Potential of cassava production as energy feedstock in Cambodia: Assessment of land suitability using GIS Approach

Teamhy Sien[1], Penwadee Cheewaphongphan[1] and Savitri Garivait[1,*]

[1] *The Joint Graduate School of Energy and Environment (JGSEE), Center of Excellence on Energy Technology and Environment (CEE-PERDO), King Mongkut's University of Technology Thonburi (KMUTT), Bangkok, Thailand*
**Corresponding Author: Tel: 02-470 8309-10 ext 4134, Fax: +66 2 872 9805, E-mail address: savitri_g@jgsee.kmutt.ac.th*

Abstract: Cassava is one of the most important upland crops in Cambodia. Most of cassava production is used for human food, animal feed, industrial feedstock, and for export. This study aims to evaluate the land suitability for cassava plantation in Cambodia. The study has developed a methodology adapted from the FAO's guidelines for selecting suitable cultivation areas. A suitability weights and scores were assigned to each physical soil parameters and climate data, followed AHP approach. In addition, land use-land cover map was accounted for this analysis to identify the present and potential land use. The land suitability then was grouped into four classes: highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and not suitable (N).
The obtained results indicated that possible area for cassava plantation as a whole are: 9.64% under highly, 5.11% under moderately, 1.11% under marginally, and 0.65% under not suitable area, respectively. Also, it was found that more than 2 million hectares of land converted from forestland but currently unused are potentially available for cassava plantation with possible high productivity. The developed land suitability map for cassava plantation can serve as references for cassava production planning in Cambodia, as well as for evaluating the national potential for this food and energy crop supply.

Keywords: Cassava production; Land suitability; Suitability map; Cambodia.

1. Introduction

In Cambodia, cassava is one of the most important economic crops for human food, animal feeds, and industrial feedstock. More recently, it becomes an important candidate for energy bioethanol. The Cambodian annual cassava production varies according to the market or demand condition [1]. Currently, the production of cassava has expanded rapidly and the export is increasing steadily driven mainly by demand (both for domestic consumption and re-export). Recently, the Royal Government of Cambodia is planning to attract more foreign investment in the cultivation of cassava to produce bioethanol [2].

In this study, we developed an analysis of land suitability for cassava plantation for energy bioethanol production, using FAO guidelines for land evaluation combined with AHP to weight the importance of each parameter involved in the calculations. All data were collected and processed in ArcGIS to geographically visualize and assess the potential of cassava production as feedstock for energy bioethanol production throughout the country.

2. Experimental

2.1 Land Suitability Assessment Method

The assessment of land suitability for cassava plantation method was developed based on the FAO guidelines [3-4], which consist in matching between land characteristics and crop requirements. We adapted the FAO guidelines to Cambodia by allocating weight to parameters involved in the calculation using the Analytic Hierarchy Process (AHP) methodology and weight values from literature review [5-8]. The degree of suitability of each parameter for a unit of land was classified into 4 classes following the FAO classification, namely: highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and not suitable (N). Land suitability classes and associate scores for cassava production are shown in Table 1.

2.2 Datasets

For land suitability assessment, 6 parameters of crop requirements including soil properties (soil fertility, soil drainage, and soil depth), climatic data (annual rainfall and mean temperature), and topography were selected from 1976 FAO guidelines. The mean temperature and annual rainfall data were estimated from their long-term observation data during 1950 to 2000 available on the World Climate Database (WCD). Data on root condition (soil depth) and oxygen availability (soil drainage), were collected from the FAO Harmonized World Soil Database. The soil fertility data were from the national database developed by Charles Crocker and a scientific Cambodian Team in 1961 for 16 soil types, which were classified into 3 main groups: higher fertility, medium fertility, and low fertility [9]. The slope data were generated from a digital elevation model from the US National Aeronautics and Space Administration (NASA) and Shuttle Radar Topographic Mission (SRTM).

Table 1 Classification of land suitability and associate score for cassava plantation.

Cassava crop requirements			Land suitability classes and scores			
Parameter	Factor	Unit	S1	S2	S3	N
			1	0.8	0.5	0
Temperature	Mean Temperature	°C	25-29	30-32 24-14	33-35 13-10	>35 <10
Soil moisture availability	Annual rainfall	mm	1,600–2,500	1,200–1,600	900–1,200	<900
Oxygen availability	Soil drainage	class	Very well/ well	Moderately well/somewhat well	somewhat poor	Very poor/ poor
Rooting condition	Soil depth	cm	>100	50-100	25-50	<25
Soil workability	Soil fertility	class	highly fertility	Moderately fertility	low fertility	Very low fertility
Erosion hazard	Slope	%	0-5	5-12	12-20	>20

2.3 Determination of Weights and Scores

Weights and scores of land suitability class for each parameter of crop requirement were determined based on Analytical Hierarchy Process (AHP) approach [10-11]. This method enables to evaluate the relative significance of all parameters involved in the calculations by assigning a weight for each of them in a hierarchical order. In this study, weights and scores for each were adapted from a research study by Phongaksorn (2012), which also used the AHP approach with experts' opinion/judgment on the relative importance between factors. Weights and their associate to factors involved in use in this study are summarized in Table 2.

Table 2 Weight of each factor.

Weight of each factor based on AHP	
Factor	**Weight**
Mean Temperature	0.041
Annual rainfall	0.117
Soil Fertility	0.417
Soil Drainage	0.218
Soil Depth	0.132
Slope	0.076

2.4 Evaluation of Land Use Change during 2002-2014

The land use – land cover (LULC) map of Cambodia set for the year 2002 was the most recent one available, and was used as the base-map. We updated this latter using the 2013 crop statistics were used to quantify the change of agriculture land during 2002-2013, and the forest cover map established for the year 2014 to document the change in forestland over 2002-2014.

3. Results and Discussions

3.1 Updated Land Use-Land Cover Map of Cambodia

The updated LULC map of Cambodia from the base-map of 2002 is shown in Fig. 1. LULC was classified into 10 LU categories, namely: forestland, paddy field, upland crops, converted (or currently unused) area, existing cassava area, grassland, shrub land, urban and built-up lands, barren land and rocks, and water bodies. The area of each LU category is reported in Table 3.

From Fig. 1 and Table 3, it was found that the converted (or unused) land covers about 10% of the whole country, which is mainly located in the north and northeastern regions. This unused land could serve as potential additional land for cassava plantation.

Table 3 Area of each LU category in the updated LULC map of Cambodia.

Land Use Category	Area (ha)	Proportion (%)
Forest Lands	8,659,112	47.69
Upland Crops	690,922	3.80
Paddy Fields	3,052,420	16.81
Existing Cassava area	421,375	2.32
Converted/Unused land	1,767,239	9.73
Grass Lands	1,078,249	5.94
Shrub Lands	1,883,692	10.37
Barren and Rocks	36,840	0.20
Urban Build-up Area	18,068	0.10
Water Bodies	552,017	2.98
Total	**18,103,895**	**100.00**

3.2 Potential of Cassava Production in Cambodia

The spatial distribution of land suitability for cassava production in Cambodia is shown in Fig. 2. The coverage area per each land suitability class is reported in Table 4. The result showed that about 80% of Cambodia is covered by S1 (highly suitable) (about 50%) and by S2 (moderately suitable) (about 30%), respectively. The S1 areas are located mainly the area of Tonle Sap basin and upper and lower Mekong River (Mekong Delta), while S2 are more prevalent in the south.

The overlaying of the updated LULC map with the land suitability for cassava plantation map enabled to document locations suitable for cassava production at provincial level (Fig. 3). The portion of land and its suitability for cassava plantation in each province is summarized in Table 5.

From Figs. 3-4 and Table 5, it was found that S1 cover 9.64% (1.7 million ha) of the whole country, and mainly located in Kampong Cham, Battambang, Kratie, Ratanakiri, Preah Vihear, Kampong Thom, and Siem Reap. S2 embraces 5.01% (0.9 million ha) of the whole country and is included also in Kratie, Preah Vihear and Siem Reap province.

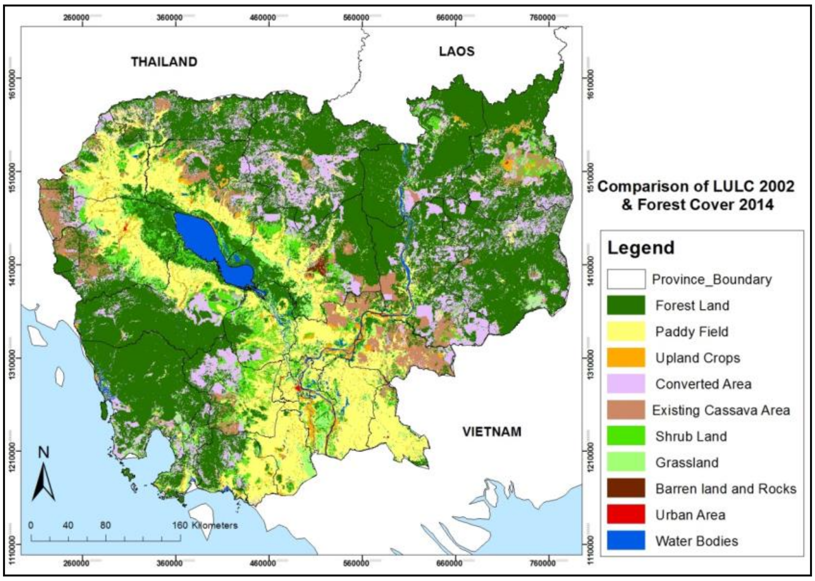

Fig. 1 Updated LULC map of Cambodia using 2002 LULC map and 2014 forestland cover map 2014

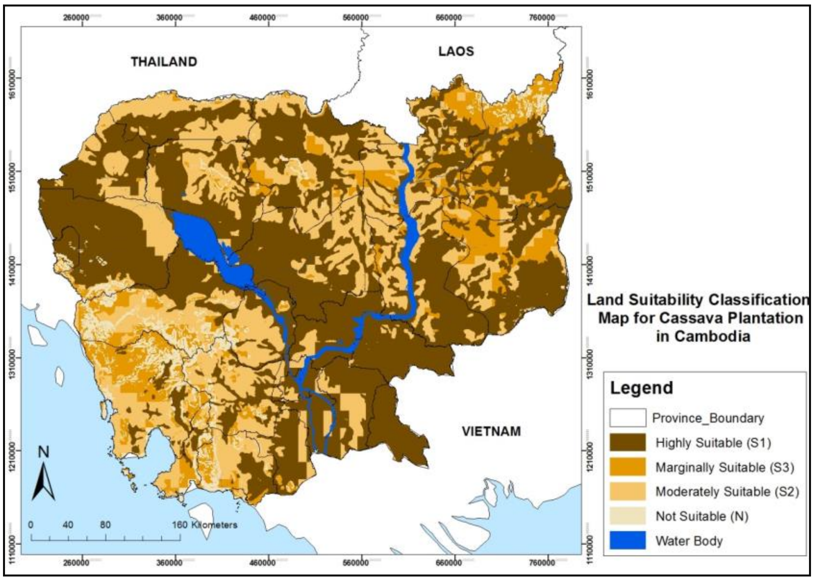

Figure 2 Map of land suitability for cassava plantation in Cambodia.

Table 4. Coverage area vs. land suitability class for cassava plantation in Cambodia.

Suitability Class	Suitability Index	Area (ha)	Proportion (%)
Highly Suitable (S1)	0.76 – 1.00	9,200,307	50.65
Moderately Suitable (S2)	0.51 – 0.75	5,340,694	29.39
Marginally Suitable (S3)	0.26 – 0.50	2,126,978	11.71
Not Suitable (N)	0.00 – 0.25	957,078	5.27
Water Bodies		552,017	2.98
Total		**18,103,895**	**100.00**

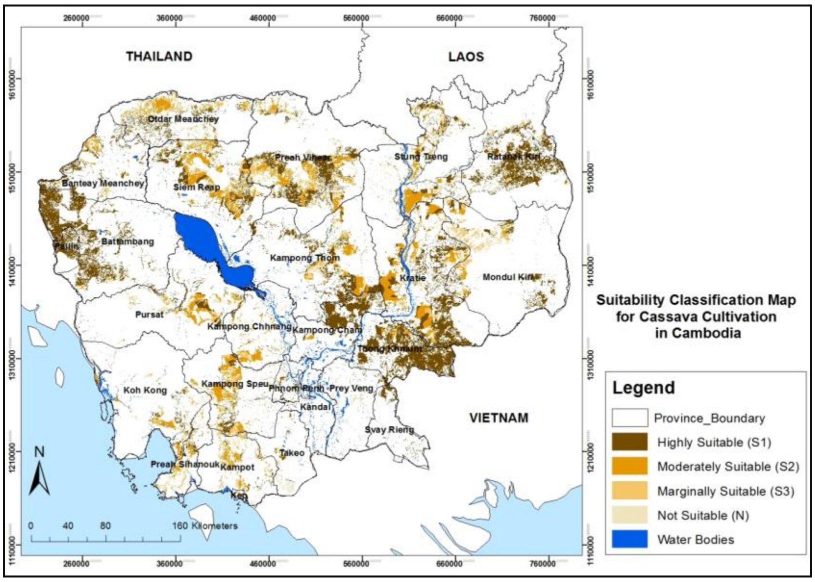

Fig. 3 Land suitability map for cassava plantation by province in Cambodia

Table 5 Coverage area vs. land suitability class for cassava plantation in Cambodia

Suitability Class	Suitable Area		Current Cassava production area	
	Area (ha)	Proportion* (%)	Area (ha)	Proportion** (%)
Highly Suitable (S1)	1,751,621	9.64	318,796	75.66
Moderately Suitable (S2)	909,234	5.01	88,352	20.97
Marginally Suitable (S3)	201,492	1.11	10,571	2.51
Not Suitable (N)	118,564	0.65	3,657	0.87
Total	**2,980,911**	**16.41**	**421,375**	**100.00**

* Share calculated from the total area of Cambodia.

** Share referring to the current total cassava production area.

4. Conclusion

In this study, we applied spatial analysis using GIS and FAO land suitability model for crop production to identify suitable areas for cassava plantation in Cambodia. The AHP method based on recent study in Thailand was used to weight and score the crop requirement parameters. The obtained results showed that a large proportion of land converted from forestland (more than 2 Mha), but currently unused is available for cassava plantation with possible high productivity, since most of it is located on highly suitable land (S1) class.

Acknowledgement

This work was supported and sponsored by the Joint Graduate School of Energy and Environment, Center of Excellence on Energy Technology and Environment (CEE) – S&T Post-Graduate Education and Research Development Office (PERDO), Thailand.

References

[1] CTIS, Cambodia Trade Integration Strategy 2014-2018 Full Report (2014) January, pp. 317–334.

[2] ERIA, *Study on Asia Potential of Bioethanol Market Working Group, Biofuel Promotion and Development in East Asia Countries* (2013) [Online].

[3] Food and Agriculture Organization of the United Nation (FAO), *A framwork for land evaluation* (1976) Soils Bullentin 32.

[4] Food and Agriculture Organization of the United Nation (FAO). *Land Evaluation for Rainfed Agriculture* (1983) Soils Bullentin 52/253.

[5] Food and Agriculture Organization of the United Nation (FAO), *Guidelines for land evaluation for rainfed agriculture* (1984) Soils Bullentin 52.

[6] Mongkolsawat C, Thirangoon P, Kuptawutinan P, Land Evaluation for Combining Economic Crops using GIS and Remotely Sensed Data, *Proceddings 2nd Asia Pacific Conf. Sustain* (1999) Agric. Pitsanulok, no. October 18–20 1999.

[7] Tunsiri K, Saifak B, *Manual of qualitative land evaluations for economic plant* (1999) Bangkok: Land Development Department, Ministry of agriculture and Cooperative.

[8] Phongaksorn N, *Geospatial and suitability modeling for biofuel crops using fussy AHP* (2012) Master Thesis, Asian Institute of Technology.

[9] GTWAW, *Technical Working Group Program Design Document Annexes for Strategy for Agriculture and Water 2010-2013* (2010).

[10] Saaty TL, A scaling method for priorities in heirarchical structure, *Journal of Mathematical Psychology* 15 (1977) 234-281.

[11] Saaty TL, *Multi criteria decision making- The Analytic Hierarchy Process* (1990) Ellsowrth Avenue: RWS Publication

.

