Application of Geospatial technique and Analytic Hierarchy Process for crop-land suitability evaluation

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Abstract

Crop-land suitability analysis is a prerequisite to achieve optimum utilization of the available land resources for sustainable agricultural production. The Food and Agricultural Organization recommended a land suitability assessment approach for crops in terms of suitability ratings ranging from very highly suitable to unsuitable based on climatic and terrain data, soil properties and social-economic data. The aim of this study was to develop a GIS-based multi criteria evaluation technique to assess suitability areas for wheat cultivation in Mollaj Administrative Unit, Korça Municipality. Four suitability criteria including soil (pH-H_2O, texture, soil depth, organic matter, Cationic exchange capacity), topography (slope) climate (rainfall) and social-economic (land use and land cover) were selected based on FAO framework and agronomist experts opinions. Weights indicating the relative importance of each criterion was determined using Analytical Hierarchical Process (AHP) in Idrisi Selva Software. The resulting weights were used to construct the suitability maps using ArcGIS software. The final output land suitability map for wheat cultivation was generated by overlaying these maps using Weighted overlay analysis in ArcGIS. The results of this research showed that in the study area, 58.6% (1487 ha) of the land is highly suitable, 31.95% (811 ha) is moderately suitable and 9.45% (240 ha) is not suitable for wheat cultivation. The results can be used by the Ministry of Agriculture and Rural Development of Albania to advice the local farmers on the suitable areas for wheat cultivation. The model of present research work can be applied to determine land evaluation for other agricultural crops.

Keywords: Multi Criteria evaluation, Geographic Information System (GIS), Analytical Hierarchical Process (AHP), Land suitability map, Spatial analysis

Introduction

Development of sustainable agriculture is one of the main objectives of all countries in the world. In today's conditions, when the agricultural land is quite limited, it is impossible to search for a larger area for cultivation, therefore farmers must familiarize themselves with the fact that they must increase food production on the land they have available. In this context, in order to use the available agricultural land in an optimal way, to have sustainable agricultural production, the analysis of the suitability of agricultural land is a necessary prerequisite [1]. Among all types of crops that grow in Albania, wheat is the major food crop which forms the basis of the food diet and is essential to our economy. However, the production level of wheat remains at a problematic level in relation to consumption. To increase the production of wheat is required to arrive at most suitable sites for their cultivation. A careful evaluation of the land would directly help in mitigating the production challenge.

Land suitability evaluation (LSE) involves the process of appraisal and grouping of specific areas of land in terms of their suitability according to the specific types of use [2]. Food and Agriculture Organization (FAO) [3] developed an approach widely used for suitability analysis, by considering different criteria. To facilitate FAO's principles, concepts and theories on land suitability evaluation for crops, much progress has been made over the last years in developing methods of multi-criteria-LSE, especially by integrating Geographic Information system (GIS), Remote Sensing (RS) with Multi criteria decision making (MCDM) [4] [5].

Currently, there are no studies and researches in Albania on the suitability of agricultural land for the cultivation of wheat. Moreover, the quantity, location and degree of suitability of agricultural land for wheat cultivation is not documented. This paper present a combined technique of AHP and GIS to evaluate land suitability for wheat cultivation in Mollaj Administrative Unit, Korça Municipality. The aim of the study is to provide an effective mechanism through combination of GIS, AHP and MCDM in order to have better decision and direct impact on farmers for cultivation of specific crops.

Material and Methods

Study area

The study was carried out for Mollaj Administrative Unit of Korça Municipality, eastern part of Albania. It is geographically located in 40° 34' 25'' N latitude and 20° 43' 57'' E longitude. The area where the research was held covers approximately 2550 ha. The Administrative Unit consist of flat area that lies on northwest, north and northeast side and hills which rise on the south western, southern, south eastern and eastern sides.

Data types and sources

Various types of datasets were used for land suitability evaluation for wheat crop. Based on literature review, analytic studies and expert opinions the main criteria and sub-criteria for suitability analysis were selected. A hierarchy of four main criteria (topographical, climatological, physical-chemical and social-economical) and eight sub-criteria (pH-H_2O, texture, soil depth, organic matter, Cationic exchange capacity, slope, rainfall, land use and land cover) were incorporated in this study. The physical-chemical soil data (pH-H_2O, texture, soil depth, organic matter, Cationic exchange capacity (CEC)) were obtained from Agriculture Technology Transfer Center, Fushë Kruje, part of Ministry of Agriculture and Rural Development of Albania. The data for precipitation were extracted from Climate Research Unit (University of East Anglia) and UK's National Centre for Atmospheric Science (NCAS) [6]. The slope raster was derived from Digital Elevation Model (DEM) with 30 m resolution, Shuttle Radar Topographic Mission (SRTM). The Land use and land cover (LULC 2022) map was extracted from Esri New 2020 Global Land Cover Map at 10-meter resolution, was built using European Space Agency (ESA) Sentinel-2 satellite imagery [7].

Methodology framework

The methodology was based on matching soil/land characteristics against agronomical requirements of wheat and then the suitability classification was assessed. In this research GIS was combined with Multi-criteria decision-making (MCDM) method [8]. This method was very useful because combine all spatial factors (criteria) and results in a map with the best locations for a certain type of land-use. To summarize, (i) criteria that determine wheat production and growth were selected and organized in an hierarchy; (ii) every criterion were mapped using GIS environment and each criterion-map were converted and geo-refereced into Universal Transverse Mercator (UTM) projection zone number 34 N of WGS 1984; (iii) criteria were compared to determine the degree of importance using AHP [9]; (iv) standardization (in GIS environment) of sub-criteria layers in suitability classes (N "not suitable" , S_3 "marginally suitable" , S_2 " moderately suitable", S_1 " highly suitable") according to wheat requirements ; (v) suitability index was calculated using weighted overlay analysis in GIS environment.

Results and Discussion

Table 1 shows the weightings obtained for each sub-criterion. The pair-wise comparison matrix (AHP) was carried out for rating and weighting of eight sub-criteria. The fundamental scales given by Satty's [9] for comparing the two sub-criteria were used. The most important sub-criteria for wheat growth and production were texture (27%), slope (22 %) and pH-H2O (17%). The consistency ratio (CR) was 7 %, less than 10 % (allowed value) and it was acceptable for further process. Table 2 showed that 58.6 % (1487 ha) of the study areas were "highly suitable", 31.95 % (811) were "moderately suitable" and 9.45 % (240 ha) were "not suitable" for wheat cultivation. Figure 1 depict the output map

with three different suitability classes for wheat cultivation generated in GIS environment by using weighted overlay analysis as an intersection of standardized and differently weighted layers during suitability analysis [10].

Conclusions

Integration GIS, MCDM and AHP is a useful combination that can create a superior database and suitability map which will serve as a guide for local farmers and decision makers for agricultural land management of different crops.

Table 1. The pair-wise comparison matrix (PWCM) for eight criteria

	Texture	Slope	pH-H2O	Soil depth	Organic matter	CEC	Rainfall	LULC 2022	**Weights (%)**	Rank
Texture	1	2	2	3	3	4	5	7	**27**	1
Slope	1/2	1	2	3	3	4	5	6	**22**	2
pH-H2O	1/2	1/2	1	2	3	4	5	6	**17**	3
Soil depth	1/3	1/3	1/2	1	2	3	5	6	**13**	4
Organic matter	1/3	1/3	1/3	1/2	1	2	4	5	**9**	5
CEC	1/4	1/4	1/4	1/3	1/2	1	3	4	**6**	6
Rainfall	1/5	1/5	1/5	1/5	1/4	1/3	1	4	**4**	7
LULC 2022	1/7	1/6	1/6	1/6	1/5	1/4	1/4	1	**2**	8
			CR= 7 %						**∑=100**	

Table 2. Land suitability areas for wheat under different classes

Classification	Index	Area (ha)	Area (%)
Highly Suitable	S1	1487	58.6
Moderately Suitable	S2	811	31.95
Not Suitable	N	240	9.45

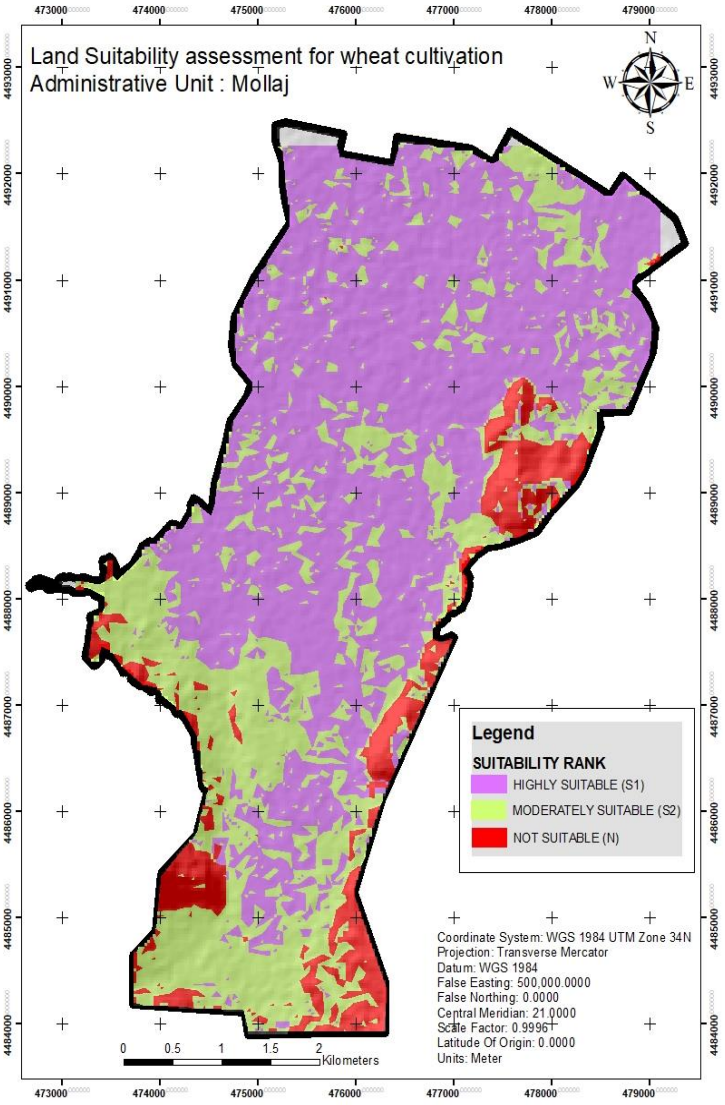

Figure 1: Land suitability map for wheat cultivation

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