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Python Driven Pathways for Wheat Cultivation Incorporating Physico-Climatic Parameters of Growth

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ABSTRACT

Agriculture has a pivotal role in the provision of food, fabric and income. Agricultural sector is backbone of Pakistan's economy, which is strongly dependent on agriculture. Pakistan is renowned globally for its wheat crop. However, wheat production has suffered due to lack of modern farming techniques, inadequate water availability, and relevant soil parameters. The main objective of this study was to monitor stages of wheat growth using Landsat 8 thermal datasets through temperature-based site maps. This study delineates suitable areas for sustainable wheat growth using Multi-Criteria Evaluation (MCE) and GIS. The total area under investigation was 5,697 km^2 and the area under wheat cultivation was 2,276.63 km^2, out of which 1,684.26 km^2 (74%) was found highly suitable, 68.3376 km^2 (3%) was moderately suitable, 61.6678 km^2 (2.7%) was least suitable, and 462.355 km^2 (20.30%) was found not suitable for wheat crop cultivation. The results interoperated that the area with temperature range of 10–18°C, and pH ranging between 6.2 and 6.5, clay loom soil texture, and 0.85 and 1.1 drainage level indicate highly suitable land for wheat production. This study highlights the local farming techniques, suitable land for wheat production, and patterns of crop harvesting.

Keywords: Analytic Hierarchy Technique (AHP), Inverse Distance Weighted (IDW), Land suitability, Multicriteria Evaluation (MCE).

INTRODUCTION

Global population data sheet suggests that the population has reached to 7.8 billion in 2020 and supposed to increase up to 9.9 billion by 2050 (IISD, 2020). The population growth has increased many folds than food supplies because agricultural land is speedily transforming into colonies and the food supply is getting declined. Agriculture is considered the backbone of Pakistan's economy that accounts for 21% of the total Gross Domestic Product (GDP) (Azam and Shafique, 2017; Islam, 1995) of Pakistan. Agricultural productivity is considered the bread and butter of almost 70% Pakistani population (Rehman and Hussain, 2016). Although most of the food demands in Pakistan are met through wheat production, rice, maize, corn and sugarcane are also cultivated. Wheat provides extensive boost to the economy, but the expansion of built-up areas has decreased the agricultural land (Rehman *et al*., 2015). Thus, sensible management of resources is required to fulfill the increasing demands of food.

Plant growth is influenced by many types of ecological factors including soil, temperature, moisture and pH of the soil (Gentili *et al*., 2018). These factors affect the nutritional quality of plants, but farmers are usually unaware of the necessity of these parameters to evaluate which affect the yield of wheat per acre (Onwuka, 2018). Therefore, farmers should be well informed about specificity of soil and association of above-mentioned parameters with the productivity and growth of wheat crop. The potential of soil effects the production of

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specific crop. Certain strategies are recommended to enhance the agricultural productivity (Department Agriculture, 2016).

The suitability of soil for a particular crop is obligatory to obtain targeted yield. The soil is classified into subclasses in order to evaluate the capability and suitability of the particular land. The suitability of soil is analyzed and mapped using Geographical Information System (GIS) in order to meet the primary objectives (Dedeoğlu and Dengiz, 2019; Muhammad *et al*., 2018). GIS is a precise tool that can attain, secure, manage and manipulate the vast spatial and temporal datasets in order to analyze the satellite data and its thematic attributes for evaluation of land suitability accurately (Muhammad *et al*., 2018). The Multi-Criteria Evaluation (MCE) techniques can be used along GIS techniques for mapping suitability zones accurately (Özkan *et al*., 2020; Zolekar and Bhagat, 2015). Land suitability procedure indicate a number of critical factors that would help managers to achieve optimum crop yield and decrease the loss of citrus production. According to experts' opinion, higher weights were assigned to minimum temperature and altitude than to all other criteria (Zabihi *et al*., 2015). Understanding spatial factors and criteria is required for locating suitable production areas to increase cassava production. In this study, a spatial model was developed to assess the suitability of land for supporting sustainable cassava production (Purnamasari *et al*., 2022). Bilgilioğlu (2021) worked for land suitability of the olive plant, which has a high economic value in the Mediterranean city of Mersin, Turkey. Zhang *et al.* (2015) constructed a model to produce results based on individual land mapping unit, which facilities the land resource allocation and management. (Mahmood *et al*., 2019)mapped the suitable site for rice cultivation through MCE and AHP techniques and investigated that physio-climatic conditions affect the growth and development of rice crop, therefore, it is necessary to carefully consider the crop growth factors for evaluation suitable sites for wheat cultivation.

The novelty of this research is that the python-based technique has been used for the first time. By the advent of machine learning techniques and python-based algorithms, it has become the need of time to consider python-based algorithms in agricultural practices. The main objective of incorporating the MCE techniques into the GIS is to recognize suitable regions taking into account wheat growth parameters through multiple criteria for wheat yield and generation of maps for land suitability. The physical factors include the soil pH, drainage, electric conductivity, and soil type and pixel based temperate values are projected to calculate the delineation of potential sites for wheat cultivation.

MATERIALS AND METHODS

Experimental Site

The study area is located in Punjab Province of Pakistan, which is Pakistan's industrial and agricultural linchpin. The agriculture industry contributes around 21.4 percent to Pakistan's agro-based economy's GDP and provides 62 percent of the rural population's means of subsistence (Ali *et al*., 2022). This province is the second biggest territory of Pakistan in terms of area having high population which is approximately 56% of the total population of country (Rehman, *et al*., 2015). Punjab is considered as bread basket for Pakistan with 12.4 million hectares of cultivated land (Khan *et al*., 2021). In Rabi season of 2020-21, the area dedicated for wheat was 6.75 million hectares (Government of The Punjab, 2021). Punjab comprises three main agro-ecological regions: (i) Potwar plateau containing 10 percent of rain fed agricultural land in the north of province (Crop Reporting Service, Punjab, 2015), (ii) The semi-arid and arid desert in the center and south part of Punjab with fewer agriculture

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production, and (iii) Indus Basin region with most irrigated crop cultivation area (*Punjab CRS: Base Line Survey Agriculture Information System Building Provincial Capacity for Crop Forecasting and Estimation*, 2012). Punjb produces wheat and other essential food to ensure food security of nearly two hundred million people and contributes significantly to state's economic growth.

Punjab produces between 56.1 and 61.5% of all agricultural products and employs around 49 percent of the labor force (Ali *et al*., 2022) . Even though the agricultural sector of Punjab makes a large contribution to Pakistan's overall economy, it is under pressure from floods and droughts caused by climate change. Wheat and cotton are two important commodities grown in Punjab that contribute significantly to Pakistan's economy. Wheat is one of Pakistan's key crops and accounts for around 10.3 percent of the country's agricultural economy (Rehman *et al*., 2020). The study area, including Vehari, Mian Channu, Burewala, and Chichawatni are considered the best producers of wheat. Geospatially, the investigation site is located between 72 to 73° E longitude and 29.5 to 30.5° N latitude with greatly fertile land. It is located at a height of roughly 130 m above sea level and receives approximately 200 mm of annual precipitation. It is nearly like being on a peneplane. Summers are hot, occasionally terribly sweltering, whilers are mildly warm. It has hotter rainy seasons and cooler dry seasons due to its location on the outskirts of subtropical deserts and its smaller scale. It is also subjected to the effects of storms on occasion, being quite wet during rainfall months and dry the rest of the year. The weather is intense from May to July, when temperatures reach 40 to 50°C, and it drops to 5 to 10°C in the winter. The study area is a subset of Landsat patch with 150/39 path/row as shown in Figure 1.

Experimental Design

We conducted field surveys for consultations with local agronomists, explored extensive literature, and got opinion of wheat crop specialists to establish

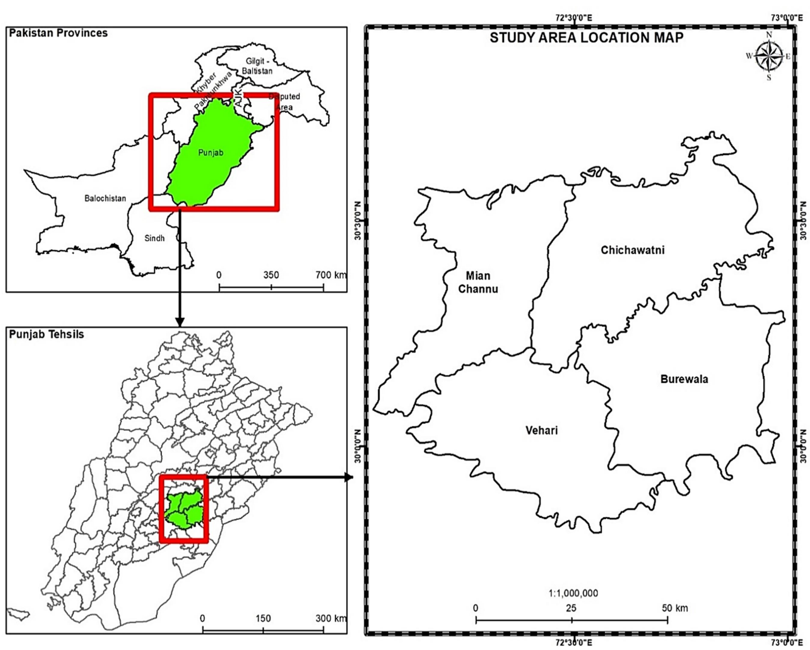

Figure 1. Study site.

important land requirements for wheat farming. The soil related parameters including soil pH, texture, electrical conductivity, and soil drainage were collected by Soil Survey Of Pakistan (SSOP) using auger. The same factors have been considered by various other researches for delineation of potential sites fo crop cultivations (Kihoro *et al*., 2013; Muhammad *et al*., 2018;Duffie *et al*., 2020; Raza *et al*., 2018) . The point data was available with SSOP and has been mapped in Figure 2 (b). The steps adopted in this study are depicted in Figure 2 (a).

We obtained a satellite image of wheat crop of the day, just before the milky dough stage, and classified it carefully using Support Vector Machine. This method provides promising results for classification of available land use features (even within vegetation).

Step 1: Calculation of Land Surface Temperature (LST) through Landsat-8 Thermal Dataset

LST is defined as the temperature emitted back to sky as reflected energy (Rajeshwari, 2014). LST is a fundamental parameter to evaluate various fields of life e.g., health monitoring of various cereal crops and vegetation, global climate change, agricultural and hydrological processes, and urban heat islands and other extreme events such as natural disasters like forest fires and volcanic eruptions (Avdan and Jovanovska, 2016). Estimation of LST through remotely sensed datasets play a vital role for controlling chemical, biological and physical processes of globe (Becker and Li, 2007). There is a developing cognizance amongst researchers regarding remote sensing data to observe ecosystem conditions and change detection (Ustin, 2004).

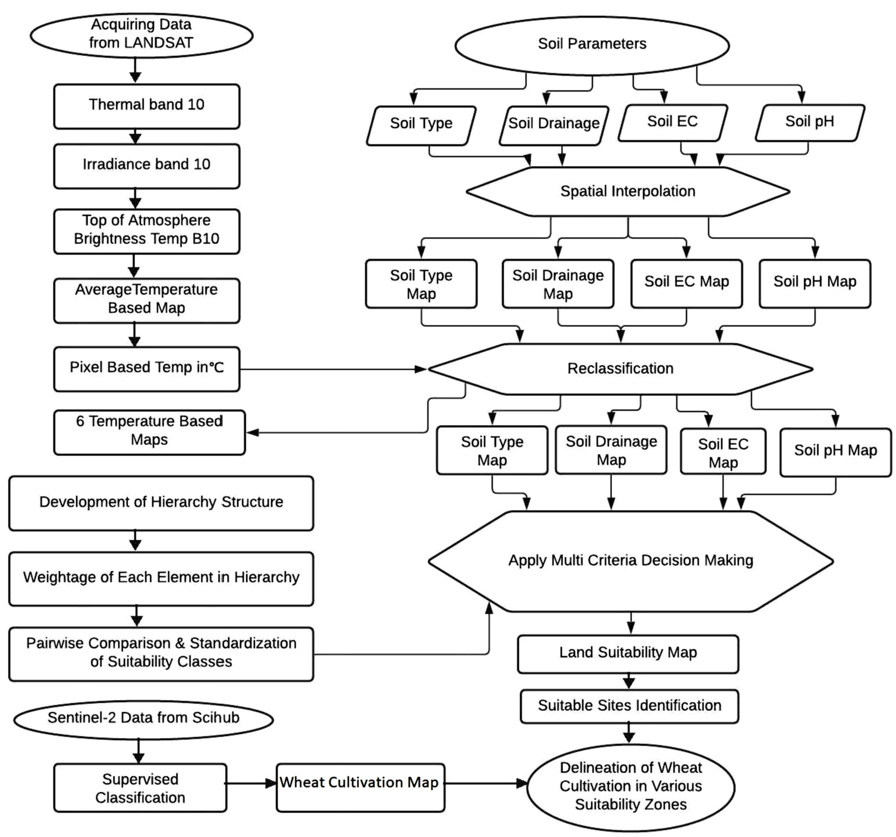

Figure 2. Flowchart of methodology.

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To assess land suitability at the different growth stages of wheat crop, land surface temperature was calculated with python using Landsat 8 level 1 data. Python code was developed to repeat the process automatically to calculate LST. Without developing a python code, the manual method of LST calculation is length and hectic with self-induced errors. Although the methods of LST calculations have been developed, an automated python program is much needed to avoid the complicated procedure of calculating LST. The code developed for this study is only for Landsat 8 data. Due to the recommendations of USGS TIRS Band 11 is not being used because of its more calibration uncertainty, only Band 10 has been used for the calculations.

calculate brightness temperature and Bands 4 and 5 were used for NDVI calculation. Metadata of satellite imagery used here is given in Table 1.

Top of Atmospheric Spectral Radiance.

The Top Of Atmosphere reflectance was computed using the equation as below according to USGS website:

$$TOA\ (L\lambda) = M_L \times Q_{cal} + A_L \quad (1)$$

Where, ML and AL represent the Multiplicative and Additive band-specific rescaling factor respectively, Qcal is B10 image, and Lλ is atmospheric spectral radiance (Barsi *et al*., 2014).

To automate the process, the following python code was developed[1]:

[1]

```
# Top of Atmospheric Spectral Radiance
# TOA = radiance.radiance(tif, ML, AL, src_nodata=0)
L = radiance.radiance(Band10, Radiance_Mult_Band_10, Radiance_Add_Band_10, src_nodata=0)
print("Display TOA     ",L)

with rasterio.open(
    data_path+newFolder+"/"+newFolder+'TOA.tif', 'w',
    driver='GTiff', width=IWidth, height=IHeight, count=1,
    dtype=L.dtype,crs=Icrs,resolution=dsBand10.res,transform=dsBand10.transform) as dstTOA:
    dstTOA.write(L, 1)
```

Following procedure in Figure 2 (a) has been adopted for LST computation using thermal bands by Landsat 8.

Landsat 8 data is freely available on the USGS website, which is comprised of various bands containing a big variety of bandwidth from visible to thermal infrared. Thermal Infrared band 10 was used to

Conversion of Top of Atmospheric Radiance Recorded by Onboard Sensor.

The Digital Number (DN) of each pixel was transformed to spectral radiance and the radiance to brightness temperature in

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

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

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centigrade by applying thermal constants extracted from metadata available in complete package of Landsat 8 image using the formula as below (U.S. Geological Survey, 2021):

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

Where, K_1 and K_2 are the constants having fixed values fed in metadata. These constants have significance to compute temperature in Celsius and L is the radiance computed in the above section (Xu and Chen 2004). The Python code used to calculate LST is as below[2]:

[2]

```
# Conversion of Top of Atmospheric Radiance to At-Sensor Temperature
# TOA to Brightness Temperature conversion
Bt = (K2_Const_Band_10 / np.log ((K1_Const_Band_10 / L) + 1)) - 273.15
print ("BT............." , Bt)

with rasterio.open(
    data_path+newFolder+"/"+newFolder+'BT.tif', 'w',
    driver='GTiff', width=IWidth, height=IHeight, count=1,
    dtype=Bt.dtype,crs=Icrs,resolution=dsBand10.res,transform=dsBand10.transform) as dstBT:
    dstBT.write(Bt, 1)
```

[3]

```
# Calculate the NDVI
# Open Band4 as red band
dsBand4 = rasterio.open(data_path+newFolder+"/"+newFolder+"_B4.TIF")
red = dsBand4.read(1).astype('float64')
print("Display Band4    ",red)

# pen Band5 as nir band
dsBand5 = rasterio.open(data_path+newFolder+"/"+newFolder+"_B5.TIF")
nir = dsBand5.read(1).astype('float64')
print("Display Band5    ",nir)

ndvi=np.where((nir+red)==0.,0, (nir-red)/(nir+red))
print("NDVI", ndvi)

with rasterio.open(
    data_path+newFolder+"/"+newFolder+'NDVI.tif', 'w',
    driver='GTiff', width=IWidth, height=IHeight, count=1,
    dtype=ndvi.dtype,crs=Icrs,resolution=dsBand10.res,transform=dsBand10.transform) as dstNDVI:
    dstNDVI.write(ndvi, 1)
```

NDVI Method for Emissivity Correction

Calculating NDVI

Red and Near Infrared bands are widely/extensively utilized to compute the green index through a dedicated index called Normalized Difference Vegetation Index (NDVI) (Weng *et al*., 2004). NDVI has been extensively used to evaluate the green index, which is an essential part to evaluate the Proportion of vegetation (P_v). The emissivity was computed by incorporating (P_v).

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

Code developed for NDVI in python was as follows [3]:

Calculating the Proportion of Vegetation

P_v is measured according to the formula given below (Avdan and Jovanovska, 2016),

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

P_v is an important factor to measure the land surface emissivity (ε). The python code developed to measure P_v was as follows[4]:

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[4]

```
# Calculate the proportion of vegetation Pv

p = np.square(ndvi-0.216901)/(0.632267-0.216901)
print("proportion of vegetation P",p)

with rasterio.open(
    data_path+newFolder+"/"+newFolder+'P.tif', 'w',
    driver='GTiff', width=IWidth, height=IHeight, count=1,
    dtype=ndvi.dtype,crs=Icrs,resolution=dsBand10.res,transform=dsBand10.transform) as dstP:
    dstP.write(ndvi, 1)
```

Calculating Land Surface Emissivity

LSE (ε) was computed to gauge blackbody radiance as (Plank's Law) to compute the emitted radiance. It is more effective and elegant method for estimation of LST (Jiménez-Muñoz *et al*., 2006). The formula to compute emissivity is as below:

$$\varepsilon = 0.004 * P_v + 0.986 \qquad (5)$$

The python code developed for the above equation is as follows[5]:

Calculating Land Surface Temperature

Finally, LST was computed using the following formula and can be calculated using Brightness Temperature (BT) and land surface emissivity (ε) according the given equation.

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

The following python code was developed for the estimation of LST [6]:

[5]

```
# Calculate Emissivity ε
#   ε = 0.004 * P v  + 0.986
Ee = 0.004*p+0.986
print("Emissivity ε",Ee)

with rasterio.open(
    data_path+newFolder+"/"+newFolder+'Emissivity.tif', 'w',
    driver='GTiff', width=IWidth, height=IHeight, count=1,
    dtype=ndvi.dtype,crs=Icrs,resolution=dsBand10.res,transform=dsBand10.transform) as dstE:
    dstE.write(ndvi, 1)
```

[6]

```
# Calculate the Land Surface Temperature
lst = (Bt/(1+(0.00115*Bt/1.4388)*np.log(Ee)))
print ("LST",lst)

#Save LST image
with rasterio.open(
    data_path+newFolder+"/"+newFolder+'LST.tif', 'w',
    driver='GTiff', width=IWidth, height=IHeight, count=1,
    dtype=lst.dtype,crs=Icrs,resolution=dsBand10.res,transform=dsBand10.transform) as dstLST:
    dstLST.write(lst, 1)
    with rasterio.open(
    data_path+newFolder+"/"+newFolder+'LST.tif', 'w',
    driver='GTiff', width=IWidth, height=IHeight, count=1,
    dtype=lst.dtype,crs=Icrs,resolution=dsBand10.res,transform=dsBand10.transform) as dstLST:
    dstLST.write(lst, 1)
```


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Step 2: Soil Suitability Parameters

The soil survey of Pakistan provided us suitability data of soil related parameters e.g. soil pH, EC, texture, and soil drainage particularly related to our study site for the wheat crop. The data comprised of geographic points having values of soil parameters. Mostly IDW technique is used for interpolation of numeric values or quantitative datasets, therefore, we preferred to apply IDW instead of other interpolation techniques (Wu and Hung, 2016). We applied the Inverse Distance Weightage (IDW) interpolation technique to map thematic variations in soil parameters for calculation of their spatial distribution. Analytical Hierarchy Process (AHP) (El Jazouli *et al*., 2019) was used to assign weights to each soil parameter. Soil suitable parameters are given in Table 3.

Step 3: Assigning Weights for Multi-Criteria Evaluation (MCE)

AHP is a pair-wise comparison method used for the comparison of each soil parameter by assigning weights according to their importance. AHP technique was used to generate soil-based suitability map. Weights were computed and assigned to each soil related parameter to express its importance regarding wheat crop growth rate. Four suitability levels were assigned to establish and reclassify the relevant factors according to the guidelines and opinions of experts for suitability wheat growth.

Soil pH for silt clay and clay loam ranges between 5.5–6.5 and EC range of 0.8-1.3 (S m^{-1}) is suitable for wheat growth (El Jazouli *et al*., 2019). Parameters were reclassified into four classes using the suitable values. The ranks for suitability levels were highly suitable, moderately suitable, less suitable, and not suitable.

Supervised Classification

Supervised classification is computer-based segmentation of a study site into its respective units based on feature types. Classification converts pixel-based values into clusters based on likelihood. It is the easiest way to predict crop estimates e.g., crop area and yield, etc.

We performed supervised classification in Erdas Imagine 15 to determine the spatial extent of wheat in various sequential stages e.g., germination, tillering, ripening, etc.

RESULTS

Temperature Based Potential Zones for Wheat Crop

Temperature along with other factors affect the suitability of wheat crop growth. The field observations are in Table 2. We observed that 18-25˚C temperature is optimum for all stages of wheat growth, but germination usually occurs at 7-20˚C. Table 2 shows literature review and observed temperature in highly suitable zones. The table shows that temperature below 10˚C and above 25˚C is not suitable for wheat growth as growth stops below 10˚C. The temperature up to 20˚C displays active metabolic activity, which justifies grain filling in upcoming stages.

Temperature between 22 to 34˚C is suitable for summer while 5 to 25˚C is suitable for winter wheat growth. Minimum temperature for wheat growth below which wheat does not grow is 0-5˚C. Optimum temperature at which maximum plant growth occurs is 25˚C and the growth usually stops above 30-32˚C of temperature. LST calculated for all thermal datasets is given in Table 2 (a). LST maps were reclassified into four classes according to their suitable ranges. Average of all LST maps were taken to obtain temperature based suitability maps. The weight analysis is applied as shown in Table 4.

All soil-based maps of Figure 3 were added and divided by their number to obtain averaged soil suitability map using raster calculator tool. The maps (a–f) in Figure 3 explains the suitability levels as follows: All

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Table 2. Literature based optimum temperature and observed temperature for different stages of wheat crop.

Phonological stage	Literature source	Literature temp (°C)	Observed temp for highly suitable site (°C)
Germination	(Russell and Wilson, 1994)	7.1-20	10 – 18
Tillering	(Qu and Wang, 1982)	> 8.5	10-16
Heading	(Salazar-Gutierrez, Johnson, Chaves-Cordoba, and Hoogenboom,2013)	10-18.4	14-19
Milk Dough	(Jenner, 1991)	20	16-20
Full Maturity	(Hossain, Sarker, Hakim, Lozovskaya and Zvolinsky, 2011)	10-25	15-22

Table 2(a). Landsat 8 image acquisition for LST calculation.

Date	Wheat plant growth stages
01/12/2018	Germination
18/01/2019	Tillering stage
03/02/2019	Heading
07/03/2019	Flowering and Milk Maturity Stage
24/04/2019	Full Maturity Stage

Table 3. Soil suitability parameters.

Scale	Soil type	Soil drainage	Soil pH	Soil EC
High Suitable	Clay Loam	0.85-1.1	6.2-6.5	0.85-1.1
Moderate Suitable	Silt Clay	1.1-1.3	5.5-6.2	1.1-1.3
Less Suitable	Saline	1.3-1.4	5.2-5.4	1.3-1.4
Not Suitable	Sandy	1.4-2.0	4.5-5.2	1.4-2.0

Table 4. Analytical Hierarchy Process (AHP) to compute weight of each parameter.

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

maps (a–f) shown by red regions were not suitable for wheat crop cultivation due to high temperature, as wheat growth is stunted in extreme weather conditions. The dark green areas, which are away from urban population and roads, appeared highly suitable for wheat cultivation and the areas that lie close to water bodies showed less suitability for wheat cultivation. Average of all temperature-based maps (a-f) was taken to prepare the final temperature-based suitability map.

Delineation of Potential Zones for Wheat Considering Weighted Soil Parameters

Loamy clay was observed likely suitable due to its property of getting imperfectly drained, whereas the sand was observed unsuitable. The silty clay was observed as well drained, therefore, it was assigned as

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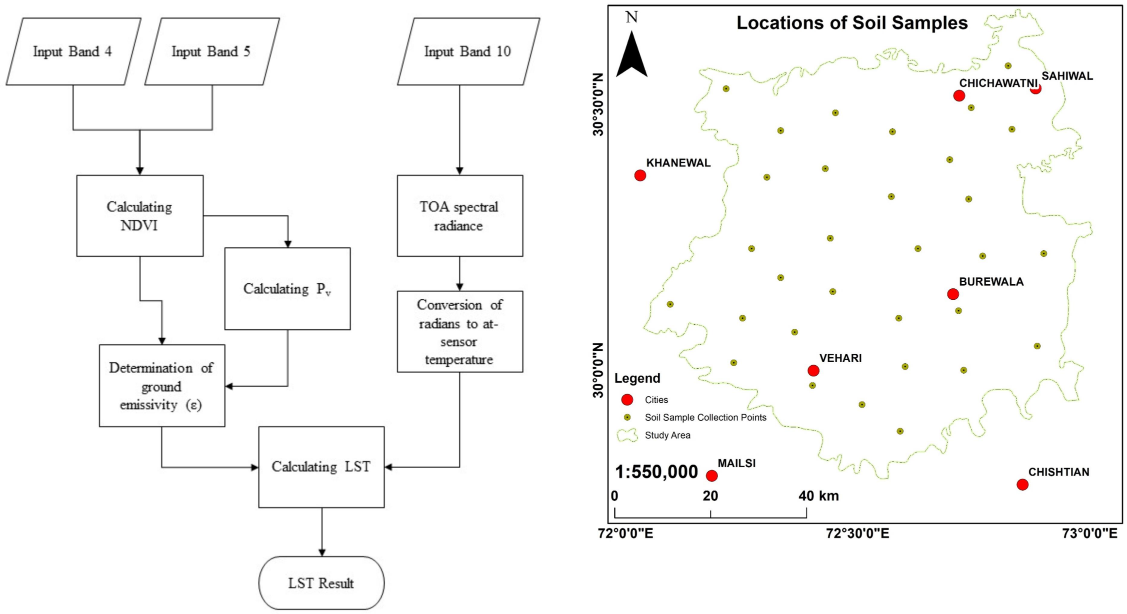

(a) (b)

Figure 2. Flowchart for LST retrieval (a) and Soil sample collection points (b).

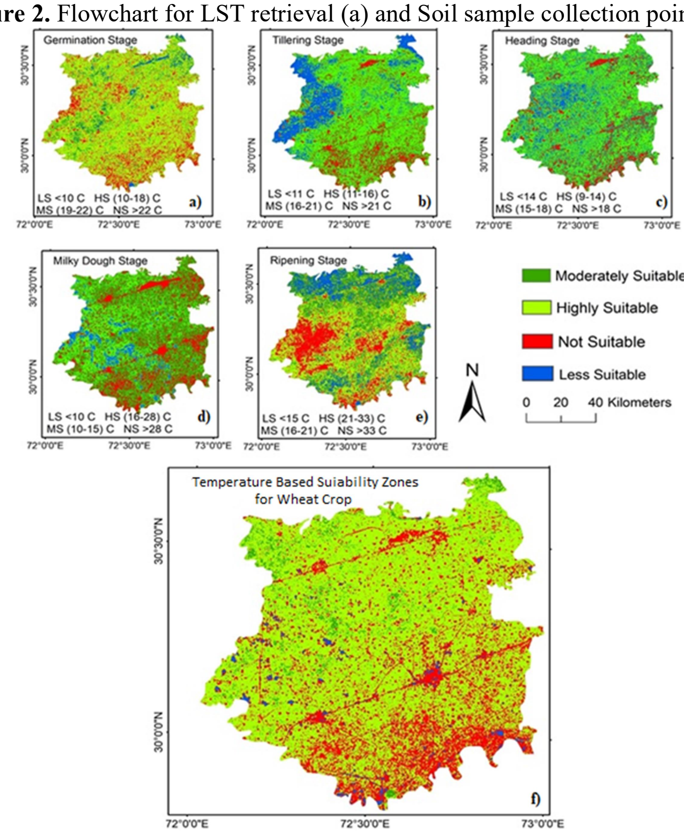

Figure 3. Wheat map representing various growth stages at variable temperatures: **(a)** Wheat crop in germination stage; **(b)** Tillering stage; **(c)** Heading stage; **(d)** Milky Dough stage; **(e)** Ripening stage, and **(f)** Temperature based integrated map incorporating all temperature-based stages.

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moderately suitable for wheat crop. The range of EC between 1.6-2 S m^{-1} was not suitable for wheat, which may lead to burning of the crop. The EC of 1.1-1.4 Sm^{-1} was observed less suitable and EC of 0.85-1.1 was observed highly suitable. Soil pH in the range of 6.2-6.5 was found highly suitable for the growth of wheat while values less than 5.2 were not suitable. The weight of these parameters was computed and the largest weight was assigned to soil type and the lowest weight was assigned to 0.0286 for drainage of soil. It determines that soil texture has the highest weight and soil drainage has the lowest, because most of the areas where wheat was planted were in the flat land where slope factor was negligible and did not affect the water distribution process. The IDW interpolation technique was applied to all soil parameters to compute their trends and mapped the results in Figure 4.

MCE Applied to Both Physical Parameters and Temperature-Based Map

The integrated map considering temperature and soil related parameters is mapped in Figure 5.

Figure 3 explains MCE techniques applied to temperature-based suitability map for

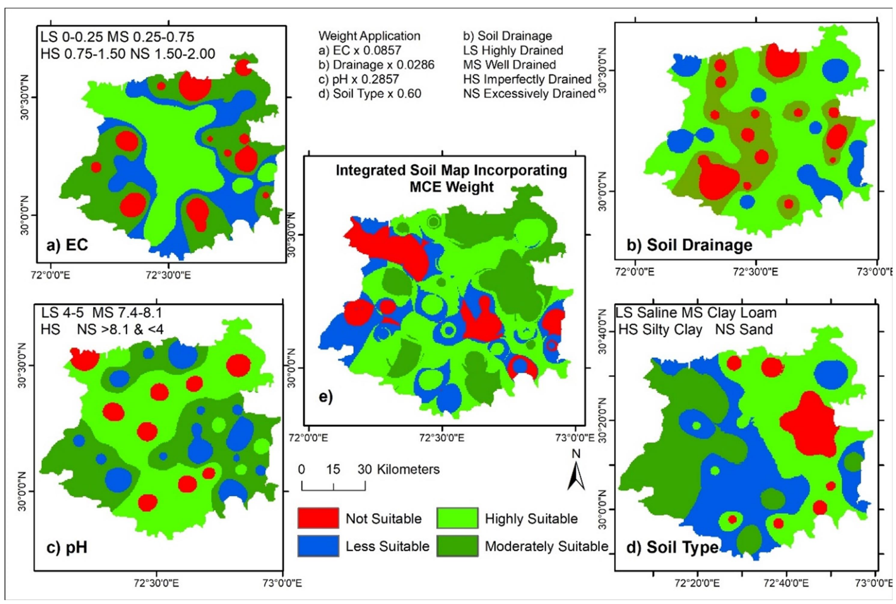

Figure 4. Soil based parameters and the wheat crop: (a) Electric Conductivity map; (b) Drainage map; (c) pH of soil; (d) Soil Type map, and (e) Integrated Soil Map Incorporating MCE Weight.

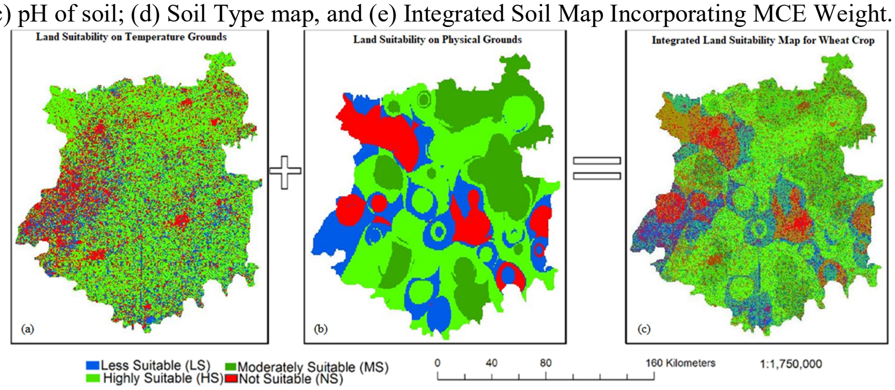

Figure 5. Study site mapped incorporating physical parameters and temperature-based maps: (a) Temperature based suitability zones; b) Soil based suitability zones, and (c) Integration of temperature and soil based zones.

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wheat crop to make a combined map shown in Figure.4. The total area under investigation was 5697 km^2 and wheat cultivated area was 2,276.63 km^2, out of which 1,684.26 km^2 (74%) was found highly suitable, 68.3376 km^2 (3%) was moderately suitable, 61.6678 km^2 (2.7%) was least suitable, and 462.355 km^2 (20.30%) was found not-suitable for wheat crop cultivation in the study site. Results show that highly suitable area was characterized by 8 and 24◦C temperature range, 6.2 to 6.5 soil pH level, soil texture was clay loam, and soil drainage level ranged between 0.85 and 1.1. Unsuitable area was characterized by urban population with extreme temperature condition, inadequate salty paned, and soil pH less than 5.

The suitability zones in Figure 5 represent the complete picture of study site but the main issue is to determine where the wheat crop was grown, keeping in view Figure 5. To do so, it was important to classify the study site to extract the area under wheat cultivation.

Supervised Classification

The classification results show that the area under wheat crop was 2382 km^2. A field survey was conducted in order to cross validate and compute the reliability of classification, along Maali Patwari and results were up to 88% reliable. The extent

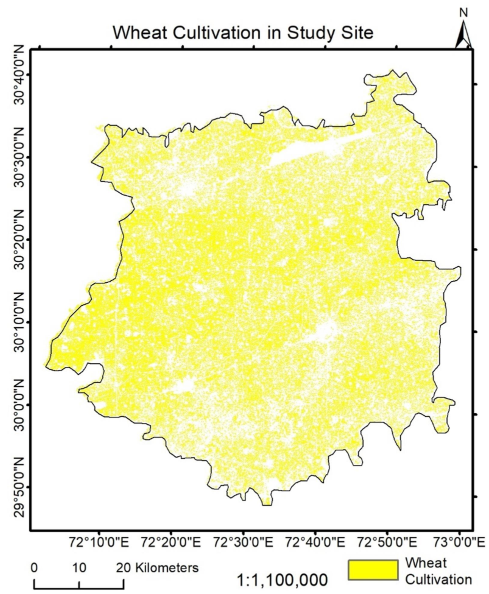

Figure 6. Spatial extent of wheat cultivation in the study site.

of wheat crop is shown in Figure 6.

The classified map was superimposed to the finally drawn suitability zones to determine the actual wheat cultivation area in less suitable, highly suitable, moderately suitable, and not suitable zones. It was found that wheat cultivation area was 2382 km2 out of which 1618 km^2 area was highly suitable, 68.447 km^2 in moderately suitable zone, 58 km^2 in less suitable zone, and 259 km^2 in not-suitable zone as shown in Figure 7.

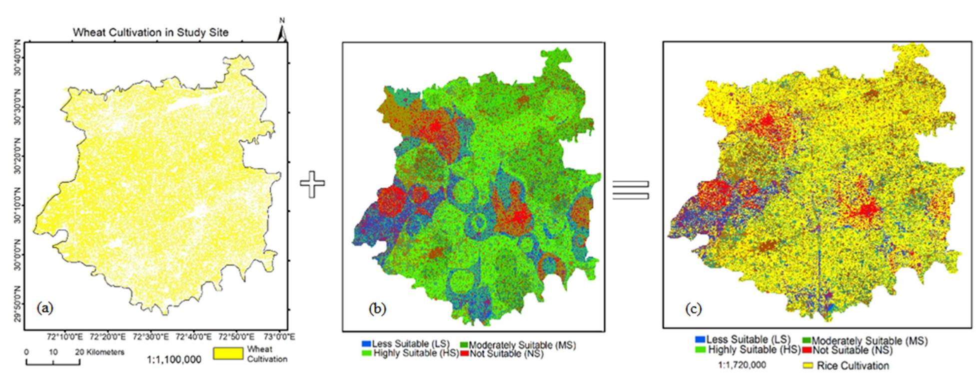

Figure 7. Final suitability maps: (A) Spatial distribution of wheat; (b) Physio-climatic zones, and (c) Integration of wheat and physio-climatic zones.

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DISCUSSION

The study site was spatially distributed on the basis of temperature ranges. The major classes were less suitable, highly suitable, moderately suitable and not suitable. We observed that the urban areas had become heat islands due to anthropogenic activities. These activities include the emission of gases including CO_2, SO_2 and particulate matter that trap the emitted heat by human activities. The optimum temperature required for wheat growth was not within this range, therefore, these are the areas where temperature is very high which is out of optimal range for growth of wheat crop. Wheat plant near to urban areas, or along the roads is short heighted and stressed due to anthropogenic activities/heat.

The area near the water body was observed less suitable for wheat plant because these areas had lower temperature; therefore, wheat crop was delayed and took more time to reach a particular growth stage. The spatial site within these urban and water body were observed highly and moderately suitable for wheat crop, because these areas fall under the optimum range of temperature required for wheat. The EC map determined the high values near the urban areas, which may be due to emission of various kinds of materials from households. These materials include iron, magnesium, cobalt, and calcium, which is directly added to soil that is good for wheat crop, but its weightage was computed much less, as 0.0857, which may not have considerable effect on the wheat crop growth.

Similarly, soil pH was observed high near the urban areas due to direct discharge of acidic content that is added to the soil. The weight of soil type was computed very high (0.6), which indicates that the soil type had a direct impact on the growth of wheat crop. The study site was distributed into a diverse soil clayish, loamy sandy, and silty. We observed that the clayish soil type was the best for wheat crop because its water holding capacity is high, however, the silty and loamy soil types are also good to some extent. The areas under sandy soil type were not-suitable for wheat crop to grow due to high seepage of water, which requires high frequency of irrigation. The weight of soil drainage was observed much less because the overall area was flat, where the slope factor did not affect the water distribution process.

We used Support Vector Machine (SVM) for classification of wheat crop, which is comparatively a better approach than other available classification methods. The SVM provided better results that were proved 87% reliable during ground truthing/field survey. About 40% of the study site was under wheat plantation in comparison to other traditional methods of classification, which provided 64% of the total area under wheat crop. The study area was comprised of a variety of vegetation types other than wheat that include grass and other kinds for cattle grazing etc. These were identified and removed to examine the exact extent of area under wheat.

The results of this research are highly accurate and reliable, but our farmer is unaware of applying the latest techniques, causing a decline in the overall production in the study site.

CONCLUSIONS

The global population is increasing in comparison to agricultural land, which is decreasing speedily. It is significant to enhance per acre yield to cater the food demands of increasing population. This is not possible without knowing the suitable zones for wheat crop. Traditional farmers ignore the suitability parameters and start agricultural practices in appropriate place which leads to decline the overall production. The suit abilities and zones for a particular crop must remain intact to ensure the optimum production. Sweet greens are widely used as a cereal crop there and the productivity must be enhanced to cater the food demands of increasing population.

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Remotely sensed high-resolution satellite images of the spatial and temporal resolutions and spatial analysis tools are freely available in the interface of GIS to map suitability zones.

There are two limitations though, one of which is related to availability of satellite data on daily basis. The results may be improved many folds if researches ensure the data availability in term of spatial, spectral and temporal domains. Secondly, the applicability of this research is only possible if the government establish centers to help the local farmer for site selection to cultivate a particular crop, sine the farmers are not capable enough to apply this model for crop cultivation.

The local farmers ignore the sites suitability characteristics and grow an irrelevant crop at an inappropriate place due to unawareness of modern technologies. Government must establish testing centers at remote locations to help local farmers to analyze a particular area by incorporation of soil and atmospheric parameters to enhance overall productivity of a cereal crop.

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مسیرهای مشتق از پایتون (Python) برای کشت گندم با ترکیب پارامترهای فیزیکی-اقلیمی رشد

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چکیده

کشاورزی نقش محوری در تامین مواد غذایی، پارچه و درآمد دارد. بخش کشاورزی ستون فقرات اقتصاد پاکستان است که به شدت به کشاورزی وابسته است. پاکستان به خاطر محصول گندمش در سطح جهانی شهرت دارد. با این همه، تولید گندم به دلیل رایج نبودن تکنیک های کشاورزی مدرن، در دسترس نبودن آب کافی، و پارامترهای مربوط به خاک آسیب دیده است. هدف اصلی این مطالعه پایش مراحل رشد گندم با استفاده از مجموعه داده های حرارتی Landsat 8 از طریق نقشه های سایت مبتنی بر دما بود. این مطالعه مناطق مناسب برای رشد پایدار گندم را با استفاده از ارزیابی چند معیاره (MCE) و GIS ترسیم می‌کند. کل مساحت مورد بررسی ۵۶۹۷ کیلومتر مربع و سطح زیر کشت گندم ۲۲۷۶/۶۳ کیلومتر مربع بود که از این

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میزان ۱۶۸۴/۲۶ کیلومتر مربع (۷۴ ٪) بسیار مناسب، ۶۸/۳۳۷۶ کیلومتر مربع (۳ ٪) نسبتا مناسب، ۶۱/۶۶۷۸ کیلومتر مربع (۲/۷٪) کمترین مقدار مناسب و ۴۶۲.۳۵۵ کیلومتر مربع (۲۰.۳۰٪) کمترین مقدارمناسب برای کشت محصول گندم را داشت. نتایج نشان داد که منطقه با محدوده دمایی ۱۰–۱۸ درجه سانتیگراد، و pH بین ۶.۲ و ۶.۵، بافت خاک لوم رسی و سطح زهکشی ۰.۸۵ و ۱.۱ نشان دهنده زمین بسیار مناسب برای تولید گندم است. این پژوهش تکنیک های کشاورزی محلی، زمین مناسب برای تولید گندم و الگوهای برداشت محصول را برجسته (highlight) می کند.

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