RES MILITARIS
REVUE EUROPEENNE D ETUDES EUROPEAN JOURNAL OF MILITARY STUDIES
Social Science Journal

Geographical Information System and Analytical Hierarchy Process Technique for Mungbean Cultivation

By

Mar Heisen A. Yanos
Email: marheisen.a.yanos@isu.edu.ph

Johna Mae B. Udan
Email: johnamae.udan@gmail.com

Abstract

Growing crops has always hinged on the availability of land. The classification of land suitability entails the appraisal and grouping of a particular geographical area based on its suitability for a specified purpose. Land appropriateness is the degree to which a piece of land is suitable for a particular use. In this study, a multi-criteria evaluation method was employed to identify and delineate the area in San Mateo, Isabela that is most conducive to the growth of the mung bean plant. Using GIS technology to develop a spatial model for evaluating land suitability for mungbean production and to generate a suitability map by classifying agricultural land in the research region into multiple suitability classes according to a set of criteria and limitations. It is vital to analyze land's appropriateness for specific agricultural output in order to avoid environmental damage. The optimal constraint approach was utilized to determine the soil qualities, agroclimatic conditions, and topography that influence the production of mungbean products. After harvesting rice, farmers in San Mateo, Isabela, known as the "Munggo Capital of the Philippines" plant mungbeans.

Keywords: Suitability analysis, map, GIS, AHP, San Mateo, Mungbean

Introduction

Use of rich natural resources, such as land, in a sensible and sustainable manner is one of the most important indicators of economic progress. Sustainable agriculture is a global priority for all nations. Due to urbanization and population growth, which make land a relatively scarce resource for agricultural and rangeland purposes, there is a greater need than ever for effective land utilization. Therefore, it is essential to match land capacities and land uses in the most efficient manner possible. (Zarkesh et al. 2010).

The application of technologies is demanded by the growing global population and the increasing demand on land resources. The combination of the geographic information system methodology and the multi-criteria decision-making method is a potent instrument for geographical analysis. (Yu et al. 2009). Geographic information system (GIS) is a computer system that can acquire, store, retrieve, manipulate, analyze, and display geographically related (spatial) data to support development-oriented management and decision-making processes. (Aboyade, 2001). The basic multi-dimensional process of determining whether a piece of land is suitable for development involves a number of different criteria and environmental elements (Patil et al. 2012). A well-known strategy to get around the challenges of assigning relative weights to several criteria when deciding whether or not to use a land mapping unit is multi-criteria analysis (Bagheri et al. 2012). The Analytic Hierarchy Process (AHP) is a commonly used method for examining many criteria that assists in resolving complex decision-making procedures including a multitude of distinct elements, scenarios, and criteria.

The primary purpose of the study was to apply a multi-criteria evaluation technique to identify and delineate the property in San Mateo, Isabela, that can optimally support the growth of mungbean plants. Using GIS technology, build a spatial model for land suitability evaluation for mungbean production and a suitability map by classifying agricultural land in the research region into several suitability classes. Analysis and mapping of appropriateness is one of the most effective management and planning techniques. Consequently, the investigation was conducted.

Methodology

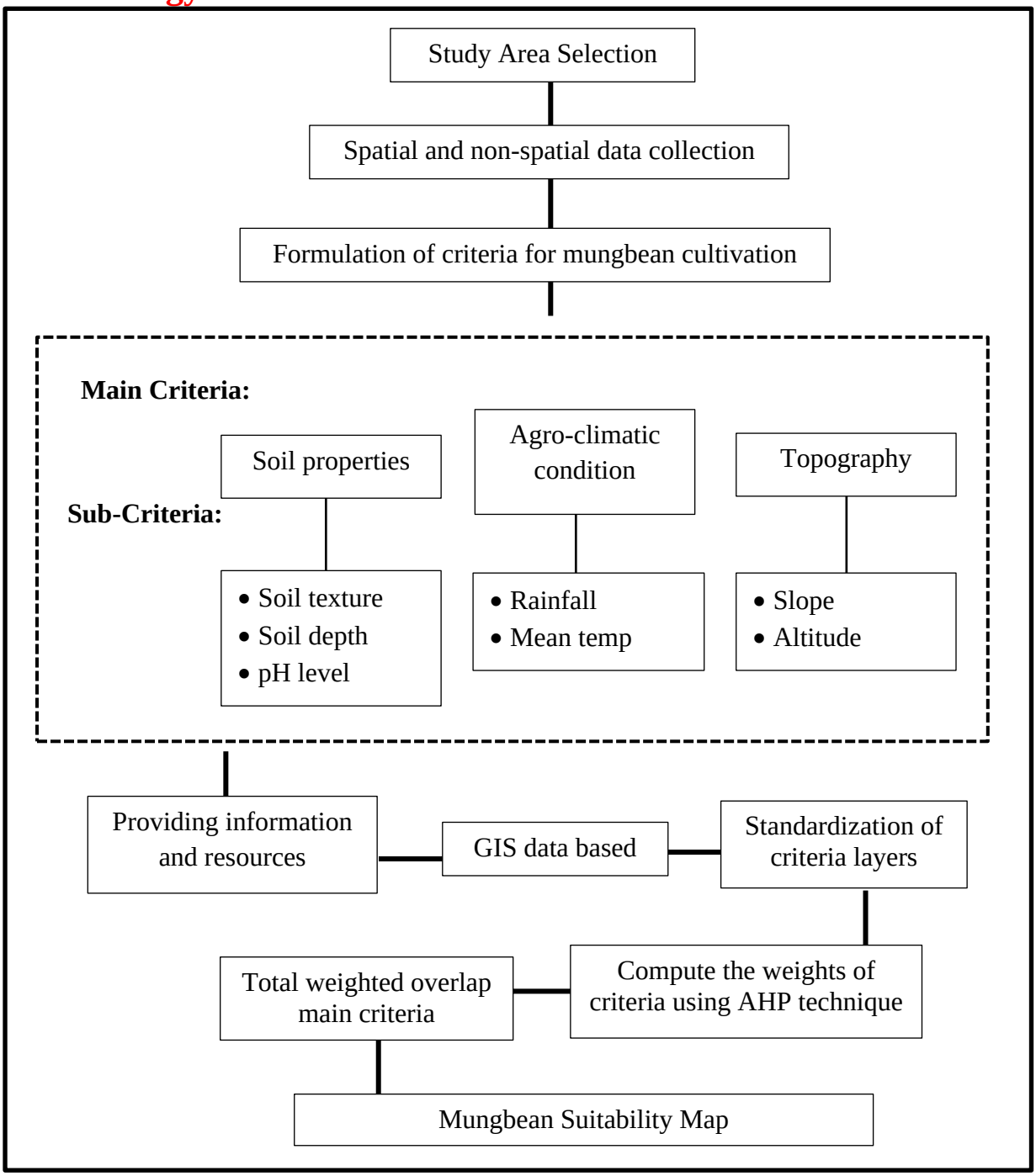

Figure 1. *Flowchart of the Study*

Study Area

The study was conducted in Region II (Cagayan Valley) in the Province of Isabela, Municipality of San Mateo (Figure 2). This municipality spans 10,059.83 hectares in southwestern Isabela between 16° 52' 52.4" north and 121° 35' 16.2" east. The elevation of the study area is 171 to 276 feet.

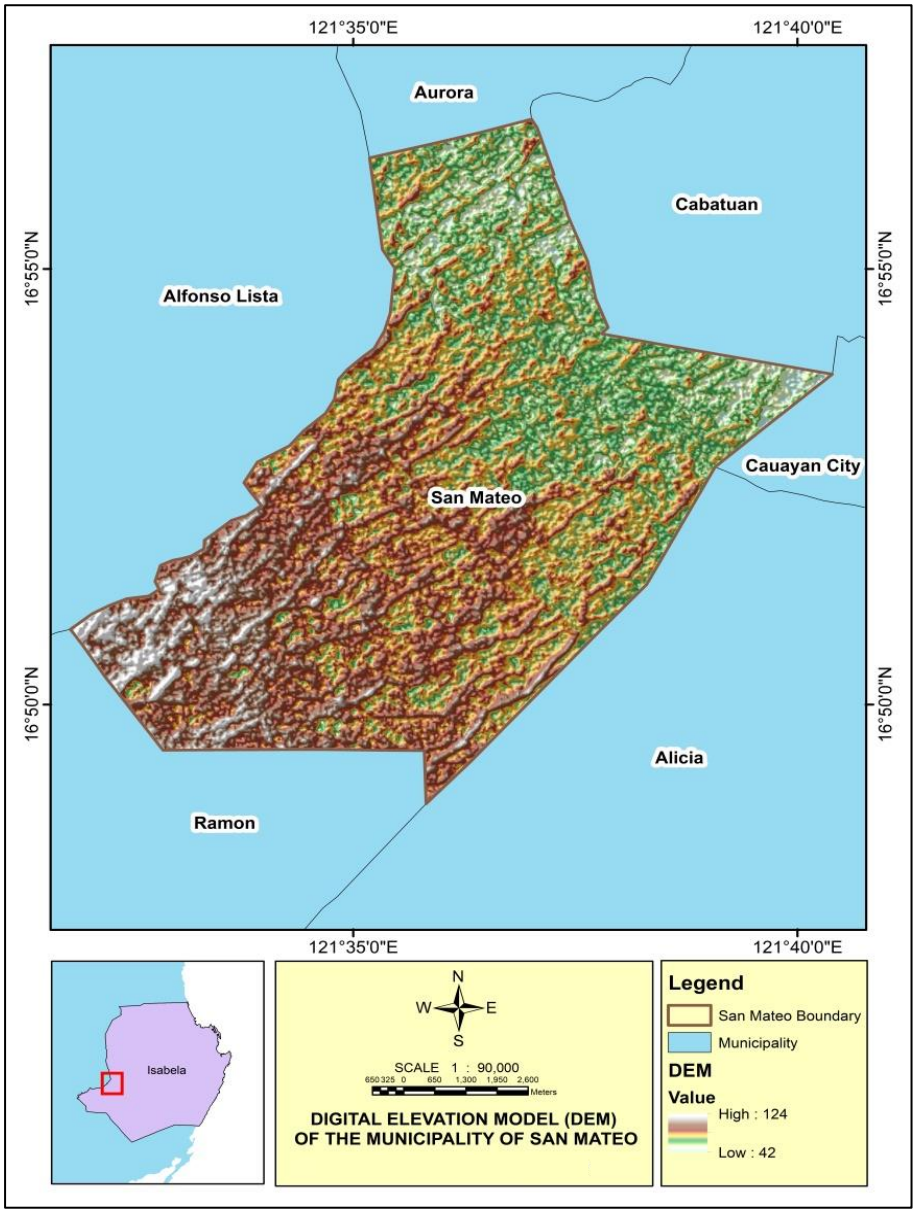

Figure 2. *The Study Area.*

Datasets Used

The following datasets were used to make this research a possibility.

1. Satellite Image (Landsat-8 UTM; Thematic Mapper) of the year 2019 used for land use map generation.
2. Elevation data.
3. 3. Soil thematic map obtained from FAO (1999).
4. ERDAS Imagine was used to analyze the study's accuracy within the study region. Per year, 40 random points were used. NAMRIA provided the study's border.

5. 5. Download USGS DEM (Digital Elevation Model) for slope and elevation map development.
6. 6. Climate data: Rainfall and temperature datasets for the current investigation were derived from regular San Mateo weather.

Selection of Evaluation Criteria

The specified criteria must guide the eventual outcome and highlight the decision-making environment (Prakash 2003; Kihoro et al. 2013). A multi-criteria assessment technique was utilized to determine a parcel's suitability, and its criteria used geographical, non-spatial, qualitative, and quantitative data (Chen et al. 2010). Soil qualities, agro-climatic conditions, and topography are key considerations.

Soil Properties

Choosing "which crops to grow where" and other associated crops is based on information from land evaluation for agricultural purposes. One of the crucial aspects of soil is texture. The majority of the soil's physical and chemical features are influenced by its texture class. (Mustafa et al. 2011). Soil texture affects water retention, infiltration, aeration, nutrient absorption, tillage, microbiological activity, and irrigation. (Foth 1990; Gupta 2004). It's a natural, untreated soil property.

When choosing soils for agricultural purposes, the depth of the soil that can be used by crops is important. Many irrigated crops give great yields with a well-drained effective root depth of 90 cm, according to expertise.

Soil reaction is the acidity or alkalinity generated by a chemical, mineral, or biological environment (Tilahun 2007). pH affects plant nutrition and soil fertility. Soil qualities were considered in the criteria.

Agro-climatic Conditions

One of the primary variables impacting the growth of plants is precipitation (rainfall). Typically, 400 mm of precipitation per year is regarded as ideal for plant growth. (Jafari and Zaredar 2010).

Extreme temperatures are crucial for forecasting thermal consequences. It is important in the treatment of living things, as well as in the production of food, beverages, and agriculture. It is uncommon for average temperatures in temperate regions to rise above those that are ideal for many crops and organisms (Deutsch et al., 2008). As a result, these two (2) criteria were fulfilled.

Topography

Slope and elevation make up topography. These factors affect agricultural land's appropriateness and must be considered while buying.

Geomorphologic characteristics are intimately related to soil formation. The primary aspect in determining erosion control is slope degree. (Koulouri and Giourga 2007). An increase in slope degree delays soil formation and reduces soil depth and fertility. (Atalay 2006).

Elevation affects agricultural land due to temperature changes and differences in plant cover. For every 100 m of elevation gain on the mountains, the seasons of vegetation and bloom

are postponed by 4-6 days. This information affects the agricultural plant species chosen. (Atalay, 2006).

GIS Software and Mapping

ERDAS Imagine software was used to construct land cover maps using Landsat photos, digital elevation models, and soil data. Land Use Land Cover (LULC) mapping data was acquired from sample sites and evaluated using supervised classification. Thematic maps of soil parameters such as soil depth, pH level, and soil texture class were created in Arc Map using the ArcGIS tools procedure. After that, the classified images were masked to the location of the study in order to quantify the areas (ha) of each class.

Standardization of Criteria

After preparation, maps needed standardization. Distinct input maps may have different meanings and measurement units (e.g. the slope map in terms of percentage, temperature in terms of degree, etc). In this work, GIS-based land suitability analysis using AHP (Joerin et al., 2001) as MCDA was used. It allows GIS-based site appropriateness modeling (Mendoza, 1997). Spatial analysis in agriculture uses AHP-based MCDM.

This study analyzed three primary (soil, climate, topography) and seven minor criteria (soil texture, soil depth, soil pH level, rainfall, temperature, slope, and elevation). The parameters were chosen after consulting crop experts and reviewing mungbean plant literature.

Computation of Weighing Factors from AHP

AHP is an intuitive method for tackling Multi-criteria Decision Making (MCDM) problems and articulating and analyzing conclusions (Saaty 1980; Weiss 1987; Jun 2000; Girard and Toro 2007).

The AHP online calculator compared mungbean study parameters. Using the Eigen vector approach of the Analytic Hierarchy Process, calculate pairwise priorities (AHP). This study used these steps. First, name all seven criteria. Next, compare each set of criteria to determine which is more important and by how much. Check consistency will provide you the results, their order, and a consistency ratio (CR) that should be less than 10%. The calculations used the 1 to 9 AHP scale.

Resulting Priorities

Priorities

These are the resulting weights for the criteria based on your pairwise comparisons:

Cat		Priority	Rank	(+)	(-)
1	Soil Texture	28.8%	1	12.3%	12.3%
2	Soil Depth	27.8%	2	11.1%	11.1%
3	pH Level	16.9%	3	7.2%	7.2%
4	Rainfall	10.0%	4	4.3%	4.3%
5	Mean Temperature	7.0%	5	3.1%	3.1%
6	Slope	4.8%	6	2.1%	2.1%
7	Elevation	4.7%	7	1.4%	1.4%

Number of comparisons = 21
Consistency Ratio CR = 6.4%

Decision Matrix

The resulting weights are based on the principal eigenvector of the decision matrix:

	1	2	3	4	5	6	7
1	1	2.00	2.00	3.00	5.00	3.00	4.00
2	0.50	1	3.00	4.00	4.00	5.00	5.00
3	0.50	0.33	1	3.00	4.00	3.00	3.00
4	0.33	0.25	0.33	1	2.00	4.00	2.00
5	0.20	0.25	0.25	0.50	1	2.00	3.00
6	0.33	0.20	0.33	0.25	0.50	1	1.00
7	0.25	0.20	0.33	0.50	0.33	1.00	1

Principal eigen value = 7.512
Eigenvector solution: 6 iterations, delta = 1.5E-8

Figure 3. *The Result of AHP Calculation*

Figure 3 shows the comparison matrices used to determine the alternative weights and scores. Weights for soil texture (28.8%), soil depth (27.8%), soil pH (16.9%), rainfall (10%), mean temperature (7.0%), slope (4.8%), and elevation (4.7%) were highest. The comparison matrix was 6.4% consistent, which means the factor matrix was consistent (less than 10%). Alternative matrices had acceptable consistencies.

The data on mungbean farming was categorized as suitable (S1), somewhat suitable (S2), and not suitable (N). Table 1 summarizes mungbean growing conditions based on research and expert opinion.

Table 1. *Factors used for mungbean cultivation.*

S/n	Factors Type	Weight (%)	Suitability Range		
			S1	S2	N
	Soil Properties	**73.7**			
1	Soil texture	28.8	Loam (sandy-loam)	Clayey-sandy (silt clay)	-
	Soil depth (m)	27.8	> 0.50	0.5 to 0.3	< 0.30
	Soil pH level	16.9	5.1 to 8.0	0 to 5.0	8.1 to 13.0
	Agro-Climatic Condition	**17.0**			
2	Rainfall (mm)	10.0	35.0 to 60.0	61.0 to 100.0	< 35.0
	Mean temperature (°C)	7.0	20 to 30	31 to 40	> 20
	Topography	**9.5**			
3	Slope (%)	4.8	0 to 10	11 to 20	> 30
	Elevation (m)	4.7	1 to 1,500	1,501 to 2,000	< 2,000

Results and Discussion

Land Suitability Classes of Mungbean Crop

AHP was used to weigh each criterion and sub-criterion (parameters). In San Mateo, Isabela, AHP and GIS were used to analyze mungbean-growing land. AHP uses a multi-criteria method to assess mungbean adaptability.

Land should be used to serve human needs and ecosystems. Incorrect land use causes land depletion, poverty, and other societal problems due to shifting requirements and pressures. FAO (1976, 1977, 2006) Using GIS techniques, this research established three (3) appropriateness classes for mungbean spatial locations. After employing spatial analytic methods to weigh and classify factors, crop suitability is determined. FAO (1976) standards generated the three classification themes. Using AHP weights for the various characteristics, maps of soil attributes (texture, depth, pH level), Agro-climatic variables (rainfall and mean temperature), and topography (slope and elevation) were superimposed to construct the mungbean suitability map of San Mateo, Isabela.

Spatial Suitability of Mungbean Crop

The multi criteria approach classification result showed that there are three (3) applicable classes in San Mateo, Isabela to estimate the mungbean crop suitability ranges.

Based on the 2019 Landsat satellite images data and using the supervised classification in Geographical Information System (GIS), the study area was classified into three (3) categories, that is, suitable, moderately suitable and not suitable. As shown in Table 2 and depicted in Figure 4, the suitable area for mungbean cultivation calculated was 6,070.86 ha of the land which gains the largest portion of 63.62 percent in the study area. The total area of

2,370.15 ha of land was computed as moderately suitable (24.84 percent). On the other hand, 1,101.60 ha (11.54 percent) of the overall research area is permanently not suitable for mungbean cultivation. Mungbean determined to be more or less equal in appropriateness for the majority of the study area, as per the suitability analysis.

Table 2. *The mungbean spatial suitability class range.*

No.	Suitability Class	Area (ha)	Percentage (%)
1	Suitable	6,070.86	63.62
2	Moderately Suitable	2,370.15	24. 84
3	Not Suitable	1,101.6	11.54
	Total	**9,542.61**	**100.00**

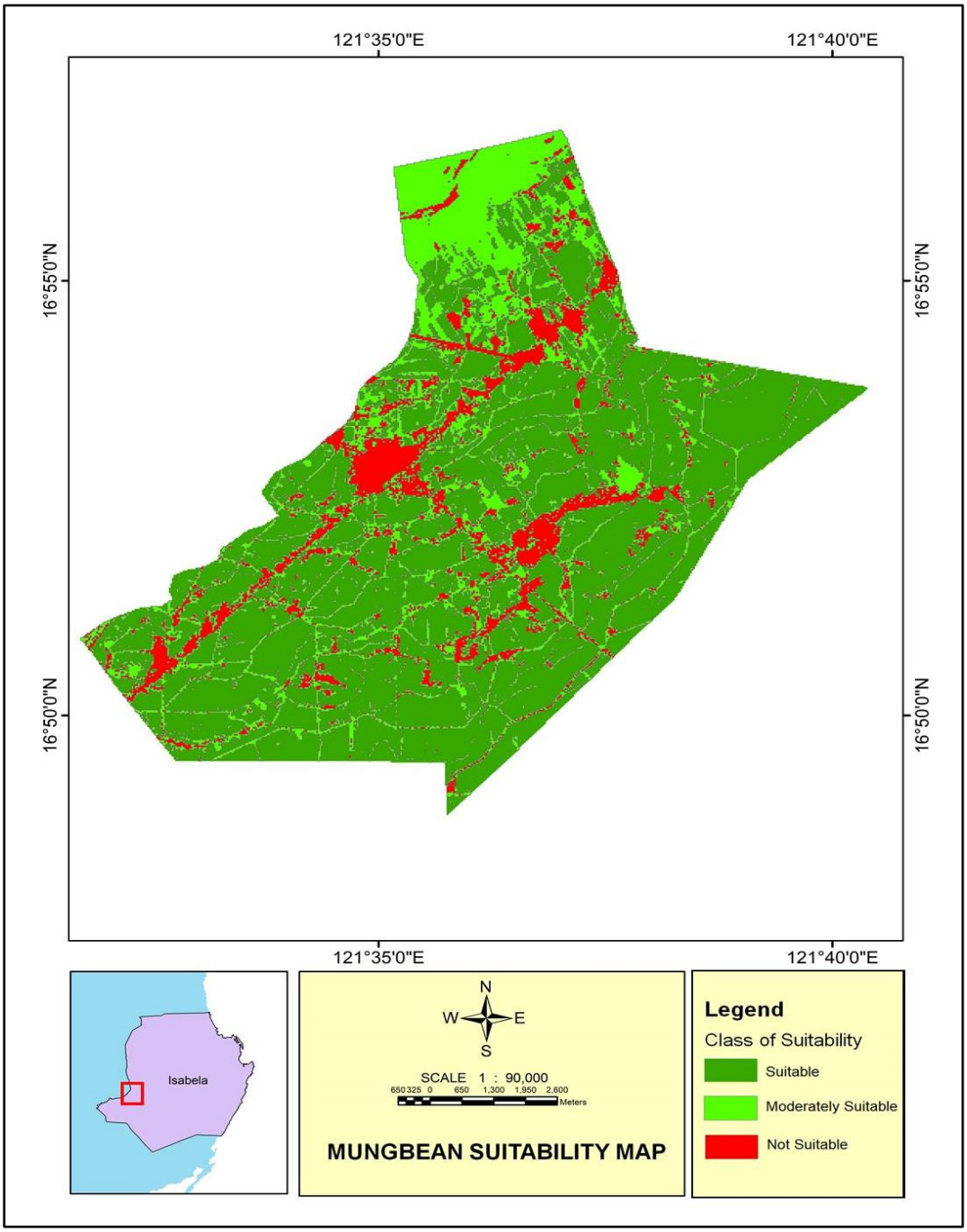

Figure 4. *The Suitability Map of the Study Area for Mungbean Cultivation*

Conclusion and Recommendation

Using GIS and AHP, researchers evaluated mungbean agriculture in San Mateo, Isabela. An applied GIS and AHP-based agricultural land suitability analysis finds productive sites. To account for AHP's influence on appropriateness classification, criterion and sub-criteria weights were estimated. 63.63% of the research area is favorable for mungbean agriculture, 24.84% is moderately acceptable, and 11.54 % is unsuitable. This study uses GIS and AHP to plan mungbean cultivation. It can also provide direction for future land use modifications and cost-effective solutions in San Mateo, Isabela, and other agro-climatic zones.

References

Chen Y., Khan S., Paydar Z. (2010): To retire or expand. A fuzzy GIS-based spatial multi-criteria evaluation framework for irrigated agriculture. Irrigation and Drainage, 59: 17–188.

Erensal Y.C., Oncan T., Demircan M.L. (2006): Determining key capabilities in technology management using fuzzy analytic hierarchy process: A case study of Turkey. Information Sciences, 176: 2755–2770.

Joerin, F., Theriault, M., and Musy, A. (2001). Using GIS and outranking multicriteria analysis for land-use suitability assessment. Int. j. of geographical information science, vol. 15, No. 2, 153-174.

Malczewski J. (2004): GIS-based land-use suitability analysis: a critical overview. Progress in Planning, 62: 3–65.

Prakash T.N. (2003): Land suitability analysis for agricultural crops: a fuzzy multi criteria decision making approach. [MSc. Thesis.] Enscheda, International Institute for Geo Information Science and Earth Observation.

Reshmidevi T.V., Eldho T.I., Jana R. (2009): A GIS-integrated fuzzy rule-based inference system for land suitability evaluation in agricultural watersheds. Agricultural Systems, 101: 101–109.

Yu J., Chean Y., Wu J.P. (2009): Cellular automata and GIS based land use suitability simulation for irrigated agriculture. In: 18th World IMACS/MODSIM Congress, Cairns, July 13–17, 2009: 3584–3590.

"More than 'munggo': Isabela's San Mateo is an Agro-ecological City in the making". BusinessMirror. Retrieved August 15, 2013.

"Province: Isabela". PSGC Interactive. Quezon City, Philippines: Philippine Statistics Authority. Retrieved 12 November 2016.

"San Mateo, Isabela: Average Temperatures and Rainfall". World Weather Online. Retrieved 31 October 2015