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Agroforestry and grassland mapping in two districts of Uttarakhand through geospatial technology

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Abstract
An assessment of agroforestry and grassland resources was done in two districts (Rudraprayag and Uttarkashi) of Uttarakhand state using medium resolution remote sensing LISS-3 data. Both pixel and sub-pixel classifiers were applied and area under agroforestry and grassland were estimated. Estimated area under agroforestry in Rudraprayag and Uttarkashi districts was 2286.31 ha (1.15%) and 5147.45 ha (0.64%), respectively. Grassland was estimated to be 18.87 and 10.88% in Rudraprayag and Uttarkashi districts, respectively. Classification accuracy of 84.4% with kappa of 0.829 was found in Rudraprayag district, whereas it was 83.8% with kappa of 0.822 in Uttarkashi district. Thus geospatial technologies can successfully be used for accurate assessment of natural resources like grassland and agroforestry, which will facilitate in better planning towards their sustainable management.

Keywords: Agroforestry, Grassland, Natural resources, Remote sensing, Sub-pixel

Introduction

Geospatial technologies (geographic information system, global positioning system and remote sensing) play an important role in mapping natural resources like forestlands, grasslands, water resources, etc. Remote sensing (RS) and Geographic information system (GIS) are being used increasingly as tools to assist in grassland inventory and as a mechanism for analysis, modelling and forecasting to support decision making (Booth and Tueller, 2003). Jadhav *et al.* (1993) have standardized the methodology for mapping and monitoring grasslands using satellite data. Remote sensing data, which is now available at regular intervals assumes a great significance and could be utilized for grassland mapping/monitoring (Mansour *et al*., 2016). A chief use of remotely sensed data is to produce a classification map of identifiable or meaningful features or classes of land cover types in a scene (Jasinski, 1996). As a result, the chief product is a thematic map with themes such as land use, vegetation types and geology. By definition, a thematic map is an informational representation of an image, which conveys information regarding the spatial distribution of a particular theme (Campbell, 2002). Numerous methods of image classification exist and classification has formed an important part of not only remote sensing but also of the fields of image analysis and pattern recognition. Therefore, image classification forms an important tool for examining digital images. Accordingly the selection of classification technique to employ has substantial effect on the results. A major problem in estimating area under agroforestry is lack of procedures for delineating the area influenced by trees in a mixed stand of trees and crops. In simultaneous systems the entire area occupied by multi-strata systems such as home gardens, shaded perennial systems and intensive tree-intercropping situations are listed as agroforestry (Nair *et al.,* 2009). However, there are various issues and limitations in mapping agroforestry using remote sensing (Rizvi *et al*., 2013).

Rudraprayag district in hilly Uttarakhand state is located between 30.17-30.81°N Latitude to 78.81-79.36°E Longitude. Elevation in the district ranges from 800 to 8000 m above msl. Most of the rainfall occurs during the period June to September when 70 to 80 percent of the annual precipitation is accounted for in the southern half of the district and 55 to 65 percent in the northern half. The highest temperature was 34°C and lowest 0°C. January is the coldest month after which the temperature begins to rise till June or July. The relative humidity is high during monsoon season, generally exceeding 70% on an average. The driest part of the year is the pre monsoon period when the humidity may drop to 35% during the afternoon.

Uttarkashi is located at 30.73°N, 78.45°E. It has an average elevation of 1165 meters (4,436 feet). Most of the terrain is hilly. The varying climate and topography produce a wide range of vegetation and serve as habitats to diverse species of wild life. Forests occupy a place of pride in the environment of the district not only for the sheer bulk of the area they occupy but also for the richness of variety of vegetation. Agriculture in these areas suffers from many constraints. The availability of cultivable land itself is the greatest restricting factor on the development of agriculture.

In the present investigation, the above mentioned two northern districts of Uttarakhand, Rudraprayag and Uttarkashi were selected and mapping of agroforestry and grassland resources was done with the help of geospatial technologies.

Materials and Methods

In order to map and estimate area under grassland in Rudraprayag district, remote sensing data of Resoursesat-2 for the period November to December, 2011 was analysed. From this data false colour composite was created and signatures for different land uses and land covers (LULC) classes *viz.* cropland, grassland, wasteland, forest, water body, snow cover, etc. were generated. Supervised classification method of maximum likelihood was applied on georeferenced LISS III data. Remote sensing data was analysed using ERDAS Imagine software and maps were prepared using Arc Map software. Kappa coefficient was computed for validating the agreement between classified and actual pixels.

***Remote sensing data and analysis*:** Multispectral remote sensing images of Resoursesat-2/ LISS III (spatial resolution 23.5m) were analysed for land uses and land covers. Geo-referenced standard LISS III data having paths and rows 96-49, 97-49 and 97-50 for the period 2011-12 were procured from National Remote Sensing Centre, Hyderabad. Pre-processing of these scenes included layer stacking, sub-setting with district boundary and mosaicing was done. Shape file of district boundaries was obtained from Survey of India, Dehradun. Maximum likelihood method of supervised classification was applied for assessment of land uses and land covers (LULC) in selected districts. These scenes were classified into ten classes viz. cropland, grassland, wasteland, plantation, agroforestry, forest, scrubland, built-ups, water bodies and snow cover (Fig 1). In this classification, only agri-silviculture/ agri-horticulture systems and block plantations were accounted for agroforestry since medium resolution data was used. Other agroforestry systems like boundary plantations or scattered trees on farmlands were missing because tree canopy cover within pixel was less than 50 percent. In order to overcome this constraint, imagine sub-pixel classifier was applied.

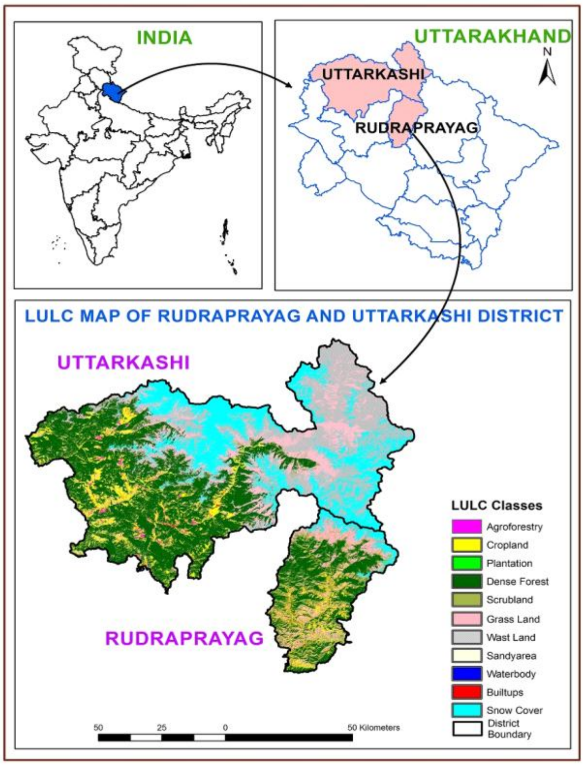

Fig 1. Location and LULC map of Rudraprayag and Uttarkashi districts

Mapping of tree cover and agroforestry: Agricultural land including cropland and fallow land was masked from false color composite with the help of LULC map of the district. On this agricultural area, sub-pixel classifier was applied because agroforestry existed on agricultural land only. Resultant image consisted of pixels of five categories i) pixels covering trees plus cropland, ii) pixels covering trees plus fallow land, iii) pixels covering trees only, iv) pixels covering cropland only and v) pixels covering fallow land only. Pixels of first three categories were considered for estimation of area under tree cover and agroforestry. This methodology was standardised for mapping agroforestry at district level (Rizvi *et al.,* 2016).

Results and Discussion

***Land use and land cover analysis*:** Area estimates for LULC of Rudraprayag and Uttarkashi were obtained by applying supervised method of maximum likelihood (Table 1). Forest covered a considerable area in the two districts. Estimated area under agroforestry in Rudraprayag and Uttarkashi districts was 2286.31 ha (1.15%) and 5147.45 ha (0.64%). As far as grassland is concerned, it was estimated to be 18.87 and 10.88 percent in Rudraprayag and Uttarkashi districts, respectively. Classification accuracy of 84.4 percent with kappa coefficient of 0.829 was found in Rudraprayag district, whereas, it was 83.8 percent with kappa coefficient of 0.822 in Uttarkashi district. Some estimates of area and production of wood for the tree cover outside forests were available (FSI, 2013), but these estimates include trees on canal side, roadside and in urban areas, thus do not represent as true agroforestry area (Dhyani *et al.,* 2014).

Table 1. Estimates of land uses and land covers in Rudraprayag and Uttarkashi districts

LULC Classes	Rudraprayag		Uttarkashi	
	Area (ha)	Area (%)	Area (ha)	Area (%)
Forest (dense + degraded)	103842.09	52.22	307653.54	38.38
Grassland	37524.81	18.87	87238.47	10.88
Cropland	16117.27	8.10	53732.36	6.70
Agroforestry + plantation	2286.31	1.15	5147.45	0.64
Scrubland	14572.44	7.33	—	—
Wasteland	7019.07	3.53	193274.40	24.11
Water body	1239.21	0.62	825.94	0.10
Builtups	720.92	0.36	1783.66	0.22
Snow cover	15530.25	7.81	151917.31	18.95
Geographical area	198852.37		801573.13	

***Assessment of grassland for different altitudes and slopes*:** Estimated grassland in Rudraprayag district was further analysed according to different slopes and elevations using digital elevation model (Table 2). Out of the total estimated grassland (18.87%), maximum (8.37%) was found in 30-45 degrees slope followed by 15-30 degrees slope (6.95%). Similarly maximum grassland (7.10%) was found in 1000-2000 m elevation followed by 4.63 per cent in 3000-5000 m elevations (Fig 2). No grassland was found above 5000 m elevation and almost negligible in more than 60 degrees slope. Estimated grassland in Uttarkashi district was also further analysed according to different slopes and elevations (Table 3). Out of the total estimated grassland (10.88%), maximum (10.60%) was confined between 0 to 60 degree slopes. Maximum grassland (3.76%) was found between 15-30 degree slopes. On the other hand, grassland was distributed between 3000 to 5000 m elevations in the Uttarkashi district. About 1.23 percent of total grassland was found above 5000 m elevation (Fig 3). Singh *et al.* (2011) used geospatial technologies (GIS, GPS and remote sensing) in conjunction with ground-truthing to assess the extent of grasslands and their productivity in Himalayan state of Sikkim. Roy and Singh (2013) also highlighted various issues associated with degradation of pasturelands and concluded that overgrazing coupled with poor management and care of these grazing lands led to deterioration to a large extent and needs amelioration or rehabilitation.

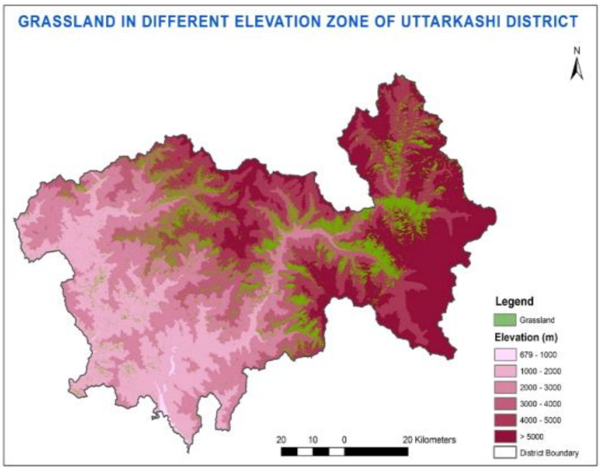

Fig 2. Grassland shown in different elevations of Rudraprayag district

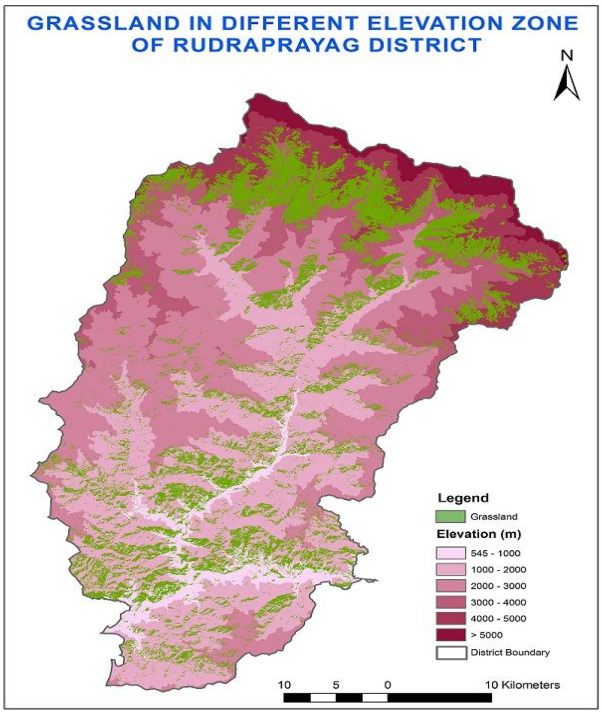

Fig 3. Grassland shown in different elevations of Uttarkashi district

Table 2. Estimated grassland according to slopes and elevations in Rudraprayag district

Slopes (degrees)			Elevation (meters)		
Range	**Area (ha)**	**Area (%)**	**Range**	**Area (ha)**	**Area (%)**
0-15	3316.95	1.67	545-1000	2961.66	1.49
15-30	13822.04	6.95	1000-2000	14109.80	7.10
30-45	16634.42	8.37	2000-3000	4271.39	2.15
45-60	3489.09	1.75	3000-4000	9201.24	4.63
>60	262.30	0.14	4000-5000	6933.67	3.49
—	—	—	> 5000	47.06	0.02
Total	37524.81	18.87		37524.81	18.87

Table 3. Estimated grassland according to slopes and elevations in Uttarkashi district

Slopes (degrees)			Elevation (meters)		
Range	**Area (ha)**	**Area (%)**	**Range**	**Area (ha)**	**Area (%)**
0-15	10286.15	1.28	680-1000	41.39	0.01
15-30	30102.28	3.76	1000-2000	3509.54	0.44
30-45	29504.10	3.68	2000-3000	6488.56	0.81
45-60	15044.60	1.88	3000-4000	34398.64	4.29
>60	2301.33	0.28	4000-5000	32909.10	4.11
—	—	—	> 5000	9891.24	1.23
Total	87238.47	10.88		87238.47	10.88

Natural grasslands constitute an important land use system in Himalayan states of India covering an area of 11.4 million ha. The temperate/alpine grasslands spread across altitudes higher than 2000 m in the states of Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh. Being an important natural resource, assessment of available grassland is useful for planning at district or state level. Singh *et al*. (2015) assessed the grassland area in Himachal Pradesh which was only 16.53 percent of the total geographical area. They also estimated the vertical distribution of grassland and found 15.38, 19.51 and 47.56 percent grassland area in low, mid and high hills, respectively.

Besides this, agroforestry is another important land use system for rural community in the state of Uttarakhand. Occurrence of agroforestry systems in the Uttarakhand state of northern India using remote sensing data in conjunction with digital elevation model (DEM) was also investigated earlier (Rizvi *et al*., 2014). The area under agroforestry was estimated to be 63543.09 ha (1.21%) in Uttarakhand state and agroforestry practices were mainly confined to terrace bunds, foothills, forest fringes and plain areas of the state.

In the present study, the vertical distribution of grassland as well as agroforestry area was assessed along altitudes and slopes using remote sensing and DEM. Indeed, altitude and slope are important factors in hilly areas; therefore, these two factors were taken into consideration. Hence, land use systems like grassland and agroforestry at district/ state level could be monitored with the help of geospatial technologies.

Conclusion

It was concluded that with judicious use of geospatial technologies, assessment of natural resources like, agroforestry, grassland, etc. can be done accurately which will provide desired spatial information for planners and decision makers.

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