding cassava, hybrid corn, and beans) accounting for a large proportion, estimated at over 70% of the total income.

In particular, the main crops in the three communes of Phi Lieng, Da K'Nang, and Dak Som are coffee with 6,449 ha, accounting for 84.4% of the agricultural farming structure.

Based on the terrain as well as analyzing the soil characteristics and the current status of agricultural land use, the buffer zone of Ta Dung is divided into three different agricultural ecological areas (Figure 1), including afforestation (Region 1), perennial industrial tree (Region 2) and fruit crops (Region 3).

- Region I: The afforestation area covering 8,301.25 ha, accounting for 17.38% of the area of three communes, including the entire high hills and mountains in the northeast of Phi Lieng and Da K'Nang commune. This region has a height of 900-1,400 m, soil is mostly red-yellow on clay rock (Fs) and red-yellow soil on magmatic acid rocks (Fa). In general, with current natural conditions, it

is suitable for planting forestry, large wood, and impurities.

- Region II: The ecological perennial plant area with the most area of 11,141.05 ha, accounting for 37.50%, the outstanding feature of this region is the average higher from 750 m to 1,000 m, can specialize in coffee trees. This area has the advantage of favorable irrigation systems and soil is mainly red-yellow on clay and yellow-brown soil on magmatic base and neutral rock (Fq), suitable for coffee tree development.

- Region III: Ecological area of fruit trees and other annual crops, with the smallest area of 272.40 ha, accounting for 0.57% of three communes. The characteristic of this region has the lowest terrain from 580 m to 900 m, the highest in Da K'Nang commune with 1,048 m. The soil in this region mainly red -yellow soil on clay rock (Fs) is suitable for many crops, but it is necessary to supplement the nutrients needed to meet the nutrition of plants. Some ideal plants for planting such as ginger, potato, sweet potato, cassava, tuber, or fruits such as jackfruit, guava, lemon, pepper, plum, and banana,...

3.2. Assessment of land suitability for sustainable farming in the buffer zone of Ta Dung National Park

Based on the socio-economic planning of the region, the results of the soil research survey, and the actual survey results on the land use situation of the buffer zone of Ta Dung National Park, the factors are considered to build a map of the land unit, as a basis for assessing the ability to adapt the land, including the characteristics of the mechanical components, exposed stone head, the slope, the soil, the irrigation conditions to create a land unit map. The results showed that the research area had all 28 land units.

Table 1. Statistic of land plots

Land unit (LMU)	Area (ha)	Land unit (LMU)	Area (ha)
1	630.92	15	0.10
2	155.15	16	75.12
3	290.03	17	369.61
4	1,941.24	18	67.66
5	2,207.67	19	606.79

6	158.91	20	439.53
7	97.02	21	640.65
8	264.44	22	389.38
9	32.76	23	6,266.27
10	342.71	24	2,516.50
11	197.78	25	6,057.39
12	89.38	26	1,153.28
13	84.14	27	15.72
14	0.43	28	1,332.25

(+) Valley land group (D): Valley land has an area of 786.07 ha and is represented by the symbols TD6 and TD13 (Phi Lieng commune). This type of soil does not promote much growth of the tree. In terms of slope, this is level II ($> 3^0-8^0$) and does not interfere with agricultural farming, but it is a low-lying area that frequently floods during the rainy season. The properties have been taken on average, the two models are mechanical C (light), hydrolysis and high acidity (respectively 10.15-8.15 meq/100 g soil, content $pH_{KCl} < 4.5$ (3.66); the soil is too acidic leading to a minimum of plant growth. The mechanical composition

includes 35.9% of clay, 52.35% of limonite, and 11.75% of sand; CEC 7.75 meq/100 g soil. Content nutrition includes 0.23% N, 0.12% P_2O_5 , 0.78% K_2O . The exchange content of Ca^{++} , Mg^{++} , and K^+ in the soil are low, plants may be lacking an equivalent value of 0.35-0.15-0.57 meq/100 g soil.

Valley land is distributed in Phi Lieng and Da K'Nang communes, and this group is now being planted with coffee trees and large timber trees in Phi Lieng and Da K'Nang communes. People in this area are limited to planting on the valley land and a small area of coffee planting.

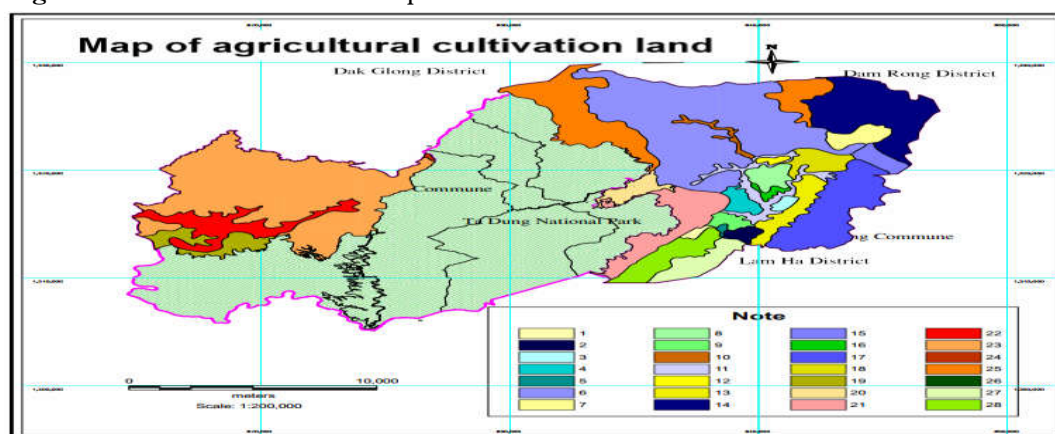


Figure 2. Map of agricultural cultivation land (LMU)

(+) Yellow-brown soil type on magmatic base and neutral rock (Fq): this soil type has an area of 1,153.28 ha; Fq representative sample symbolizes MC1 (main form) and TD1 (only available in Dak Som commune). This soil type represents full good properties such as reddish-brown soil, moister property, and more moist climates which

can grow many crops. Regarding the slope here, level I ($< 3^0$) does not interfere with agricultural farming. Mechanical cultivation layer with D (average) and low hydrolysis and exchange acidity content (average values with 5.31 meq/100 g soil and 0.38 meq/100 g soil, respectively; the content of pH_{KCl} 4.4-6.21 (Light acidic layer of A). The

mechanical composition includes 26.66% of clay, 15.47% of limonite, 49.15% of sand; CEC 8.15 meq/100 g soil. Content nutrition includes 0.26% N, 0.08% P₂O and 0.14% K₂O). Exchange cations Ca⁺⁺, Mg⁺⁺, and K⁺ are abundant in soil with values of 3.90-0.30-0.14 meq/100 g soil, respectively.

Yellow-brown soil on magmatic base and neutral rock (Fq) is only distributed in Dak Som commune; now this soil type is being planted with coffee trees for high productivity.

(+) Red- yellow soil on clay rock (Fs): This soil type covers an area of 17,353.77 ha which is the largest soil type in the three studied communes. Representative soil samples with Fs sample symbols: MC2 (main sample) and TD2, TD3, TD4, TD7, TD8, TD9, TD12, TD14. This soil is generated from sandstone shale, clay schist, mica schist, gneiss,... Mechanical composition is medium and heavy with exposed rock structure, and rather porous topsoil. Humus content is good, total nitrogen is average (0.25% N), total phosphorus 0.07% P₂O₅, and total potassium 0.02% K₂O, as well as easily digestible as Ca⁺⁺ (0.83 meq/100 g soil), Mg⁺⁺ (0.24 meq/100 g soil), K⁺ (0.09 meq/100 g soil) are poor.

The slopes here are of grades I and II (< 8°) which do not cause much impediment to agricultural cultivation. The content of hydrolytic acidity and exchange acidity (average of the main sample's cultivation layer is 9.41-1.24 meq/100 g soil, respectively), pH_{KCl} content of 4.06 (<4.5 is acidic). The mechanical composition includes 40.93% of clay, 14.24% of limonite, and 42.34% of sand; CEC 7.06 meq/100 g soil. Currently, this soil type is being planted with many types of trees such as coffee, big trees, banana, and macadamia trees bringing high economic value.

(+) Red-yellow soil on magmatic acid rock (Fa): this soil type has an area of 4,438.94 ha, located entirely to the east, bordering Lam Ha district, belonging to Phi Lieng and Da K'Nang communes. Representative soil samples Fa with sample symbols: MC3, MC4 (main sample), and

TD10. This soil type has light mechanical composition, often poor structure, and a thin soil layer (usually less than 1.2 m). This soil is acidic (pH_{KCl} - 3.94), poor in humus, 0.14% N, 0.06% P₂O₅, and 0.89% K₂O. The potassium content is better than the yellow-red soil on clay and metamorphic rocks, the soil has low clay content (28.77%) so the absorption capacity is low, and the ability to retain water and nutrients is poor.

This soil type is being used to grow large trees, mixed crops, intercropping coffee - macadamia, banana.

(+) Yellow-brown soil on base and neutral magma (Fu): this soil type has an area of 1,342.79 ha, distributed mainly in the Da K'Nang commune. Representative soil samples with Fq sample symbols: MC5 (main sample) and TD11. The soil has heavy mechanical composition, the thick soil layer is over 2 - 3 m, the soil is acidic (pH_{KCl} - 4.06-4.11), and the total nitrogen and phosphorus are quite good (0.17% N and 0.05% P₂O₅, respectively). Total potassium is poor (0.03% K₂O), and easily digestible substances are quite good (Ca⁺⁺, Mg⁺⁺, and K⁺ values are 0.69-0.07-0.11 meq/100 g soil, respectively); average absorption capacity (7.6-5.5 meq/100 g soil).

This soil type is suitable for many perennial crops such as existing coffee but needs to be supplemented with organic matter, fertilizer, and erosion control.

(+) Red-yellow humus on clay rock (Hs): This soil type covers an area of 1,407.23 ha, mainly distributed in Da K'Nang commune, bordering Ta Dung National Park. Representative soil sample with Hs sample symbol: TD5. This soil has a medium and light texture. Soil response from acidic to very acidic pH_{KCl} - 3.61. Phosphorus nutrient content 0.86% P₂O₅, but other nutrients such as total nitrogen and potassium as well as digestibility are poor (0.278% N and 0.16% K₂O, respectively). This soil is currently being used effectively in coffee production.

Table 2. Description of land units

Ord.	Soil	Ground compartment	Characteristics
1	Valley soil as a result of steep product accumulation (D)	11, 14	Advantages: The valley soil group has almost no advantages, only advantages when improving the land. Disadvantages: low yield, low terrain frequently flooded → gley occurs, acidic reaction, many toxins affect plants, fast drainage does not accumulate for plants.
2	Red-yellow soil on magmatic acid rock (Fa)	18, 19, 27	Advantages: potassium content is better than yellow-red soil on clay and metamorphic rocks. Disadvantages: this soil type has a light mechanical composition, frequently poor texture, and strong erosion, so its ability to retain water and nutrients is poor.
3	Yellow-brown soil on magmatic base and neutral rock (Fq)	1, 2, 3, 4, 6, 9, 10, 12, 13, 16	Advantages: almost none Disadvantages: light mechanical composition, very high sand grain rate, unstructured soil, or very poor texture. Soil is eroded, and leaching occurs strongly.
4	Red-yellow soil on clay rock (Fs)	5, 7, 8, 15, 17, 20, 21, 22, 25, 28	Advantages: medium and heavy mechanical composition, the texture of lumpy and granular, and the topsoil is quite porous. Disadvantages: other nutrients such as total phosphorus and potassium are poor as well as easily digestible.
5	Yellow-brown soil on base and neutral magma (Fu)	24	Advantages: this soil is used for agricultural production with many perennial or annual dry crops. Plants were grown on Fu soil grow well and give good yields. Disadvantages: a thin effective soil layer due to many shallow formations, limiting the growth of some perennial plants with deep roots such as durian.
6	Red-yellow humus on clay rocks (Hs)	23, 26	Advantages: this soil has a good content of humus and nitrogen in the surface layer and rich exchangeable potassium. Disadvantages: medium-light mechanical composition, easy to erode, Ca^{2+} , Mg^{2+} are washed away strongly, the soil has an acidic reaction

3.3. Elaboration of land use requirements and decentralization for LUT's current and prospective

Based on the results of analysis and assessment of the current state of land use, natural socio-economic conditions, and the market in the study area, the results have presented three types of promising LUTs: coffee tree LUTs, macadamia tree LUTs, and specializes in durian cultivation. The research used FAO's greatest limiting factor assessment method. Specifically, the suitability of a land unit to a type of land use is the most

appropriate classification of the characteristics of the land. In other words, as long as one of the natural conditions (soil, mechanical composition, slope, exposed rock, and irrigation conditions) is not favorable, a certain type of land use will not be possible although the remaining natural conditions are favorable. Restrictions are often represented as land rank, for each feature or property, a class S1 (very suitable), a class S2 (moderately suitable), a class S3 (poorly suitable), and a class N (not suitable and cannot be adjusted) can be defined.

The average adapted area for coffee in the study area is 8,087.48 ha, poorly adapted is 16,201.31 ha, and non-adapted is 2,134.03 ha, there is no highly adapted area. Respectively, suitable area of macadamia tree: (S1) 6,564.58 ha, (S2)

18,782.14 ha, (S3) 786.07 ha, no non-adapted area. The adaptive area of durian is: (S1) 6,564.58 ha, (S2) 17,724.21 ha, (S3) 1,347.96 ha and non-adapted 7,860.69 ha.

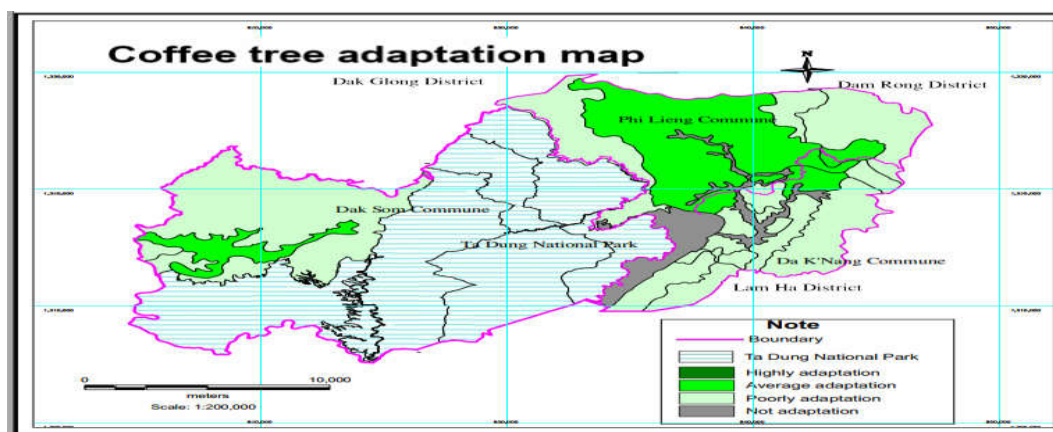


Figure 3. Coffee tree adaptation map

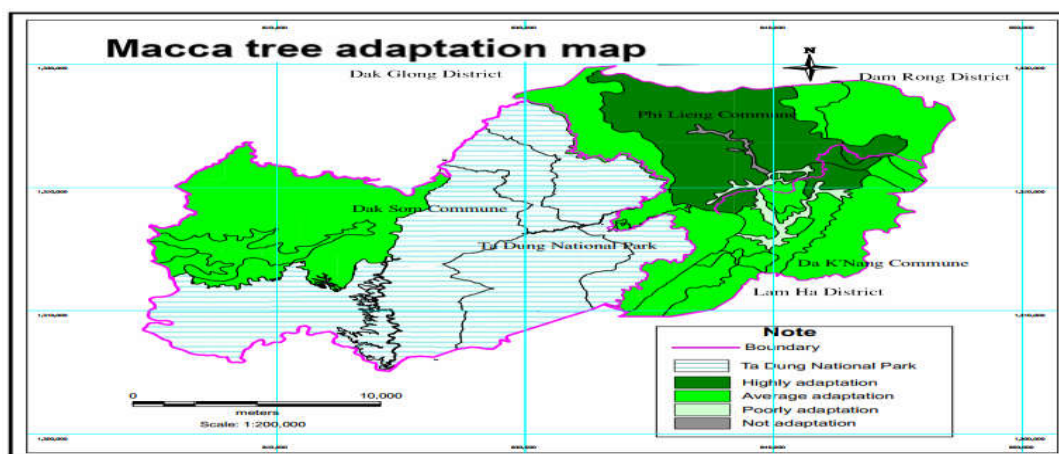


Figure 4. Macca tree adaptation map

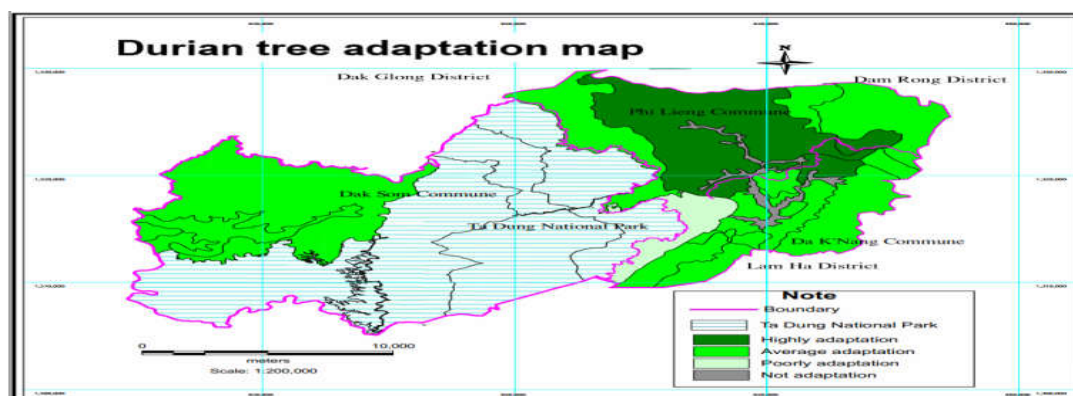


Figure 5. Durian tree adaptation map

The limiting factors of the above farming models in the study area are the inhospitable nature of the valley soil, the majority of mechanical components having a light structure, and the content of soluble nutrients that are easily washed out, drifting on steep slopes of red-yellow soil on acidic igneous rocks. In addition, there are exposed rocks in some places near Ta Dung National Park and semi-active irrigation conditions in locations far from water sources.

4. CONCLUSION

The study assessed the appropriate level of agricultural farming models in the buffer zone of Ta Dung National Park to propose sustainable farming models and minimize the impact on forest resources. Three different agricultural ecological areas were divided including afforestation (Region 1) that is suitable for planting forestry, large tree; perennial industrial crop that is specialization for coffee (Region 2) and the ecological area of fruit trees such as ginger, potato, sweet potato, cassava, or fruits such as jackfruit, guava, lemon, plum, pepper, banana, ... (Region 3).

The results of adapting the current situation of crops (coffee) are very suitable for natural conditions in the three communes of Dak Som, Phi Lieng, and Da K'rang. Three promising agricultural farming models were coffee, macadamia, and durian fruit planting model, which resulted in the map for assessing the adaptability

of the two models based on ecological requirements.

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