Land Use Risk Assessment in Sakaeo Province Using Geoinformation Technology

Pratueng Vongtong[1],
Narong Pleerux[2],
Narumon Intarawichian[3],
and Anake Phutidetch[4]
[1, 2, 3]Faculty of Geoinformatics,
Burapha University, Chonburi, Thailand
[4]Faculty of Science and Technology,
Rajamangala University of Technology Suvarnabhumi, Ayutthaya, Thailand
[1]pratuang.w@rmutsb.ac.th
[2]pleerux_n@hotmail.com
[3]Narumoni@go.buu.ac.th
[4]ped_ku57@yahoo.com

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***Abstract* - This study aims to do land use risk assessment in Sakaeo Province by using Analytical Hierarchy Process (AHP) technique and Geo-Informatics System (GIS) technique. Many factors have been taken into consideration such as digital elevation model (DEM), slope, average annual maximum temperature, average monthly rainfall, distance to a road (km), distance to Stream (km), distance to Villages (km) and population density. The study found that in Sakaeo Province, 1,157.55 km^2 (16.09%) of the area is falling into the low-risk level; 5,298.16 (73.63%) is medium risk area, and 740.22 km^2 (10.29%) is a high-risk level area. In addition, the study found that most of the risky area is at Mueang Sakaeo district, Aranyaprathet district and Khao Chakan district where it's land use pattern used for field crop, paddy field and water body respective.**

***Keywords* - Analytical Hierarchy Process (AHP); Geo-Informatics System (GIS); Spatial Data Model; GIS**

I. INTRODUCTION

Sakaeo Province is located at the eastern part of Thailand and bordered with Cambodia. It is the biggest border market of ASEAN. In 2017, Thailand – Cambodia border trade value is 72,829.19 million baths which are 1.12% increased from 2015. While the Gross Domestic Product (GDP) and industrial investment value increased by about 1.12% and 2% respectively [1]. In 2017, Sakaeo Province has a number of populations at 585,706 people. It is 1.05% increased from 2015 [2]. Besides, there is a national park and wildlife sanctuary in Sakaeo Province [2]. From the above information, an expansion of economics and societies will lead to a change in land use pattern in response to meet people needs and area development [3] found that there was land use in coastal areas for purpose of occupation, tourism, and dwelling which caused more coastal erosion. There is a study on land use risk assessment in Yangtze estuary area, China [4] and coastal area of Thailand [5]. It found that both study areas are at a very high-risk level.

Regarding the above mentioned, physical characteristics, economic expansion and population growth of Sakaeo Province may lead to a change in land use pattern of its province in order to meet its people needs such as dwelling, occupation, and infrastructure development. Therefore, it is necessary to use informatics for land use risk assessment for prevention and mitigation plan [6]. The study aimed to do area-base risk assessment by using Analytic Hierarchy Process (AHP), which is a process used to measure the level of decision-making effectively and give correctly decision [7], together with GIS technique to analyzed various criterion [4-5]. The result will show in the special data model to explain and present information in the form of a map. The result of the study can be used for prevention and mitigation plan in case of bad effects that might occur from land use in Sakaeo Province.

II. OBJECTIVE

This study aims to assess the risk of land use in Sakaeo Province.

III. RESEARCH METHODOLOGY

The data and methodology used in this study and its process as follows;

1) ***Data:*** Data used in this study and its source as shown in Table I.

2) ***Study Area:*** The Study Area of this research is in Sakaeo Province, with a total area of 7,195.924 km2 or 4,497,452 Rai. Sakaeo Province divided its administration into 9 districts, 58 subdistricts, 731 villages [2] as shown in Figure 1.

3) ***Methodology:*** The Methodology started from the Analytical Hierarchy Process (AHP), factor preparation, analysis, and present risk assessment information in raster form with these following steps;

TABLE I
DATA AND SOURCES OF DATA

Data	Type of Data	Source of Data
Digital Elevation Model: DEM	Shape file	GISTDA[1]
Road map	Shape file	GISTDA
Hydrological map	Shape file	GISTDA
Village map	Shape file	GISTDA
Highest temperature (2006 – 2014)	Attribute Data	TMD[2]
Total precipitation (2006 – 2014)	Attribute Data	TMD
Population Information (2006 – 2014)	Attribute Data	DOPA[3]

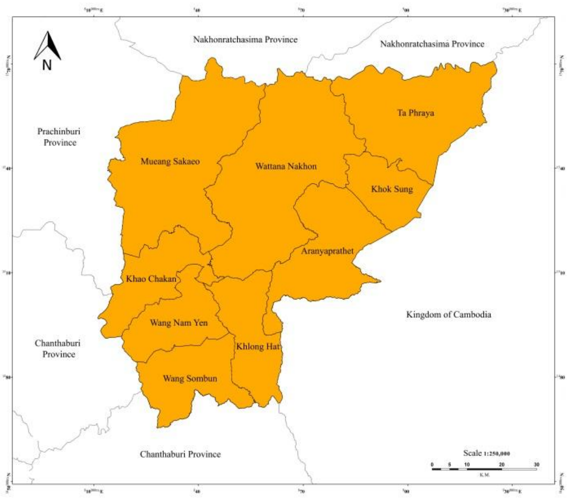


Figure 1. The Study Area, Sakaeo Province

[1] GISTDA stand for "Geo-Informatics and Space Technology Development Agency (Public Organization)"
[2] TMD Stand for "Thai Meteorological Department"
[3] DOPA stand for "Department of Provincial Administration"

1) ***Weight Factor Analysis***

Weight factor analysis by using AHP analysis will be function by weighting method as expert judgment, following by considering the acceptable consistency rate. The analysis process will be done as the following;

1.1 Weight value of factors will be set by 5 experts. The intensity of importance scale in the numerical value of 1 – 9 as shown in Table II.

TABLE II
THE FUNDAMENTAL SCALE OF ABSOLUTE NUMBERS [4]

Intensity of Importance	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong or demonstrated importance
9	Extreme importance
2, 4, 6, 8	Intermediate values (when compromise is needed)

The weight value of factors received from experts will be comparing its importance with the pairwise comparison matrix as shown in Table III.

1.2 Consistency Ratio (CR) Calculation; the acceptable value of the consistency ratio must less than or equal to 0.1 as shown in formula (1) [4].

TABLE III
PAIRWISE COMPARISON MATRIX FOR RISK CRITERIA

Factors	Digital Elevation Model (DEM)	Slope	Average Annual Max. Temperature	Average Monthly Rainfall	Annual Surface Runoff	Distance to Road	Distance to Stream	Distance to Villages	Population Density
Digital Elevation Model (DEM)	1.00	0.78	7.14	1.00	1.18	8.33	0.70	1.00	1.00
Slope	1.29	1.00	9.09	0.78	1.52	1.00	1.14	1.30	1.30
Average Annual Maximum Temperature	0.14	0.11	1.00	0.14	0.17	0.11	0.13	0.14	0.14
Average Monthly Rainfall	1.00	1.28	7.00	1.00	1.18	0.78	0.88	1.00	1.00
Annual Surface Runoff	0.85	0.66	6.00	0.85	1.00	0.67	0.75	0.86	0.86
Distance to Road	0.12	1.00	9.00	1.28	1.50	1.00	1.14	1.30	1.30
Distance to Stream	1.42	0.88	8.00	1.14	1.33	0.88	1.00	1.15	1.15
Distance to Villages	1.00	0.77	7.00	1.00	1.16	0.77	0.87	1.00	1.00
Population Density	1.00	0.77	7.00	1.00	1.16	0.77	0.87	1.00	1.00

$$CR = CI/RI \quad (1)$$

where CR is Consistency Ratio
CI is Consistency Index can be calculated from formula (2) [4]
RI is Random Consistency Index, shown in Table IV

$$CI = (\lambda_{max} - n) / (n-1) \quad (2)$$

where λ_{max} is Maximum Eigenvalue of matrix A
n is Number of criteria

TABLE IV
RANDOM CONSISTENCY INDICES (RI) [8]

n	1	2	3	4	5	6	7	8	9	10	11	12
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48

2) ***Range of Factors and Scores Determination***

Every factor in this study was set its range according to the risk level by 5 experts. The scores of factors had been set as shown in Table V.

3) ***Factors Preparation***

3.1 Digital Elevation Model (DEM): collected from GISTDA, then grouping DEM into 3 levels as shown in Table V.

3.2 Slope: slope value from DEM data were calculated in percent (%), then grouping slope into 3 levels as shown in Table V.

3.3 Average annual maximum temperature: maximum temperature between the 2006 – 2014 received from TMD. These number is calculated from a daily maximum temperature of each month, then use that number to find an average of average annual maximum temperature. This data is collected in a form of attribute data where it has coordinated of the station, therefore, it needs to convert into "point" spatial data. Then, estimate interpolation value and grouping average annual maximum temperature into 3 levels as shown in Table V.

3.4 Average monthly rainfall: the study used average monthly rainfall data between year 2006 – 2014 from TMD. It calculated by finding an average of total average monthly rainfall of each month. It will be kept in a form of attribute data and process as 3.3, then grouping annual average rainfall into 3 levels as shown in Table V.

3.5 Surface runoff: calculate by using runoff coefficient method from total annual rainfall data, slope, and runoff coefficient as shown in formula (3). Then, grouping surface runoff into 3 levels as shown in Table V.

$$R = P * RC * Area \qquad (3)$$

where R is Volume of annual runoff (m^3)
P is Volume of annual rainfall (millimeter: mm.)
Area is Area (m^2)
Rc is Runoff coefficient, can be calculated from formula (4)

$$Rc = (a * P) + b \qquad (4)$$

where a is Formula coefficient
b is Coefficients of Rc

whereas "a" and "b" depend on the slope of the area [9]

3.6 Distance to road, stream and villages calculation: it can be calculated by using "Euclidian Distance" menu of Arc GIS Desktop 10.0 program, then grouping data into 3 levels as shown in Table V.

3.7 Sub-district population density calculation (pop./km^2) Sub-district population density calculation (pop./km^2) can be calculated by using sub-district population data DOPA (2018), then grouping data into 3 levels as shown in Table V.

4) ***Land Use Risk Assessment***

All prepared factors have been used to analyzed land use risk assessment using "overlay technique" as shown in formula (5) [4].

$$S = \sum_{i=1}^{n} W_i R_i \qquad (5)$$

where S is Risk scoring from change in land use pattern
W_i is Weight of criteria i
R_i is Appropriate score of criteria i

Then, grouping land use risk level into 3 groups by using average ($\bar{x}$) and standard deviation (S.D.) [6] as shown in formula (6) - (8).

Low risk level value less than $(\bar{x})$ - S.D. (6)

Moderate risk level value from $(\bar{x})$ -S.D. to $(\bar{x})$ +S.D. (7)

High risk level value more than $(\bar{x})$ + S.D. (8)

TABLE V
WEIGHT, SCORES, AND RANGES OF FACTOR

Factors	Ranges of Factor	Score	Weight
Digital Elevation Model (DEM) (m)	> 500	1	19
	100 – 500	2	
	< 100	3	
Slope (%)	> 35	1	13
	20 – 35	2	
	< 20	3	
Distance to Stream (km)	> 1	1	12
	0.50 – 1	2	
	< 0.50	3	
Average annual rainfall (mm./year)	< 123	1	11
	123-135	2	
	> 135	3	
Distance to road (km)	> 1	1	11
	0.50 – 1	2	
	< 0.50	3	
Distance to Villages (km)	> 3	1	10
	1 – 3	2	
	< 1.00	3	
Population Density (pop./km^2)	< 200	1	10
	200 - 400	2	
	> 400	3	
Average annual surface runoff (million m^3/year)	< 7,000	1	9
	7,000 – 21,000	2	
	> 25,000	3	
Average annual maximum temperature (°C)	< 25	1	1
	25-40	2	
	> 40	3	

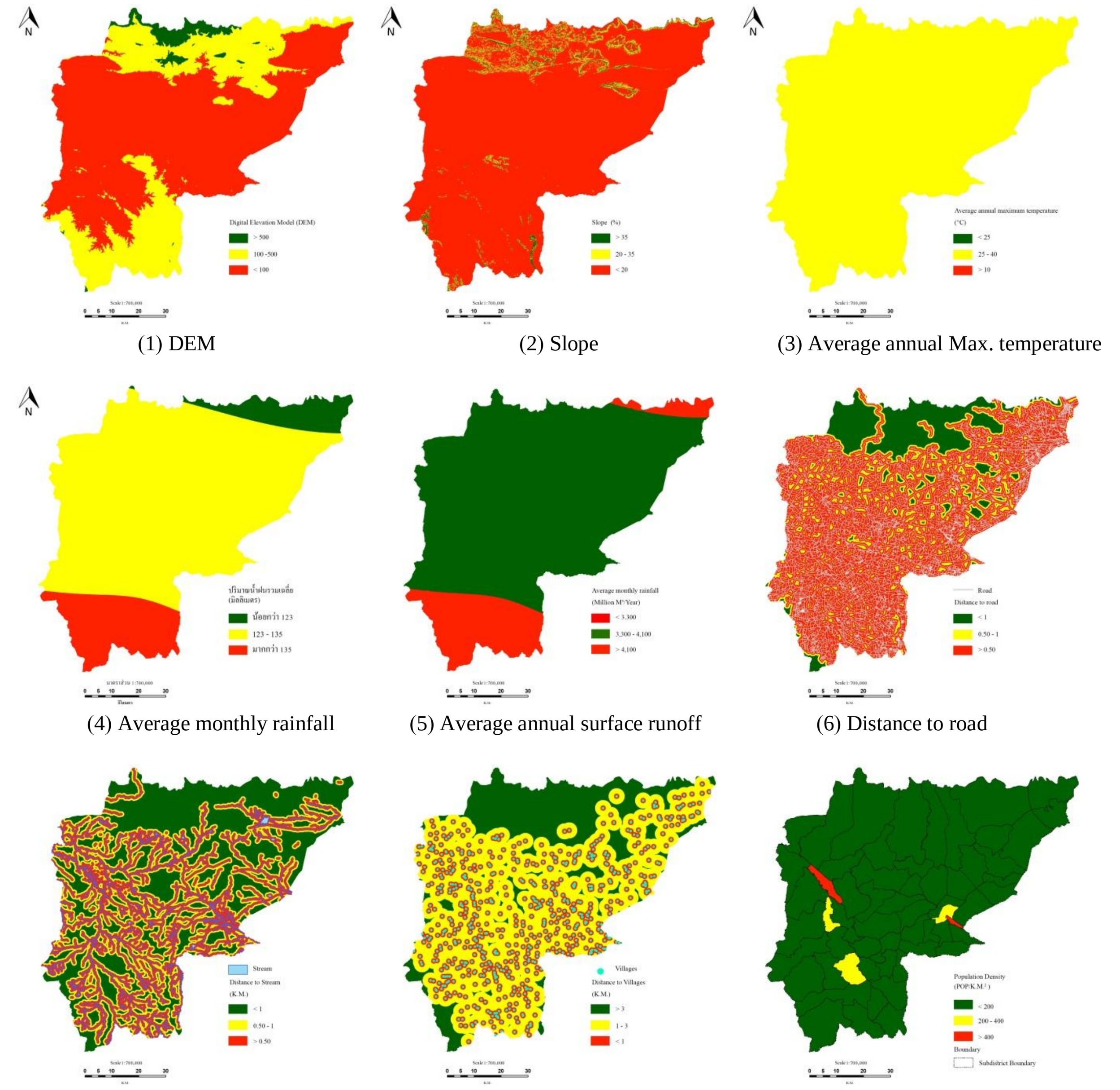
5) ***Evaluation of Land Use Pattern in Various Risk Areas***

By overlaying risk map from 3.4 with land use map in the year 2014, it illuminated land use in risk area in each level. This study divided land use into 7 patterns which are urban and built-up land, paddy field, field crop, perennial and orchard, forest land, water body, and miscellaneous land.

IV. RESEARCH RESULTS

1) ***Weights, Scores, and Range of Factors***

The analysis found that maximum eigenvalue is 9.708 and CR value is equal to 0.061 (CR $\leq$ 0.01), which is acceptable [8]. For the weight of factors, the maximum weight is DEM, followed by slope and distance to stream at 19, 13 and 12 respectively. The lowest weight of factor is the average annual maximum temperature. Its weight is equal to 1 as shown in Table V. When range of factors and scores were prepared and grouped as shown in Table V, it can display as Figure 2.



(1) DEM (2) Slope (3) Average annual Max. temperature

(4) Average monthly rainfall (5) Average annual surface runoff (6) Distance to road

(7) Distance to Stream (8) Distance to Villages (9) Population Density

Figure 2. Range of Criteria Classification from Experts

2) ***Land Use Risk Assessment***

Land use risk assessment divided into 3 levels are low risk, moderate risk, and high-risk levels. The study found that there are 1,157.55 km^2 (16.09%) of low risk area, 5,298.16 km^2 (73.63%) of moderate risk area, and 740.22 km^2 (13.29%) of high-risk area. The top three vulnerable districts are Mueang Sakaeo district, Aranyaprathet district and Khao Chakan district with an area of 242.24 km^2, 165.66 km^2, and 114.25km^2 respectively. While moderate and low-risk areas are also located at Mueang Sakaeo district with the area of 1,107.56 km^2 and 482.75 km^2 respectively, as shown in Table VI.

TABLE VI
RISK OF LAND USE AREAS

District	Risk Level (km^2)				Percent (%)
	Low	Moderate	High	Total	
Mueang Sakaeo	482.75	1,107.56	242.24	1,832.55	25.47
Aranyaprathet	4.05	651.56	165.66	821.27	11.41
Khao Chakan	394.77	1,051.11	114.25	1,560.12	21.68
Wattana Nakhon	13.19	612.27	148.85	774.31	10.76
Wang Nam Yen	10.91	253.45	60.69	325.05	4.52
Khok Sung	30.01	371.44	38.25	439.70	6.11
Khlong Hat	11.50	383.03	22.55	417.08	5.80
Ta Phraya	165.79	459.32	17.24	642.35	8.93
Wang Sombun	27.68	349.86	5.96	383.50	5.33
Total	**1,157.55**	**5,298.16**	**740.22**	**7,195.92**	**100.00**
Percent (%)	**16.09**	**73.63**	**10.29**		

Figure 3, shown that most of Sakaeo Province area is moderate risk area (Yellow color). It covers the whole Sakaeo Province except the upper part of the province. High-risk area (red color) is shown by many small red spots spread all over Sakaeo province. While the low-risk area can be found at the upper part of the province such as some area of Mueang Sakaeo district, Wattana Nakhon district, and Ta Phraya district.

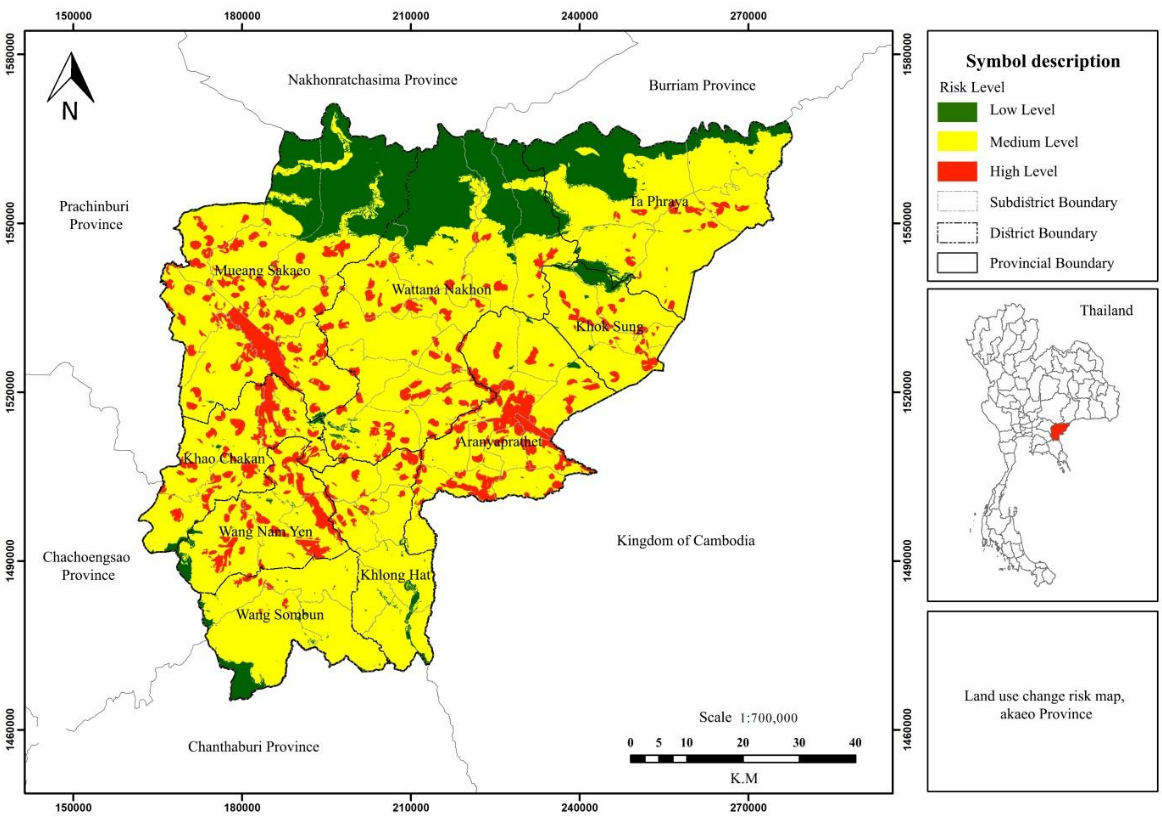


Figure 3. Land Use Change Risk Map

3) ***Land Use Pattern in Various Risk Areas***

When overlaid risk map with 2014-land use map, it showed that most of the low-risk area is 1,085.04km^2 of forest area, followed by 35.60km^2 of field crop and 16.31 km^2 of paddy field respectively. Most of the moderate risk area is 2,235.71 km^2 of field crop, 1,680.50 km^2 of paddy field, and 384.67 km^2 of perennial and orchard respectively. On the other hand, most of the high-risk areas were found at field crop with an area of 287.67 km^2, followed by 264.31 km^2 of paddy field and 75.60 km^2 of water body respectively, as shown in Table VII.

TABLE VII
LAND USE PATTERN IN VARIOUS RISK AREAS

Land Use Pattern	Risk Level (km^2)			Total	Percent (%)
	Low	Moderate	High		
Urban and Built-up Land	0.92	286.78	69.06	356.76	4.96
Paddy Field	16.31	1,680.50	264.31	1,961.12	27.25
Field Crop	35.60	2,235.71	287.67	2,558.98	35.56
Perennial and Orchard	15.04	384.67	29.09	428.80	5.96
Forest Land	1,085.04	351.95	6.23	1,443.22	20.06
Water Body	4.56	290.43	75.60	370.58	5.15
Miscellaneous Land	1.04	66.13	9.29	76.46	1.06

V. CONCLUSION

The study on land use risk assessment in Sakaeo Province found that Mueang Sakaeo district has the maximum number of high-risk areas which relevant to Land Development Department (LDD) report on land use of Sakaeo Province in 2013. The 2013 LDD report found that Mueang Sakaeo district is high-risk area because Mueang Sakaeo district is Sakaeo Province administrative center, especially central and lower parts of the district have a high density of transportation and water body. Besides, Mueang Sakaeo district has the highest population density of Sakaeo province. So, it caused the area of Mueang Sakaeo district to be high-risk area. This finding relevant to the study of [10-13] who concluded that number of population and villages that close to roads and water body is an accelerating factor of change in land use pattern and cause risk in the areas.

While the upper part of Sakaeo Province is a national park that has high elevation and very steep slope. At the same time, it has a volume of average rainfall and surface runoff more than other areas. This area has very few roads, no people live here and people are not allowed to do things or take advantages in the national park and forest sanctuary areas. With all the above facts, the upper part of Sakaeo Province is the low-risk area.

For land use planning in Sakaeo Province, the most land use pattern that should be monitored is field crop, paddy field, and water body respectively. These land use pattern can be found in a high-risk area. It is relevant to criteria of area height and low slope level which is suitable for land use. Most of it is in the middle part of the study area.

When the study overlaid land use risk maps with study criteria, it found that high-risk area has smaller value of distance to roads, distance to streams and distance to villages than other risk level area. While, population density of high-risk area has larger value than other risk level area.

Field crop and paddy field land use pattern are in a high-risk area when compare to other land use pattern. When the study overlaid it with a factor of rainfall and runoff volume, it showed that these areas have a lower level of risk than other study areas, which may cause drought in the area. While in the high-risk area found that the less distance to the stream will have more population intensity which can be seen that people tend to choose to live nearby water body if they have less effect from rainfall and runoff volume. This is because if people live nearby water body, even less rainfall or runoff volume, people still able to reserve water for consumption and occupation. Therefore, land use pattern for a water body is a second high-risk level followed from field crop and paddy field.

The results of the study can be used for planning and land use monitoring in Sakaeo Province. This includes the importance of infrastructure development and other constructions. Because area and economic development will affect land use and may cause those areas to be at risk. For example, transportation construction to facilitate people access to those areas and leads to population growth. However, apart from government officials who are mainly responsible persons for land use planning or setting up measurements, all stakeholders such as people, entrepreneurs and other; should get involved in determining appropriate operational guidelines that acceptable by all parties. This will make the operation go as planned and successful.

VI. ACKNOWLEDGMENTS

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(Arranged in the order of citation in the same fashion as the case of Footnotes.)

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