ASSESSMENT OF LAND SUITABILITY AND CAPABILITY BY INTEGRATING REMOTE SENSING AND GIS FOR AGRICULTURE IN POTWAR REGION PAKISTAN

S. Batool [1]*, S.A. Mahmood[2], M. Muhammad Ali[2]

[1] Centre for Integrated Mountain Research University of the Punjab Lahore, Pakistan. Saira.cimr@pu.edu.pk
[2] Department of Space Science University of the Punjab Lahore, Pakistan. amer.spsc@pu.edu.pk, maryamalirehan@gmail.com

KEY WORDS: Land Suitability, crop suitability, Remote Sensing, MCE, AHP, GIS, Potwar-Pakistan

ABSTRACT:

The assessment of land suitability and capability to reduce the anthropogenic pressure on is significant for the agricultural yield management in rainfed Potwar Region Pakistan. This study examines phases of wheat growth using Landsat-8 thermal bands and temperature based site maps, and demarcates suitable sites in potwar region for sustainable crops through Multi-Criteria Evaluation (MCE), Analytical Hierarchy Process (AHP), python and geospatial techniques. The total investigation area was 22168 km^2 out of which 12256 km^2 (55%) declared highly suitable, 2998 km^2 (13%) was moderately suitable, 4843 km2 (22%) was less suitable and 2069 km^2 (10%) was found not suitable for wheat crop cultivation (WCC). The results indicated that the areas having temperature ranging between 10–18◦C, pH between 6.2-6.5 and clay loom soil type with drainage level 0.85-1.1 corresponds to extremely suitable for wheat production. Various land quality factors; that is slope, flooding, soil texture, erosion, depth and coarser bits under different land-units were assessed for the crops. Consequently, all these factors were combined to make an integrated land suitability and capability (LSC) map for each landuse and suitable soils for agricultural productions. It is concluded that better landuse practices can be implemented to enhance the suitable agricultural sites.

1. INTRODUCTION

According to the World Population dataset, there was an increase of 8 billion populations in 2022 and will be around 10 billion until 2050 (Roser et al., 2013). This rapid growth has put the planet in danger and has caused a food and water deficit as a result. The world is currently facing multiple threats from this sudden rise in population, including threats to the food supply chain and the availability of fresh water as urban sprawl is quickly displacing agricultural land. Pakistan's economy is based primarily on agriculture, which accounts for 23.3% of the country's GDP. It represents 42.3% of total employed labour force in Pakistan. Agriculture's role to the broader national economy has, however, been declining (from 27.3% in 1985 to 19.8 % to date) as compared to other sectors. Lack of significant advancement in agricultural production from major crops and yield stagnation are emerging as serious challenges for the agriculture sector (Islam, 1995).. Lack of true-to-type seeds, climate variability, deteriorating water availability, progressive changes in soil nutrients, and cultivation of some crops in inopportune locations are the causes of this yield stagnation (planting rice in areas better suited to cotton). Agribusiness is the Around 70% of Pakistanis depend on agricultural produce for their daily sustenance (Rehman, 2016). While the majority of Pakistan's crop needs are satisfied by the production of wheat, other crops such as rice, sugarcane, corn, and maize are also grown in addition to wheat. Wheat significantly boosts the country's economy, but at the same time, the amount of agricultural land has been diminished by urbanisation, infrastructural projects (Motorways, industrialization, housing schemes, etc.), and other factors (Rehman et al., 2015) To meet the rising demand for food, careful resource management and decision-making are therefore required. Ecological elements, such as different soil parameters (soil, temperature, moisture, and pH of the soil), as well as soil temperature and moisture, have an impact on plant growth (Al.karaki, 2012; Porter & Gawith, 1999; Russell & Wilson, 1994) These factors affect a plant's nutritional value, but farmers are not aware of their importance in determining how they will affect the amount of wheat produced on an acre (Onwuka & Mang, 2018). Therefore, farmers need to be aware of the special significance of the soil and the related elements that affect wheat output and growth. A particular crop's production and growth are influenced by the soil's nutrients and physical characteristics. A clear strategy is proposed to increase agricultural productivity. To get the desired yield from a partial harvest, the LSC is crucial. To evaluate the LSC of a certain landcover, the soil must be divided into its subclasses. To achieve the major goals of this study, the LSC of soil is examined and thematically mapped utilising geospatial techniques (El Baroudy, 2016). The vast spatiotemporal satellite data sets can be obtained, secured, handled, and manipulated with the help of the relatively accurate GIS tool in order to examine their thematic features and perform a more correct assessment of LSC. To accurately map LSC zones, geospatial methods can be combined with MCE methodologies (Zolekar & Bhagat, 2015). The primary goal is to incorporate the MCE techniques at GIS platform to identify LSC regions by taking into account a variety of variables to produce LSC maps and wheat production. Using MCE, possible LSC sites are evaluated based on drainage parameters and soil pH. Site data are collected using AHP methodologies and weighted linear sum, and the results are then merged into a GIS environment. (Anees et al., 2014). Without taking into account the specific use, the LSC assessment describes and rates land development units (LDUs) in a broad framework. Classes I through VIII are clearly and formally defined This classification is useful because specific soil types may be suitable for particular crops while being ineffective for others (Hossain et al., 2011). As a result, accuracy in terms of land use types is crucial. It might be portrayed in terms of different crop productions, but also in terms of how specific crops are planted and harvested (Rehman et al., 2015; Sys et al., 1991). The LSC refers to a piece of land's ability to sustainably support crop production. Its analysis provides details on the land use prospects and constraints and, as a result, leads to conclusions about the best way to use the natural resources, the information from which is a crucial requirement for LUDs. Based on the qualities of the soil, the characteristics of the terrain, and an examination of the existing land use, land may be divided into spatially allocated agriculture prospective sectors (Khan et al., 2016; Bandyopadhyay et al., 2009). Only through scientific soil surveys, assessments of the potential for a wide range of land uses, and the creation of flexible, socially acceptable, and environmentally friendly land use regulations could agri-production be met (Khan, 2018; Sathish & Niranjana, 2010). Agricultural indices, biophysical parameters, and land use and Landcover (LULC) evaluations can all be estimated using remotely sensed data (RSD), in addition to cropping strategy research (Ahmad, 2013; Rao et al., 1996 and Panigrahy et al., 2006). However, unless the datasets are combined with site-specific climatic and soil data, RSD only cannot suggest crop compatibility for a given place. The RSD can identify several physiographic units and generate auxiliary information on site characteristics, such as the investigation area's aspect and slope direction. To begin assessing crop suitability, complete information on the properties of the soil profile is necessary. The goal of the current study is to demonstrate how soil data sets and GIS approaches may be used to assess wheat yield and LSC in the Potwar Region and apply crop sustainability. Numerous academics have already confirmed the value of combining geospatial approaches to quantify the land evaluation)

2. MATERIALS AND METHODS

2.1. Experimental Site

The study area is located in Pakistan's Punjab province. With over 56% of the country's population, Punjab is the province with the most population. It has a size of roughly 205,344 Km^2 and is situated at 31.17° N and 72.70° E. About 26% of Pakistan's total land area is covered by it. Additionally, it has ties to Rajasthan and Punjab in India. The powerful Indus River and its tributaries left behind soil deposits in the Punjab during the Quaternary Period. Upper Indus Plain (UIP) is the Pakistan's primary agricultural region. It is also known as Pakistan's "Grain Basket" (Khan et al., 2015). The area set aside for wheat in the 2014–15 Rabi season was 6.98 mh (Becker et al., 1990; Khan, 2018) Punjab is classified into three zones based on its agro-ecological characteristics: I Potwar Region, which has 10% of Punjab's rain-fed agricultural land (Ahmad, 2013) (ii) the central-south region of Punjab's semi-arid-to-arid desert, which produces less agricultural output The majority of irrigated crop production is located in the Indus basin (iii). Punjab contributes greatly to the state's economic growth and provides almost 200 million people with food security by growing wheat and other necessary foods (Barsi et al., 2014). More than 68% of rural population depends on agriculture for their livelihood. In Pakistan, Punjab province is in a semi-arid region with temperatures typically fluctuate from 2 to 45°C, which can reach 50°C in the summer and 7°C in the winter. The yearly maximum temperature ranges from 28° to 32°C, while the annual minimum temperature ranges from 15° to 19°C. The trend toward continuous temperature rises that cause global warming is observed to be greater than 1°C overall. With a total variance of 228mm during the previous 50 years, there was an upward tendency in rainfall. Punjab has three main seasons according to climate classification: rainy season (April to June), when temperatures soar to 45 to 50 °C (monsoon) Between July and September, there is an average yearly rainfall of between 508 and 630 millimeters on the plains and between 1140 and 1270 millimeters in the sub-mountain region. From October to March, the temperature dips below freezing. From 53 to 62%, the humidity changes, fluctuating with the climate conditions. The length and duration of sunny days are reflected in sunlight hours; for example, May, June, and July have longer, sunnier days with more sunshine hours than December and January.

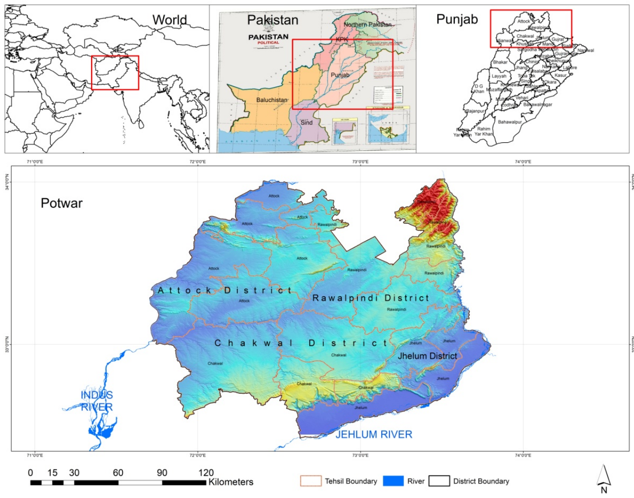

Figure 1: Location of Potwar Region

2.2. Experimental Design

Significant LSC needs for wheat production were established with the help of discussions and conversations with local agronomists, the Wheat Crop Monitoring Center, literature research, and wheat crop specialists. soil types and pH The first variables examined in this research to create adequate wheat growing areas were temperature, soil drainage, and soil electrical conductivity. The flowchart below outlines the methodical procedures needed to compute various parameters Figure 2.

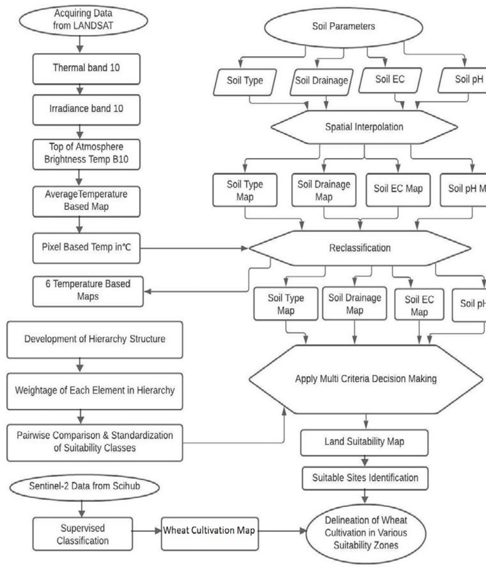

Figure 2: Flow Chart Showing Systematic Steps to Generate Various Maps

2.2.1. Python Based LST Maps from Landsat-8

According to Rajeswari and Mani (2004; Xu et al., 2004), LST is the radiative skin temperature of the land generated from infrared radiation (Weng et al., 2004). LST is a key factor in determining the behaviour of the Earth's thermal environment because it effectively regulates the radiant temperature of the planet, allowing researchers to assess a variety of aspects of life, including climatic changes and variabilities, the health of cereal crops and vegetation, agricultural and hydrological processes, and extreme events like forest fires and volcanic eruptions (Jimenez et al., 2006). On global scale, controlling Earth's surface's chemical, physical, and biological processes depends on LST evaluation using RSD (Becker et al., 1990). Numerous scholars share a same understanding of RSD for the various growth stages of wheat crop and LST computations using Python and Landsat-8 level 1 data. Since manual LST calculation is time-consuming, chaotic, and prone to accumulation of errors, Python code was created to compute LST automatically with repeat process. This study's code was specifically designed to work with Landsat-8 data. USGS instructions state that Band-11 of the TIRS should not be used owing to calibration uncertainty, and that Band-10 should only be used for calculations. The approach that is used in the next step uses thermal bands from Landsat-8 to compute LST.

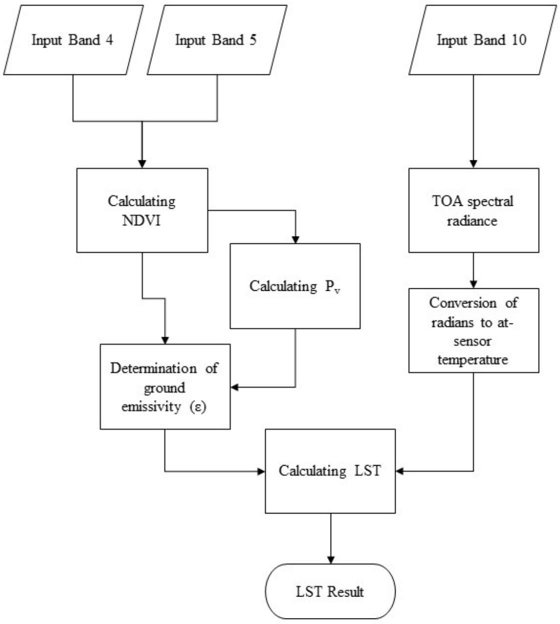

Figure 3: Flow Chart to Compute LST

Thermal Infrared band-10 was used to compute brightness temperature value (BTV) and Bands-4, 5 were used for NDVI. Metadata of satellite image used here is provided in Table 1 below.

	Thermal constant, Band-10	
K1	Rescaling factor, Band-10	1321.08
K2		777.89
ML	Correction, Band-10	0.000342
AL		0.1
Oi		0.29

Table 1: Metadata of satellite thermal bands to compute Temperature in C°.

2.2.2 Top of Atmospheric Spectral Radiance (TOA)

The TOA was estimated through the given equation below in accordance with the according to USGS,

$$TOA\ (L_\lambda) = M_L * Q_{cal} + A_L \tag{1}$$

where, A_L, M_L and Band-10 are the additive and multiplicative band specific rescaling parameters correspondingly and L_λ is TOA (Barsi et al., 2014) To automate the technique subsequent python script was developed.

2.2.3 Conversion of TOA Recorded by Onboard Sensor

The Digital Number (DN) of every pixel was converted to spectral radiance and the radiance to temperature in degree Celsius through thermal constants derived from metadata accessible in entire package of Landsat-8 imagery by the following formula (USGS, 2013).

$$BT = \frac{K_2}{\ln[(K_1/L)+1]} - 273.15 \tag{2}$$

Where

K_1 and K_2 = are the thermal constants with a fixed values provided in metadata.

These constants are significant to calculate temperature in degree Celsius and L is the radiance estimated earlier. The Python script was used to compute LST

2.2.4 NDVI Method for Emissivity Correction

Red and Near Infrared bands are commonly used to compute the green index called Normalized Difference Vegetation Index (NDVI) (Weng et al.,2004) NDVI estimates the amount of vegetation (P_v). The emissivity was calculated by integrating (P_v).

$$NDVI = \frac{NIR(Band5) - R(Band4)}{NIR(Band5) + R(Band4)} \tag{3}$$

2.2.5 Computing the P_v

Pv is computed by the given formula below,

$$P_v = \frac{(NDVI - NDVI_{min})^2}{(NDVI_{max} + NDVI_{min})^2} \tag{4}$$

Where P_v = land surface emissivity (ε).

2.2.6 Calculating Land Surface Emissivity (LSE (ε))

LSE (ε) was computed to estimate blackbody radiance (Plank’s Law) to calculate the released radiance. It is much efficient and precise technique for the assessment of LST. The formula to compute emissivity is as below,

$$\varepsilon = 0.004 * P_v + 0.986 \tag{5}$$

2.2.7 Computing LST

Finally, LST was measured by using BTV and LSE (ε) by the following equation.

$$LST = \frac{BT}{1 + \left(0.00115 * \frac{BT}{1.4388}\right) * \ln(\varepsilon)} \tag{6}$$

2.2.8 Soil Suitability Parameters

The LSC data and related characteristics, such as pH, EC, soil type, and drainage factor, were provided by the Soil Survey of Pakistan (SoP), primarily in relation to the examination site for the wheat crop. Ground-controlled points with values for soil characteristics made up the LSC data. In order to trace thematic changes in the soil parameters and estimate their geographical distributions, we used inverse distance weighting (IDW) interpolation. The Analytical Hierarchy Process (AHP) was chosen to give each soil attribute a varied weight.

2.2.9 Multi-Criteria Evaluation (MCE)

The AHP is a pair-wise comparative method that assigns weights based on the significance of each soil characteristic in order to evaluate each one. LSC maps based on soil are created using AHP. All soil-related parameters were given weights in order to clarify their importance in relation to the growth rate of the wheat crop. Four LSC levels were allotted to implement and reclassify the relevant elements in accordance with the advice and recommendations of experts on their suitability for wheat growth. Clay loam and silt clay soils have a pH range of 5.5–6.5 and an EC range of 0.8–1.3, which is suitable for the growth of wheat crops. Based on the LSC values, four kinds of soil parameter were created. There were four categories of suitability: very, somewhat, less, and not suitable.

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3. RESULT AND DISCUSSION

3.1 Temperature Based Potential Zones for Wheat Crop

Temperature effects the appropriateness of wheat growth in addition to other parameters. Table 1 presents the field observations and literature review. We found that whereas germination often takes place between 7 and 20 degrees Celsius, the ideal temperature range for all phases of wheat growth is 18 to 25 degrees Celsius. Temperatures in highly appropriate zones are shown in Table. 1 along with a literature evaluation. Wheat crops cannot develop at temperatures below 10°C and beyond 25°C because growth halts at these levels. At temperatures up to 20°C, the metabolic activity increases significantly, which is necessary for grain filling in the next stages. Summer wheat can grow in temperatures between 22 and 34 °C, while winter wheat may grow in temperatures between 5 and 25 °C. 0 to 5°C is the bare minimum temperature below which wheat crops cannot thrive (Aydan et al, 2016). The ideal temperature for wheat plant growth is 25°C, while above the temperature ranges of 30-32°C, wheat growth typically ends. For the whole thermal datasets listed in Table 1, LST were calculated. Based on their appropriate ranges, the maps for LST were categorized into four classes. In order to obtain temperature-based suitability maps, the average of all LST maps was taken (TBSMs).

Phonological Stage	Literature Source	Literature Temp(?C)	Observed Temp for Highly Suitable Site(?C)
Germination	(Russell & Wilson, 1994)	7.1-20	10 – 18
Tillering	(Qu & Wang, 1982)	> 8.5	10-16
Heading	(Salazar-Gutierrez, Johnson, Chaves-Cordoba, &Hoogenboom,2013)	10-18.4	14-19
Milk Dough	(Jenner, 1991)	20	16-20
Full Maturity	(Hossain, Sarker, Hakim, Lozovskaya,&Zvolinsky, 2011)	10-25	15-22

Table 2: Literature Based Optimum Temperature and Observed Temperature for Different Stages of Wheat Crop.

Scale	Soil Type	Soil Drainage	Soil PH
High Suitable	Clay Loam	0.85-1.1	6.2-6.5
Moderate Suitable	Silt Clay	1.1-1.3	5.5-6.2
Less Suitable	Saline	1.3-1.4	5.2-5.4
Not Suitable	Sandy	1.4-2.0	4.5-5.2

Table 3: Soil Suitability Parameters

Soil Parameter	Soil Type	EC	Drainage	pH	Weight
Soil Type	1				0.6000
EC	3	1			0.0857
Drainage	1/3	1/3	1		0.0286
pH	1/5	1/3	1/7	1	0.2857
Accumulated					? =1

Table 4: AHP to Compute Weight of Each Parameter

Through raster calculator in ArcMap, the soil-based maps in Figure 4 were put together and then split by their individual statistics to produce the averaged soil suitability maps (SSMs) shown in (Figure 4). The following is how the TBSMs (a-f) in (Figure 7) describe the appropriateness ranks. Due to rising temperatures, all the maps (a–f) that showed red zones were unsuitable for the growth of WCC as wheat growth is hindered in adverse climatic conditions. While the areas closest to water bodies indicated less suitability for wheat cultivation and growth, the green areas that are away from urban built-up areas appeared to be moderately to highly favorable for wheat cultivation and growth. The final TBSMs were created by averaging all the TBSMs (a-f).

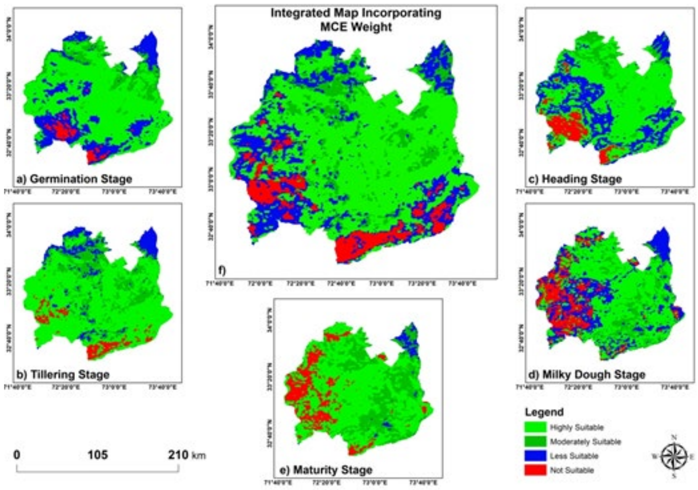

Figure 7.: Wheat Map Representing Various Growth Stages at Variable Temperatures (a), Wheat Crop in Germination Stage (b), Tillering Stage and Wheat Crop (c), Wheat Crop Heading Stage, (d), Wheat Crop in Milky Dough Stage, (e), Wheat Crop in Ripening Stage (f) Temperature Based Integrated Map incorporating all temperature-based stages.

3.2 Delineation of Potential Zones for Wheat Crop Cultivation (WCC)

Due to its propensity to behave poorly when drained, loamy clay is believed to be highly suitable (HS), whereas sand is perceived to be unsuitable (NS). The silty-clay behaves well-drained; thus it was classified moderately acceptable (MS) for the development of the wheat crop. Electrical conductivity (EC) range as 1.6 and 2.0 was NS for wheat growth and may cause the wheat crop to burn up. The EC value range between 0.85 and 1.1 was deemed extremely acceptable, while the region between 1.1 and 1.4 was shown to be less suitable (LS) (HS). For the growth of a wheat crop, a pH between 6.2 and 6.5 is considered HS, whereas a pH below 5.2 is considered NS for growing wheat. When these characteristics' AHP weights were calculated, soil type received the highest weight and soil drainage received the lowest weight (0.0286). Because the majority of wheat was grown on flat terrain, where the slop factor was small too little because it didn't alter the water distribution course, it is established that soil drainage has the lowest weight and soil types have the highest weight. Finally soil parameters were subjected to the IDW interpolation approach to examine trends and geographic variations, and the outcomes were mapped in (Figure 4.)

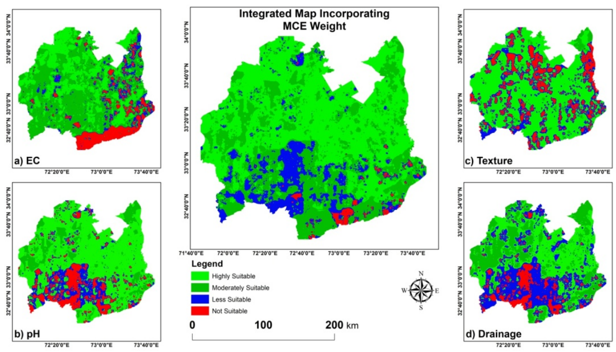

Figure 4: Soil Based Parameters and the Wheat Crop (a) Electric Conductivity Map. (b) Drainage Map. (c) pH of Soil (d) Soil Type Map. (e) Integrated Soil Map Incorporating MCE Weights

3.3 MCE Applied to Both Physical Parameters and TBSMs as in Figure 8

The integrated map considering temperature and soil related parameters is mapped in (Figure 8).

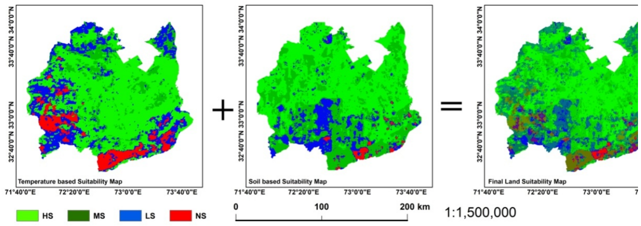

Figure 8: Study Site Mapped Incorporating Physical Parameters and Temperature Based Map.

(Figure 4) describes the MCE methods used to create the integrated map in (Figure 8) from TBSMs (for wheat crop). The overall investigation area was 22168 km^2, of which 12256 km^2 (or 55%) were deemed extremely suitable, 2998 km^2 (or 13%) were deemed moderately acceptable, 4843 km^2 (or 22%) were deemed least suitable, and around 2069 km^2 (10%) were deemed NS for WCC. Results are shown for the HS area, which has a temperature range of 8 to 24 °C, a pH level of 6.2 to 6.5, a soil type of clay loam, and a soil drainage level of 0.85 to 1.1. The NS region was distinguished by dense urban development, extremely high temperatures, and soils with a pH of less than 5.

3.4 Supervised Image Classification

Prior to the milky dough phase, we obtained satellite photographs of a wheat crop on that specific day, and we meticulously classified the images using machine learning techniques (MLTs). The classification of existing land use features using the MLTs yields encouraging results (even within the vegetation). The categorized findings show that WCC covered 16371 km2 of land. In order to cross-authenticate and determine the consistency of picture classification, along with Maali/Patwari, a ground-truthing survey was conducted, and the results were consistent up to 84%. Figure 3.4 depicts the wheat crop's size.

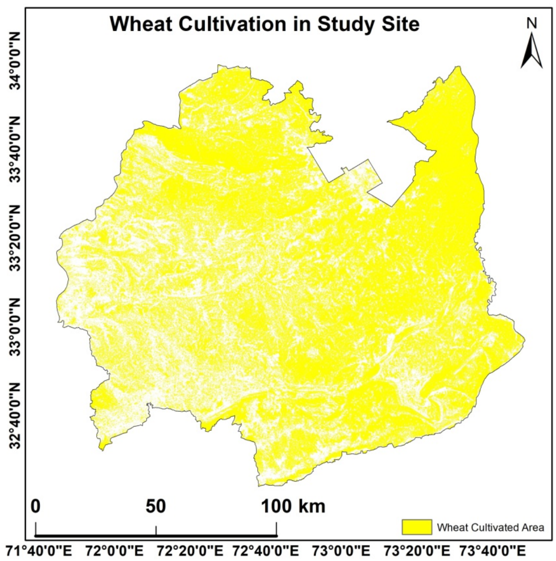

Figure 5.: Spatial Extent of Wheat Cultivation in the Study Site

To establish the actual WCC area in the LS, HS, MS, and NS LSC-zones, the categorized map was placed on the final suitability zones. The WCC areas were discovered to be as follows: Figure 3.5 shows that of the total 16371 km2, 9567 km2 were in the HS zone, 9245 km2 in the MS zone, 1203 km2 in the LS zone, and 356 km2 were in the NS zone.

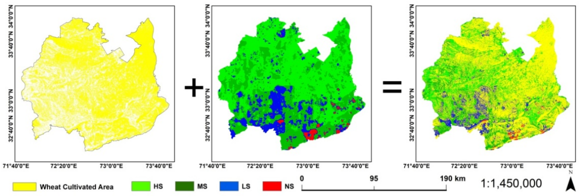

Figure 6.: Final Suitability Maps

4. DISCUSSION

Prior to the milky dough phase, we obtained satellite photographs of a wheat crop on that specific day, and we meticulously classified the images using machine learning techniques (MLTs). The classification of existing land use features using the MLTs yields encouraging results (even within the vegetation). The categorized findings show that WCC covered 16371 km2 of land. In order to cross-authenticate and determine the consistency of picture classification, along with Maali/Patwari, a ground-trothing survey was conducted, and the results were consistent up to 84%. Figure 3.4 depicts the wheat crop's size. To establish the actual WCC area in the LS, HS, MS, and NS LSC-zones, the categorized map was placed on the final suitability zones. The WCC areas were discovered to be as follows: Figure 3.5 shows that of the total 16371 km2, 9567 km2 were in the HS zone, 9245 km2 in the MS zone, 1203 km2 in the LS zone, and 356 km2 were in the NS zone. Based on the temperature ranges, a spatial distribution of the investigation site was created. LS, HS, MS, and NS were the primary classes. We saw that urban/built-up regions have developed into urban heat islands (UHI) as a result of anthropogenic activity, microclimate differences, and global warming. These activities include the production of GHG such as CO_2, SO_2, and aerosols which trap these emissions, at the local, national, and international levels. These regions were observed NS for WCC since the ideal temperature range required for WCC does not occur within this range. It is observed that the wheat crop in the nearby urban regions was short stressed and heighted. Due to the extremely low temperatures in these places, which made them LS for WCC, wheat crop growth there was substantially slowed down and required more time to reach the necessary stage of growth. Since these regions fell within the ideal range of temperatures required for wheat WCC and growth, the spatial sites within urban/built-ups and water bodies were discovered to be HS and MS for WCC and growth. Higher values are visible on the EC map, which may be caused by domestic emissions from urban homes and vehicle exhausts. The iron, magnesium, cobalt, and calcium components of these materials are directly given to the soil, which is excellent for WCC, but their weight is just 0.0857, which may not have a significant impact on WCC and growth.

Similar to this, it was discovered that the soil pH was higher close to the inner-city because of the direct interfaces of acidic wastes from both industrial and home sources that became the part of soil. The type of soil was given a relatively high weight (0.6), which indicated that it had a direct impact on the WCC. The investigation locations were split up into different types, including clayish, loamy, and silty soil. We discovered that clayish soil, which has a better capacity to retain water, was optimal for growing wheat crops, however loamy and silty soils are also somewhat beneficial. Due to greater rates of water seepage that call for frequent and reliable water supply, locations with sandy soil types were identified as NS for WCC. In relatively level places, it was found that the soil drainage weight was quite low, although the process of water distribution was unaffected by the slope factor. In contrast to other classification methods that are currently available, we used support vector machine (SVM) classification for the wheat crop. During ground validations and field surveys, the SVM produced significantly better results, up to 88% accuracy. In comparison to other conventional image classification techniques the total area under WCC is 65% and treated many types of vegetation e.g. wheat crops, about 45% of the investigation site was discovered to be under the WCC. The investigation's findings were determined to be extremely accurate and in line with the available data, however because our farmers do not use the most recent methods, the growth of the wheat crop has decreased in terms of the site's overall productivity.

5. CONCLUSION

The global population is increasing gradually in contrast to shrinkage of agricultural land which is decreasing rapidly as well. To address the difficulties of global food security, it is important to increase agricultural yield per acre, which is unattainable without an understanding of LSC zones. A typical farmer disregards the suitability criteria and begins agricultural techniques in the wrong locations, which decreases overall agricultural yield. To guarantee the best possible yield, the LSC zones for a specific crop must remain maintained. To map the LSC zones remote sensing and GIS spatial analytic tools can be used. The investigation area's physiographic units matched up with its appropriateness for orchards and crops. Crops were MS in the lowlands whereas slope made them MS in the uplands. The LS were caused by slope and organic carbon restrictions. Because of their low levels of organic carbon and average drainage, the midlands were MS. The study shows a strong correlation between soils and physiography. The variety in topography that results in erosion, leaching, sedimentation, and other pedogenic processes influenced by water table is responsible for the production of the diverse group of soil

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