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Application of Geographic Information Systems in identifying accessible sites for Jatropha curcas production in Ethiopia

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Abstract

Jatropha curcas L. is an oil bearing plant growing in tropical and subtropical regions of the world. This plant is considered to be a potential solution to the prevailing shortage of fossil fuel and the resulting environmental impacts. Cognizant of this, governments have given considerable attention to develop biodiesel technologies including that of jatropha. Development of biodiesel technologies has also attracted interest of national and international investors in Ethiopia.

However, there is a gap of information with regard to how much land can potentially be allocated for biodiesel development. In this study, Geographic Information System (GIS) was used to identify those potential areas. Data of relevant environment factors influencing growth and productivity of jatropha such as climate, soils and topography were used for this purpose.

Generally, results of overlay analysis for biophysical suitability evaluation using GIS identified 15.07 % and 76.57 % of the land as highly suitable and moderately suitable for jatropha production, respectively. The main limiting factors identified in this study are elevation, climate and water logging condition of soils. Sensitivity analysis based on land use change patterns shows that the size of suitable sites decreases significantly. Around 42 % of the suitable sites were also identified as accessible by road and railway transport systems at distances less than 20 kilometres.

In general, adequate land is available for jatropha investment in the country. However, allocation of land for jatropha production should be done based on accessibility of the identified suitable sites to transport facilities.

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Keywords: GIS; land suitability; Jatropha curcas L.; sensitivity analysis; Ethiopia; consistency ratio.

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1. Introduction

Declining trends in the global energy supply and consequences of climate change have created huge global concern. As a result, many countries are making efforts in developing clean energy options [1, 2, 3]. High fossil fuel prices and national security concerns have also sparked interest in bio-based fuel development in different parts of Africa [4].

As a result of its huge population, which reached about 89.2 million in 2013 [5], Ethiopia's energy demand is increasing tremendously and cost of petroleum import exceeded export earnings by 2008 [6]. Hence, Ethiopia has designed a biodiesel development strategy to promote biodiesel investment. The strategy is expected to help the country evade its reliance on import of fossil fuels for its energy consumption and reduce impacts of climate change [7, 4, 8]. Jatropha, palm tree and castor bean were identified in the strategy as promising biodiesel bearing plants. In addition to the strategic support, this paper was inspired by the multiple products and services obtained from jatropha to ameliorate land degradation, negative energy balance, soil fertility loss and poor health condition of the rural community [9, 10, 11].

Some survey reports, estimates using conventional methods, and author's personal observation revealed presence of jatropha around home gardens and farmlands in different parts of Ethiopia. Plantations were also established in different regions by various actors; however, the methods used so far for site identification were ineffective [4, 12]. Consequently, failure accounts of investment projects have been reported due to improper techniques of site selection and use of old data [13].

This study employs Spatial Analytic Hierarchy Process (SAHP) and Geographic Information System (GIS) to generate reliable information in land allocation for jatropha production. A mechanistic suitability modelling approach was used since environmental requirements of the species are well documented [14].

Findings of this study have paramount significance in supporting decision making in the biodiesel energy development sector since a considerable amount of the land area (about 15 %) is suitable for growing jatropha. Local communities, universities, investors, researchers, community-based organization and non-governmental organizations will benefit from the research results.

2. Methods

2.1. Selecting and standardizing factors

Factors that define suitability for jatropha production were selected through an intensive literature review on site requirements of jatropha for optimum growth and yield. Besides review of international experience from literature about the subject matter, expert consultation was used in rating of factors using pair-wise comparisons. Availability of data was also a key element considered during selection of factors for this study.

To compare the criteria, values of each dataset were transformed to the same unit of measurement scale. Each input dataset was converted into raster data format. Pixels of the derived raster data were classified into suitability classes for jatropha production. After classification, all raster data of each factor had values of 3, 2 and 1 representing "suitable", "moderately suitable" and "not suitable" areas, respectively.

2.2. Weighing of the criteria

For determining the relative importance of each criterion in the resultant overlay analysis, a pair-wise comparison matrix using a modified form of Saaty's nine-point weighing scale was applied [15].

For preventing bias during criteria weighing, the consistency ratio was calculated. The consistency ratio is a general measure of the comparative judgments' goodness in building up decision matrices within the Analytical Hierarchy Process (AHP). Consistency ratio is a decision tool to evaluate whether an AHP is acceptable for decision making or not [16].

Values of consistency ratio exceeding 0.10 are indicative of inconsistent judgments; whereas values of 0.10 or less indicate reasonable level of consistency in the pair-wise comparison.