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STUDY ON SUITABILITY FOR NANG XUAN RICE VARIETY BY COMBINATION OF HANOI SOIL DATABASE AND CLIMATE CHANGE SCENARIO

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ABSTRACT

In land-use management, it is important to identify the suitable area for each unique plant in order to have a good development planning. The issue becomes more essential for the rapid developing city like Hanoi, Vietnam that has large amount of agricultural land after re-organization in 2008 and being under the high pressure of economic development. The knowledge of which area is needed to be preserved for agriculture is important. Moreover, the changing climate plays a significant role in the effect on plants; including varying temperatures and rainfall year to year. In this study, we tried to combine soil classification with climate condition in order to sketch the changes in suitable areas for the most important plant in Vietnamese agriculture: rice. These results could be beneficial in land-use management in order to ensure food security by preserving agriculture land out of the urbanization process.

Keywords: rice, soil classification, climate change, terminal condition.

1. INTRODUCTION

Hanoi, the capital of Vietnam, which was enlarged in 2008, had increased its area from approximately 1,000 sq.km to 3,324.92 sq.km and became one of 17 largest capitals all over the world. Along with increasing general area, the agriculture area increased as well. Unfortunately, the rapid economic development is threatening these areas. It is essential to identify which areas are suitable for cultivating, then preserve them in the midst of developmental activities. Moreover, in the suitable area, the rice life is affected by climate change.

Nang Xuan, a new rice variety, has been widely cultivated in recent years throughtout Northern Vietnam. It has advantages such as high yield, good cold endurance, and overall is high quality. In the study area, Nang Xuan rice is cultivated with much of human effort on controlling ecological factors. It plays an important role in local yield, therefore it is chosen as plot study in this research.

Geographic Information System (GIS) technology is commonly used developed in Vietnam. It has mostly been applied in land-use management, especially in soil evaluation suitable for agriculture. The previous studies, mostly based on ecological and geological, show preferences of soil as well as plants' demand. Not only applied in cultivation (Huynh Van Chuong *et al*., 2012), land evaluation is done for fishery (Dao Huy Giap *et al*., 2005) and even predicting the risk of erosion and so on. On the other hand, predicting the impact of climate change using global climate models and climate change scenarios of IPCC (Vu Van Manh *et al*., 2010) has been done in recent years. However, there is still a lack of synthesis in study on multi-aspect impact in order to predict the habitat of plants and animals in the future, especially for agriculture. This study aims to: i) evaluate soil in the study area in regards to specific cultivation demands; ii) monitor the dynamic of climate change in study area in regards to ecological limitation of Nang Xuan rice; and iii) combine those in a map to show which area is needed to preserve.

2. MATERIAL AND METHOD

2.1. Data

Soil data sets are classified according to standard procedure issued by Ministry of Agriculture and Rural Development of Vietnam with 24 soil types (excluding non-agriculture land-use), accounting for 197, 696 ha. The soil types are mapped at VN2000 projection.

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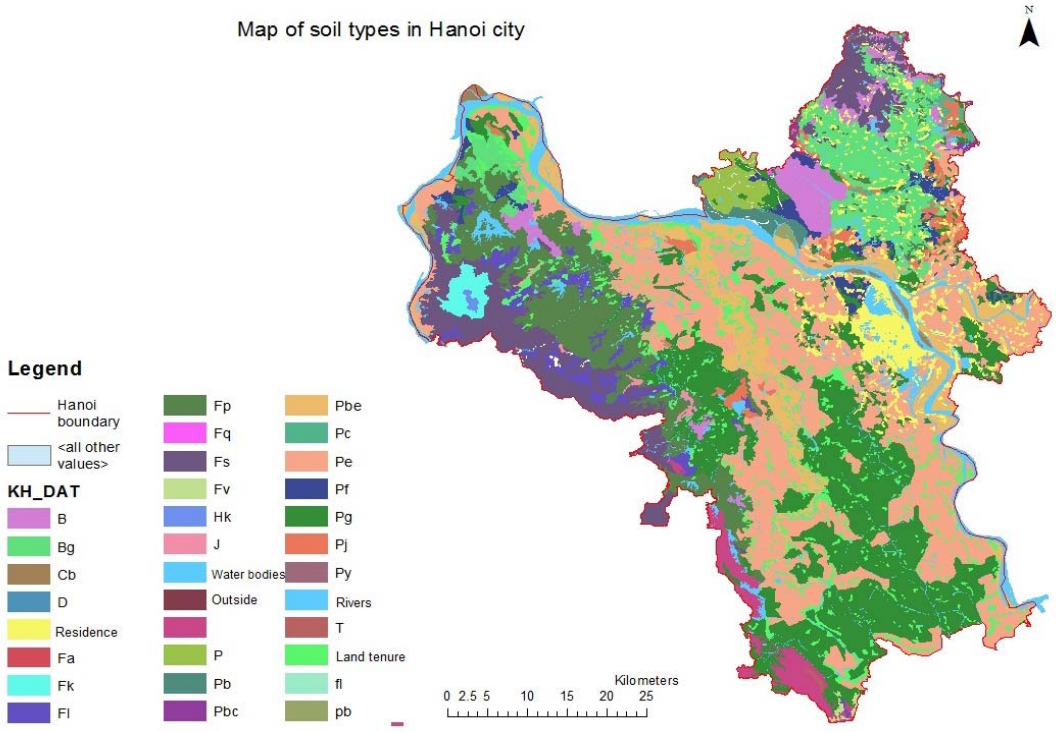

The climate data is derived from two sources. The current condition is interpolated data from WorldClim (http://worldclim.org/). The future data is derived from Vietnam's climate change scenarios, according to Vietnam Institute of Meteorology, Hydrology and Environment (IMHEN), and modeled according to the Forth Report of IPCC (2007) scenario A1B (the medium scenario). The data set includes a mean temperature, average minimum temperature, average maximum temperature and average rainfall. Predicted data is calculated for the years 2050 and 2090.

This study was done on the rice variety Nang Xuan, which has temperature limitations from 12°C to 30°C.

2.2. Method

2.2.1. Soil classification

Purpose-oriented Soil Classification is the comparison of land-use requirements to soil properties in order to define the suitability. The classification was done based on the terminal condition according to FAO. The classification is divided into 5 levels as following:

- **S1:** Highly suitable
- **S2:** Moderately suitable
- **S3:** Marginally suitable
- **N:** Currently not suitable
- **N2:** Permanently not suitable

With the description as below:

- **Class S1 highly suitable:** Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.
- **Class S2 moderately suitable:** Land having limitations which in aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on Class S1 land.
- **Class S3 marginally suitable:** Land having limitations which in aggregate are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified.
- **Class N1 currently not suitable:** Land having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at currently acceptable cost. The limitations are so severe as to preclude successful sustained use of the land in the given manner.
- **Class N2 permanently not suitable:** Land having limitations which appears as severe as to preclude any possibilities of successful sustained use of the land in the given manner.

This classification is done based on a number of natural factors such as groups of soil types with similar condition of slope (for highland area), topography (for

delta area), the thickness of clay soil layer, mechanical components, irrigation and flooding.

Each land-use purpose requires unique soil properties and other natural factors. The definition of land-use requirements are based on:

- Soil properties.
- Physiological and ecological requirement of plants.
- Ensuring economic efficiency.
- Protecting soil quality and the environment.
- Significant concerning on local cultivation practices and other conditions.

2.2.2. Climate model

The climate data in current conditions is derived from WorldClim (http://worldclim.org/). According to WorldClim, the data layers were created by interpolating of average monthly climate data from weather stations all over the world and scaled to 30 arc-second resolutions. Variables included are monthly total precipitation, monthly mean, minimum and maximum temperature, and 19 derived bioclimatic variables.

The WorldClim interpolated climate layers were made using:

- Major climate databases compiled by the Global Historical Climatology Network (GHCN), the FAO, the WMO, the International Center for Tropical Agriculture (CIAT), R-HYdronet, and a number of additional minor databases for Australia, New Zealand, the Nordic European Countries, Ecuador, Peru, Bolivia, among others.
- The SRTM elevation database (aggregated to 30 arc-seconds, "1 km").
- The ANUSPLIN software. ANUSPLIN is a program for interpolating noisy multivariate data using thin plate smoothing splines. We used latitude, longitude, and elevation as independent variables.

The predicted climate data is derived from Vietnam's climate change scenarios. According to Vietnam Institute of Meteorology, Hydrology and Environment (IMHEN), the data is reported in format of differences to baseline data, which is the averaged data from 1980 to 1990. The climate model is built based on IPCC's climate change scenarios.

Synchronizing with current climate data from WorldClim, the predicted data includes the difference of total precipitation, average minimum temperature, average maximum temperature and average mean temperature.

2.2.3. Calculation

First of all, the suitable area for Nang Xuan rice must be separate and is shown on the map. In this study, we only select S1 and S2 area. S3 area is not selected because it serves quite low yield with much of effort in irrigation, fertilizer and is not environmental friendly. The suitable area is showed on the map below.

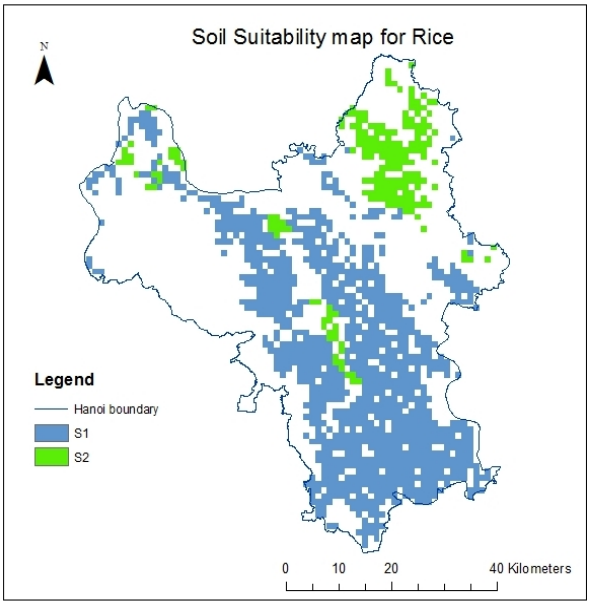

Figure-1. Soil suitability map for Nang Xuan Rice.

The study aims to learn about the lower limitation of Nang Xuan rice, in the coldest month of the year in Hanoi area. According to the current condition, the temperature varies from 6.5 to 14.6 Celsius degree through the area. Combining with the ecological limitation of Nang Xuan rice: when the temperature is in ranges of 17 and 22°C, rice grows slowly. If the temperature is 16°C or less, rice stops growing, therefore the lifetime is enlarged. If the temperature falls under 12°C, rice dies. From 23°C is suitable for its growth, this temperature ranges is divided into 3 levels: >16, 12-16 and <12 ^{0}C.

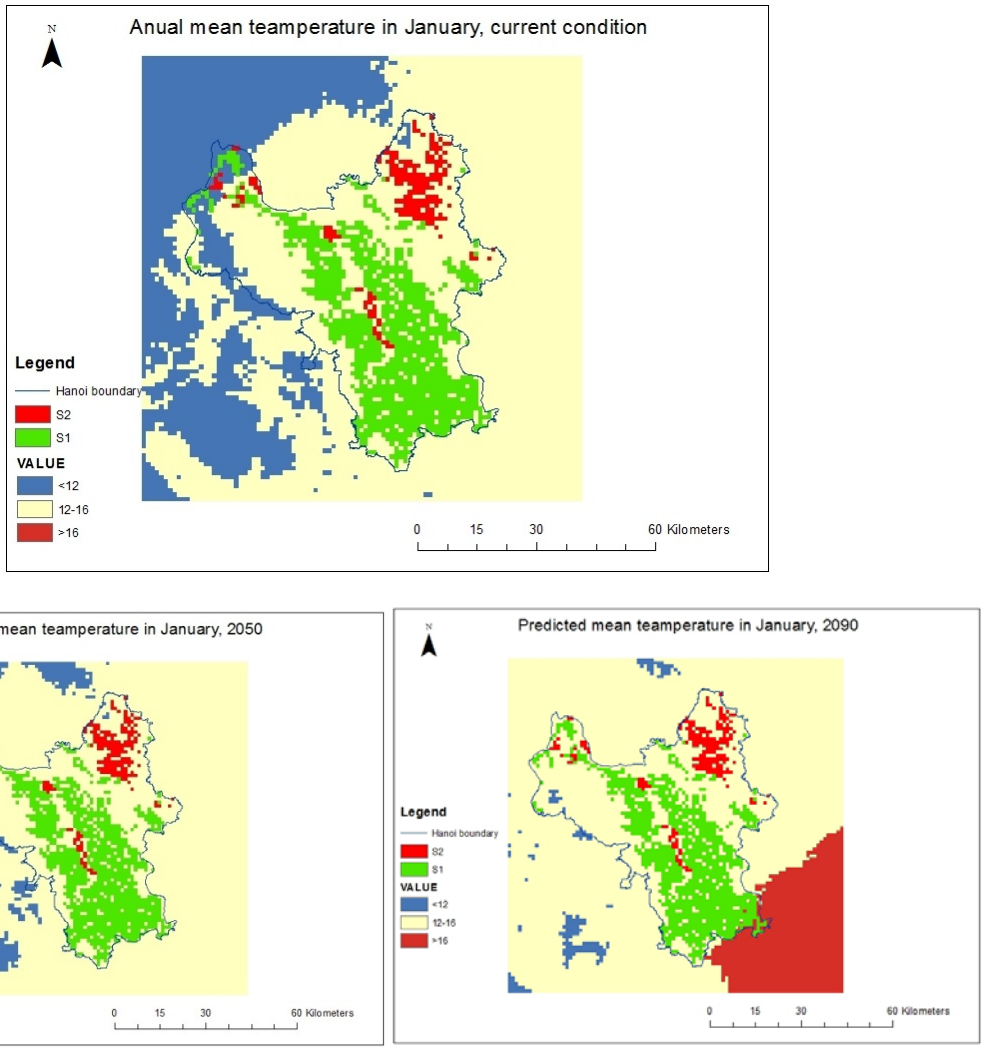

Figure-2. Temperature and suitable area for Nang Xuan rice, in current and future condition.

3. RESULTS AND DISCUSSIONS

3.1. Results

3.1.1. Soil evaluation

Based on current land-use and the study objectives, three cultivation purposes are chosen to evaluate the suitability: rice-, vegetation- and flower specialized farming

The results for these 3 types of cultivation include 22 types of suitability (see in Table-1). Each of them can be suitable for one or more cultivation purpose with different level.

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Table-1. Suitability and area.

ID	For rice	For vegetation	For flower	Area (ha)
1	S1	S2	S2	28,995.01
2	S1	S2	S3	46.99
3	S1	S3	N	29.57
4	S1	N	S3	49,568.10
5	S2	S1	S2	231.14
6	S2	S2	S2	1,189.06
7	S2	S2	N	3,539.37
8	S2	S3	S2	794.15
9	S2	N	S3	9,080.24
10	S3	S2	S1	9,660.53
11	S3	S3	N	25,205.10
12	N	S1	S1	1,776.81
13	N	S1	S2	8,617.54
14	N	S2	S2	19,727.13
15	N	S2	S3	3,885.41
16	N	S2	N	65.79
17	N	S3	S1	16.24
18	N	S3	S2	34.52
19	N	S3	S3	1,260.34
20	N	S3	N	1,725.78
21	N	N	S3	1,450.04
22	N	N	N	30,797.13
Agriculture area			197,696	
Non-Agriculture area			135,193	
Total			332,889	

For each cultivation purpose, the area of suitability levels is show in Table-2:

Table-2. Suitability level.

No.	Cultivation purpose	Level				Total area (ha)
		S1	S2	S3	N	
1	Rice	78,639.68	14,833.96	34,865.63	69,356.73	197,696.00
2	Vegetation	10,625.49	67,109.29	29,065.71	90,895.51	197,696.00
3	Flower	11,453.57	59,588.57	65,291.12	61,362.74	197,696.00

- **Rice specialized farming:** Area at S1 level is 78,639.68 ha; S2 is 14,833.96 ha, limited by type of soil and irrigation mode; S3 level is 34, 865.63 ha, limited by high elevation leading to difficulties in cultivation.
- **Vegetation specialized farming:** Area at S1 level is 10,625.49 ha; S2 is 67,109.29 ha, limited by type of soil; S3 level is 29,065.71 ha limited by low elevation, leading to flooding in rainy season.
- **Flower specialized farming:** Area at S1 level is 11, 453.57 ha; S2 is 59,588.57 ha, limited by irrigation mode; S3 level is 34,865.63 ha, limited by type of soil and flooding.

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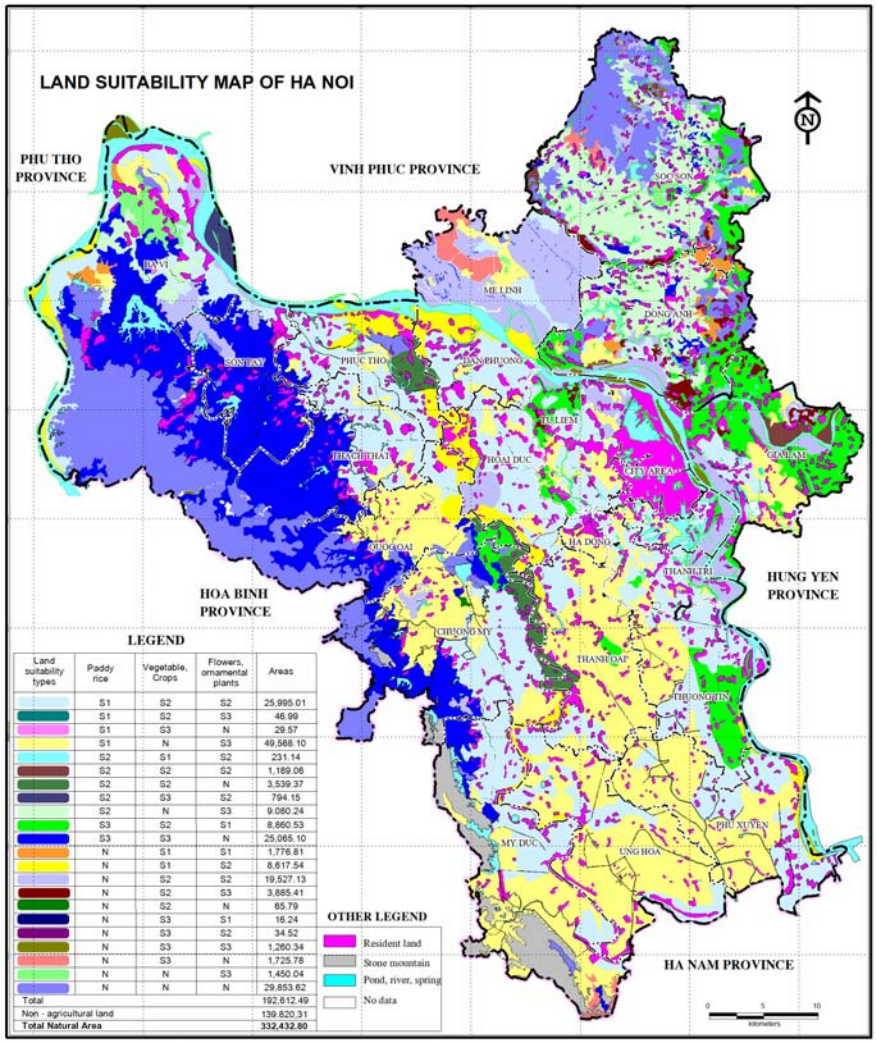

Land suitability types	Paddy rice	Vegetable, Crops	Flowers, ornamental plants	Areas
	S1	S2	S2	25,995.01
	S1	S2	S3	46.99
	S1	S3	N	29.57
	S1	N	S3	49,568.10
	S2	S1	S2	231.14
	S2	S2	S2	1,189.06
	S2	S2	N	3,539.37
	S2	S3	S2	794.15
	S2	N	S3	9.080.24
	S3	S2	S1	8,860.53
	S3	S3	N	25,065.10
	N	S1	S1	1,776.81
	N	S1	S2	8,617.54
	N	S2	S2	19,527.13
	N	S2	S3	3,865.41
	N	S2	N	65.79
	N	S3	S1	16.24
	N	S3	S2	34.52
	N	S3	S3	1,260.34
	N	S3	N	1,725.78
	N	N	S3	1,450.04
	N	N	N	29,853.62
Total				192,612.49
Non - agricultural land				139,820.31
Total Natural Area				332,432.80

Figure-3. Soil suitability map of Hanoi.

3.1.2. Apply climate change scenarios to monitor the change of suitability for rice specialized farming area

The soil and temperature are re-classed as number, and then calculate with each other with even weight. The result has 4 levels of suitability:

- **Level-2:** Lowly suitable
- **Level-3:** Moderately suitable
- **Level-4:** Suitable
- **Level-5:** Highly suitable

In which the areas in level 2 come with the disadvantages both in temperature and soil type, meanwhile areas in level 5 come with highest advantages in both sides.

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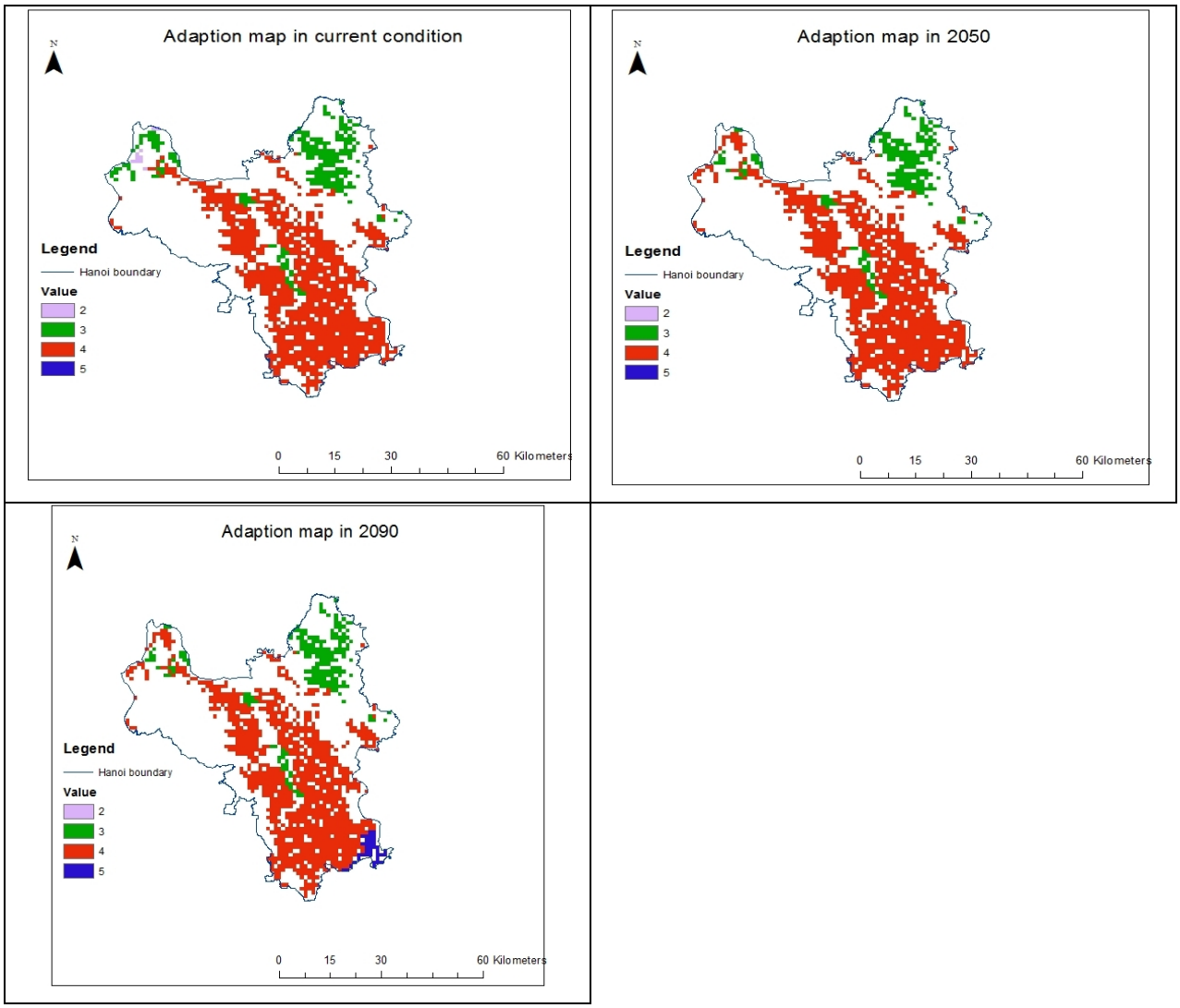

Figure-4. Predicted map of suitability for Nang Xuan rice in Hanoi area.

Comparing the 3 maps of current condition, 2050 condition and 2090 condition, we can see the trends of raising temperature. Although the change is not much, we can clearly see that the lowest temperature areas is decreased and gradually disappeared. The most suitable areas (in blue and red) are on the enlarged area of Hanoi (i.e. "new Hanoi"), where agricultural land is still large. It could be a good starting for the conservation of agricultural land for Hanoi. Up to 2090, along with the disappearance of the lowest suitable area, the highest suitable area appears at the southeastern corner.

These changes are shown below:

Table-3. Suitability level.

Area (km^2) **Level**	**Current**	**2050**	**Change**	**2090**	**Change**
2	11.49	-	-100%	-	-100%
3	270.19	244.90	-9%	244.90	-9%
4	1229.21	1,265.99	3%	1,222.16	-1%
5	0.00	-	100%	43.83	100%
Total	1,510.90	1,510.90		1,510.90	

3.2. Discussions

This study aims to combine the soil classification with climate condition and ecological limitation of Nang Xuan rice in order to generate the overview of suitability area for cultivation, as well as show how the urban development should occupied in regards to agriculture. The results is especially meaningful in context of enlarged Hanoi, when a huge agricultural land was added to the capital and the urbanization is being rapidly spreading, therefore management methods are urgently needed.

However, the assumption "land-use situation is not changed" in the time of 90 years is not realistic. The idea for this assuming is to fix one factor and see the dynamic of the other. Climate changing is an un-returnable (irresistible) process that we can neither stop nor prevent its impact in local extent. In order to ensure the food security, agricultural land should be preserve in a long term land-use planning. Therefore the authors decided to fix this factor and monitor the dynamic of climate change. Under the impact of rising temperature and other factors (e.g. increase the frequency and damage of tsunami, change in precipitation and so on) the land-use planning should be made flexibly and responsibly. By choosing the lower ecological limitation, the study show which areas have many difficulties in cultivating and which needed to preserve.

Certainly the growth of rice depends on not only the temperature; the temperature is, however, the first and main function of climate changing. On the other hand, some can be ignore like moisture, since rice in Hanoi is cultivated drown and people can easily control, therefore rainfall does not influence much unless it changed too much. Meanwhile, hydroelectricity dams should be calculated on in planning since it affects the irrigation.

CONCLUSIONS

The study has combined some independent factors: soil type, geo-ecological condition of soil (slope, thickness of clay layer, irrigation etc.), climate condition and ecological limitation of rice. The result is a general view of many factors which affect on rice growth, under the influence of climate change. It is meaningful for decision-makers to preserve agriculture land area under pressure of urbanization.

ACKNOWLEDGEMENT

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