

Agro-climatic zonation of Uttarakhand using remote sensing and GIS

HIMANI BISHT*, A.S. NAIN, SHWETA GAUTAM and HARSH VARDHAN PURANIK

Department of Agrometeorology, G. B. P. U. A. & T., Pantnagar

*E-mail: himanibisht29@gmail.com

ABSTRACT

The climatic data of 32 stations of Uttarakhand and adjoining region were collected and the thematic layers of climatic parameters, annual average temperature and precipitation were generated using the spatial analyst Extension of ARC-View. The grid interpolation was applied to generate the surface of annual average temperature and later it was rectified with Digital Elevation Model (DEM) prepared with ASTER data and employing environmental lapse rate (0.65°C / 100 m).

Decision Tree Classifier (DTC) embedded in ENVI image processing software was used for agro-climatic zonation of Uttarakhand by considering climatic parameters of annual average temperature and precipitation. During the process of zonation, the temperature map of Uttarakhand was divided into four thermal regimes 1) <0°C, 2) 0°C - 10°C, 3) 10°C - 20°C and 4) >20°C, thereafter, boundaries of the precipitation distribution (in three regimes 1) < 800 mm, 2) 800-1400 mm, and 3) > 1400 mm) in the state have been overlaid on temperature regimes, which divided entire state of Uttarakhand into twelve Agro-climatic zones.

Key words: Agro-climatic zonation, remote sensing, interpolation, GIS

The climate is among the most important factors that determine the agricultural potentialities of a region and the suitability for a specific crop, whereas the yield is determined by weather conditions (Pereira, 1982). Agriculture is highly dependent on environmental conditions, a quantitative understanding of the climate of a region is essential for developing improved farming systems (Reddy, 1983). A practical zoning approach thus arises because climate represented by thermal and moisture regimes forms small geographic areas, resulting in a variable mosaic of specialized areas, capable of supporting varied land use systems (Troll, 1965). The approach is used to categorize agro-climatically uniform geographical areas for agricultural developmental planning and other interventions.

Agro-climatic zone (ACZ) is a land unit in terms of major climate, superimposed on length of growing period (moisture availability period) (FAO, 1983). It has a characteristic inter-relationship between agronomy or farming systems and climate. The delineation of homogeneous agro-climatic zones can help to interpret present cropping pattern, as well as suggest new cropping patterns (Adhikari *et al.*, 2001). Agro-climatic zonation scheme is a standard tool for prioritising agricultural research because they offer relevant, available information

about target environment (Corbett, 1996). Proper descriptions of the target environment also enable research efforts to be more clearly focussed at local issues and needs.

It is expressed as mean values of intensity, duration, frequency and moment of occurrence of the weather variables or in values of their integral effects of all parameters upon living organisms and soil formation. The values refer to the agro climatic indices which express the relationship between climate and agricultural production in quantitative term. Based on these indices, agro climatic region are delineated into homogeneous units appropriate for agricultural practices. The essential elements in demarcating or defining of an agro-climatic zone are bioclimatic based on thermal regimes, moisture regimes and biomass variability.

MATERIAL AND METHODS

Study area

Uttarakhand is located between latitude 28°43'N and 31°27'N and longitude 77°34'E and 81°02'E. The geography of Uttarakhand is so much varied that it can be easily divided into various smaller climatological units; however it has been geographically divided into two parts,

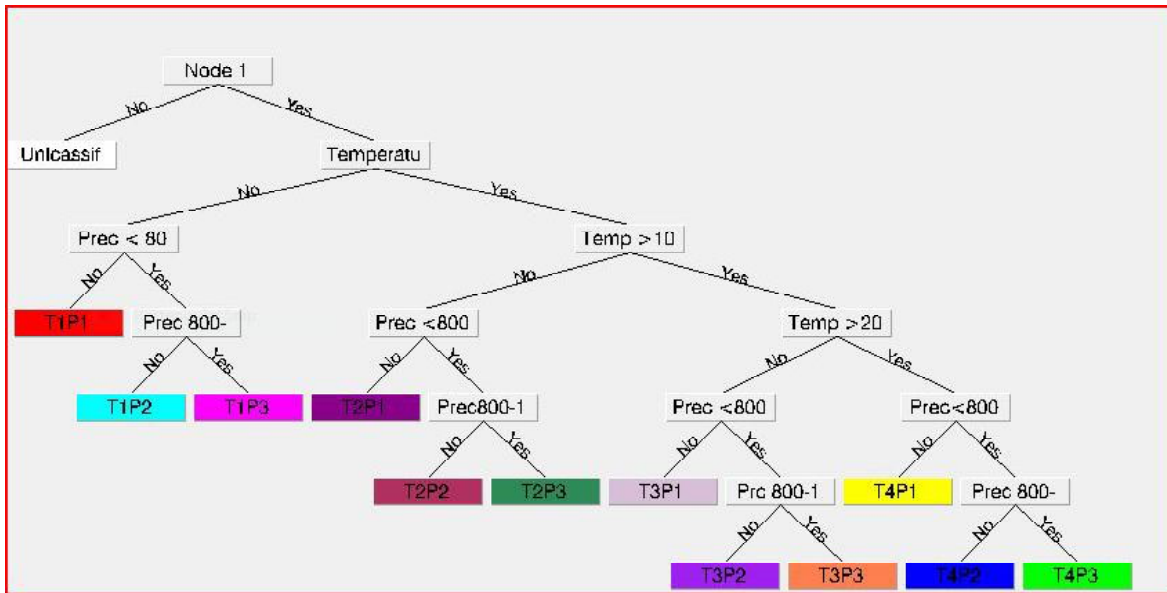


Fig. 1: Decision Tree of agro-climatic zonation of Uttarakhand

the western half known as Garhwal and the eastern region as Kumaon for managing administratively and forming policies for larger area. Uttarakhand is situated on the southern slope of the mighty Himalayas. Glaciers being located at the highest elevations have coolest weather and are covered by ice and bare rock. However there is dense tropical forest at the lower elevations.

Data collection

The data of some meteorological stations were downloaded from the website of www.ncdc.noaa.gov, www.climatetemp.info/china/changsha.html and www.weatherbase.com while some other stations data were taken from published IMD periodicals, monthly climatic data for the world (WMO, 1980). Different weather stations located in Uttarakhand like VPKAS Almora, ARIES Nainital, DEBER Haldwani, CRC Pantnagar, College of Forestry and hill Agriculture, Hill campus Ranichauri, FRI Dehradun. In addition to that data of some stations covered in UPROBE project of IIT, Roorkee were also taken. The interpolated world rainfall data was downloaded from www.worldclim.org.

Creation of layers

The layers of different meteorological parameters viz. temperature and rainfall were generated using the spatial analyst Extension of ARC-view 3.2a GIS software. Then grid interpolation was applied to generate the surface of different climatic variables. The temperature surface was prepared by using the IDW interpolation technique and considering the air temperature data of various

stations. Thereafter, an elevation surface was also generated using the elevation of meteorological observation used in the present surface. A difference elevation surface (DEM-Interpolated Elevation) surface was generated. The difference surface represents the actual difference in the original elevation of cell and interpolated elevation of cell. The environmental lapse rate which describes that with increasing elevation by 1 km the temperature will decrease by 6.5°C was used to correct the interpolated temperature surface using following equation.

$$T_{corrected} = T_{interpolated} - \text{Elevation difference} * 0.0065$$

Here, $T_{corrected}$ in °C, $T_{interpolated}$ in °C and Elevation difference in m.

Ustrnull *et al.* (2005) constructed the air temperature maps for the territory of Poland through the application of contemporary GIS techniques. Several geographic parameters, including elevation, latitude, longitude, and distance to the Baltic coast (for stations located within 100 km) were used as predictor variables for air temperature interpolation.

Agro-climatic zonation

The agro-climatic zones in Uttarakhand were delineated using the Decision Tree Classifier (algorithm) embedded in ENVI software. Decision Tree Classifier (DTC) classifies the geographical region into homogeneous zone based on logical instruction by the user. During process of zonation the temperature map of Uttarakhand was divided into four thermal regimes 1) <0°C, 2) 0°C to 10°C, 3) 10°C to 20°C and 4) >20°C. Thereafter boundaries

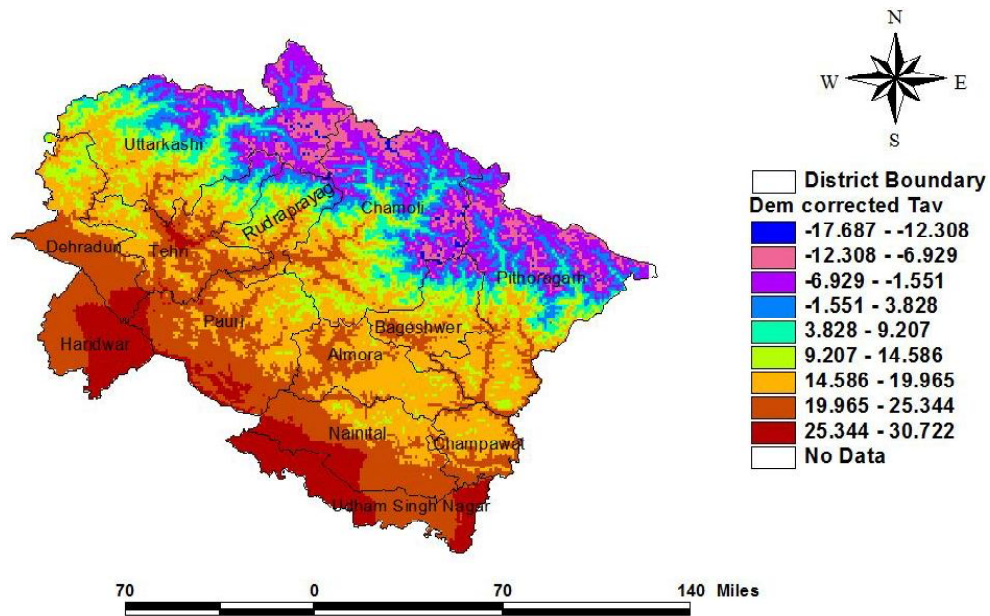


Fig 2: Thematic map of average temperature over Uttarakhand

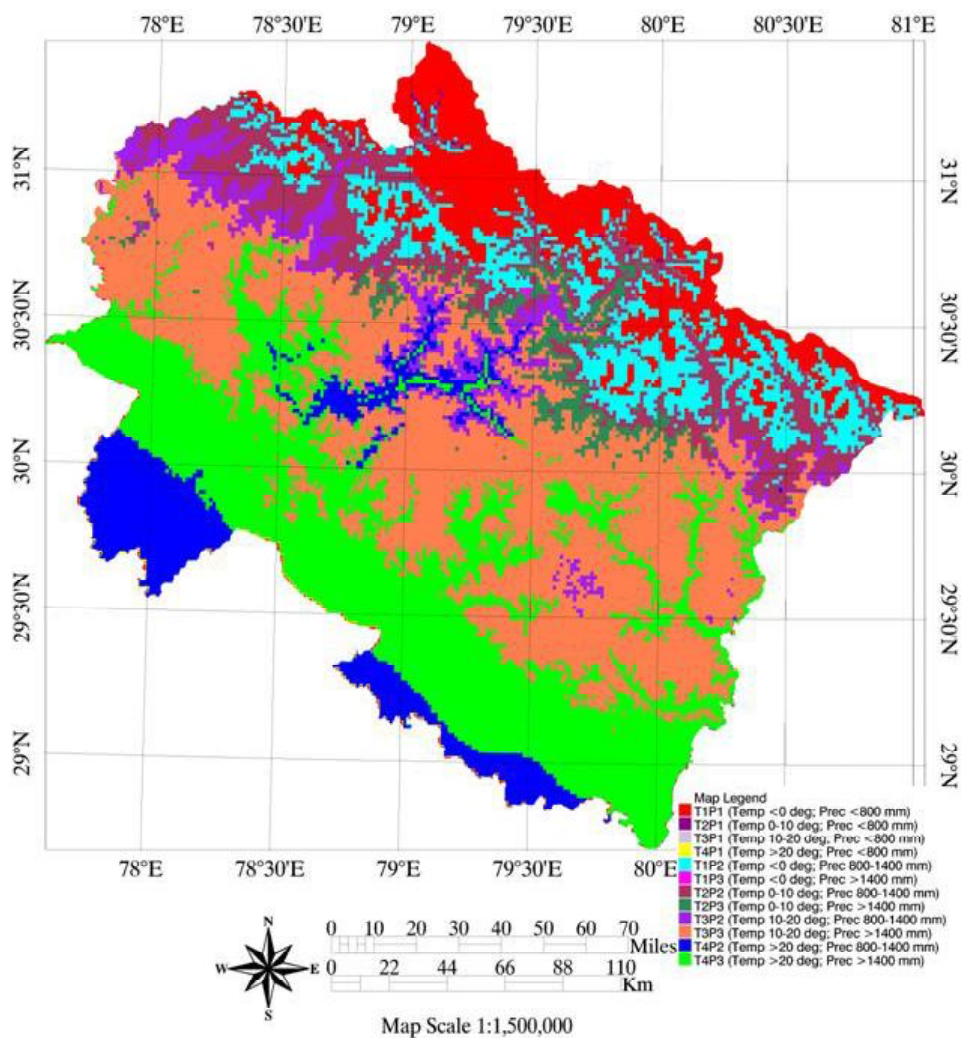


Fig. 3: Agro-climatic zones of Uttarakhand

Table 1: Characteristics of Agro-climatic zones of Uttarakhand

Agro-climatic Zone (ACZ)	Agro-climatic zones initials	Temperature(°C)	Precipitation (mm)	% Area
1	T1P1	< 0	< 800	10.26
2	T2P1	0-10	<800	0.14
3	T3P1	10-20	<800	0.004
4	T4P1	>20	<800	0.18
5	T1P2	< 0	800-1400	8.06
6	T1P3	<0	>1400	0.07
7	T2P2	0-10	800-1400	9.07
8	T2P3	0-10	>1400	2.66
9	T3P2	10-20	>800-1400	4.96
10	T3P3	10-20	1400	31.39
11	T4P2	>20	800-1400	7.116
12	T4P3	>20	>1400	26.09

of the precipitation distribution (in three regimes 1) precipitation < 800 mm, 2) precipitation 800-1400 mm and 3) precipitation > 1400 mm) in the state have been overlaid on temperature regimes. Hence, Uttarakhand has been divided into various agro-climatic zones on the basis of annual average temperature and annual precipitation. A scheme of classification is given in Fig. 1.

RESULTS AND DISCUSSION

Spatial variation of temperature and rainfall

Uttarakhand is predominantly a hilly state with small plain region. Therefore, climate is quiet variable depending on physiographical features of the region. Temperature and rainfall, in terms of quantity and spatiotemporal variability, are variables which determine the type of crops suitable to a given location (Mavi and Tupper, 2004). Even though crop production depends on every environmental condition, almost all agro-climatic classifications take into account these variables. These climatic parameters in combination with soil type and geomorphology can determine areas where high levels of production are appropriate, avoiding the threat of degrading the natural resources (Mavi and Tupper, 2004).

To delineate the agro-climatic zones the climatic data of various stations across the state were collected.

Dehradun, capital of Uttarakhand experiences annual average temperature of 20.8°C and annual rainfall is about 1874.0 mm. Mussoorie experiences annual average temperature of 14.3°C annual rainfall 2033.4 mm and Pantnagar experiences annual average temperature and rainfall of 23.6°C and 1613.0 mm respectively. The annual average temperature and rainfall of Mukteshwar and Nainital are 13.7°C and 1296.60 mm and 15.7°C and 1876.2 mm respectively. Almora experiences annual average temperature of 18.3°C and rainfall 879.4 mm. The annual average temperature and rainfall of Tehri and Joshimath are 22.0°C and 962 mm and 15.1°C and 1225.6 mm respectively.

Agro-climatic zones of Uttarakhand

On the basis of annual average temperature and annual precipitation Uttarakhand was divided into 12 agro-climatic zones. The map of agro-climatic zone of Uttarakhand has been illustrated in Fig. 3, while zones have been summarized in Table 1. The general descriptions of these agro-climatic zones are following:

T1P1: This zone consists of 10.26 % of the total geographical area of the state. The annual average temperature and precipitation of this zone are <0 °C and <800 mm, respectively. This zone is situated basically in the higher hills of the state where temperature remains less than 0 °C throughout the year. The region witnesses perpetual snow cover and is not suitable for any kind of the agricultural activity.

T2P1: This zone is found in 0.14 % of total geographical area of Uttarakhand. The annual average temperature of this zone is in between 0-10°C and precipitation is <800 mm. This zone is found at high hills of Uttarakhand and form the transition zone between the snow bound region and moderate temperature zones of Uttarakhand at some parts.

T3P1: The annual average temperature of this zone is in between 10-20 °C and precipitation is <800 mm. The zone is not much important as it is confined to only 0.004 % of total geographical area of the state. It is scattered in the mid hills of the state therefore the presence is clearly invisible.

T4P1: The temperature of this zone is >20 °C and precipitation is <800 mm. This zone is limited to only small portion of the state and cover 0.18 % of total geographical area of Uttarakhand, which is scattered in lower hills and some parts of western Tarai region.

T1P2: This agro-climatic zone is found in 8.06 % area of Uttarakhand. The annual average temperature of this zone is <0 °C and the precipitation varies from 800-1400 mm. This zones form the snowbound region of upper hills and moderate temperature zones of middle hills at most of the parts of Uttarakhand. Very limited scope for forest during summer season because at temperature <0 °C vegetation is not possible.

T1P3: This zone covers 0.07 % of total geographical area of Uttarakhand. The annual average temperature of this zone is <0 °C and the precipitation is >1400 mm. As the annual temperature of the zone is below freezing point it is not useful for agricultural activities.

T2P2: The annual average temperature of this agro-climatic zone is 0-10 °C and the precipitation is in between 800-1400. This zone is found in 9.07 % of total geographical area. This zone is found at mid high hills of the Uttarakhand. The temperature during winter month is below freezing point while that of summer is around 10 °C, therefore crop for limited duration can be grown in summer season.

T2P3: The area covered by this agro-climatic zone is 2.65 % of total geographical area. The temperature is in between 0-10 °C and annual rainfall is >1400 mm. This zone is limited to upper hills of the Uttarakhand and is mainly found in Rudraprayag and Chamoli districts of Uttarkhand. Limited duration summer season crop can be practised in this zone.

T3P2: This agro-climatic zone is found in 4.96 % area of Uttarakhand. The annual average temperature of this zone is in between 10-20 °C and annual rainfall is 800-1400 mm. This zone can be chiefly seen alongside the rivers basically in valley regions of Upper hills, where rainfall activities are quite high and temperature is moderate because of relatively low elevation than surrounding. This region is good for various crops as fairly good amount of moisture is supplied most part of the year.

T3P3: This agro-climatic zone covers maximum area of Uttarakhand. It covers 31.39% of total geographical area of Uttarakhand. The average annual temperature range of this zone is in between 10-20 °C and the annual precipitation is >1400 mm. This zone is mainly found in moderate to mod-high hills of the Uttarakhand and is very suitable for most of the crop requiring low thermal environment. This zone is very suitable for vegetable

cultivation in protected environment.

T4P2: This agro-climatic zone is found in 7.11 % area of total geographical area of Uttarakhand. The average annual temperature range of this zone is >20 °C and the annual precipitation is 800-1400 mm. The zone is distributed in the Tarai and Bhabar region and lower hills of Uttarakhand. This zone is enriched in case of soil and water availability and is the home of some of the most fertile soils of the world. Any crop (as per season) can be grown in this region.

T4P3: The area covered by this agro-climatic zone is 26.09 % of total geographical area. The average annual temperature range of this zone is >20 °C and the annual precipitation is >1400 mm. This zone is chiefly found in Haridwar and Udham Singh Nagar districts of Uttarakhand and forms the southern boundary of the state. The soils of the region are very fertile and irrigation facilities are available in plenty. Different agricultural activities are performed in this region ranging from rice cultivation to sugarcane cultivation to agro-forestry as they receive good support in form of irrigation facilities.

CONCLUSION

In the present study, the entire state of Uttarakhand was classified into 12 Agro-climatic zones on the basis of annual average temperature and annual precipitation. The delineation of homogeneous agro-climatic zones can help interpret present cropping patterns, as well as suggest new cropping patterns. The information of agro-climatic situations is very important for different agencies, governmental institutions and NGO's involved in developmental activities. The policies as per the climatic condition can be formed in order to minimise the agricultural inputs and maximizing outputs, which will form the basis of macro level precision crop management.

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