Indian Journal of Agricultural Sciences **89** (11): 1792–6, November 2019/Article
https://doi.org/10.56093/ijas.v89i11.95291

Agro-ecological zonation of Uttarakhand using geo-spatial techniques

HIMANI BISHT[1], SHWETA GAUTUM[2], HARSHVARDHAN PURANIK[3] and A S NAIN[4]

Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand 263 145, India

Received: 16 March 2018; Accepted: 23 July 2019

ABSTRACT

In this study, the Agro-ecological zones (AEZs) of Uttarakhand were delineated based on land use/land cover, slope, soil texture, temperature and length of growing period (LGP) by using remote sensing and GIS. The Decision Tree Classifier (DTC) algorithm technique was used for delineation of Agro-ecological zones (AEZs). The land use/land cover map was used as base map and slope map of entire state (other than snow bound region) having five classes (0-5°, 5-15°, 15-30°, 30-50° and >50°) was overlaid on soil texture map having three soil classes (frigid soils, loamy soils and sandy soils). Thereafter, temperature map with three thermal regimes (<0°C, 0-15°C, and >15°C) and length of growing period with two distinct classes (<120 days and >120 days) were overlaid on existing map. The small classes having number of pixel <1000 and the regions having temperature <0°C and slope of >50° were removed from the analysis because agriculture is not possible over these regions. Thereafter, the entire state of Uttarakhand was divided into 38 agro-ecological zones (AEZs).

Key words: Agro-ecological zones, Length of growing period (LGP), Remote Sensing and GIS

Sustainable development of mountainous state like Uttarakhand is a challenging task because of highly diverse and fragile ecosystems which makes the planning of the use of natural resources more complex than any other area. Agro-ecological zonation is the division of an area of land into land resource mapping units, having unique combination of landform, soil, climatic characteristics and land cover having a specific range of potentials and constraints for land use (FAO 1996). Large numbers of crops are being grown in Uttarakhand traditionally in many areas especially in hilly areas without any consideration to the fitness of the climate, soil, land use etc. Climatic information on evapotranspiration, temperature and rainfall and on derivatives such as onset of growing season, length of growing period along with soil, land use etc. are vital in weather sensitive sectors like agriculture (Geerts *et al.* 2006, Kipkorir *et al.* 2007, Garcia *et al.* 2007) for better planning of resources to enhance crop productivity and sustainability. Unfortunately, little relevant information is available in the State especially in the upper hilly region. Therefore, the development of agro-ecological zones of the entire state is essential as it provides a concise inventory of potential and constraints for land use. Naidu *et al.* (2013) also delineated 17 Agro-ecological zones in Tamil Nadu state of India based on variability of soil, landform and length of growing period. Geospatial technologies such as satellite remote sensing and GIS have been used effectively in agro-climatic (Bisht *et al.* 2012) and agro-ecological zonation (Bal *et al.* 2018) for suitability of different crops (Goswami *et al.* 2012, Abdel Rahman *et al.* 2016) and for sustainable development. Remote sensing and GIS has the ability to capture and analyse geographic data at a very large spatial and temporal scale, thereby providing a more systematic and dynamic approach to agro-ecological zonation for better use of natural resources and agro-technology transfer than the traditional and somewhat limited approaches. This paper details the process of integrating land use/land cover, slope, soil texture, temperature and length of growing period (LGP) to delineate agro-ecological zones of Uttarakhand.

Present address: [1]Scientist (himanibisht29@gmail.com), Water Technology Centre, ICAR-Indian Agricultural Research Institute; [2]Assistant Professor (gautam.shweta808@gmail.com), School of Forestry and Environment Science, SHIATS, Allahabad; [3]Assistant Professsor (puranik.harshvardhan104@gmail.com), Department of Agrometeorology, College of Agriculture, IGKV, Raipur; [4]Head (nain_ajeet@hotmail.com), Department of Agrometeorology, G. B. Pant University of Agriculture and Technology, Pantnagar.

MATERIALS AND METHODS

The study was carried out during 2014–15, Uttarakhand, India which is situated on the southern slope of the mighty Himalayas (latitude 28º43'N to 31º27'N and longitude 77º34'E to 81º02'E). Geographically Uttarakhand has been divided into two divisions- Garhwal (Northwest portion) consists of seven districts (Uttarakashi, Chamoli, Tehri, Pauri, Dehradun, Haridwar and Rudraprayag) and Kumaon (Southeast portion) comprises of six districts (Almora, Nainital, Pithoragarh, Champawat, Bageshwar and Udham Singh Nagar), with a total of 13 districts. Uttarakhand has diverse climate and vegetation which vary greatly with elevation from the sub-tropical humid climate of the *Terai* region to the tundra-like climate of the Great Himalaya ridges.

Data and method of data analysis

Climatic data: The climatic data were collected from different weather stations located in Uttarakhand, viz. VPKAS, Almora; ARIES, Nainital; GB Pant University of Agriculture and Technology, Pantnagar; College of Forestry and hill Agriculture, Ranichauri; IIT, Roorkee and FRI, Dehradun. The Data of some other stations were taken from published IMD periodicals, UPROBE project of IIT Roorkee and from the website of www.ncdc.noaa.govand www.weatherbase.com.

Soil data: The soil maps of the region at a scale of 1:500000 were acquired from National Bureau of Soil Survey and Land Use Planning (NBSSLUP), Nagpur.

Satellite images: Satellite images to cover entire State were downloaded from the website http://Edcsns17.cr.usgs.gov/EarthExplorer/ or http://glovis.org. Mainly two types of the satellite data were used 1; multi-spectral data of LANDSAT 7 satellite with spatial resolution of 30 m and temporal resolution 16 days and 2; Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) satellite date with spatial resolution of 30 m and temporal resolution 16 days.

Creation of layer of average temperature: In order to construct the air temperature surface, as a first step the temperature surface and elevation surface were prepared by using the Inverse Distance Weightage (IDW) interpolation technique by using the annual average temperature and elevation data of different stations. Thereafter, another elevation surface was also created by using Digital Elevation Model (DEM) data retrieved from ASTER satellite. A difference in elevation surface (DEM-Interpolated Elevation) and environmental lapse rate 0.0065ºC/m was used to correct the interpolated temperature surface as:

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

Where, $T_{corrected}$ and $T_{interpolated}$ are corrected and interpolated temperature (°C).

Creation of layer of soil texture: The soil maps were scanned and mosaicked (combined) using the pixel base algorithm and geo-referenced using image to image registration technique embedded in ENVI-4.8 image processing software. Thereafter, the geo-referenced map was digitized with utmost care and the layer of soil texture was created by attaching attribute file containing information on soil texture with digitized soil map in Arc View 3.2a GIS software.

Creation of layers of length of growing period (LGP): The length of growing period (LGP), defined as the number of days when precipitation (P) is greater than or equal to half of the potential evapotranspiration (PET) (Doorenbos and Kassam 1979) was estimated by using mean weekly rainfall (P) and PET as:

$$LGP = \sum (D) \text{ when P/PET ratio is } >0.5 \text{ for continuous period}$$

Where D, number of days.

PET was calculated by Thornthwaite method (Thornthwaite 1948). All the continuous weeks having more than 0.5 ratios were summed to get the length of growing period. In order to generate the thematic layer of LGP, the following statistical equation was developed between the multi-locations point data of LGP and point rainfall (P):

$$LGP = 0.647*(P)\hat{}(0.730)$$

Creation of slope and aspect maps: The DEM data of ASTER satellite covering 1×1 degree geographical region were mosaicked and the slope and aspect maps were derived by using Hydrological module embedded in ENVI-4.8. Thereafter, the slope map of state was categorized into five classes (0-5°, 5-15°, 15-30°, 30-50° and >50°), while aspect map was classified into four classes as per four natural directions: North East, South and West.

Creation of land use/land cover map: The land use/land cover map was created by using the seven scenes of LANDSAT-ETM/TM images to cover the entire state . The images were mosaicked and pre-processed for geometric correction, atmospheric correction and image enhancement. Thereafter the minimum distance classification algorithm of supervised classification scheme was used for the classification of different land uses based on spectral signature and their spectral profile.

Ago-ecological zonation: Agro-ecological zones (AEZs) were delineated using the Decision Tree Classifier (DTC) algorithm (Xu *et al.* 2005) by overlaying the land use/land cover, slope, soil texture, temperature and length of growing period (LGP) maps on each other. The flow diagram depicting the methodology of agroecological zonation has been shown in Fig 1.

RESULTS AND DISCUSSION

Agroecological zones of Uttarakhand: Agro-ecological zones (AEZs) of Uttarakhand, India were created based on land use/land cover, slope, soil texture, temperature and length of growing period (LGP). The land use/land cover map having six classes i.e. forest, agricultural land, built-up land, barren land, water body and snow bound region (Fig 2) was used as base map in the analysis. The snow bound region was separated out in the first step and rest other regions was divided into different AEZs based on slope, soil texture, air temperature and LGP. Entire Uttarakhand (other than snow bound region) was divided into five slope zones (0-5°, 5-15°, 15-30°, 30-50°and >50°). A soil texture map having three classes, viz. frigid soils, loamy soils and sandy soils was overlaid on slope map, which theoretically divided state into 16 zones (15+ one zone of snow bound region). Thereafter, temperature map with three thermal regimes (<0°C. 0-15°C, and >15°C) was overlaid, which theoretically increased the number of zones to 46. Lastly, the length of growing period with two distinct classes (<120 days and >120 days) was overlaid on existing map, which increased the theoretical number of AEZs to 91. The Length of Growing Period (LGP)

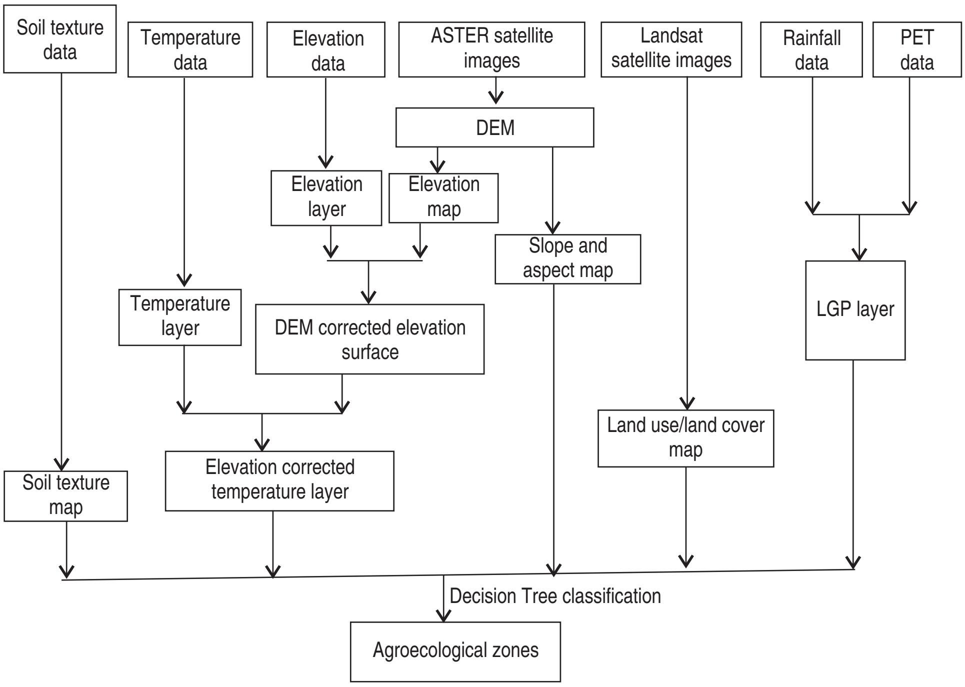

Fig 1 Methodology of agroecological zonation.

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.

Zone 13 (class-34): This zone comprises of some high altitude parts of the Pithoragarh and Uttarkashi, Uttarakhand. The soil of this zone is frigid. The temperature and LGP of this zone are 0–15°C and <120 days, respectively. The slope of this zone ranges from 30–50°. Various topographic and agro-climatic conditions are congenial for different kind of fruits cultivation at different altitudes e.g. apples, peaches, plums, apricots, walnuts, pecans, cherry are grown successfully in this zone.

Zone 14 (class-36): This zone is found in the high altitude parts of the Pithoragarh, Chamoli, Uttarkashi and some parts of the Dehradun, Champawat and Pauri, Uttarakhand. The soil of this zone is loamy. The temperature and LGP of this zone are 0–15°C and <120 days, respectively. The slope of this zone varies between 30 and 50°. Fruit crops almonds, kiwis etc. can be grown in this zone.

Zone 19 (class-51): This zone comprises of Udham Singh Nagar, Nainital and Dehradun, Uttarakhand. The soils are generally loamy. The slope is <5° with temperature range of 0–15°C and LGP of this agro-ecological zone is >120 days.

Zone 23 (class-59): This zone comprises of few parts of the Chamoli, Uttarkashi, Champawat, Pithoragarh, Rudraprayag and Almora, Uttarakhand. The soils are loamy with slope ranging from 5–15°, temperature from 0–15°C and LGP >120.

Zone 24 (class-60): It is found in some parts of the Dehradun, Pauri, Almora, Chamoli, and Pithoragarh, Uttarakhand. The soil of this zone is loamy. The temperature and length of growing period of this zone is 0–15°C and >120 days, respectively. The slope of this zone varies between 5 and 15°.

Zone 27 (class-68): It is spreaded in some parts of the Almora, Pithoragarh, Chamoli, Champawat and Uttarkashi, Uttarakhand. The soil of this zone is loamy. The temperature ranges between 0–15°C and length of growing period of this zone is >120 days, while slope of this zone varies between 15–30°.

Zone 28 (class-69): This zone is found in some parts of the Hilly regions of Uttarakhand. The soil of this zone

explains the continuous period of the available moisture to support the water demand of crops and has also been considered one of the very important parameter for the crop suitability zoning and agro-ecological zoning by many researchers (Mugandani *et al.* 2012, Naidu *et al.* 2013, Bal *et al.* 2018). However, map shows the range of class from 0–102, which is due to the fact that DTC also considers nodes as classes. The classes having number of pixel <1000 have been removed from the analysis. The snow bound region and the regions having temperature <0°C and slope of >50° was not considered for further classification because agriculture is not possible over these regions. Therefore, after removing small classes and not considering the snow bound/frozen region in analysis, Uttarakhand is finally divided into 38 AEZs (Table 1). The general descriptions of some of the most important agro-ecological zones contributing significant area of the state are discussed in Fig 3.

Zone 3 (class-19): It comprises of Haridwar and some parts of Udham Singh Nagar districts. The soils are generally loamy. The slope is <5° with temperature >15°C and LGP of this agro-ecological zone is <120 days. 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. In horticultural crops mango, litchis, jackfruits, and papaya can be easily grown. The areas of expansion should be taken up strategic locations in accordance to the topography, agro climatic zone and soil conditions.

Zone 4 (class-21): This zone comprises of some parts of the Haridwar, Uttarakhand. The soil of this zone is Sandy. The temperature and LGP of this zone are >15°C and >120 days, respectively. The slope of this zone is <5°.

Table 1 Characteristics of Agro-ecological zones of Uttarakhand

Zone No.	Map Class	Slope (degree)	Soil	Temperature (°C)	LGP (days)	Contri-bution of zone (%)
1	0			Snow bound region		
2	17	<5	Frigid	>15	<120	0.030
3	19	<5	Loamy	>15	<120	3.494
4	21	<5	Sandy	>15	>120	1.120
5	22	5-15	Frigid	>15	<120	0.067
6	24	5-15	Loamy	0-15	<120	0.033
7	25	5-15	Loamy	>15	<120	0.069
8	27	5-15	Sandy	>15	<120	0.039
9	28	15-30	Frigid	0-15	<120	0.254
10	30	15-30	Loamy	0-15	<120	1.215
11	31	15-30	Loamy	>15	<120	0.137
12	32	15-30	Sandy	0-15	<120	0.207
13	34	30-50	Frigid	0-15	<120	1.693
14	36	30-50	Loamy	0-15	<120	3.113
15	37	30-50	Loamy	>15	<120	0.158
16	38	30-50	Sandy	0-15	<120	0.889
17	39	5-15	Sandy	>15	<120	0.031
18	48	<5	Frigid	>50	>120	0.668
19	51	<5	Loamy	>15	>120	12.575
20	54	<5	Sandy	>15	>120	0.277
21	56	5-15	Frigid	0-15	>120	0.011
22	57	5-15	Frigid	>15	>120	0.006
23	59	5-15	Loamy	0-15	>120	0.266
24	60	5-15	Loamy	>15	>120	6.273
25	63	5-15	Sandy	>15	>120	0.194
26	65	15-30	Frigid	0-15	>120	0.062
27	68	15-30	Loamy	0-15	>120	5.101
28	69	15-30	Loamy	>15	>120	26.222
29	71	15-30	Sandy	0-15	>120	0.382
30	72	15-30	Sandy	>15	>120	0.636
31	74	30-50	Frigid	0-15	>120	0.499
32	75	30-50	Frigid	>15	>120	0.011
33	77	30-50	Loamy	0-15	>120	8.072
34	78	30-50	Loamy	>15	>120	21.558
35	80	30-50	Sandy	0-15	>120	1.499
36	81	30-50	Sandy	>15	>120	1.167
37	90	<5	Frigid	<0		0.066
38	102	>50	Frigid	<0		2.496

is loamy. The temperature and LGP of this zone is >15°C and >120 days, respectively. The slope of this zone is <30°.

Zone 33 (class-77): This zone comprises of high altitude region of Chamoli, Rudraprayag, Pauri and some parts of the Uttarkashi and Pithoragarh, Uttarakhand. The soil of this zone is loamy. The temperature ranges from 0–15°C and LGP of this zone is >120 days, respectively. The slope of this zone is quite high with a range of 30–50°.

Zone 34 (class-78): Most of the parts of hilly regions come under this zone of Uttarakhand which covers about 21.6% of total geographical area of the state. The slope of this zone varies in between 30–50°. The temperature is varied from 0–15°C and LGP of this zone is >120 days respectively. The soil of this zone is loamy. Since land holdings of this region are small, the farmers should move from subsistence farming to high-valued crops like vegetables, fruit, medicinal and aromatic plants.

Zone 35 (class-80): This zone is confined to some parts of the Pithoragarh and Chamoli, Uttarakhand. The soil of this zone is Sandy. The temperature varies between

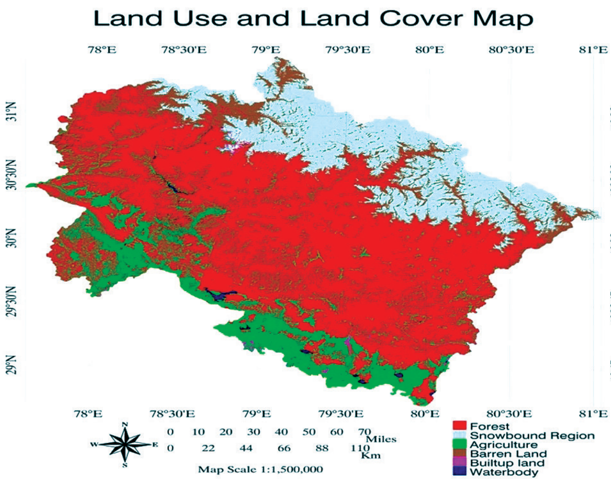

Fig 2 Land use and land cover map of Uttarakhand.

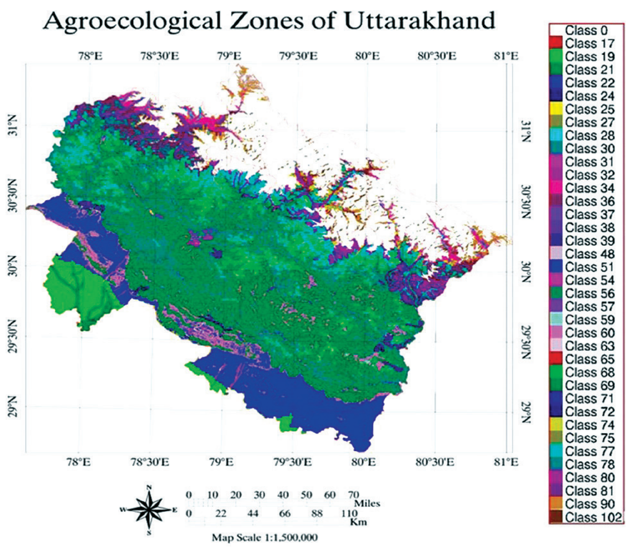

Fig 3 Agro-ecological zones of Uttarakhand with legends.

0–15°C, while LGP of this zone is >120 days. The slope of this zone ranges from 30–50°.

Uttarakhand has the advantage of very fertile *Terai* and *Bhaber* region comprising of Nainital, Haridwar and Udham Singh Nagar, which contributes maximum of its cereal production. But the production and productivity in hilly districts is relatively quite low due to small land holdings, adverse geo-climatic condition, non-availability of agricultural inputs and difficulty in transfer of technology. Given the constraints on the productivity of field crops, a shift from the cultivation of low value field crops to high value crops, such as fruits, vegetables, pulses, millets, aromatic and medicinal plants seem to be the most obvious option in the state (Bist *et al.* 2006), especially in hilly zones. Agroecological zoning in these regions of the state has widespread applications in land use planning; design of appropriate agricultural adaptations strategies and reducing vulnerability to climate change. GIS and Remote Sensing are very powerful tools and techniques for capturing, storing, integrating and analysing all input data used for agroecological zonation. However, there is a future need of more availability of climatic database for better planning and management of natural resources especially for higher altitude regions of the state which are more vulnerable to climatic variability and change.

REFERENCES

Abdel Rahman M A E, Natarajan A and Hegde R. 2016. Assessment of land suitability and capability by integrating remote sensing and GIS for agriculture in Chamarajanagar district, Karnataka, India. *The Egyptian Journal of Remote Sensing and Space Sciences* **19**: 125–141.

Bal S K, Choudhury B U, Sood A, Mukherjee J and Singh H. 2018. Geo-spatial analysis for assessment of agro-ecological suitability of alternate crops in Indian Punjab. *Indian Journal of Soil Conservation* **46**(3): 283–92

Bisht H, Nain A S, Gautam S and Puranik H V. 2013. Agro-climatic zonation of Uttarakhand using remote sensing and GIS. *Journal of Agrometeorology* **15**(1): 30–35.

Bist L D, Dixit A K and Sharma A K. 2006. Status of Temperate Fruit in Uttarakhand: Problems and Prospects, pp. 19–26. New India Publishing Agency, New Delhi.

Das P and Let S. 2013. Digital Elevation Model is a Tool for Terrain Analysis: Implication and Interpretation with Reference to Kuya River Basin. *International Journal of Engineering Science and Innovative Technology* **2**(1): 271–75.

Doorenbos J and Kassam A H. 1979. Yield response to water. FAO Irrigation and Drainage Paper No. 33. FAO, Rome, Italy.

FAO 1996. Guidelines: Agro-ecological zoning; Soils bulletin. Rome, FAO.

Garcia M, Raes D, Jacobsen S E and Michel T. 2007. Agro-climatic constraints for rain-fed agriculture in the Bolivian Altiplano. *Journal of Arid Environment* **71**: 109–21.

Geerts S, Raes D, Gracia M, Del Castillo C and Buytert W. 2006. Agro-climatic suitability mapping for crop production in the Bolivia Altiplano: a case study for quinoa. *Agricultural and Forest Meteorology* **139**: 399–412.

Goswami J, Chutia D and Sudhakar S. 2012. A Geospatial Approach to Climatic Zone Specific Effective Horticultural Planning in East Khasi Hills District of Meghalaya, India. *Journal of Geographic Information System* **4**: 267–72.

Kipkorir E C, Raes D and Bargerei R J. 2007. Evaluation of two risk assessment methods for maize in Kenya. *Agricultural and Forest Meteorology* **144**: 193–99.

Mugandani R, Wuta M, Makarau A and Chipindu B. 2012. Re-classification of agro-ecological regions of zimbabwe in conformity with climate variability and change. *African Crop Science Journal* **20**(2): 361–69.

Naidu L G K, Ramamurthy V, Srinivas S, Natarajan A and Thayalan S. 2013. Delineation of Agro-ecological Zones of Tamilnadu. *Agropedology* **23**(2): 83–92.

Thornthwaite C W. 1948. An approach toward a rational classification of climate. *Geographical Review* **38**(1): 55–94.

Xu M, Watanachaturaporn P, Varshney P K and Arora M K. 2005. Decision tree regression for soft classification of remote sensing data. *Remote Sensing of Environment* **97**: 322–36.