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Assessment of Land Suitability for Tea Cultivation Using Geo-Informatics in the Mansehra and Abbottabad District

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Abstract. Pakistan is a major tea consumer country and ranked as one of the largest importer of tea worldwide. This research has been conducted over district Mansehra and district Abbottabad in Khyber Pakhtunkhwa province of Pakistan where the most favourable conditions for tea cultivation already exist and National Tea Research Institute has done successful experiments to cultivate high quality tea. High tech approach is adopted to meet the objectives of this research by using the remotely sensed data i.e. Aster DEM, Land sat8 Imagery. Results showed that in study area 13.24% (778.3 sq.km.) is highly suitable, 33.44% (1966 sq.km.) is suitable, 30.71% area (1805 sq.km.) is moderately suitable, 16.13% area (948.5 sq.km.) is less suitable, and 6.46% (379.3 sq.km.) is not suitable for tea cultivation. This geomatics based model and approach could be used to identify more areas for tea cultivation to meet country's demand.

Keywords: Agrarian country, remote sensing, GIS, geo-informatics, tea cultivation

Introduction

Pakistan is a major tea, referred as favourite beverage for the people of the country by (Islam *et al*., 2012), consumer being ranked as the second largest importer of tea in the world (Waheed *et al*., 2002). It is one of the most consumed beverages in Pakistani cuisine. The per capita consumption of tea in Pakistan is one kilogram. Pakistan imports the tea from abroad to fulfill it requirements. Thus, the total annual import of black tea in 2010-11 was 127,316 tons (costing around Rs=0·25 billion) and that of green tea was 3,322 tons (costing around Rs=0·353 million) with highest imports from Kenya, Vietnam and China (Ahmad *et al*., 2014). With rapid population growth in Pakistan, this demand is increasing at an enormous rate and putting pressure on the import bill of the country (Latif *et al*., 2008). Tea cultivation started at village Baffa, district Mansehra for the first time in Pakistan in 1958, in collaboration of Pakistan Tea Board but these efforts could not prove productive due to lack of Government attentions (Hamid, 2007). The second attempt was made in 1964 by Pakistan Agricultural Development Corporation (PADC) along Misriot Dam near Rawalpindi, but again the efforts could not achieve a productive outcome in tea cultivation. After wards in 1982, Chinese tea experts were invited under the technical co-operation program, they surveyed the potential tea growing areas of northern Pakistan in order to study the feasibility of tea cultivation in the country (Waheed *et al*., 2002). They Identified 150,000 acres (60,000 ha) of land suitable for tea plantation in Hazara and Swat, 85% of which lies in district Mansehra. In result of tea quality evaluation, it ranked 2nd best in grade at the International Tea Market in London in 1989. Geographic Information System (GIS), deal with spatial data analysis and mapping and Remote Sensing, deal with remotely sensed satellite images and products, plays a significant role in identification for suitable site selection for various purposes including tea cultivation sites (Günerog and Acar, 2013; Li *et al*., 2012). GIS and multi criteria methods for the selection of criteria weightage assignment, like analytical hierarchy process (AHP) or Decision making trial and evaluation laboratory (DEMATEL), provide opportunity to combine knowledge from various diverse sources in order to identify potential suitable sites for a number of purposes (Jayasinghe *et al*., 2019).

Districts of Mansehra and Abbottabad of Khyber Pakhtunkhwa (KPK) province of Pakistan have been selected as the study area for this research. This region is chosen because of more suitable climatic condition, soil type and available resources for tea plantation as

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this area was already considered by national tea research institute (NRTI), Pakistan and 30 acres land was devoted for tea cultivation (Rehman *at al*., 2012). But this area has not been utilized to its maximum potential and ability for tea production. The successful cultivation of tea has been proved, its quality and yield potential have been assessed to be economically feasible and the extent of potential area has been successfully identified by National Tea and High Value Crops Research Institute (NTHRI). The study area lies between 72.8220 longitude, 33.8072 latitude and 74.1179 longitude and 35.2222 latitude and covers 5971 sq. kilometers located at the offshoots of the great Himalayan mountain system. The area bounds to Kohistan and Batgram districts in the north, in the east it extends to Muzaffarabad district of Azad Jammu & Kashmir, in the south, it stretches to Rawalpindi and Haripur districts and to Shangla and Buner districts in the west as shown in the Fig. 1.

Statement of problem. Pakistan was most probably self-sufficient in domestic tea production before separation of west Pakistan. While, Bangladesh after the separation Pakistan had to import all its tea from abroad. Pakistan is the 2nd largest importer of tea in the world next to United Kingdom. This is a big need to identify the suitable areas and grow our own tea to reduce millions of expenditures on tea. There is a large area in Pakistan which seems favourable condition to grow tea but this is a highly expensive practice to identify a suitable area so, it is neglected while, identification of suitable areas can be done by geomatics techniques proved in this research. There is also lack of research in this sector and this research is the first of kind in Pakistan and can be very valuable if applied.

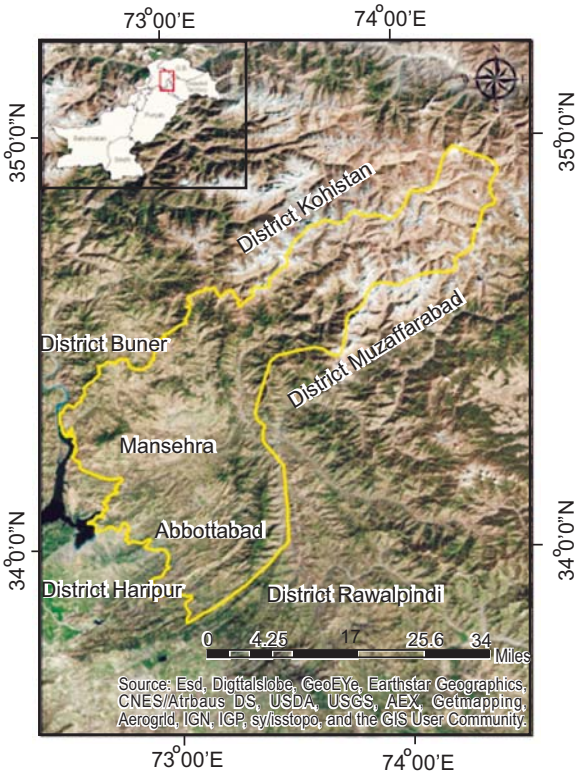

Fig. 1. Study area map (Mansehra and Abbottabad districts).

Objectives. This study focused on the following objectives:

- Classification of landuse/ land cover of the study area using remote sensing techniques
- Identification of the suitable area for tea plantation using Remotely Sensed Imagery and Geo-Spatial Techniques.
- Assessment of the sustainable development of area and expected yield potential of tea.

Materials and Methods

Present research aims to identify the suitable areas for tea cultivation by using GIS and remote sensing techniques in northern highlands of Pakistan. The materials required for the research include Landsat satellite imagery, Digital Elevation Model (DEM), temperature, Precipitation, soil properties data, soil pH map, geological map, drainage and GIS based vector datasets of study area boundary. Various software have been utilized for data input, processing and analysis which includes Arc GIS 10.2, ERDAS Imagine 9.3, global mapper, MS Word 2013, Excel 2013 and Adobe Acrobat Reader and writer. Detailed flow chart is given below. Analytical Hierarchy Process (AHP) and Weighted Linear Combination (WLC) models were applied to acquire the final results. Fig. 2 presents a comprhensive overview of the methodology adopted for current research.

Satellite images. Landsat satellite Image with spatial resolution of 15m has seven bands was taken from USGS open source. Images were of September 10, 2009. This imagery was processed in ERDAS Imagine software. Image rectification, Layer Stacking for band combination, sub-setting the area of interest and image enhancement was performed Google earth imagery was also used to visually interpret the study area.

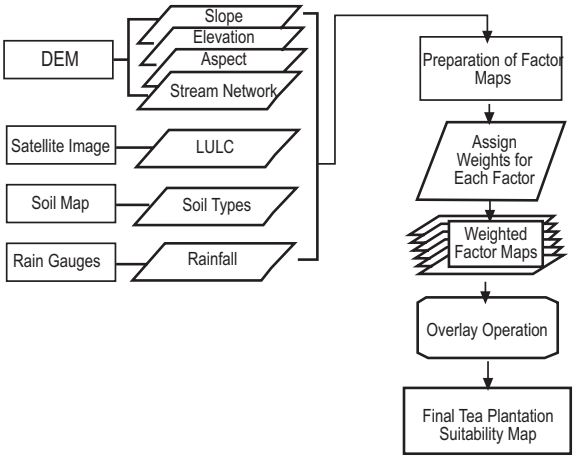

Fig. 2. Methodological flowchart for identification of potential tea cultivation sites in the study area.

Digital elevation model (DEM). Digital Elevation Data of Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) with 30m resolution was downloaded from ASTER website (Fig. 3). Using Global Mapper software, the study area was clipped and the output raster was used to extract further topographical factors i.e. aspect, elevation and slope.

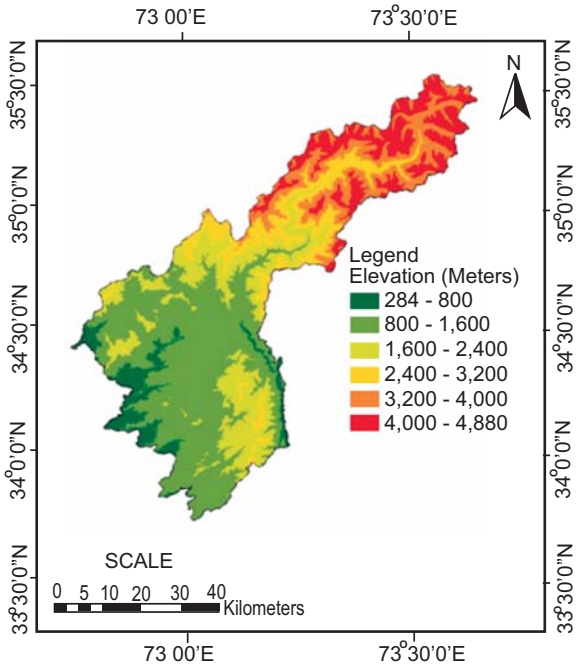

Fig. 3. Digital Elevation Model (DEM) of the study area.

Geological map. Geological map of the study area was taken covering the study area as shown in Fig. 4. Major classes of geological landform are found Molasse (Pre-Holocene) while, others are Molasse (Holocene), Indian plate sediment (PC to eocene) Indian plate basement in the north part of study area which is divided by Main Boundary Thrust (MBT). Northern Potwar deformed zones also exist in the south west of study area.

Soil map. This soil map (Fig. 5) has been used in the research was produced and classes were identified using associated data tables. The study area had different types of soil with respect to pH, which is mainly defined with respect to some ranges. The soil map significantly helped to identify the potential areas with respect to soil properties.

Precipitation data. Precipitation data of nearby four meteorological stations was taken from Pakistan meteorological department Lahore office. These stations are located in Abbottabad, Balakot, Mansehra and Naran. Using inverse distance to weighting (IDW) interpolation technique, the data from these locations was interpolated and map was generated as shows in Fig. 6.

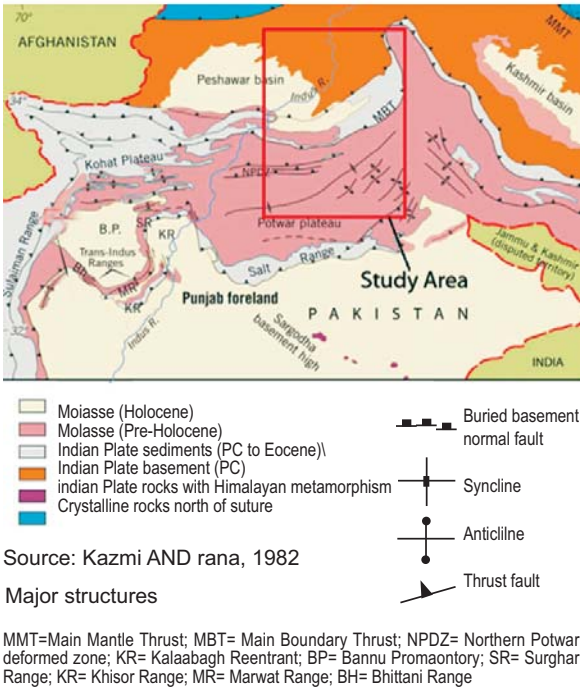

Fig. 4. Geological map of the study area

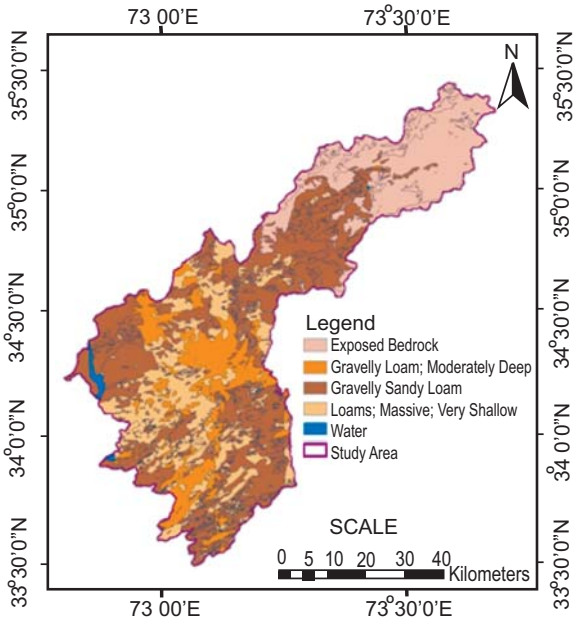

Fig. 5. Soil map of the study area

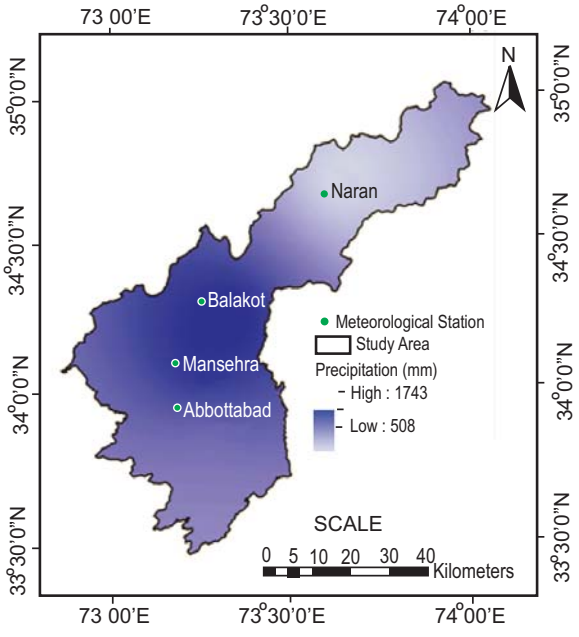

Fig. 6. Precipitation map of the study area

Land use land cover map. Visual interpretation techniques are used to extract ground features. Supervised classification was done on Landsat images to extract land use land cover (LULC) of the study area (Fig. 7). Following major classes were extracted from satellite images: (a) Forest (b) Shrubs & Bushes (c) Range land (d) Settlement (e) Agriculture land (f) Barren land (g) Water bodies (h) Alpine pasture (i) Snow & Glacier.

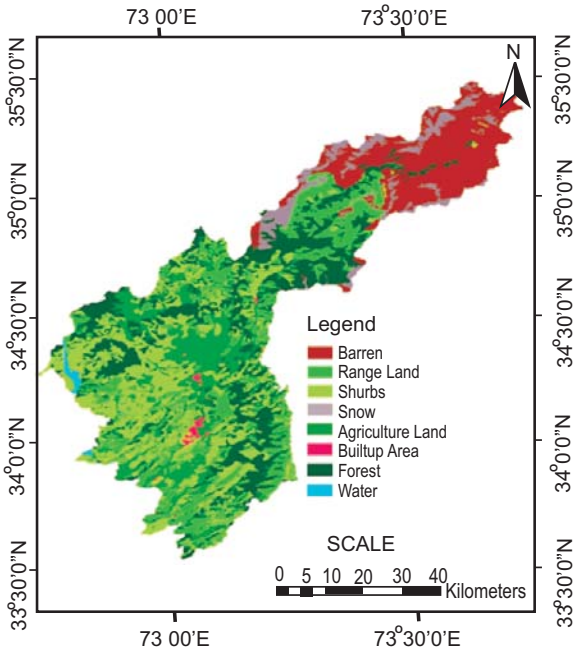

Fig. 7. Land use/ land cover map of study area

Results and Discussion

Analytical hierarchy process (AHP) model was used to solve factor weightage problems. In this method, a matrix is produced to analyze a different tea production factor which was developed by (Saaty, 2005). In the calculation of tea production assessment, values differ from minimum 0 to maximum 9. The outcomes have relative suitability for tea production assessment and higher index shows more suitability for tea production. High values show the higher suitability for tea production and lower values show less suitability for tea production. Table 1 presents pair-wise comparison matrix for the weightages against each criterion calculated using AHP.

A tea production suitability map displaying five different classes using natural breaks method. These classes are named as highly suitable, suitable, moderately suitable, less suitable and not suitable (Fig. 8), and areas percentage of each suitable zone is presented in Table 2.

The results have relative suitability for tea production assessment and higher index shows more suitability for tea production. High values show the higher suitability for tea production and lower values show less suitability for tea production. A tea production suitability map

Table 1. Pair-wise comparison matrix for calculating weight of each criterion

Name	Soil	Precipitation	Temperature	Slope	Elevation	LULC	Aspect	Weight
Soil	0.40	0.47	0.42	0.38	0.32	0.25	0.19	0.35
Precipitation	0.20	0.23	0.28	0.28	0.27	0.25	0.17	0.24
Temperature	0.13	0.12	0.14	0.19	0.16	0.18	0.17	0.15
Slope	0.10	0.08	0.07	0.09	0.16	0.18	0.17	0.12
Elevation	0.06	0.05	0.05	0.03	0.05	0.11	0.15	0.07
LULC	0.06	0.03	0.03	0.02	0.02	0.04	0.15	0.05
Aspect	0.04	0.03	0.02	0.01	0.01	0.00	0.02	0.02
Total	1	1	1	1	1	1	1	1.00

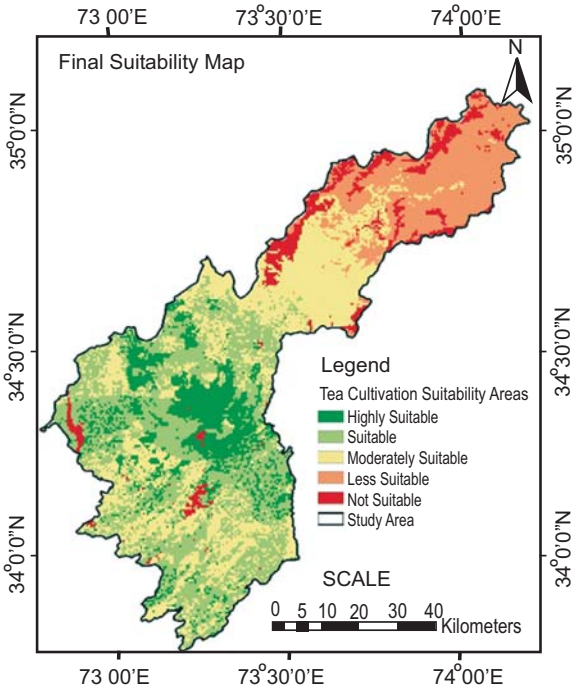

Fig. 8. Final suitability map for tea plantation in the study area

Table 2. Percentage of covering area ofeach suitable zones

Suitability Zone	Pixels	Suitability index value	Area (sq. km)	Area (%)
Highly suitable	2709	7.1 – 9.0	778.3	13.24
Suitable	6838	6.1 – 7.0	1966	33.44
Moderately suitable	6291	4.1 – 6.0	1805	30.71
Less suitable	3327	1.0 – 4.0	948.5	16.13
Not suitable	1330	0	379.9	6.46

showing five different classes prepared based on natural breaks in analysis. These classes are named as highly suitable, suitable, moderately suitable, less suitable and not suitable. Results show that in study area 13.24 percent (778.3 sq.km.) is highly suitable, 33.44 percent (1966 sq.km.) is suitable, 30.71 percent area (1805 sq.km.) is moderately suitable, 16.13 percent area (948.5 sq.km.) is less suitable, and 6.46 percent area (379.3 sq.km.) is not suitable for tea cultivation. The area is naturally lies at quite favourable conditions for the tea cultivation which can contribute a vital role in country's economy.

Conclusion

Geo-informatics (GIS and remote sensing) techniques proved to be fruitful for spatial assessment and suitability of tea cultivation sites. A worth of Rs.30.35 billion is being used to import black tea in Pakistan from 45 countries. During 2011- 2012, black tea having a volume of around 113,994 tons was imported in Pakistan. Kenya stayed at first rank as 55.1% of tea imported from there. Pakistan also imports tea from India that fulfilled around 17.13% of tea consumption needs. Due to rapid growth in consumption of tea in the country it also increased the rate of tea imports. In 2008-09, Pakistan Imports 85,350 tons of tea having worth of US $193 million and it increased to 123,892 tons having worth of US $351 million in 2011-12. Around 46% area from the selected districts fall under suitable to highly suitable classes which is a great potential for a commodity mainly used in a country like Pakistan. This study can be taken as pilot and further national level studies can be replicated by using improved datasets including DEM, satellite imagery and other spatial factors in order to measure suitability more precisely.

Conflict of Interest. The authors declare that there is no conflict of interest

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