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LAND SUITABILITY ASSESSMENT FOR MAIZE CROP IN OKARA DISTRICT USING GIS TECHNIQUES

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Abstract: **Identification of suitable land for Maize crop in Okara District by using Geographic Information System (GIS) techniques was the primary goal of this study. Maize crop grow in all provinces of Pakistan especially in Punjab and Khyber Pakhtoonkhwah (KPK). This crop gets importance as a commercial/industrial crop because a large number of products such as; starch, protein, oil, fiber, and sugar are produced from its grains. Beside its tremendous demand/requirement in Pakistan, this crop has to face a lot of threats to grow which include; soil erosion, land degradation, water shortage, environmental / meteorological problems, and soil fertility. Moreover, due to rapid increase in urbanization, availability of fertile land is decreasing and a land for certain crops must be determined in order to achieve higher productivity. This research focused to find suitable sites for Maize crop in Okara district of Punjab province – covered an area of 4,378 km^2. The main goals of this research to establish a spatial model for land evaluation by applying Analytical Hierarchy Process (AHP) method and then merged it with GIS techniques. The parameters used for land suitability analysis were soil pH, EC, soil texture, organic matter and ground water quality. On the basis of these parameters suitability maps were generated. Land suitability analyses performed by using the AHP method through assigning different weights to all parameters. Different Hierarchies placed under test through hit and trial method but preferred the hierarchy which précised and near to the real environment referred by SSOP. In this model all required parameters work together and according to their suitability ratios, highly, moderately, marginally and not suitable areas were identified for this specific crop. From this study highly suitable area was accurately identified through AHP model under certain limitations. A strong correlation was found between the ground sampled results by SSOP and suitable site which was identified through GIS. The result of this study shows that approximately 74% area of the Okara District was identified through AHP, is highly correlated with Punjab Soil Survey Report (2005). This study evaluates that it is an easy approach to get suitable land which improve Maize crop production by using AHP method. It is highly useful for decision makers including farmers, resolve land degradation problems and full fill the requirements of food for population which increase drastically.**

Keywords: **Land Suitability Assessment, Agriculture, Soil, GIS.**

1. INTRODUCTION

After Wheat and Rice, Maize crop is an ancient and 3rd rank planted cereals in all over the world as well as in Pakistan. Maize crop is cultivated in all provinces of Pakistan especially in Punjab and KPK [1]. Different regions of Punjab and KPK produce 95% of Maize crop and only 5% is produced in Sindh and Baluchistan [2].

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Around 90% of Maize crop is using for making animal feed and rest of it, use for industrial purposes in advance countries, but the criteria is different in developing countries. 80-90% Maize is used to fulfill the deficiency of food for human beings. This crop also gets importance as a commercial/industrial crop, because a large number of products manufactured through its grain like 10% protein, 66.70% starch, 4.8% oil, 3% sugar, and 8.5% fiber [3][4]. In industry, Maize is used as a raw material for preparation of corn starch, corn oil, corn syrup, corn flax, cosmetics, wax etc. The survey report of Pakistan 2006-2007 indicates that Maize crop covers an area of 1.02 million hectare and its annual grain production is 2.96 and annual grain yield is 2,896 kg/ha in Pakistan [5]. Pakistan has agriculture based economy, and most of the income and employment is provided by this sector. Pakistan is a developing country and production of Maize crop has been 2.4% increased since 2009-2011[6]. A healthy food with full of nutrition is essential for healthy life cycle but the difference is too large between rate of grain yield and population. Okara, Sahiwal, Pakpattan and Khanewal districts of Punjab are lying in the central belt of Maize crop. Unfortunately the yield of the Maize is 6.4% in total food grains production in Pakistan which is very low as compare to the other countries.

Land use suitability maps and analysis is the most useful application of GIS for planning purposes [7]. For analyzing, displaying, and reporting spatial information, GIS proves as an efficient tool. The purpose of this study is to develop a model by using GIS techniques, which illustrates that which area of land is suitable for Maize crop in Okara District.

STUDY AREA:

Around 69% (3,008 km^2) of the total area of Okara District consists on land with a very high economic potential under irrigation. Moisture shortage is the major problem and being met out by tube-wells. However, water is essential which used to boost up crop yield and cropping intensity to get full potential from this land. The area near to Ravi and Sutlej rivers ground water is adequate for irrigation. It also includes 197 km^2 of moderately deep silty soils underlain by sand at 60-90 cm, which uses for major crops of the area except rice and orchards. A little part consists on slightly saline soils that ameliorated by leaching with good quality water. Around 178 km^2 areas consist on clayey soil having high potential for irrigated agriculture [Soil Survey]. The land is well suited to intensive cultivation of diversified crops. The crop production could be increased considerably by adopting modern technology and agricultural practices.

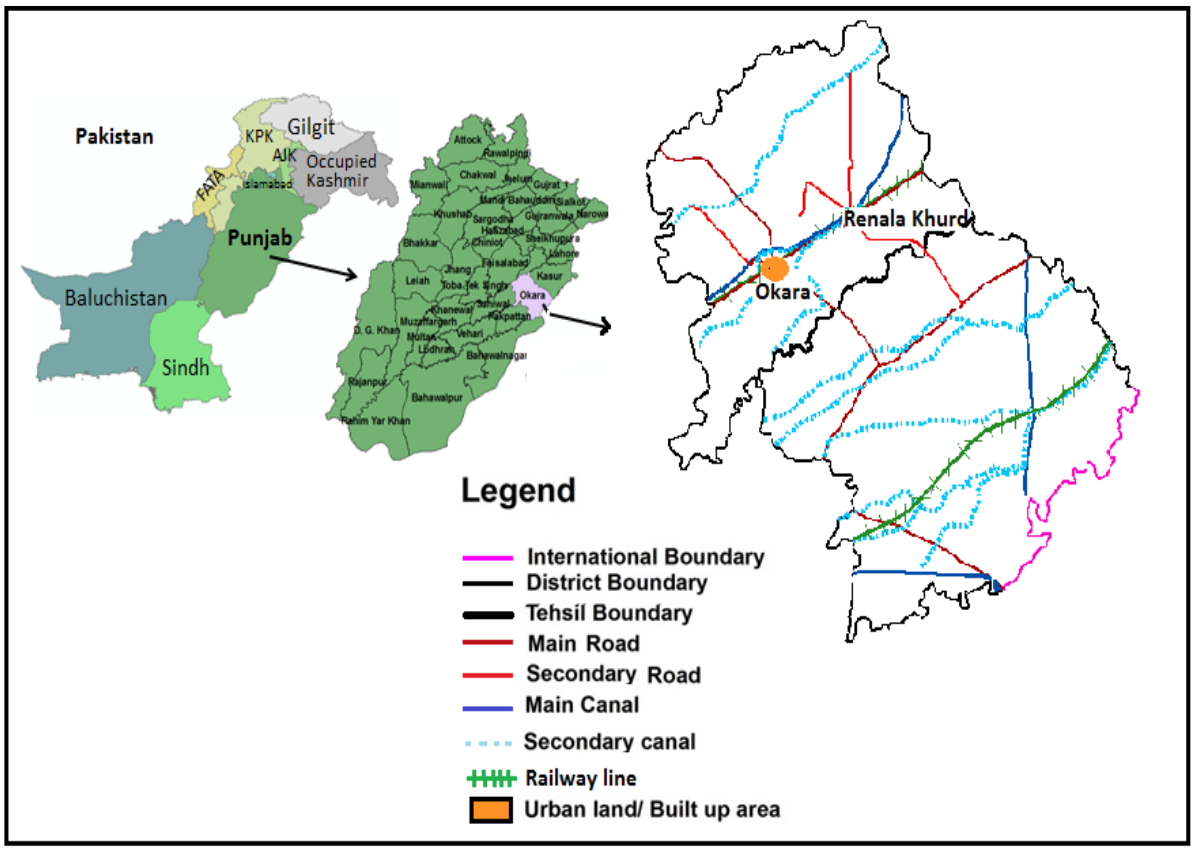

Fig 1: Study area located in Pakistan

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MATERIAL USED:

A healthy yield of crop depends upon soil parameters and ground water conditions. Soil pH, texture, salinity, organic matter, and water quality are the most important factors that affect crop growth and help to determines where plants would grow best. Suitability scores categorize that how crop behaves under certain circumstances by using these essential parameters. The term "overall suitability" refers to a combine measure of the some selected referenced factors. The data requirements for this study based on soil and ground water. The data used in this study surveyed by the Soil Survey of Punjab, Lahore and groundwater data obtained from International Water-logging And Salinity Research Institute (IWASRI), Lahore. Irrigated agriculture depends upon usable quality water. Ground water used for irrigation varies greatly in quality depending upon type and amount of dissolved salts and have significant effect on crops [9]. Assessment of water quality for the study area based on four parameters i.e. Electrical Conductivity (EC), total dissolved solids (ppm) and Sodium Absorption Ratio (SAR).

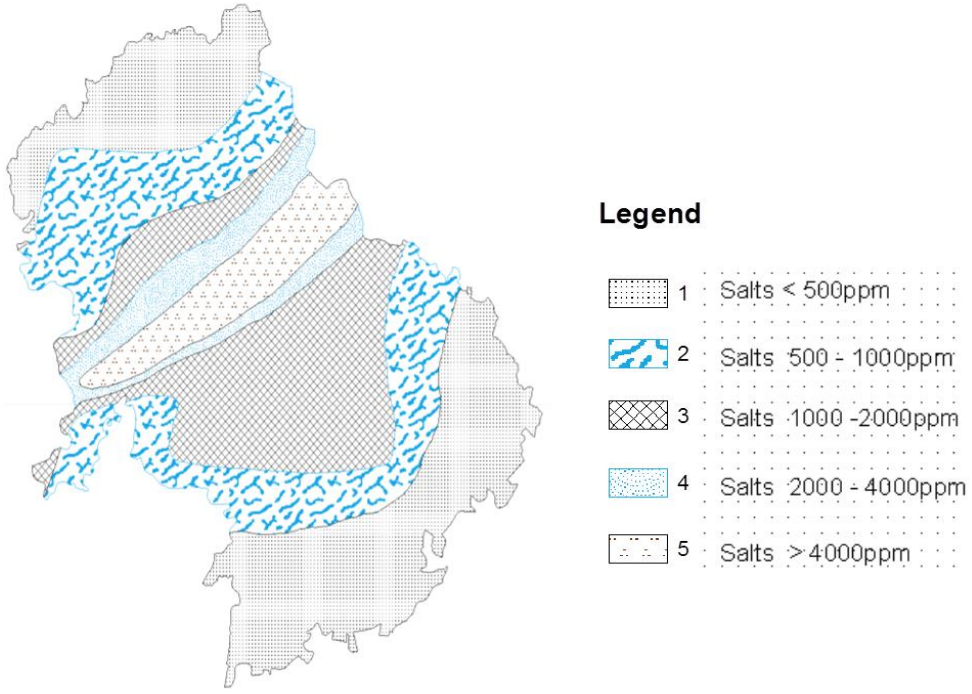

Fig 2: Okara District Salts in Ground Water

2. METHODOLOGY

Land use for specific type of crop plays an essential role for production of best quality crop. Initially GIS & remote sensing were only used for mapping, but with the passage of time and advancements in these fields, it becomes easier for researchers to use these tools and consult with experts belonging to agriculture and soil sciences in case of land suitability assessment to find out precise results for analysis. Different parameters, which used for land suitability evaluations, their value varies differently at different points but they connected with each other. The best decision could finally be achieved after testing several methods and models while making-decisions, under experts guide lines for land suitability analysis and evaluation. The most common and precise method for land suitability analysis and evaluation being in practice at large is "Analytical Hierarchy Process (AHP)", which comes under the Multi Criteria Evaluation methods. AHP method introduced by Saaty (1977) and used to calculate the required weighting factors. This method used, to derive ratio scales from paired comparison. Human is not always consistent in judgment, so AHP allows some small inconsistency in judgment. The ratio scales derived with the help of Principal Eigen Vectors and the consistency index derived through Principal Eigen Value. In order to make some decisions compare one or more alternatives with one or more criteria to make some conclusion, this based on this comparison. Some of the criteria have more importance than others and according to their importance, assigned them weights. These all identified relevant criteria compared against each other with reproducible preference factors and this all done by the help of preference matrix [8][9][10].

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The Organizational Hierarchy used in this study shown in Fig.3.

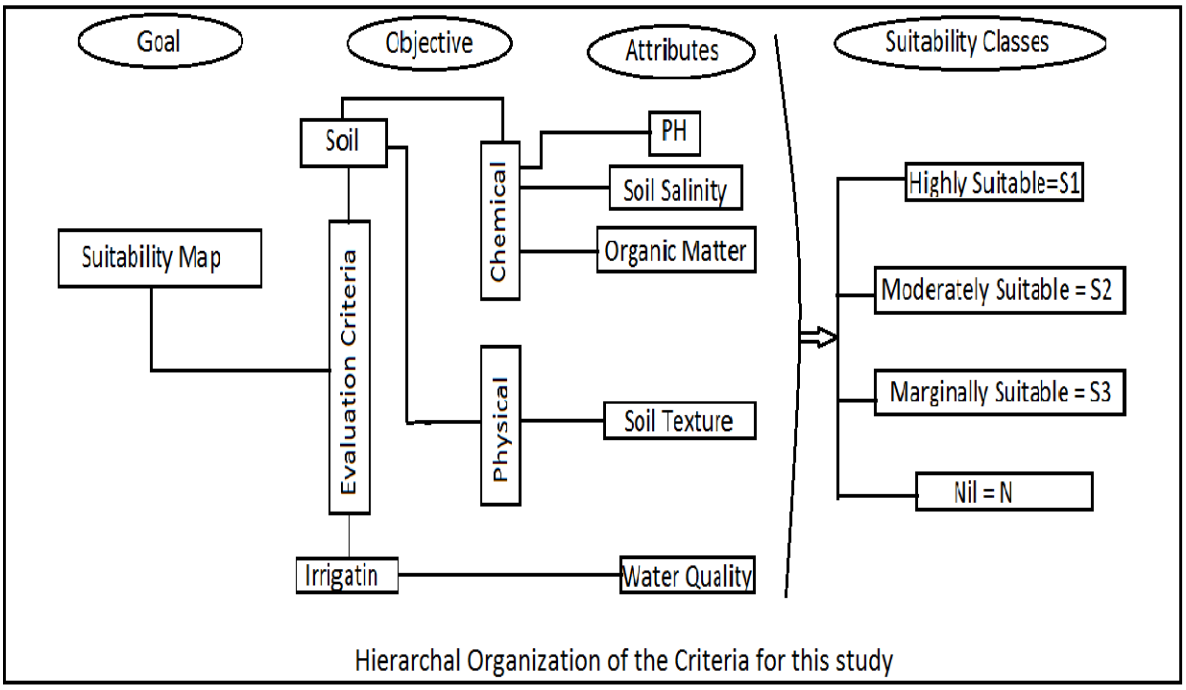
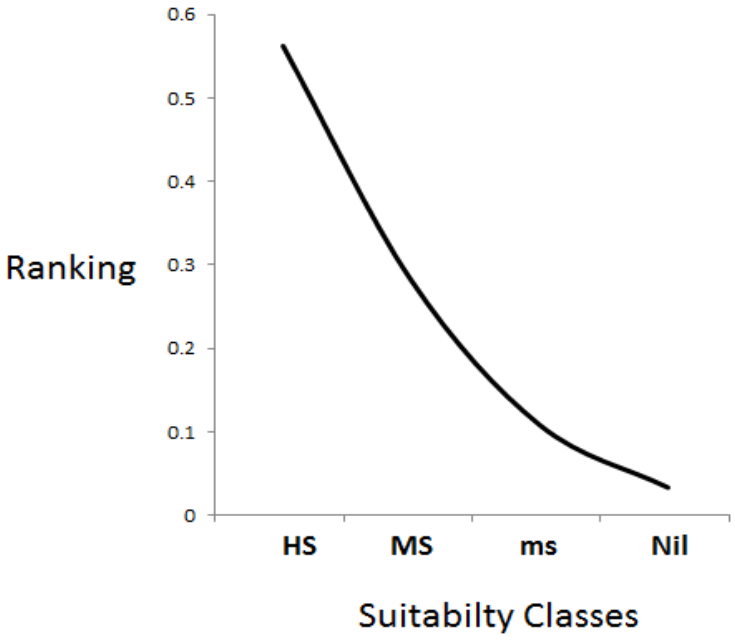


Fig 3: Hierarchy Organization of the Criteria for this Study

3. ANALYSIS AND RESULTS

In this model, all these required parameters work together and according to their suitability ratios identified the areas which are Highly Suitable (HS), Moderately Suitable (MS), Marginally Suitable (ms), and not suitable (Nil) for this specific crop in Okara District. This model is efficient and accurately identifies the regions which are good or bad for this crop under certain limitation of the ratio of criteria. Criteria standardization for pH that is in mathematically formed and plotted graphically as shown in Graph-1 and a linear smooth relationship exist between ranking and suitability of the classes.



Graph 1: Visualization of Standardized pH Score

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Suitability of the Maize crop evaluated through this method for all parameters. Weights of all parameters calculated based on their mutual importance and shown in Table 1.

Table 1: Pair-wise weight matrix for soil parameters used in the study area

Criteria	PH	EC	WQ	ST	OM	WEIGHT
PH	1	1	3	5	7	0.37
EC	1/1	1	3	5	7	0.37
WQ	1/3	1/3	1	2	4	0.14
ST	1/5	1/5	1/2	1	2	0.08
OM	1/7	1/7	1/4	1/2	1	0.04

Based on these weights, association maps of each parameter generated as vector layers and later on these maps rasterized to use for AHP in ArcGIS, as shown in Fig.3.

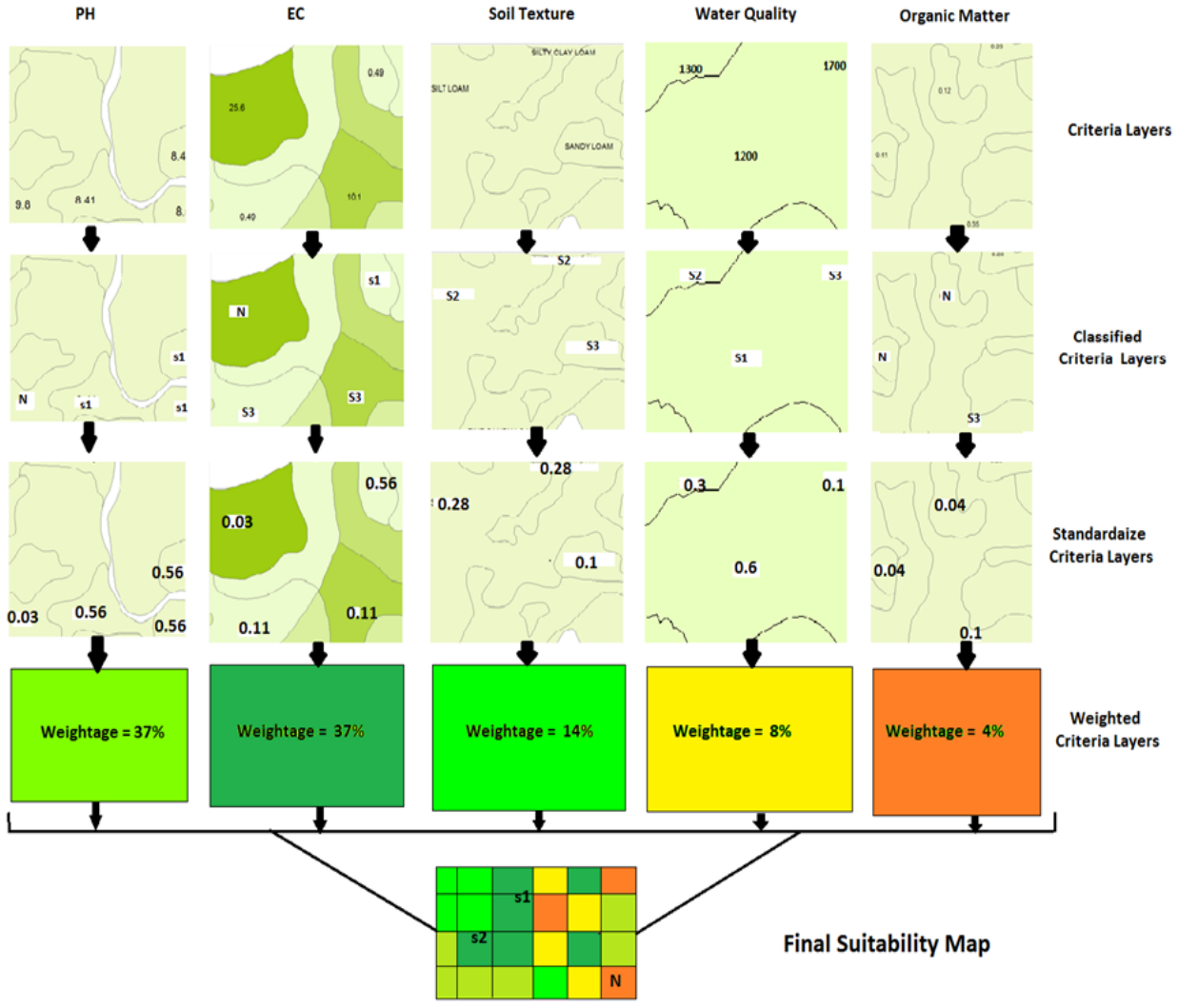

Fig 4: Aggregation of the Rating and Weight Over Heriarachy

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Using these weights for each parameter and masking out from the district boundary of Okara, soil association maps were generated, shown in Fig. 5.

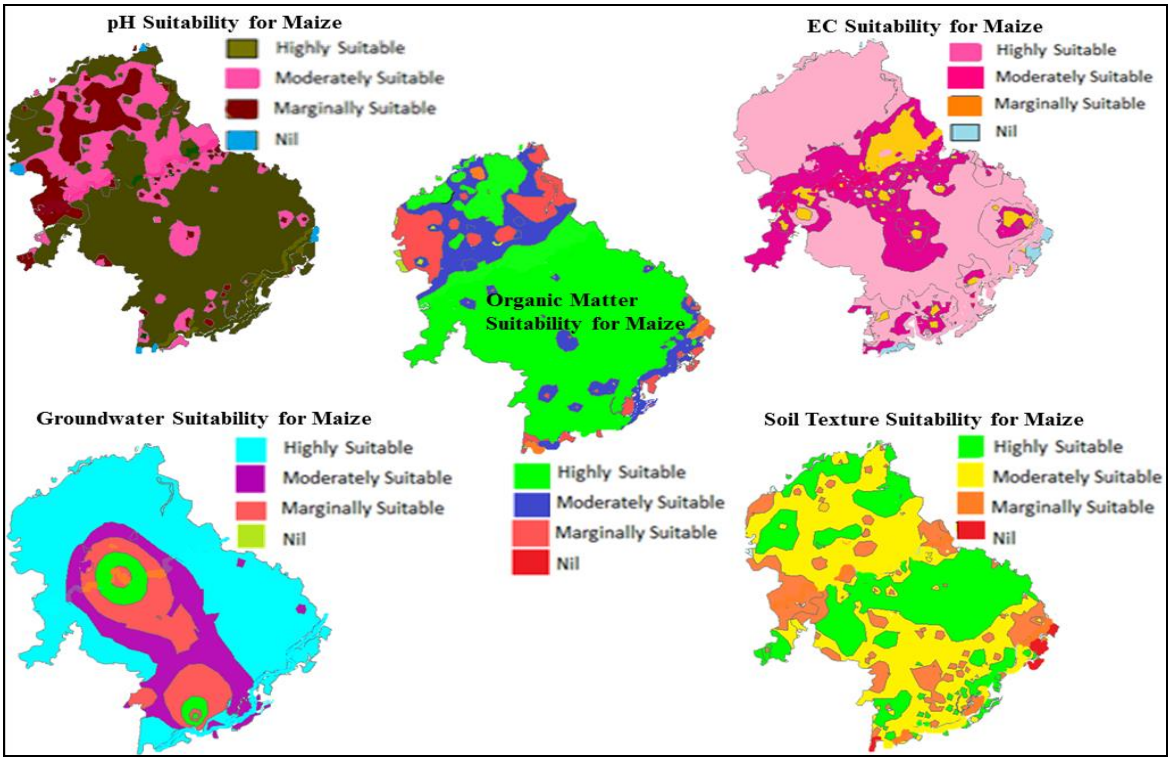

Fig 5: Soil Association Maps based on their Weights

AHP applied on these all association maps and a final thematic map derived for the study area as shown in Fig.6. This map provides a comprehensive and cumulative soil suitability assessment for Maize crop in the study area based on each soil parameter. These association maps of each soil parameter according to their suitability criteria supply agriculture practitioner's first-hand information about the spatial distribution of these Maize crop cultivation affecting factors. Ultimately, these are helpful for sowing requisite crop(s) for farmers.

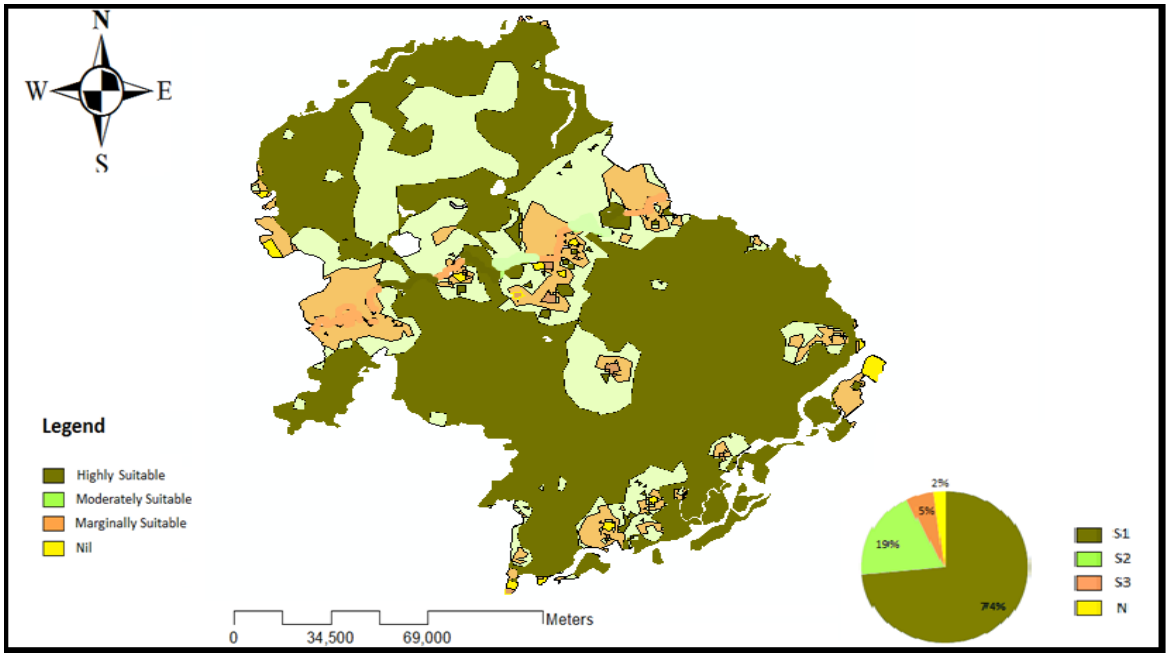

Fig 6: Overall Land Suitability Map for Maize Crop Cultivation in Okara District

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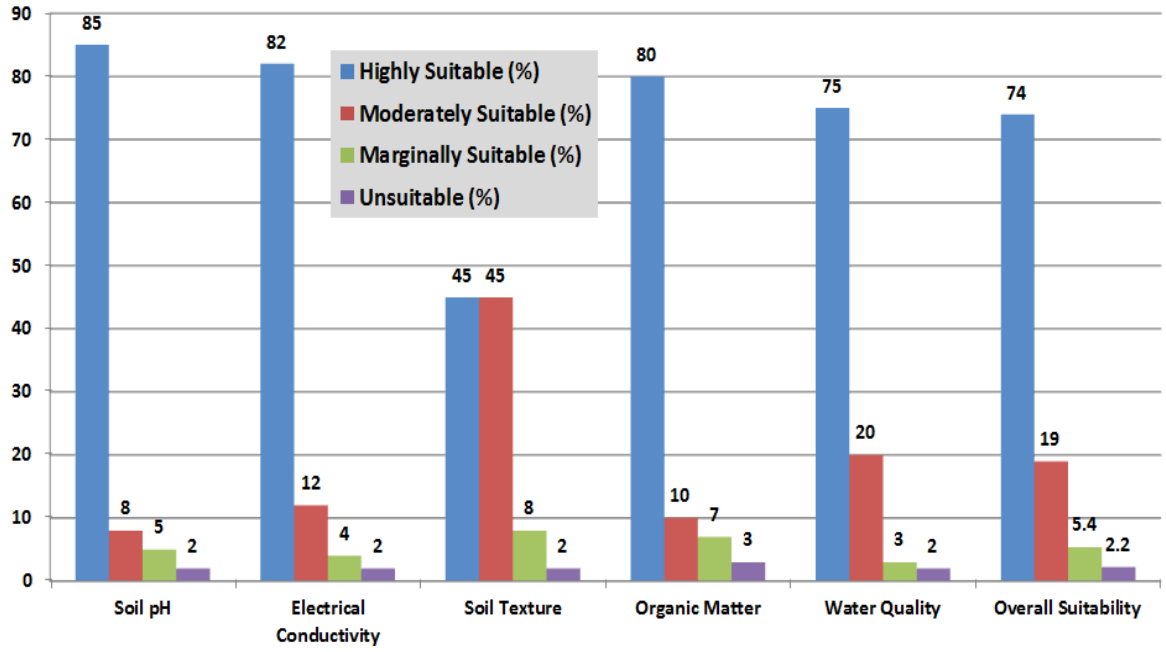
After statistical investigation, the following Table 2 provides a comparative analysis of these soil parameters based on their suitability criteria. A graph using this table was also generated (Graph-2) for synoptic understanding and monitoring the trend of suitability analysis in the study area using all parameters.

Table 2: Overall Land Suitability for Maize cultivation based on 5 parameters (% Area)

Criteria	Highly Suitable (%)	Moderately Suitable (%)	Marginally Suitable (%)	Unsuitable (%)
Soil pH	85	8	5	2
Soil Salinity(EC)	82	12	4	2
Soil Texture	45	45	8	2
Organic matter	80	10	7	3
Water Quality	75	20	3	2
Overall Suitability	74	19	5.4	2.2



Graph 2: Overall Land Suitability for Maize cultivation based on 5 parameters (% Area)

4. CONCLUSIONS

The research area consist on Okara district of Punjab province covered an area of 4,378 km^2 focused to find suitable site for Maize crop. A model was established for land suitability analysis by using methodology known as Analytical Hierarchy Process (AHP) and then merged it with GIS techniques. The parameters used for land suitability analysis were soil pH, EC, soil texture, organic matter and ground water quality. Land suitability analyses performed by using the AHP method through assigning different weights to all parameters. The parameters were placed in well-defined hierarchy after passing through hit and trial method and also incorporated with expert knowledge from various discipline. On the basis of all these factors suitability maps were generated. In this model all required parameters work together and according to their suitability ratios, highly, moderately, marginally and not suitable areas were identified for this specific crop.

From this study highly suitable area was accurately identified through AHP model under certain limitations. A strong correlation was found between the ground sampled results by SSOP and suitable site which was identified through GIS. The results of this study area inferred that approximately 74% area of the Okara District which was identified through AHP is highly correlated with 76.9% area referred by Punjab Soil Survey Report (2005). The results of this research evaluate that 19% area of Okara District was moderately suitable, 5% and 2% areas were marginally and not suitable respectively. This study concludes that it is an easy approach to get suitable land which improves Maize crop production by using AHP method. It is highly useful for decision makers including farmers; resolve land degradation problems and full fill the requirements of food for population which increase drastically.

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This study conducted through collaboration with the National Institute of Research in Soil and Geomatics, Soil Survey of Punjab (SSOP), Lahore, Pakistan who provided data, maps, and reports along with logistic supports free of cost. The authors are highly grateful to the Director General (SSOP) and their staff for providing valuable data, guidance and support throughout this study. We are also thankful to International Water-logging And Salinity Research Institute (IWASRI), Lahore for providing water related data.

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