ORIGINAL RESEARCH ARTICLE

MAPPING LAND SUITABILITY OF *SUBAK* ON BASED ON GEOGRAPHYC INFORMATION SYSTEM (GIS) IN DENPASAR, BALI

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ABSTRACT

This study aims to identify and provide land suitability database of *Subak* to support sustainable agricultural development and provide spatial information such as land suitability maps with existing inhibiting factor. The method used was field survey to obtain data characteristics/quality of land through soil sampling on several land units sample, and soil analysis in the laboratory. Land suitability classification was done using the criteria from the Technical Instructions Evaluation of Land for Agricultural Commodities by matching between the quality/characteristics of the land with the growing requirements of rice crop being evaluated. The analysis of actual land suitability both of S2 (little suitable) with limiting factors included drainage, texture, depth of planting, salinity, N- available, P-available and K-available, and slope; and S3 (marginally suitable) with limiting factors such as N-available, P-available and salinity. The assumption of business improvements that can be made to the determine quality/characteristics of the land *Subak* was an inhibiting factor, with optimization by improved drainage channels, N and P in accordance with the needs of the rice plant. Therefore the suitability of potential land for irrigated rice crops can be mapped by GIS and can be increased to very suitable (S1) level. In conclusions, the actual land suitability was categories as 72% little suitable (S2) and 28% marginally suitable or S3 with inhibiting factors included rooting medium, availability of nutrients, slope and salinity. While the suitability of potential land consisted of all of *Subak* that invery suitable (S1)level, so that the existence of *Subak* in Denpasar should be protected.

Keywords: Mapping, land suitability, Geographical Information Systems

INTRODUCTION

Denpasar city is the center of the provincial capital of Bali which is a center of education, trade and tourism. The high rate of population growth is largely due to the movement of people (migrants) from outside the region, especially from outside Bali/Java (Pemerintah Kota Denpasar, 2007). The increasing rate of population growth led to the use of land for residential, commercial and tourism infrastructure, which resulted in the decrease of agricultural land in urban areas. As a result, *Subak* as cultural heritage will be affected by decreasing the number of lowland rice fields that indirectly caused the decline in environmental quality.

According to Fahar ((2012), the problem of food encountered in national food today is degradation of soil fertility, import of rice, increasing competition in water use, and agricultural infrastructure is still inadequate (irrigation networks are damaged) as well as the rampant conversion of agricultural land into non-agricultural land.

Wetland conversion should be examined within the regulation of Act No. 41 of 2009,which refers to the protection of sustainable food. According to Denpasar in Figures (2015), the amount of irrigated land was only 2,605 ha which was still lagging behind when compared to the previous year are 2.519 Ha. Although Denpasar is the city center, Denpasar still maintains the rice field with water control system. Subak is a community organization with members of farm households that are priorities set irrigation system for its members one attempt to optimize remaining *Subak* that can increased land productivity is by maintaining self-sufficiency to evaluate the suitability of the land.

Land suitability is the process of estimating the level of suitability of land for alternative uses of land, both for agriculture, forestry, tourism, soil conservation or another type of use (Ritung *et al*., 2011). Land evaluation requires physical properties of the environment that is elaborated in the quality of land, each land quality is composed of one or more characteristics of the land (FAO, 1983). Some characteristics of land generally has a relationship with one another as water availability patronizing. cropping patterns quality of land will affect the type of use and/growth of plants and other commodities. This research foccussed on the suitability of riceland support food security in Denpasar which is currently experiencing food deficits is 97,224.94 ton/ha (Lanya et al., 2015)

Based on the analysis of suitability evaluation of wetland characteristic or quality of the rice field it can be predicted. Beside that, limiting factors of the land suitability will also be addressed by improvements of limiting factor. We can obtain information system about the suitability of wetland in Denpasar that will be manifested in the form of land suitability map-based geographic information system (GIS). Due to these problems, it is

necessary to study the suitability mapping of irrigated land in Denpasar based on geographic information system (GIS).

The purposes of this study are to : (1) identify and map the suitability of the actual and potential of wetland-based GIS and (2) determine the suitability of wetland limiting factor in Denpasar, Bali.

MATERIALS AND METHODS

This research was conducted in Denpasar with an area of 127.78 km^2 or 12,778 ha (Denpasar in Figure, 2015). The research location was geographically located at 08º36'56 "- 08º42'01" south latitude and 115º10'23 "- 115º16'27" East Longitude. The study was conducted from March to October 2015 which is located around the area of wetland in Denpasar. Denpasar region has an average annual rainfall of 1000 to 2000 mm, with humidity of 76-82% and temperature 26,7-28,7 ^{0}C.

The materials used in this study include (a) the laboratory analysis using materials such as chemical reagents i e : H_2SO_4, Selent, Calgon, H_2HPO_3, H_2O_2, HCl, for the analysis of soil. The maps include: soil type maps, land use maps, slopes class maps for overlay for the manufacture of land units. Beside that the materials that also needed for this research were the topographic maps/topographical maps (Bakosurtanal, 2000), the productivity maps and satellite imagery (Quick Bird Denpasar, 2015).

The instruments used in this study include: (1) a set of computers with the program Arc-GIS that was used for the preparation of thematic maps, which consists of hardware, software and printer; (2) The analysis in the laboratory requires ovens, pH meters, Conductometer, Spectrophotometer, measuring flask 1000 ml, Erlermeyer 50 ml, pipette, burette, sieve, water heater, hood, apparatus for distillation, boiling flask, ring samples, and filter paper , Instruments needed for the field survey include: drill belgi, airy knives, altimeter, Abney level, compass, plastic bags, labels, meter and GPS as well as stationeries.

The type of data needed to support this study were qualitative and quantitative methods. Quantitative method is a method used to measure data with a specific measuring instrument necessary for the needs of quantitative analysis in the form of

numbers. In this study a quantitative method included was a method of surveying and analysis in the laboratory. The parameters observed in this study such as the suitability of land ie : physical properties of soil are: soil texture and soil chemical properties, namely: Total N, P - available, K- available, organic C, soil pH, salinity CEC (cation exchange capacity), BS (base saturation).

Qualitative methods in this study included data collection (1) literature, the data from related agencies (Bappeda, Department of Agriculture and Hortculture, Office of Population, Denpasar and satellite imagery maps, base maps and thematic maps.Land suitability classification using the criteria of the Technical Instructions Evaluation of Land for Agricultural Commodities by Ritung *et al*., (2011), with matching between the quality and land characteristics with land use requirements of crops being evaluated. Types of agricultural crops evaluated is rice.

There were seven stages in the study namely : (1) Preparation, (2) preliminary study (identification and description). The preliminary study included : data and information analyseis from satellite imagery and map-based: the base map (roads, rivers, irrigation canals, administrative boundaries), maps of land use, site planning observation homogeneous land units. Interpretation of satellite imagery to map making tentative: land use, (3) Field study include: inventory, description of the area, surveying and soil samples for laboratory analysis. (4) The collection of data on land characteristics and land management, (5) Tabulation and analysis of data (observational data on the characteristics of the field or in the laboratory collected in the form of tables in facilitating the interpretation of the data. Interpretation of satellite imagery to map making tentative: land use. Analysis and interpretation of the data was conducted to determine the suitability of land and its boundary factor. (6) Evaluation of land suitability was-carried out by matching between the growing requirements of rice crops with characteristics/quality of existing land. Land suitability classification criteria was done using the technical manual evaluation of land for agricultural commodities compiled by Ritung *et al*., (2011).

Land suitability classification can be divided into four levels, namely: orders, sses, subclasses and units (Merit *et al*., 2015). Order is the state of the general land suitability, consisting of the order suitable (S) and the order does not suitable (N). Land suitability classes are distinguished the order level. In the grade level, the land belonging to the order in accordance divided into classes is very suitable (S1), a little suitable (S2), marginally suitable (S3), and is not suitable (N). Subclass is a state level in the land suitability classes, differentiated by the quality and characteristics of the land as the limiting factor. The unit is a subclass levels in the state of land suitability, which is based on additional properties that influence the management. Depth land suitability analysis used in this study is the classification level of the unit. (7) Update maps of actual and potential land suitability as a support forum as spatial data based on analysis of satellite imagery and GIS.

RESULTS AND DISCUSSION

Land characteristics and Qualities of Rice Field

Analyses of soil samples in the laboratory showed that the physical properties of soil analyzed was composed predominantly of soil texture rather fine texture (clayey loam, clay, clay loam dusty), medium texture (clay and clay dusty). The condition of soil was in the range of rather somewhat poorly drained (SPDr) to poorly drained (PDr). Coarse material,surface rock and rock outcrops are not found on all irrigated rice in the city of Denpasar. Slope study site ranged from 2% (flat) to 5% (ramps). Chemical properties and soil fertility which include soil pH ranged from slightly acid (6.24) to neutral (7.16), salinity levels ranging from low (0.42) to very high (3.01), C-Organik ranges from very low (0.8 %) to high (3.07%), CEC varies from moderate (19.60 me / 100g) to very high (90 , 20 me / 100g), base saturation ranging from moderate (51.83%) to very high (196.21%). N-total classified as very low (12:06%) to moderate (0.29%), P-available relatively low (15.75 ppm), up to very high (125.81 ppm); and K-available are moderate (35.9 mg/100 g) to high 269 mg/100 g). Qualities Data and wetland Characteristics at Research Area were presented in Table 1.

Table 1. Evaluation Results Actual and Potential Land Suitability and Rice in Denpasar

Nu	Location (Village/Districs)	Actual Land Suitability	Potential Land Suitability	Nu	Location (Village/ Distric)	Actual Land Suitibility	Potential Land Suitibility
1	Ubung Kaja/North Denpasar	**S2rc2,4xcna1,3**	**S1**	14	Penatih Dangri Puri/East Denpasar	**S3rc1xc**	**S1**
2	Peguyangan Kangin/ North Denpasar	**S2rc1na1**	**S1**	15	Tembau/ East Denpasar	**S3rc1na2**	**S1**
3	Peguyangan Kaja/ North Denpasar	**S2rc1,2,4na1**	**S1**	16	Renon/South Denpasar	**S3na1S2rc1xc**	**S1**
4	Ubung Kaja/North Denpasar	**S2rc1**	**S1**	**17**	Sanur Kauh/ South Denpasar	**S2rc1na1**	**S1**
5	Peguyangan Kaja/ North Denpasar	**S2nr4**	S1	**18**	Sanur Kauh/ South Denpasar	**S2n1,2**	**S1**
6	Peguyangan/ North Denpasar	**S2rc2na2**	**S1**	**19**	Sanur/South Denpasar	**S2rc1,4xcna1**	**S1**
7	Pemecutan Kelod/West Denpasar	**S2rc1,2na2**	**S1**	**20**	Kesiman/East Denpasar	**S3rc1na1,2**	**S1**
8	Kesiman Petilan East Denpasar	**S2rc1**	**S1**	**21**	Sidakarya/ South Denpasar	**S2rc1,2na1S3xc**	**S1**
9	Sumerta Kelod/East Denpasar	**S3na1S2rc2na2**	**S1**	**22**	Pemogan/ South Denpasar	**S2rc1xcna2**	**S1**
10	Kesiman Kertalangu/ East Denpasar	**S2rc1**	**S1**	23	Pemogan/Denpasar Selatan	**S2rc1xcna1,2**	**S1**
11	Penatih DanginPuri/ East Denpasar	**S3na2S2rc1na1**	**S1**	**24**	PadangsambianKelod/West Denpasar	**S2rc1**	**S1**
12	Kesiman Kertalangu/ East Denpasar	**S2rc1xcna1**	**S1**	25	PadangsambianKaja/West Denpasar	**S3rc1na1**	**S1**
13	Penatih/East Denpasar	**S2rc1xcna1eh1**	**S1**				

Note : S1 = very suitable S2 = Moderatly Suitable S3 = Marginal Suitable
CL = Clay Loam C = Clay L = Loamy
Si =Silty eh = slide danger fh = flood danger
lp = land preparation S = Sandy SiCL = Silty Clay Loam

Based on data covering agroclimate annual average temperature and rainfall taken from Meteorology and Geophysics Central Region III Denpasar. The annual average temperature ranges from 26.7 to 28.7^{o} C, humidity ranges from 76-82%, the average annual rainfall ranges from 1,000 mm - 2,000 mm/years. The geological map of Bali, Denpasar has soil of types dominated by Yellowish Brown Latosol, then successively followed by the type of Regosol Yellowish Brown, Regosol Brown Grey, Alluvial Brown Grey and Alluvial Hidromorf.

Land Suitability

Food sustainable agriculture can be measured from one parameter, namely the suitability of land agro-ecosystem. Land suitability for particular cultivation is one of the first factors to be studied in preparing for plant cultivations. Determination of the class/subclass of the actual land use system suitability by the matching and comparing the characteristics/quality of land witgrowing crop requirement were conducted.

Land suitability criteria used in this study is the evaluation oftechnical manual evaluation of land for agricultural commodities from Ritung *et al*., (2011). The actual land suitability stating the suitability of land based on survey data of land or land resources.The results of the analysis of actual and potential land suitability rice plants are presented in Table 1. The type of the actual land suitability of paddy land obtained were between little suitable (S2) to the marginally suitable (S3). The limiting factor is the rooting medium (drainage, texture and depth of planting), nutrient retention (C-organic), toxicity (salinity), and available nutrients (Total-N,Avalaible-P. The actual land suitability can be increased to a potential of S2 and S3 to S1 by fixing the limiting factor. The limiting factor rooting medium such as drainage can be improved by making the drainage channel, soil texture improvements can be done by silting. The limiting factor C-organic can be improved by adding organic material, while limiting toxicity factor can be improved by providing irrigation. Available nutrient limiting factor is total-N and available-P can be improved by adding fertilizer Nitrogen and Phosphate.

The actual land of suitability mapping contains sample locations

with the quality/characteristics of the land with the limiting factor at each sample points. Sample points are yellow furnished with white boxes are equipped with the status of land suitability. Actual land suitability maps is presented in Figure 1.

Based on the observations of all units of homogeneous surveyed wetland, it turns out all paddy fields in Denpasar analyzed with potential land suitability, including very suitable (S1), through the improvement of its boundary factor, so that wetland in Denpasar can be preserved. Potential suitability of wetland rice crops in the paddies rice in Denpasar as very suitable (S1) or 100%. Potential land suitability maps rice crops in Denpasar can be presented in Figure 2.

Table 2. Result of Analyses : Soil pH, Salinity, C-organik, Total-N, Avalaible-P, Avalaible-K, CEC and, Base Saturation

Nu	Nu . Sample/field number	Temperature	Water available	Rooting Media (rc)				Nutrient Retention (nr)					Nutrient (na)			Slide damage (eh)		Flood Damage (fh)		Land preparetion (Ip)		Location
			RH	Drainage	Texture	Course Material	Depth Planting	CEC	BS	pH H_2O	C-Org	Toksisity (xc)	N-total	P-Avalaible	K2O	slope	Slide damage	Hight	duration	Stone surface	Singkapan Batuan	(Village/Districts / *Subak*/Districts)
		(tc)	(wa)	(rc1)	(rc2)	(rc3)	(rc4)	(nr1)	(nr2)	(nr3)	(nr4)	Salinity	(na1)	(na2)	(na3)	(eh1)	(eh2)	(fh1)	(fh2)			*Subak*/Districts)
		(0C)	(%)			(%)	(cm)	(me/100 g)	(%)		(%)	(mmhos/cm)	(%)	ppm	(mg/100 g)	(%)		(cm)	(hari)	(%)	(%)	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	2/24	26,7-28,7	76-82	SPDr	L	0	45	28.58	82.39	6.82	2.49	2.61	0.14	42	199	3	0,12	10	0	0	0	Ubung Kaja/North Denpasar
2	3/12	26,7-28,7	76-82	PDr	CL	0	50	38.78	86.74	7.16	3.45	1.21	0.19	41.76	59	3	0,14	9	0	0	0	Peguyangan Kangin/ North Denpasar
3	2/17	26,7-28,7	76-82	PDr	L	0	48	31.46	66.62	7.00	2.54	1.35	0.12	125.81	106	3	0,10	6	0	0	0	Peguyangan Kaja/ North Denpasar
4	2/14	26,7-28,7	76-82	PDr	SCL	0	75	32.28	68.38	6,.63	1.28	1.15	0.08	52.18	155	2	0,14	8	0	0	0	Ubung Kaja Kaja/ North Denpasar
5	2/15	26,7-28,7	76-82	SPDr	SiC	0	75	34.89	69.87	6.63	0.86	1.55	0.22	31.88	213.6	3	0,12	5	0	0	0	Peguyangan Kaja/ North Denpasar
6	2/18	26,7-28,7	76-82	SPDr	SiL	0	55	31.23	57.90	6.5	1.70	1.82	0.18	20.44	269	2	0,12	7	0	0	0	Peguyangan/ North Denpasar
7	2/5	26,7-28,7	76-82	PDr	L	0	50	22.18	53.08	6.69	1.25	1.00	0.12	17.43	209	3	0,13	9	0	0	0	Pemecutan Kelod/West Denpasar
8	2/6	26,7-28,7	76-82	PDr	CL	0	70	27.04	84.64	6.82	2.42	1.65	0.2	37.46	196	2	0,14	6	0	0	0	Kesiman Petilan/East Denpasar
9	2/7	26,7-28,7	76-82	SPDr	SiL	0	80	31.27	83.64	6.86	1.28	0.42	0.06	20.84	198.2	3	0,12	4	0	0	0	Sumerta Kelod/East Denpasar
10	3/9	26,7-28,7	76-82	PDr	CL	0	70	94.67	59.18	6.82	2.97	2.62	0.27	61.41	231.3	3	0,10	4	0	0	0	Kesiman Kertalangu/East Denpasar

Continuous Table

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
11	3/13	26,7-28,7	76-82	PDr	SiCL	0	75	33.67	96.21	6.7	1.29	1.83	0.18	15.75	156.9	3	0,14	6	0	0	0	Penatih Dangin Puri /East Denpasar
12	2/8	26,7-28,7	76-82	PDr	CL	0	60	30.38	55.46	6.47	1.26	2.34	0.18	70.53	214.5	3	0,12	8	0	0	0	Kesiman Kertalangu/East Denpasar
13	2/16	26,7-28,7	76-82	PDr	CL	0	75	90.20	63.33	6.63	1.71	2.13	0.19	36.43	169.1	5	0,13	6	0	0	0	Penatih//East Denpasar
14	3/10	26,7-28,7	76-82	PDr	SiCL	0	80	40.23	68.62	6.58	2.60	3.11	0.29	63.35	95.6	3	0,14	5	0	0	0	Penatih DangriPuri/East Denpasar
15	3/15	26,7-28,7	76-82	PDr	SiC	0	80	33.27	58.27	6.57	3.02	1,54	0.28	24.13	201.5	3	0,12	6	0	0	0	Tembau/East Denpasar
16	2/1a	26,7-28,7	76-82	PDr	SiCL	0	80	32.00	97.67	6.82	2.85	2.28	0.07	44.65	123.6	3	0,14	10	0	0	0	Renon/South Denpasar
17	4/1b	26,7-28,7	76-82	PDr	SiCL	0	75	19.60	98.20	6.86	1.29	2.75	0.17	51.96	78.2	3	0,14	14	0	0	0	Sanur Kauh/South Denpasar
18	2/2	26,7-28,7	76-82	SPDr	CL	0	55	32.37	91.76	6.92	2.43	1.32	0.11	17.87	123.4	3	0,12	13	0	0	0	Sanur Kauh/South Denpasar
19	2/3	26,7-28,7	76-82	PDr	SC	0	40	34.25	94.74	6.73	1.28	3.45	0.17	55.51	88.1	2	0,13	10	0	0	0	Sanur/South Denpasar
20	2/4	26,7-28,7	76-82	PDr	SiC	10	60	28.46	67.09	6.9	2.18	1.56	0.18	19.83	33.3	3	0,14	8	0	0	0	Kesiman/East Denpasar
21	2/19	26,7-28,7	76-82	PDr	L	0	75	35.16	51.63	6.92	1.28	5,06	0.15	35.09	35.9	3	0,10	15	0	0	0	Sidakarya/South Denpasar
22	2/20	26,7-28,7	76-82	PDr	C	0	70	44.40	72.39	6.88	3.07	3.01	0.25	22.24	97.1	8	0,14	20	0	0	0	Pemogan/South Denpasar
23	2/21	26,7-28,7	76-82	PDr	C	0	65	37.07	99.63	8.85	1.76	2.96	0.14	18.09	107.5	3	0,12	15	0	0	0	Pemogan/South Denpasar
24	6/21	26,7-28,7	76-82	PDr	C	0	95	36.23	93.87	6.71	3.03	1.80	0.25	28.33	161.5	2	0,13	20	0	0	0	Padangsambian Kelod/West Denpasar
25	2/23	26,7-28,7	76-82	PDr	SiCL	0	75	37.85	58.83	6.86	1.73	1.39	0.16	34.59	62.4	2	0,14	15	0	0	0	Padangsambian Kaja/ West Denpasar

Note: C = Clay; CL = Clay Loam; SiCL = Silty Clay Loam; SiC = Silty Clay; SC = Sandy Clay; L = Loamy ; PDr = Poorly darainage
SPDr = somewhat poorly drainage; CEC = Capasity Exchange Cation; BS = Base Saturated

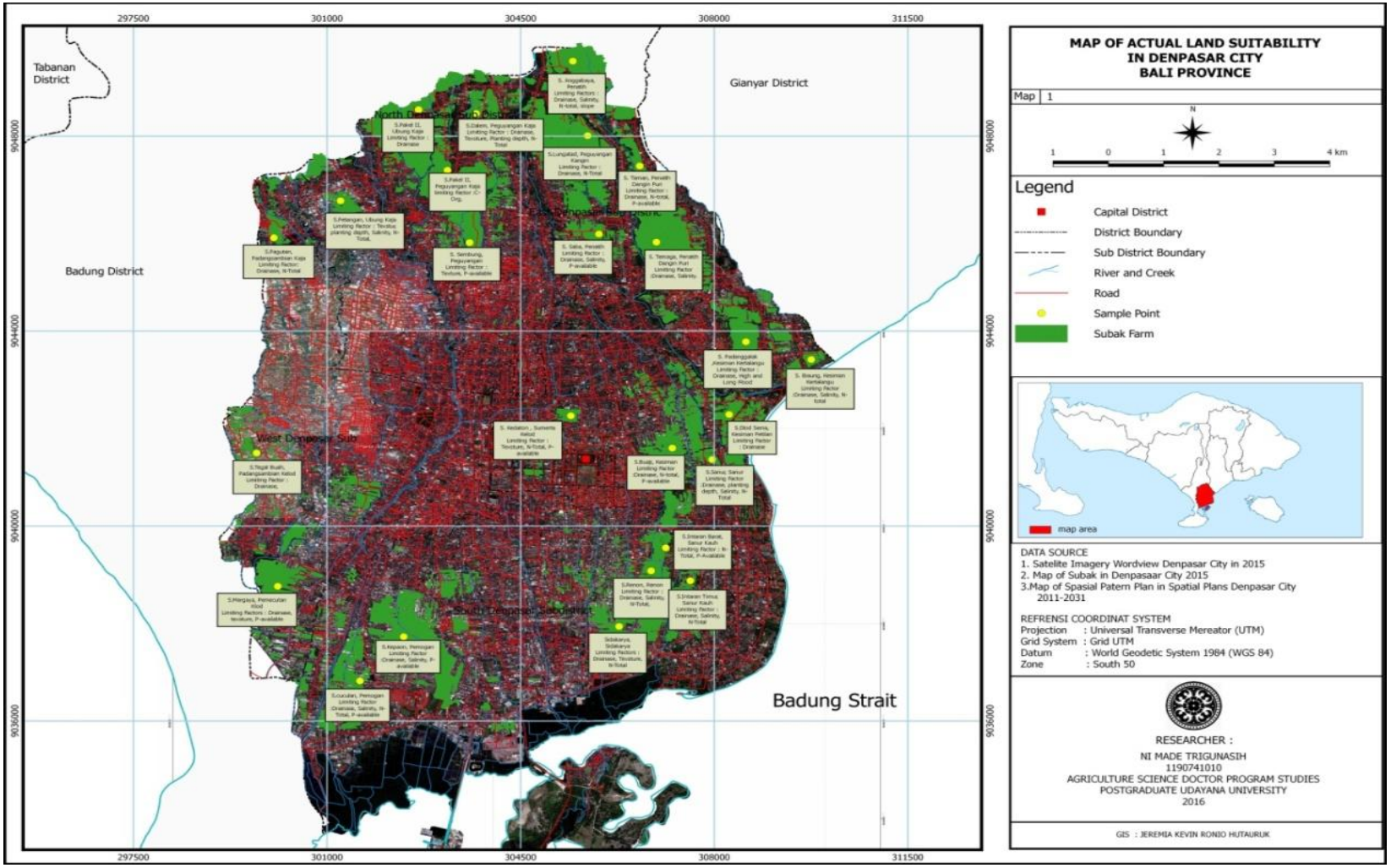

Figure 1. Map of Actual Land Suitability rice field in Denpasar City

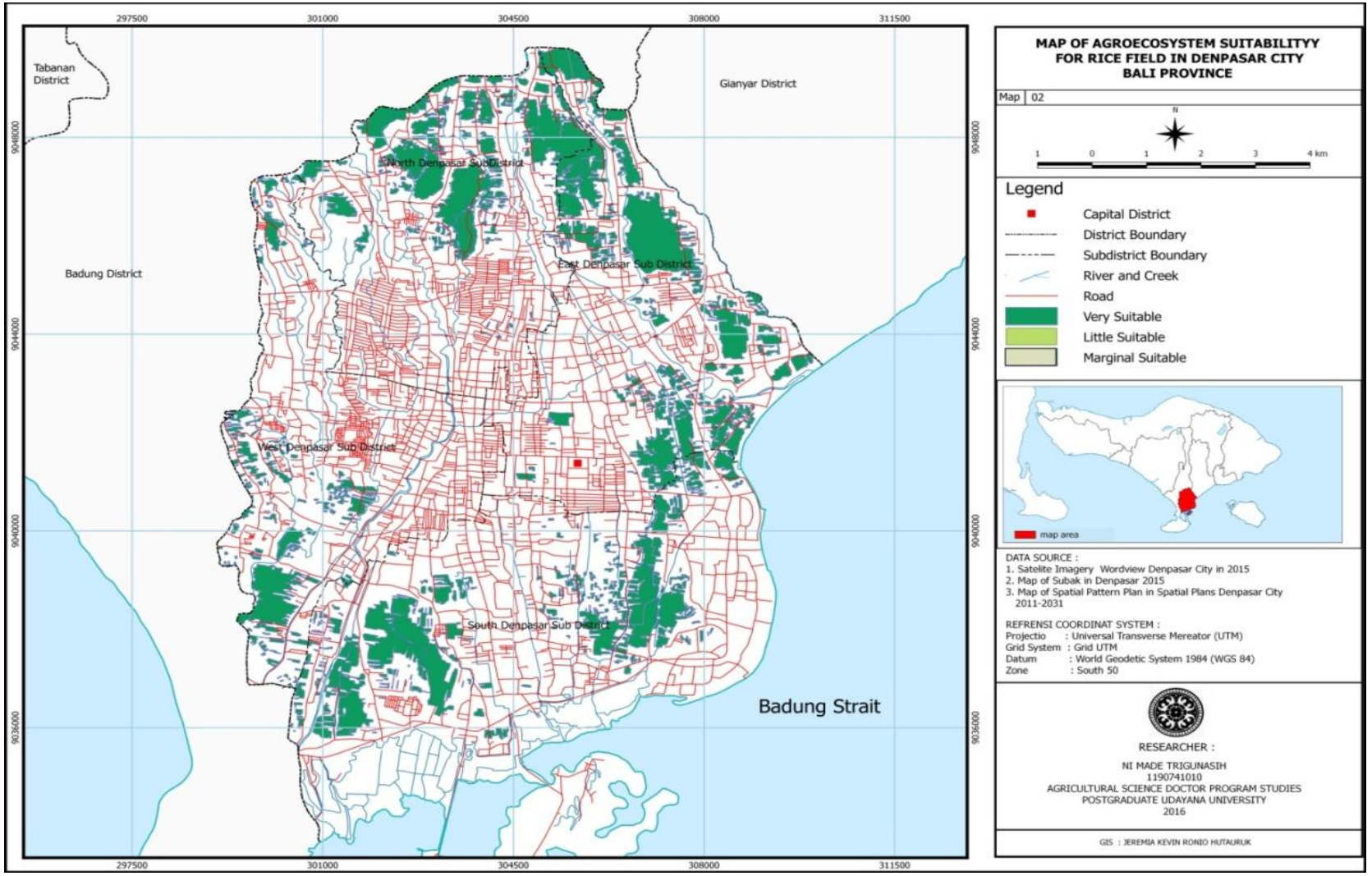

Figure 2. Map of Potential Land Suitability Rice Field in Denpasar.

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