The Assessment of Soil Nutrients for Rice Plantation by Geographic Information System in Savannakhet Plain, Lao PDR

Xaysavanh Inthavong and Naruemon Pinniam Chanapaitoon

Abstract— In response to the National Agricultural Land Use Plan of Lao PDR, which has the target of increasing the yield of rice to 4.7 million tons per year to feed the 7.5 million population projected for 2020, operation and management planning could be made more efficient by integrating technology such as GIS and soil fertility assessment. This study assessed soil nutrient level for rice production in Savannakhet Plain, Lao with Outhoumphone District as the study area. By applying GIS with the Pairwise Comparison method and Simple Additive Weighting (SAW), soil fertility mapping against geographical coordinates was used to create an overall database. Land and soil characteristics of an area of 108,237 ha were classified by slope and soil texture (sand, silt, and clay). Field investigations were conducted and 44 samples taken in location. These were analyzed in the laboratory using standard soil survey and laboratory analytical methods. Macronutrient elements and properties were analyzed: amount of Nitrogen (N), Phosphorus (P), Potassium (K), soil acid-alkaline (pH), soil organic matter (OM), the cation exchange capacity of the soil (CEC) and base saturation (BS). A in soil suitability assessment was made by applying a mathematical database management model. The results were used to evaluate the land potential by creating maps and overlaying the soil suitability data.

It was found that soil in 94.37% of the study area was sand, a minor was silt area 6,090 ha representing (5.63 %), next was loam area with strongly to very strong acidity together with the low to lowest amount of N, P, K, OM, and BS scattering around the district area. However, the data of high CEC level in the soil implied that land potential for rice plantation should be risen up with suitable soil nutrients management. Since soil fertility level in the major area were in moderately low to low level 78,946 ha. (72.94%) and 29,291 ha. (27.06%) together with strongly acidity sandy soil, appropriate soil management are recommended to meet food security level and the sustainable national agricultural land use plan of Lao PDR.

***Keywords*— Soil nutrient assessment, rice plantation, Savannakhet plain; Lao PDR, geographic information systems.**

1. INTRODUCTION

Rice is the staple food grain produced in Lao PDR, as well as in all other Southeast Asia countries, with greater than 60% of all agricultural land devoted to its cultivation. [1] Laos has a limited ability to expand production, since it has the smallest amount of arable land (4% of total national area) in SEAsia. Food security is a major challenge, since surplus rice production generally occurs in lowland areas along the Mekong River, while a large proportion of the population is dispersed throughout the remote mountainous highlands, which are largely deficient in staple grain production. This is the primary location of persistent annual rice shortage. In the past, the majority of Laotians regularly faced food grain shortages.

To ensure food security and generate income for farmers and the nation as a whole, the Ministry of Agriculture and Forestry, Lao PDR, established a strategic plan for land use conservation and agricultural development for 2015-2020. One of its main targets is the enhancement of crop production to meet both domestic food consumption and the exports. Rice yields should increase from about 4.0 million tons per annum (in 2015) to 4.7 million tons, from the arable area of 4.5 million hectares (19% of the landmass, to meet the demand from the 7.5 million-population forecast for the end of 2020. This is bases on the average consumption rate of 450-500 kilograms per capita. The plan incorporates a range of procedures such as crop zoning, soil fertility analysis, and assessment at the micro level of the nationwide targets [2].

The spatial target of the national rice plantation development plan is the 7 large plains, 16 moderate plains, 12 small plains and the mountainous highlands (Fig. 1). Savannakhet large plain plays a vital role in rice production, feeding both local and regional demand. This province lies in the centre of Laos at the junction of the East West Economic Corridor (Road no. 9) and the North-South Axis (Road no. 13). It is the largest province in Laos, covering one-ninth of the national area, covering an area of 21,774 square km (8,407 sq. mi.). It borders Khammouane province to the north, Quảng Trị and Thừa Thiên–Huế provinces of Vietnam to the east, Salavan province to the south, and Nakhon Phanom and Mukdahan provinces of Thailand to the west. The population is 906,440, spread over 15 districts: Kaisone Phomvihan, Outhoumphone, Atsaphanthong, Phine, Sepone, Nong, Thapangthong, Songkhone, Champhone, Xonnabouly, Xaybouly, Vilabouly, Atsaphone, Xayphouthong and Phalanxay [3].

Xaysavanh Inthavong is a graduate student in Department of Rural Technology, Thammasat University Rangsit Campus. E-mail: xaysavanhinthavong@yahoo.com.

Naruemon Pinniam Chanapaitoon (corresponding author) is with the Department of Rural Technology, Faculty of Science and Technology, Thammasat University Rangsit Campus, Klong Luang, Pathumthani 12120, Thailand. Phone: +66-0-2564-4482; Fax: +66-0-2564-4482; Email: napin2008@yahoo.co.th.

Since the Mekong River Delta is an important water source flowing through South East Asia which primarily feeding the rice fields of large areas in many countries. Number of studies on soil for rice production by various aspects and techniques has been done. Borneman (2016) discussed on using remote sensing to Map Rice Paddy Drop in the Mekong Delta and the satellite's imagery which showed that rice production in the Mekong Delta has decreased in the past year due to the weather effects of El Niño, threatening the livelihoods of local farmers as well as food security worldwide.[4] According to, Vo Q.M. and Le Q.T. (2017) rice cultivation in the Mekong Delta is usually irrigated and highly productive, featuring multiple rice crops but with serious problems, including the unsustainable exploitation of water and soils, inefficient use of chemical inputs, and emerging or worsening disease and pest problems.[5] In Thailand, Northeastern region, as a close border to Laos PDR, different practices have been used; Duangjai et al., (2017) referred to the former studies and revealed the finding that in rain fed lowland rice in Northeast Thailand, water shortage is common as rainfall only between 1000 and 1500 mm per annum. When the soils are no longer submerged or saturated, the reduced soils begin to oxidise, soil acidity increases, and the availability of plant nutrients, particularly phosphorus (P) decreases, while the adapted rice cultivars were not only drought-tolerant, but also grew well under low fertility and low pH, common features of soils[6]. Nevertheless, there is little information on which nutrients limit the growth of rice and how the nutrient availability is affected by water supply. Other factors for long term cultivation has been studied in China by analyzing the effects of fertility on soil microbial biomass and soil nutrient supplying capacity, and at considering implications for the long-term management of paddy soil fertility. (Qi-chun Zhang Q. and Wang G., 2005) [7].

Recently, more of integrated nutrient management for sustainable agricultural production and protecting environment quality has been widely investigated by applying the spatial variability of soil nutrients to develop a regionalized nutrient management system using GIS technologies. The regionalized maps are a practical alternative to site-specific soil nutrient management approaches in areas where it is not practical, because of small farm size or other constraints, to use intensive soil sampling and chemical analyses. (Qiang Zhang, et.al., 2009)[8] Mongkolsawat et al. (2002) used GIS to develop a spatial model for land evaluation for rice cultivation in the lower Namphong watershed in northeastern Thailand. They determined that the highly suitable land covered an area that some 17.7% of the watershed is unsuitable for rice, which corresponds to the sloping land. [9] Moreover, Pimsen et.al., (2013) applied of GIS to assess the spread of rice bug in Phatthalung Province, in order to identify areas that are vulnerable to the spread and outbreak of rice bug to prevent yield loss and find out the prevention and the method to get rid of rice bug properly and correctly. [10]

Rice has long been cultivated using conventional methods in Savannakhet Plain, as in the rest of the country. Although soil fertility is recognized as a primary constraint on agricultural production, the guidelines for soil management have provided only broad guidance on soil classification due to the limitation of soil data at the micro level (subdistrict or village level). Geographic Information Systems (GIS) have been widely applied to collect and record resources and environment information in the form of spatial references for the purposes of planning, managing, and simulating real conditions. This detailed spatial data can be queried and analyzed instantly.[11] The complex and large scale data on various soil specifications in different land areas should be systematical managed. The operational plan could be made more efficient by integrating the GIS technology and soil fertility assessment.

Due to the resource limitations, land use in Savannakhet plain at the district level was selected as the study area. It is located in the northeast of the province in Outhoumphone district. This district covers an area of 108,237.08 ha in which has been grown rice on unsuitable sandy soil for decades. Yields have been low due to natural soil degradation and inappropriate soil management by the local farmers. [12]

The study aimed to assess soil nutrients and their role in increasing rice production in Outhoumphone District. A Pairwise Comparison method and Simple Additive Weighting (SAW) were used to combine soil fertility mapping with geographical coordinates for rice plantation. The results were used for soil suitability assessment by applying a mathematical database management model to evaluate land potential. This was done by creating maps and overlaying soil suitability data showing the potential for rice cultivation. This could provide soil management guidelines at the subdistrict or the village level, and be used as the model for other areas of Laos.

2. MATERIALS AND METHODS

2.1 *Materials*

2.1.1 Terrain maps of Lao PDR, scale 1: 1,000,000, Outhoumphone District, scale 1: 50,000, and sub districts of Outhoumphone, scale 1: 50,000. [10]

2.1.2 The tools used for geospatial analysis: GPS for the soil survey, cameras, and the ArcGIS for desktop 10.1 software. [13]

2.1.3 Soil sampling and soil testing laboratory tested were conducted for soil texture, acidity-alkalinity of the soil (pH), Organic matter (OM), Nitrogen (N), Phosphorus (P), Potassium. (K), Cation Exchange Capacity (CEC) and Base Saturation (BS) of the soil. [14]

2.1.4 Information of the topography, climate, and socio-economic conditions of Outhoumpone district were collected. [15]

2.2 *Educational process*

Based on the soil survey and data collection methods of USDA (Soil Survey Division Staff, 1993), soil data was initially collected for land slope, soil drainage, crop management history and soil texture (sandy soil (S), loamy sand (LS), sandy loam (SL) and clay (C)). Since the study focused on rice growing areas the land for other purpose was excluded. The total Outhoumphone paddy included in the survey was approximately 14,105 ha. (Fig 1).

Sampling spot collection was chosen by land potential for soil improvement, based on soil texture. [9] Sandy soil (S, LS, SL) is predominant in this district (99.82%), with some clay (0.18%). At 44 points soil samples were collected for laboratory analysis based on spatial soil texture (S, LS, SL and C). (Fig 2)

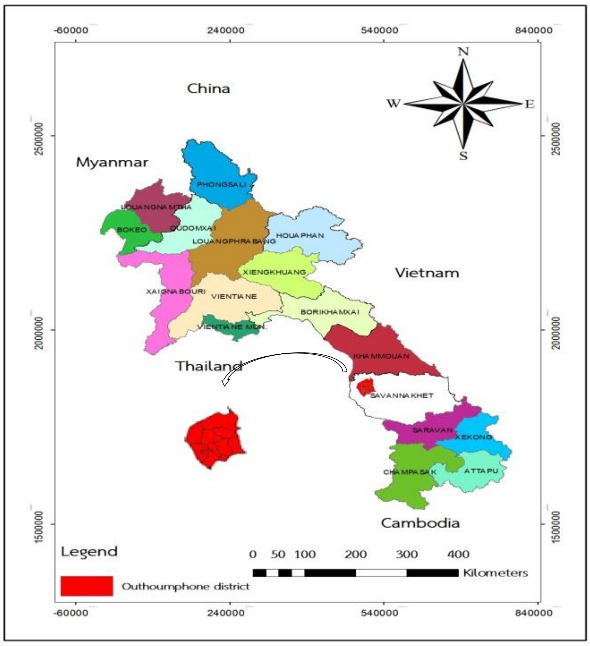

Fig. 1. The study area in Outhoumphone district.

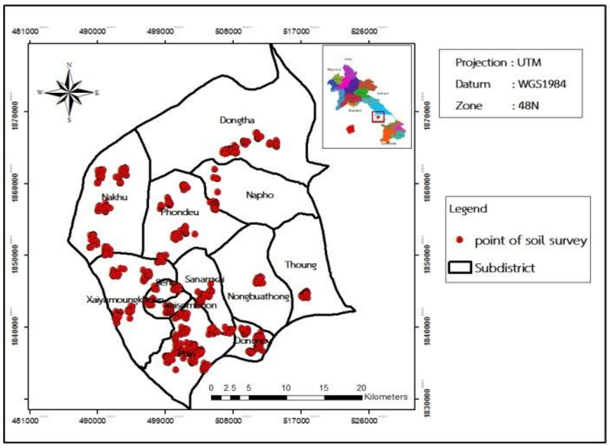

Fig. 2. The map of soil sample spot in Outhoumphone district.

2.2.1 Data collection in the field

Soil samples were collected at depths of 0-30 cm. Each sample was made by combining equal amounts of 15-20 subsamples taken from the area. After mixing thoroughly, the composite samples were analyzed for pH, N, P, K, CEC and BS in the laboratory. The geographical coordinates of each sampling point were recorded by an area Global Positioning System (GPS) for map creation.[10]

2.2.2 Soil analysis in laboratory

The composite samples from the 44 sampling pointeas were analyzed in the laboratory of the Land Development Department of Thailand and Department of Agriculture Land Development and Management, Lao PDR, [14] using the following method:

(1) The acid - alkalinity of the soil. Soil and water were mixed in a ratio 1: 2.5, then checked in vitro following the method of Orstom.

(2) Organic matter in the soil was tested using the methods of Walkley and Black, (1934). [11]

(3) Nitrogen testing followed the Kjeldahl method of Bremner (1996). [12]

(4) Phosphorus testing used the Bray II method (Bray and Kurtz, 1945). [13]

(5) Potassium, Cation Exchange Capacity, and Base Saturation were analyzed by the 1 N ammonium acetate and pH 7 Jones method, (2001).

2.2.3 The data was analyzed by Geographic Information Systems (GIS) with ArcGIS for desktop 10.1 and interpolation methods in format kriging/reclassify. To evaluate the quality of the plant nutrients in the soil, the texture, pH, N, P, K, CEC and BS were mapped onto the coordinates of soil sampling.

Table 1: Consistency Ratio of factors

Consistency Ratio		
pH	2.617	7.84
OM	1.244	7.952
N	1.011	7.819
P	0.867	7.664
K	1.091	7.406
CEC	0.534	7.245
BS	0.341	7.357
Sum		53.283
λ		7.612
CI		0.102
CR		0.077

Table 2: Important Weighting and Rating Score of Maximum-Minimum

Factors	Weight	Rating _min	Rating _max	WxR_ max	WxR_ min
pH	0.334	0.052	0.257	0.0858	0.0174
OM	0.156	0.105	0.395	0.0616	0.0164
N	0.129	0.085	0.402	0.0519	0.011
P	0.113	0.092	0.379	0.0428	0.0104
K	0.147	0.099	0.386	0.0567	0.0146
CEC	0.074	0.066	0.311	0.023	0.0049
BS	0.046	0.076	0.28	0.0129	0.0035
Total of Maximum - Minimum				0.3348	0.078

2.2.4 Each factor in the study was assessed and compared for score weighting by the matrix layer comparison method in a couple. [15] The calculation of weighted criteria was the sum of each column Normalized Matrix and calculate the Consistency ratio (CR) of each factor, which was a comparison between

Consistency Index and Random Consistency Index (RI):

$$CR = CI / RI$$

If the value of CR is less than 10%, the inconsistency level is acceptable. If the Consistency Ratio is greater than 10%, the subjective judgments need to be reconsidered.

2.2.5 The factors influencing to soil fertility assessment in the area was analysed by the overlay function:

$$A = \sum_{t=1}^{n} (W_1 x R_t)$$

$A =$ Soil fertility

$W_i =$ Weight of each factor

$R_i =$ Score of each factor

Soil fertility in the study area was classified into five levels: very low, low, moderate, high and very high by the integration analysis of soil qualifications on plant nutrients (soil texture, pH, OM, N, P, K, CEC and BS) in the soil and GIS with Pairwise comparison and Simple Additive Weighting (SAW) (Table 3). Soil management recommendations were produced for each subdistrict/village level.

Table 3: Median value of soil fertility as the Maximum and Minimum for rice plantation

Class	Level of soil fertility area	Soil fertility score
1	Very low	0.0780 – 0.1293
2	Low	0.1293 – 0.1806
3	Moderate	0.1806 – 0.2319
4	High	0.2319 – 0.2832
5	Very high	0.2832 – 0.3345

3. RESULTS AND DISCUSSION

3.1 Sandy soil accounted for 102,146.12 ha. (94.37%) of the land area, comprising 12 subdistricts, while silty soil was found in three subdistricts. The survey also found that the soil texture at depths of more than 30 centimeters was sandy clay, which is able to absorb water for rice cultivation. (Table 4 and Fig. 3)

Table 4: Spatial distribution area of Soil texture

Soil Texture	Area	
	ha	%
Sand	102,146.12	94.373
Silt	6,089.65	5.626
Loam	1.32	0.001
Total	108,237.08	100.00

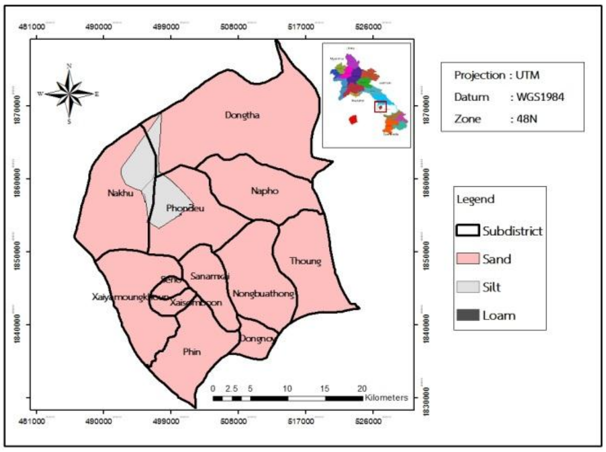

Fig. 3 Spatial distribution of Soil Texture.

3.2 The spatial distribution analysis of pH found that most of the area was strongly or very strongly acidic. The strongest was found in Dongnoy subdistrict and Nongboathong the southeast part of subdistrict. (Table 5 and Fig. 4).

Table 5: Spatial distribution of pH

Class of pH	pH	Area	
		ha	%
Very strongly acidity	<4.5	75,756.81	69.99
Strongly acidity	4.6-5.0	30,049.78	27.76
Acidity	5.1-5.5	2,430.49	2.25
Total		108,237.08	100.00

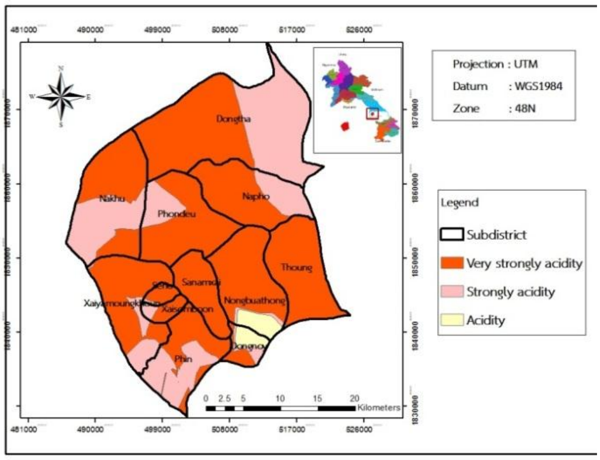

Fig. 4. Spatial distribution of pH in soil.

3.3 Organic matter (OM) was very low in 98.87% of the survey area, and low in the remaining 1.13%. The lowest OM ws found in the northern part of Phondea and Sanamxai Subdistrict. (Table 6 and Fig. 5).

Table 6: Spatial distribution area of OM

Class	OM %	Area	
		ha	%
Very Low	<0.1	1,221.45	1.13
Low	0.11-2.0	107,015.63	98.87
Total		108,237.08	100.00

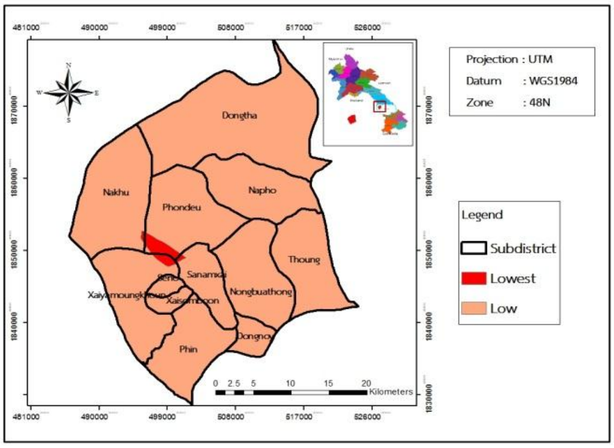

Fig. 5. Spatial distribution of OM in soil,

3.4 The spatial distribution of Nitrogen matched the OM distribution. (Table 7 and Fig. 6).

Table 7: Spatial distribution area of N

Class	N %	Area	
		ha	%
Very low	<0.01	1,221.45	1.13
Low	0.02-0.15	107,015.63	98.87
Total		108,237.08	100.00

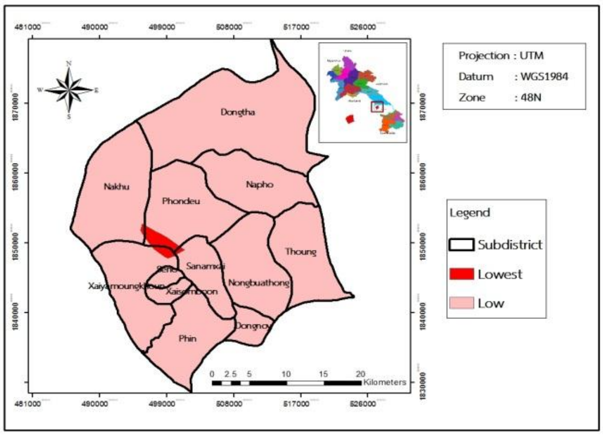

Fig. 6. Spatial distribution of N in soil.

3.5 The Phosphorus levels in the soil were mostly very low or low, at 51.89% and 42.13% respectively. Napho, Xaiyamounkun, the southern part of Dongtha and the southwest part of Phondea Subdistrict exhibited these very low or low levels. (Table 8 and Fig. 7).

Table 8: Spatial distribution area of P level

Class	P (mg/kg soil)	Area	
		ha	%
Very low	<3.0	56,158.91	51.89
Low	3.1-10	45,604.10	42.13
Moderate	10.1-25	4,975.63	4.60
Very high	>25	1,498.44	1.38
Total		108,237.08	100.00

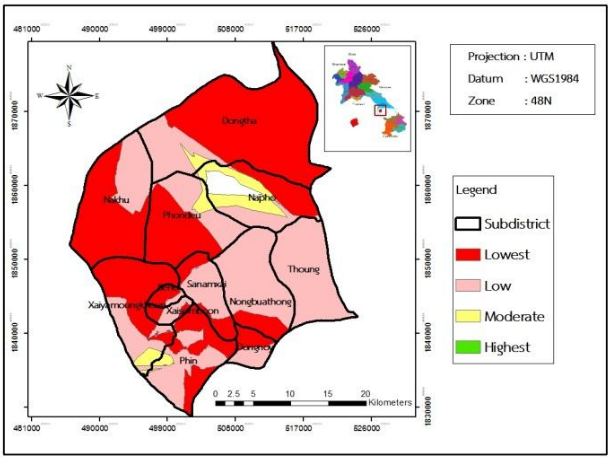

Fig. 7. Spatial distribution of P in soil.

3.6 Most areas had the very low levels of Potassium in the soil (82.70%). (Table 9 and Fig 8).

Table 9: Spatial distribution area of K level

Class	K (mg/kg soil)	Area	
		ha	%
Very low	<40	89,507.46	82.70
Low	41-80	18,729.63	17.30
Total		108,237.08	100.00

3.7 Most areas had very high or high levels of CEC, at 46.88% and 30.83%, respectively. Moderate to low CEC in the soil of Dongtha and Napho Susdistrict. (Table 10 and Fig. 9).
3.8 The spatial distribution of BS was mostly low to moderate. (Table 11 and Fig 10).
3.9 Overall, soil fertility was found to be very low in 72.94% of the survey area, and low in the remaining 27.06%. Napho, Nakhu, Phin, and Xaiyamoungkhun subdistrict and the western part of subdistrict, had the lowest soil fertility. (Table 12 and Fig. 11).

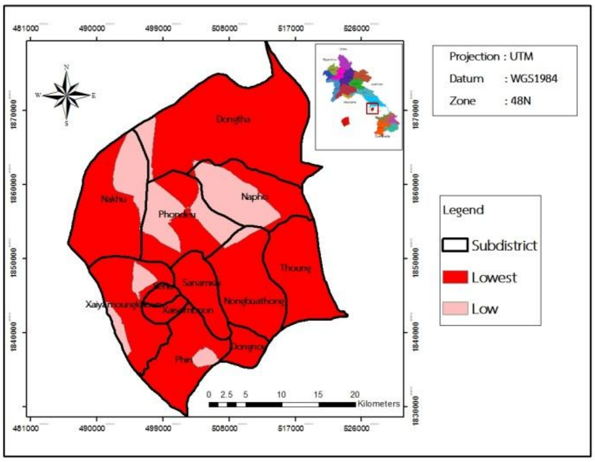

Fig. 8 Spatial distribution of K in soil.

Table 10: Spatial distribution area of CEC

Class	CEC (Cmol/kg)	Area	
		ha	%
Low	5-10	8,080.09	7.47
Moderate	10-15	16,039.97	14.82
High	15-20	33,374.80	30.83
Very high	>20	50,742.21	46.88
Total		108,237.08	100.00

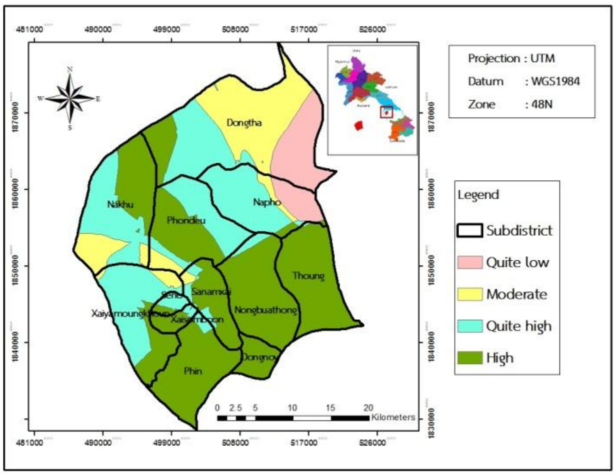

Fig. 9. Spatial distribution of CEC in soil.

3.10 The study found that the application of GIS has been supported the assessment of land potential for rice plantation in systematic, adjustable, and explicitly process shown in maps of the area. The experiment models of soil adjustment and land management could be tested for the future treatments. Beside the adjustment of soil property treatment, the future practices could consider the suitable land utilization for proper crops or applying the selective varieties of rice in the future.

Table 11: Spatial distribution of BS

Class	BS %	Area	
		ha	%
Low	<20	34,302.69	31.69
Very low	20-35	38,048.95	35.15
Moderate	35-50	22,376.00	20.67
High	50-75	13,509.45	12.48
Total		108,237.08	100.00

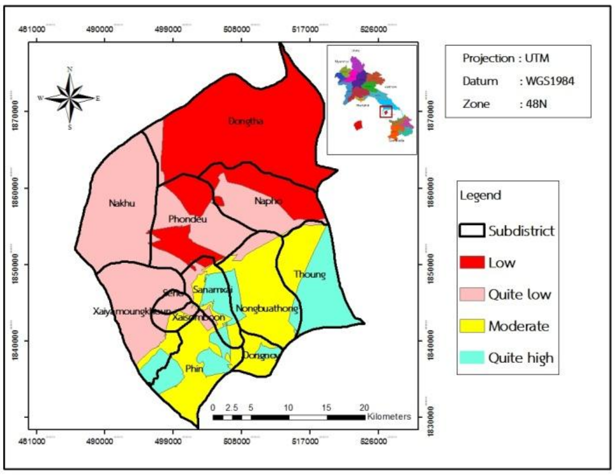

Fig. 10. Spatial distribution of BS in soil.

Table 12: Spatial distribution area of Soil Fertility

Area level of Soil Fertility	Area	
	ha	%
Very low	78,945.79	72.94
Low	29,291.29	27.06
Total	108,237.08	100.00

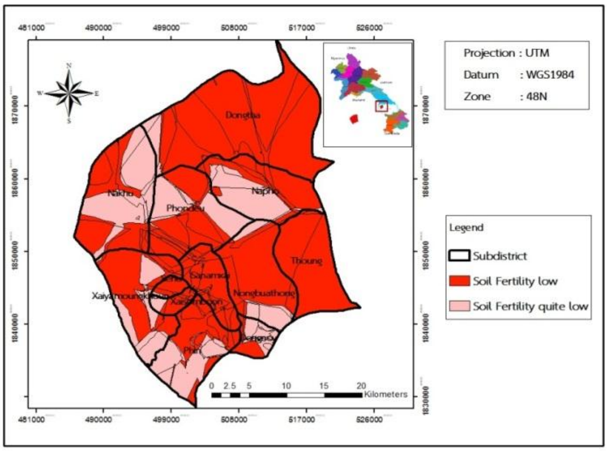

Fig. 11 Spatial distribution of Soil Fertility for rice plantation.

4. CONCLUSION

To support an increase in rice yield to 4.7 million tons per annum for the expected population of 7.5 million in 2020, soil texture and plant nutrients in the soil were investigated and analyzed by the integration of conventional laboratory testing and GIS map using the Pairwise Comparison method and Simple Additive Weighting (SAW). The study aimed to assess soil nutrients and the potential for increasing rice production in the Savannakhet Plain of Lao PDR, with Outhoumphone district as the study area.

GIS data and soil fertility data were combined to create a spatial database for rice cultivation. Land and soil characteristics of an area of 108,237 ha were classified by slope and soil texture (sand, silt, and clay) using field investigations and collection of 44 soil samples from each location. The samples were analyzed in the laboratory using standard soil survey and analytical methods to quantify the macronutrient elements and properties. Seven factors were analyzed: the amount of Nitrogen (N), Phosphorus (P), Potassium (K), soil acid-alkalinity (pH), soil organic matter (OM), the cation exchange capacity of the soil (CEC), and base saturation (BS).

A map and dynamic data on plant nutrients in the soil were generated to support planners and decision makers in visualizing the distribution of plant nutrients at different across the geographical coordinates of this district.

Future research direction

- To ensure the accuracy of soil qualification and plant nutrient measurement, the analysis should be conducted in a single laboratory.
- The results from this study could be used as a guideline for rice growing in the similar conditions of high plain in Laos.
- Further studies should be conducted at the higher resolution, to analyze the quality of plant nutrients and extend the database.
- The application of chemical fertilizer to adjust soil fertility should take account of the farm conditions of the farm environment and farming practices. The use of organic fertilizer or appropriate rice species should also be considered, to help raise the rice yield.

ACKNOWLEDGMENTS

Special Thanks to a scholarship under the patronage of Her Royal Highness Princess Maha Chakri Sirindhorn for supporting the study in Thailand.

Thanks to Department of Rural Technology, Faculty of Science and Technology, TU., Land Development Department of Thailand, Department of Agriculture, Land Development and Management of Lao PDR and Outhoumphone District.

REFERENCES

[1] FAOSTAT, (2014). Food and Agriculture Organization of The United Nations Statistics Division, Retrieved February 14, 2005 from the WWW: https://th.wikipedia.org/wiki/ Rice.

[2] Department of Agriculture Land and management, 2015. Strategic of agriculture and vision Agriculture, Ministry of Agriculture and Forestry, Lao PDR, p. 2, 5, 39, 53-54.

[3] Department of Agriculture Land and management, 2013. Strategic of agriculture and vision agriculture, Ministry of Agriculture and Forestry, Lao PDR, p. 13-15.

[4] Borneman E., 2016. Using Remote Sensing to map rice paddy drop in the Mekong Delta. Retrieved September 25, 2017. from the WWW: https://www.gislounge.com/using remote sensing map rice paddy drop mekong delta.

[5] Vo Quang Mihn. and Le Quang.Tri. 2017. Rice soil fertility classification and constraints in the Mekong Delta. Retrieved September 1, 2017. from the WWW: https://www.researchgate.net/publication/266511556.

[6] Duangjai S.et al., 2017. Identification of Nutrients Limiting Rice Growth in Soils of Northeast Thailand under Water-Limiting and Non-Limiting Conditions. Plant Production Science, 3:4, 417-421, DOI: 10.1626/pps.3.417.

[7] Qi-chun Zhang and Guang-huo Wang, 2005. Studies on nutrient uptake of rice and characteristics of soil microorganisms in a long-term fertilization experiments for irrigated rice. Journal of Zhejiang Univ. Sci B. 2005 Feb; 6(2): 147–154.

[8] Qiang Zhang, et.al., 2009. Spatial variability of soil nutrients and GIS-based nutrient management in Yongji county, China. International Journal of Geographical Information Science. Volume 24, 2010 - Issue 7.

[9] Mongkolsawat C. et.al., 2002. A physical evaluation of land suitability for rice: A methodological study using GIS. Retrieved July 16, 2017. from the WWW: geospatialworld.net. Sept. 2009.

[10] Pimsen et.al., 2013. The Application of Geographic Information System (GIS) to assess the risk area of Rice Bug (*Leptocorisa oratorius* (Fabricius)) outbreak in Amphoe Paphayom and Amphoe Khuankanun, Phatthalung province. GMSARN International Journal 7 (2013) 133 – 138.

[11] Chaiudom, S. 2007. Applications of Geographic Information Systems (Web-based: GIS) and asset management database using open source software, Information Technology Office and Communications.

[12] District Agriculture and forestry office, 2013. The report agriculture of District Agriculture and Forestry Office, Outhoumphone district, Savannakhet Province, Lao PDR.

[13] Jirakajonkool, S. 2013. Learn Geographic Information Systems: GIS ArcGIS 10.1 for Desktop, p. 31-54.

[14] FAO, 1983. Guidelines, Land Evaluation for Rainfed Agriculture, Soils Bulletin No.52, Italy.

[15] District Agriculture and forestry office, 2015. The report agriculture of District Agriculture and Forestry Office, Outhoumphone district, Savannakhet Province, Lao PDR.
[16] Soil Survey Division Staff, 1993. Soil Survey Manual. Department of Agriculture Handbook, No. 18. U.S. Government Printing office, Washington, D.C., U.S.A. pp. 437.
[17] Land Development Department, 2010. Guide of land development, for soil doctors and farmers, Ministry of Agriculture and cooperative, p. 13-14, 91-93.
[18] Walkley, A. and Black, C.A. 1934. An Examination of the Degtjareff Method for Determining Soil Organic Matter and a Proposed Modification of the Chromic Titration Method Soil Science, USA.
[19] Bremner, J.M. 1996. Nitrogen-Total, In D.L. Sparks, A.L. Page, P.A. pp.1085-1121.
[20] Bray, R.H and Kurtz, L.T. 1945. Determination of Total Organic and Available Forms of Phosphorus in Soils. Soil Sci. Soc. Am. J. 59: 39-45.
[21] Jones, J.B. 2001. Laboratory Guide for Conducting Soil Tests and Plant Analysis. CRC Press, USA.
[22] Malczewski, J. 1999. GIS and Multicriteria Analysis, John Wiley&Sons, INC. Canada.