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Evaluation of state and community/private forests in Punjab, Pakistan using geospatial data and related techniques

Naeem Shahzad[1,2], Urooj Saeed[1,2], Hammad Gilani[3*], Sajid Rashid Ahmad[2], Irfan Ashraf[1] and Syed Muhammad Irteza[4]

Abstract

Background: Forests are fundamental in maintaining water supplies, providing economic goods, mitigating climate change, and maintaining biodiversity, thus providing many of the world's poorest with income, food and medicine. Too often, forested lands are treated as "wastelands" or "free" and are easily cleared for agricultural and infrastructure expansion.

Methods: In this paper, the sustainability of two forest ecosystems (state and community/private owned) was evaluated using SPOT-5 satellite images of 2005 and 2011. This study was conducted in a sub-watershed area covering 468 km^2, of which 201 km^2 is managed by the state and 267 km^2 by community/private ownership in the Murree Galliat region of Punjab Province of Pakistan. A participatory approach was adopted for the delineation and demarcation of forest boundaries. The Geographic Object-Based Image Analysis (GEOBIA) technique was used for identification and mapping of ten Land Cover (LC) features.

Results: The results show that between the years 2005 to 2011, a total of 55 km^2 (24 km^2 in state-owned forest and 31 km^2 in community/private forest) was converted from forest to non-forest. The conclusion is that conservation is more effective in state-owned forests than in the community/private forests.

Conclusions: These findings may help to mobilize community awareness and identify effective initiatives for improved management of community/private forest land for other regions of Pakistan.

Keywords: Forest management; SPOT-5 satellite images; State and community/private owned forests; Murree Galliat; Pakistan

Background

Forest ecosystems are fundamental in securing water supplies, providing economic goods, mitigating climate change, and maintaining biodiversity thus providing many of the world's poorest with income, food and medicine. Too often, forested lands are treated as "free wastelands" and are cleared for agricultural and infrastructure expansion. Local and regional practices are different and often do not match national policies, and it is difficult to keep up with the impacts of international trade and investment flows on forests. International initiatives such as timber certification or environmental conventions can succeed only if local realities are considered and are meaningful to local stakeholders, which is rarely the case. In many countries, tenure rights are so ill-defined that it is difficult to know who has the right of access to particular forests, which leaves a vacuum open to unbridled exploitation (Bengston 1994; Scarpa et al. 2000; McAlpine et al. 2006).

According to FAO (2010) 2.2% or about 16,870 km^2 area of Pakistan is forested with 3,400 km^2 of planted forests. Between 1990 and 2010, Pakistan lost around 8,400 km^2 (33.2%) of its forest cover, averaging 420 km^2 (1.66%) per year (FAO 2010). At the national level the most recent study "Land Cover Atlas-2011 of Pakistan" conducted by the Pakistan Forest Institute (PFI) reported a total forest cover of Pakistan, excluding alpine pastures,

* Correspondence: Hammad.Gilani@icimod.org
[3]International Centre for Integrated Mountain Development (ICIMOD), GPO Box 3226, Kathmandu, Nepal
Full list of author information is available at the end of the article

farmland trees and plantations, of 5.1% (Ali 2013). Two main categories of forests exist in Pakistan from the tenure point of view, i.e., state and community/ private owned. A total of 66% of the forest area is managed by the State forest department, whereas 34% is in private ownership (FAO 2010). The state-owned forest land has been legally categorized into five classes: state, reserved, protected, un-classified and resumed lands. The community/private forestland has been classified as *guzara* forests, communal forests (Section 38 of the Areas and Chos Act; Wani 2002). Land tenure systems in Pakistan are highly complex, especially in the mountainous regions where natural forests are located. Many tribal communities have inhabited these areas for centuries, but tenure rights are not well defined or documented in government records (Shahbaz et al. 2007).

Remote sensing data and related analysis techniques provide a unique possibility for quantifying changes, especially those caused by anthropogenic activities over time (Huang et al. 2009a). Satellite images offer the possibility to examine spatial changes historically with synchronization of the present situation and ground realities. Multi-temporal Land Cover and Land Use (LCLU) changes and simulation is well recognized in the scientific community as aiding decision makers in improving management and resource allocation (Kumar et al. 2011; Vogelmann et al. 2012; Townshend et al. 2012; Niraula et al. 2013). Satellites such as SPOT, IKONOS, QuickBird, OrbView, GeoEye, WorldView, and Pleiades, which have been launched in recent years, deliver data at fine resolutions (<5 m). They have been used to replace aerial photographs with detailed investigation of the Earth's features (Aplin et al. 1997; Giada et al. 2003; Herold et al. 2003). Very High Resolution (VHR) satellite imagery on large scale maps (1:50,000 up to 1:5,000) is much simpler and more cost effective than aerial photographs. It is also efficient in terms of mathematical modeling for further analysis to extract parameters for decision making (Boyd and Foody 2011). With the advent of VHR satellite data, it is possible to derive detailed LCLU information compatible with watershed-level planning and management decisions (Mathieu et al. 2007; Pu et al. 2011).

A number of satellite image classification algo rithms has increased rapidly with developments in the geospatial domain (Stathakis and Vasilakos 2006; Thessler et al. 2008; Knorn et al. 2009; Blaschke 2010; Quintano and Cuesta 2010). In the 1980s, image segmentation techniques were developed but used to a lesser extent in geospatial applications (Blaschke 2010). Geographic Object-Based Image Analysis (GEOBIA) is the method to electronically segregate feature/object boundaries within digital images to facilitate classification and further analysis (Hay and Castilla 2008). In VHR satellite images, objects are visually composed of many pixels, which can be easily validated after applying GEOBIA (Blaschke 2010; Blaschke et al. 2014). Pu et al. (2011) used IKONOS imagery of April 2006 to examine the GEOBIA technique, which significantly improved the classification accuracy when compared with the pixel-based method. Similarly Mathieu et al. (2007) used IKONOS imagery for Dunedin City, New Zealand and adopted an object-based classification to identify 20 LCLU classes. The ground reality is very important and information can be gathered through coordinates recorded using Global Positioning System (GPS) receivers, field photographs, topographic sheets, interviews etc. for an accurate assessment of thematic outputs (Stehman and Czaplewski 1998; Foody 2002).

This study focuses on the changes in forests by taking one of the sub-watershed areas of the Murree, Galliat region, in Punjab Province, Pakistan where state-owned and privately/community owned forests exist. The selected site has been under threat by influential groups for the conversion of 7.58 km^2 natural forest into other land. On January 2010, the provincial Lahore High Court took up suo motu proceedings and stopped further distortion of the forest ecosystem (Abbasi 2011). On the instruction of the judiciary, state and community/private owned forested land boundaries were delineated in close consultation with representatives of the Forest Department, Revenue Department and local communities. GEOBIA's multi-resolution segmentation technique was used on VHR satellite images of ortho-rectified SPOT-5 (2.5 m) image of the years 2005 and 2011. The accuracy of the classified images were assessed from reference ground points. Consequently, the objectives of this study are:

- Boundary delineation of state and community/ private owned forests through a participatory GIS approach
- VHR satellite data based LC change assessment and comparison between forest regions (state and community/private owned) over the years 2005 and 2011
- Gross deforestation (forest to non-forest) and forest regeneration (non-forest to forest) calculation in sub-watershed areas and two forest regions to identify the drivers or forces behind these change, over a time period of six years

Materials

The methods used in this study are divided into two parts: 1) field data collection including boundary delineation of state and community/private owned forests and collection of ground samples for identification of LC features on satellite images and 2) image/data analysis and comparison within the two different forest regions.

Site selection

The Murree Galliat area, in the Punjab Province of Pakistan is a mountainous region of the sub-tropical continental Himalaya highlands with elevations ranging from 550 to 2600 m above mean sea level. The study area is located between 33°46′50.60″N, 33°56′1.48″N latitude and 73°9′36.76″E, 73°33′29.66″E longitude (Figure 1). Within the total area of 468 km^2 studied, 201 km^2 is managed by the state and 267 km^2 by community/private ownership. The dominant tree species in Murree are *Pinus wallichiana* (Blue Pine), *Pinus roxburghii* (Chir Pine), *Quercus incana* (Oak), *Aesculus indica* (Chestnut), *Dodonea* spp. (Sanatha) and *Olea* spp. (Indian Olive). The selected site is located within an seismically active zone in the major thrust fault region, which also includes the Main Boundary Thrust (MBT) and Main Frontal Thrust (MFT) in the north and south of Murree (Khan 2001; Kamp et al. 2008). The selected site is ecologically important as it contains wildlife habitats which are under continuous threat of conversion by influential groups and remote sensing was used to support a judicial process initiated by the Lahore High Court.

Data and software used

For this study, VHR satellite images of *Système Pour l'Observation de la Terre* (SPOT-5) were chosen which were acquired on 25 October, 2005 and 16 May, 2011. The SPOT-5 was launched on 4 May 2002 offering a higher resolution of 2.5 to 5 m in the panchromatic mode and 10 and 20 m in the multispectral mode. In this study, multispectral images and panchromatic images were used. As the study area was located on a hilly terrain, ortho-rectification of procured images was essential to overcome non-systematic errors (Townshend et al. 2012). Band by band SPOT-5 images for both years were ortho-rectified using the Rational Polynomial Coefficient (RPC) files and 30 m (1 arc second) Global Digital Elevation Model (GDEM) of Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER).

Methods

Satellite image pre-processing

For the years 2005 and 2011, multispectral bands (10 m) were separately stacked for fusion with the panchromatic image (2.5 m) by adopting the Principal Component

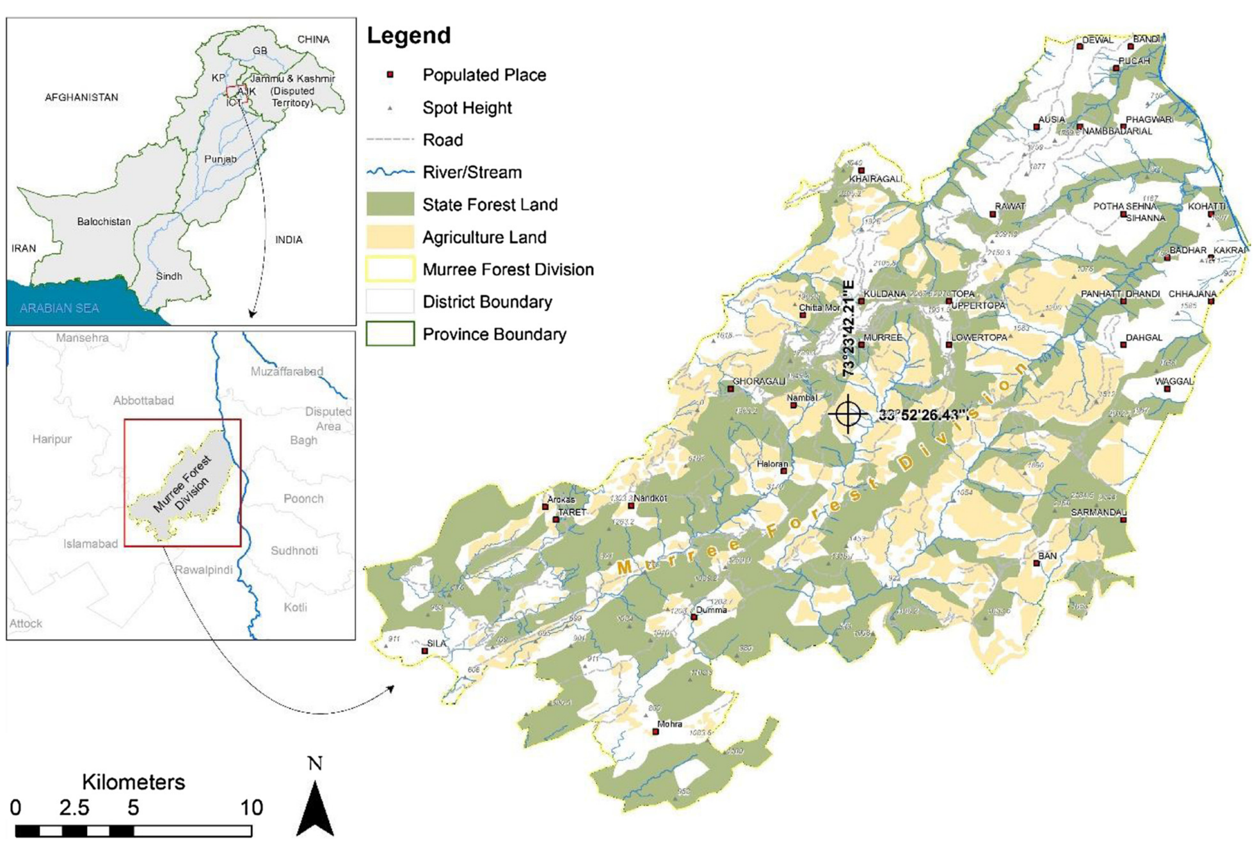

Figure 1 Study area.

Analysis (PCA) method and bilinear resampling technique (Santurri et al. 2012). The PCA and bilinear resampling technique provided good quality High Resolution Multispectral Image (HRMI) for the SPOT data set specifically in this landscape. These HRMIs (2.5 m) were taken for image classification through GEOBIA.

The processed satellite images were edge matched in AutoSync tool of ERDAS Imagine in order to overcome the displacement error of generated thematic layers so that accurate change analysis could be done.

The GDEM of ASTER, with add-on products such as slope and aspect were used for the topographic information and classification of LC features. Base layers, like settlements, roads, contours etc. in Geographic Information System (GIS) format (i.e. shapefiles) were used both as baseline information for the maps and for LC extraction. For satellite image processing and classification, ERDAS imagine 9.3 and eCognition Developer 8.7 were used respectively. Map formation and statistical analysis were done in ArcMap 10.

Field campaign

In this study, a field campaign was carried out 1) to delineate boundaries of forest regions, 2) collect ground samples for the LC mapping and validation and 3) interact with the local communities to identify their perceptions and key motives for deforestation activities.

Through a participatory GIS approach, the boundaries of the state-owned forest land were delineated and the remaining forest areas were declared as community/private owned forest. Forest boundaries were delineated involving more than 200 field staff of the Forest Department, Revenue Department, Survey of Pakistan and WWF-Pakistan. Field maps were prepared using SPOT-5 2011 satellite images on A0 size paper. The legal boundaries of state and community/private owned forests were verified by using Differential Global Positioning System (DGPS) and Total Stations (Ashraf et al. 2014). The demarcated boundaries were converted into GIS layers (digitized sfhapefiles). A similar procedure was adopted in Dolkha District, Nepal for community forest boundary delineation by Niraula et al. (2013). The output of this activity were boundaries of state and private forests, which were used to segregate forest statistics by clipping LC maps of the forest regimes.

A Stratified Random Sampling (SRS) technique was used to plot 299 samples (30 m × 30 m) on various LC features e.g. forest, agriculture, grassland, built-up area, water body etc. GPS readings (latitude, longitude and altitude) were recorded with digital camera photographs against each sample, which were added into a geo-database for record keeping. These GPS points were also used as input for satellite image classifications and to measure accuracy.

Although the main aim of this study was to apply remote sensing data techniques in forestry, to understand the current scenario, key drivers and forces behind the deforestation and forest regeneration, informal interactions were also organized with the local communities.

Satellite image classification and change analysis

Satellite image classification, from manual to pixel-based and object-based is emerging with the applications of geospatial data and techniques in multi-disciplinary fields (Blaschke et al. 2014). In the 1980s, image segmentation techniques were developed but used to a lesser extent in geospatial applications (Blaschke 2010). Hay and Castilla (2008) introduced the terminology of Geographic Object-Based Image Analysis (GEOBIA) rationale to geospatial researchers (Blaschke et al. 2014). In this study we adopted GEOBIA in the eCognition software for the independent classification of pan-sharpened 2.5 m spatial resolution SPOT-5 (2005 & 2011) images. The classification process was divided into the following steps: 1) input images, 2) multi-resolution segmentation, 3) image object hierarchy, 4) creation of class hierarchy, 5) classification using training samples and standard nearest neighbor, 6) classification base on segmentation, 7) repetition of steps for best result, and 8) final merge classification (Laliberte et al. 2004). The scale-25, shape-0.1, and compactness-0.5 used in segmentation of SPOT-5 images fulfilled the condition of segregating two adjacent features. The Estimation of Scale Parameter (ESP) tool was used to estimate best suitable scale parameters for multi-resolution image segmentation (Drăguţ et al. 2010). Approximately 75% of the total segments were used to define rule sets for each LC class (see Table 1) and 25% to assess the accuracy of the defined rules over the entire classified image. In this work a total of 182 sample plots were used. The relationship of satellite images resolution with minimum mapping unit is complex but helps to smooth the final LC products (Saura 2002). For this study, classified objects with an area smaller than the Minimum Mapping Unit (MMU) (1 ha = 9 pixels or 3 × 3 pixels) were fused with the neighboring LC classes.

In this study, an accuracy assessment of the classified year 2011 image was performed on the basis of 117 ground samples out of 299 plots. The overall, user and producer accuracies were determined using a confusion matrix. Kappa value, standard error, and weighted error, with a 95% confidence interval for kappa were also calculated. In addition to the confusion matrix, visual comparisons of the LC maps with Environmental Systems Research Institute (ESRI) online freely available high resolution satellite images were made for spatial comparison of different forest types.

Table 1 LCCS-based legend for LC mapping

No	LCC code	LCC own label	LCC own description	LCC label
1	21499-127505	Dense needleleaved forest	Close canopy *Pinus wallichiana*	Needleleaved evergreen closed (100–60)% high trees
2	21499-127505		Close canopy *Pinus roxburghii*	Needleleaved evergreen closed (100–60)% high trees
3	20134-1		Open canopy *Pinus* spp.	Needleleaved evergreen open (40–20)% high trees
4	20132-6011//20134-1	Mixed needleleaved & broadleaved forest	Open canopy *Quercus* spp. and *Aesculus* spp.	Semi-deciduous (40% – (20–10)%)woodland // needleleaved evergreen (60–40)% woodland
5	21476 - 121340	Scrub forest	*Dodonea* spp./*Olea* spp./*Buxus* spp.	Broadleaved deciduous closed to open (100–40)% woody vegetation
6	20026-1	Grasses	Grasses	Closed and open open ((70–60)% - 40%) herbaceous vegetation
7	11239-11376	Agriculture land	Vegetable cultivation, irrigated or rainfed conditions	Permanently cropped area with surface irrigated herbaceous crop(s) (one additional crop) (herbaceous terrestrial crop sequentially)
8	6005-//66002-1	Barren area	Soil/Rock	Stony bare soil and/or other unconsolidated material(s)//bare rock(s)
9	5001	Built-up area	Settlements, Infrastructures	Built up area(s)
10	8001	Water body	Water channels, small lakes	Natural water bodies

Final LCs were extracted based on demarcated boundaries of state and community/private forests. A change matrix and cross-tabulations were used to identify changes over the past six years. Gross deforestation (forest to non-forest) and forest regeneration (non-forest to forest) were then examined in the two different forest ownerships. Sometimes, one to one LC classes do not show changes, so in this case change matrix helps identify the extract numbers of deforestation (forest to non-forest) and afforestation (non-forest to forest).

The Stratified Random Technique (SRT) was used to select 117 end members out of 299 samples for the accuracy assessment. The overall accuracy of 94.01% of the derived 2011 LC map achieved with a kappa value of 0.93, standard error kappa 0.02, 95% confidence interval 0.88 to 0.98 and weighted kappa 0.96 is presented in Table 2.

Results

Demarcated legal forest boundaries of state-owned forest and community/private forest were used for the assessment of the forest cover in 2005 and 2011. The boundaries were mapped and verified on VHR image (Figure 2). The accuracy of these boundaries was assessed and validated on the ground using DGPS as well as historic forest maps. The delineated boundaries were then used to assess the LC and forest cover change from 2005 to 2011 individually for the state-owned forest and community/private forest.

The study produced statistics for 10 LC classes and maps for two types of forests (state and community/private) which are shown in Figures 3 and 4.

The results show that there is a decrease of about 5 km^2 of 'closed canopy *Pinus wallinchiana*' forest from 2005 to 2011 in the state managed area, whereas, and a decrease of about 2 km^2 in the community/private forest. Similarly, a reduction of closed canopy *Pinus roxburghii* forests of about 3 and 15 km^2 is observed in state and community/private forests respectively. The decrease in the *Pinus wallichiana* and *Pinus roxburghii* forests in turn resulted in an increase in the open canopy covers of both the *Pinus* species (see Table 3).

Considering the status of non-forested classes within the boundaries of state and community/private forests, it can be assumed that the greatest pressure on forests is on private lands, while in state forests exploitation decreased from year 2005 to 2011, although the expansion in the built-up class in the state-owned forest is greater than in other forest ownerships. Moreover, grassland and water bodies are season dependent, so the increase and decrease in these classes highlights the use of images of at least two different seasons as the season always effect agriculture and grass cover.

Based on a change matrix and cross-tabulation 122 km^2 remain forested after conversion of 24 km^2 to non-forested land within the state-owned forests, from 2005 to 2011. Only 24 km^2 were transformed from non-forested land to forest while about 31 km^2 remained unchanged. On the other hand, in the community/private forest, about 31 km^2 was converted from forest to non-forested land while about 52 km^2 remained unchanged. An area of about 49 km^2 was converted from non-forest classes to forest classes while 135 km^2 remained unchanged within the non-forested land (see Table 4 and Figure 5).

Table 2 Accuracy assessment of LC 2011

LC classes	Close canopy *Pinus roxburghii*	Close canopy *Pinus wallichiana*	Open canopy (*Pinus roxburghii* and *Pinus wallichiana)*	Open canopy (*Quercus* spp. and *Aesculus* spp.)	Scrub forest	Grasses	Agriculture land	Barren area	Built-up area	Water body	Total	User's accuracy (%)
Close canopy *Pinus roxburghii*	15	0	0	0	0	0	0	0	0	0	15	100.00
Close canopy *Pinus wallichiana*	0	11	0	0	0	0	0	0	0	0	11	100.00
Open canopy (*Pinus roxburghii* and *Pinus wallichiana)*	0	0	11	0	0	0	0	0	0	0	11	100.00
Open canopy (*Quercus* spp. and *Aesculus* spp.)	1	1	0	17	1	1	0	0	0	0	21	80.95
Scrub forest	0	0	1	0	6	0	0	0	0	0	7	85.71
Grasses	0	0	0	0	0	12	0	0	0	0	12	100.00
Agriculture land	0	0	0	0	0	0	9	0	0	0	9	100.00
Barren area	0	0	0	0	0	2	0	11	0	0	13	84.62
Built-up area	0	0	0	0	0	0	0	0	9	0	9	100.00
Water body	0	0	0	0	0	0	0	0	0	9	9	100.00
Total	16	12	12	17	7	15	9	11	9	9		
Producer's accuracy (%)	93.75	91.67	91.67	100	85.71	80.00	100	100	100	100		

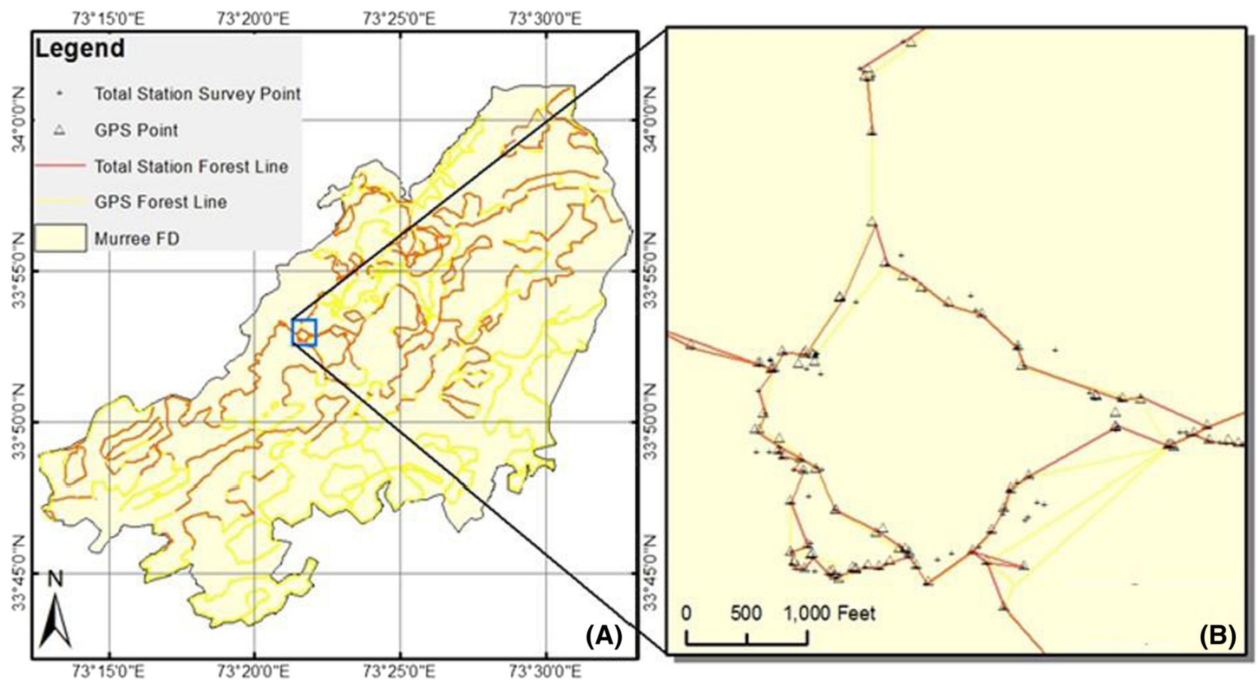

Figure 2 Comparison of delineated and historic forest boundary. (A) Delineated forest boundary **(B)** forest history map.

Discussion

The Murree forest division lies in the western Himalaya ecoregion, which is important in terms of forests and various biodiversity contributions regarding expected climate change effects (Chawla et al. 2012). In this study, the deforestation rate in two forest ownerships (state and community/private) was assessed to demonstrate the change of conifer forests in the Punjab Province, Pakistan.

The forest policy formulated in 1894 for Pakistan highlighted the goal that the main objective of managing state-owned forests for public benefit was to restrict and regulate the rights and privileges of the local forest-dependent population. The top-down (colonial) approach

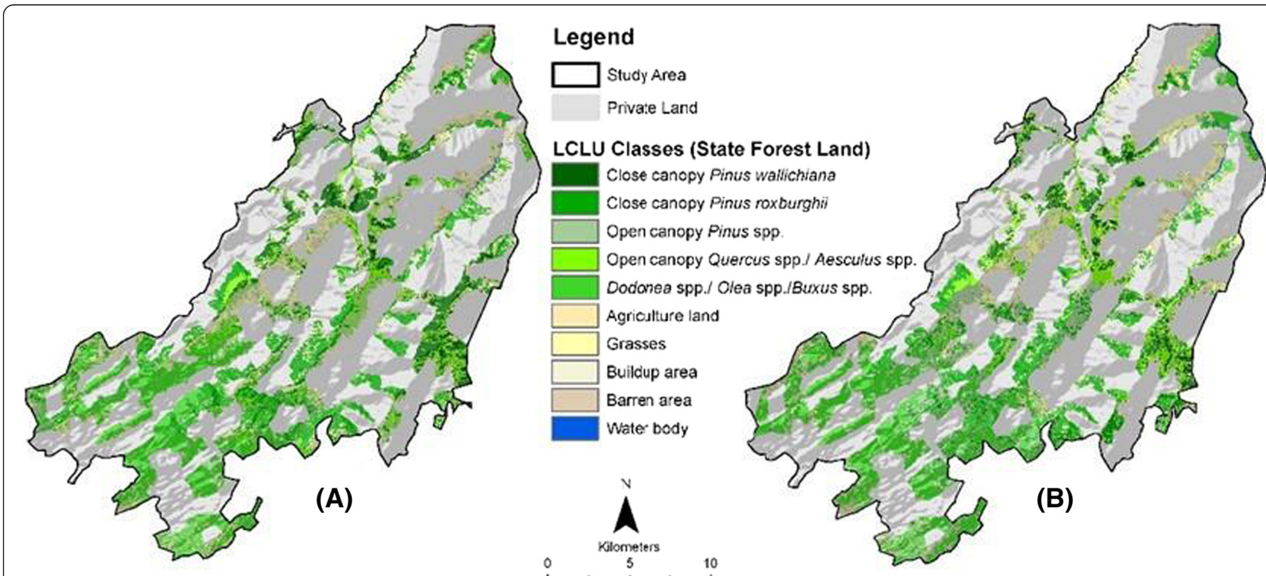

Figure 3 LCs of state owned forest - comparison. (A) LC for the year of 2005 **(B)** LC for the year of 2011.

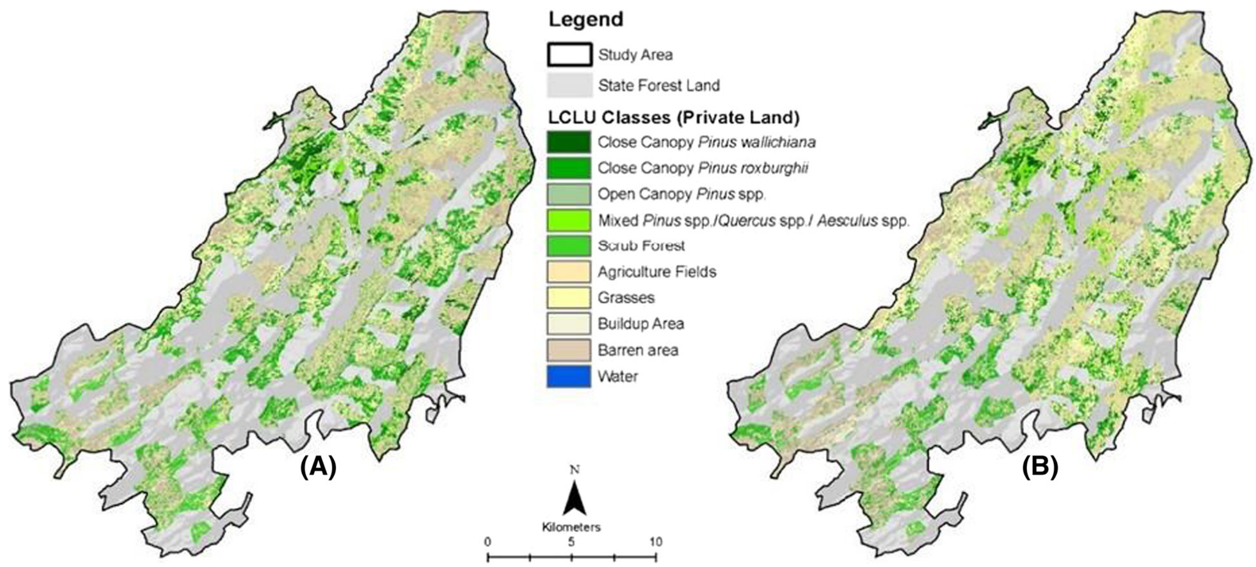

Figure 4 LCs of community/private owned forest – comparison. (A) LC for the year of 2005 **(B)** LC for the year of 2011.

of governance was also reflected in the first national forest policy of 1962 which recommended severe penalties. The 1975 forest policy was the first policy to recognise the rights of communities living in and around forest areas as stakeholders. If these policies were implemented, it would be possible to prevent encroachment by local communities (Wani 2002). The Murree area is called "Queen of the Hills" and is a popular tourist destination, especially in the summer season. A number of influential authorities are trying to convert forested area in this region into commercial property (e.g. hotels, plazas, shopping complexes etc.). Therefore, rights of ownership and land tenure arrangements need to be clarified and addressed for the sustainability and conservation of the forest resource.

Forest cover plays an important role and acts as a shield against landslides in mountainous areas (Kamp et al. 2010; Rahman et al. 2013). This study reveals that between 2005 to 2011 a total of 55 km^2 (24 km^2 in state-owned forest and 31 km^2 in community/private forest) has been deforested. The rocks of this area are composed of clay, and hard gray to reddish sandstone which are inter-bedded with soft red calcareous shale and have high drift during landslides. Atta ur et al.

Table 3 LC 2005 and 2011 (assessment based on satellite images)

LC classes		State forest (km^2)		Community/private forest (km^2)	
		2005	**2011**	**2005**	**2011**
Dense Needleleaved forest	Close canopy *Pinus wallichiana*	17.52	12.39	9.88	7.69
	Close canopy *Pinus roxburghii*	43.34	39.84	40.39	25.22
	Open canopy *Pinus* spp.	15.55	26.1	17.81	19.58
Mixed needleleaved & broadleaved forest	Open canopy *Quercus* spp. and *Aesculus* spp.	16.94	16	10.51	13.55
Scrub forest	*Dodonea* spp./*Olea* spp./*Buxus* spp.	52.3	51.73	22.43	16.26
Total forested land		**146**	**146**	**101**	**83**
Grasses	Grasses	24.98	26.89	71.84	95.37
Agriculture land	Agriculture land	7.91	1.89	20.17	20.93
Barren area	Barren area	17.24	17.59	58.09	52.42
Built-up area	Built-up area	3.55	6.2	14.24	14.98
Water body	Water body	0.87	0.94	1.44	0.62
Total non-forested land		**55**	**55**	**166**	**184**
Grand total		**201**	**201**	**267**	**267**

Table 4 Change in forested area

2011/2005	State forest (km^2)		
	Forest	**Non forest**	**Total (2011)**
Forest	122	24	146
Non Forest	24	31	55
Total (2005)	146	55	201
2011/2005	**Community/private forest (km^2)**		
	Forest	**Non forest**	**Total (2011)**
Forest	52	31	83
Non Forest	49	135	184
Total (2005)	101	166	267

(2011) calculated a gross economic loss of more than PKR158 million during the past 20 years resulting from landslides, in particular: 1) damage to shelter, 2) impacts on institutional buildings, 3) damage to various sources of livelihood earnings and 4) damage to infrastructure.

Our results illustrate very high deforestation rates in community/private forests as compared to state-owned forests (see Table 4). Qamer et al. (2012) examined 0.58 km^2 of deforestation during the conflict period in Swat and Shangla districts of Pakistan and 12.68 km^2 of gross annual deforestation during the peaceful interval. Within the Himalayan region, Nepal's Community Forestry Programme is one of the best examples in securing and improving forest cover (Niraula et al. 2013). Even in Bhutan, another country with limited social forestry, forests are not only largely intact but are also improving (Gilani et al. 2015). In developing countries, low literacy and poverty are the main obstacles to forest protection, and awareness on environmental issues, and provision of alternative sources of energy for local communities can reduce forest degradation (Mollicone et al. 2007). Performance based payment mechanisms are being implemented in the developing countries through Reducing of Emissions from Deforestation, Degradation and Enhancement Carbon Stocks (REDD+) programmes. At the government and welfare organizations levels, annual tree planting campaigns appear to be a useful alternative to manage the forest cover on mountains.

During the literature review and after meetings with local communities, the authors of this study realized that illegal cutting, poor management, forest fires, an increasing influence of a "land mafia", the lack of proper record-keeping and of an effective monitoring system are the major causes of forest decline in the study area. The major threats to these forests are illegal cutting of trees, commercial over-exploitation, overgrazing, illegal land encroachment and poor management (Irshad et al. 2011). Hasan (2008) relates these problems to a lack of understanding of Land Tenure Arrangements before the birth of Pakistan since British Rule and quotes Atje and Roesad (2004) who refer to "Weak and ineffective government institutions unable to monitor and enforce regulations also drive deforestation mechanisms."

In Pakistan, many business minded people are investing their money in real estate and hence provide incentives for encroachers to intrude on state-owned land. Forests, due to their natural beauty and as a source of a double benefit, i.e., timber and land, are especially threatened by illegal land grabbing. Lack of forest boundary demarcation and monitoring activities encourage infringements on forested land. Hasan (2001) reported, due to half-hearted demarcation by government officials, *guzara* and state forests are facing serious threats of illegal encroachment (see Figure 6).

Large forest areas are also lost every year due to uncontrolled fires. In most of the areas, natural forests have no fire belts to prevent fires and hence it is very difficult to fight this particular threat (Khan et al. 2014). Out of all types of forests available, sub-tropical broad-leaved evergreen shrub forests and sub-tropical Pine forests are the most fire-prone ecosystems in Pakistan (Bukhari 1997; NIDM 2011). The "Himalayan Environmental Degradation" (Ali and Benjaminsen 2004; Hasan 2008) is caused by an increasing human population which has resulted in increased demands for natural resources, leading to severe resource depletion, especially deforestation. Hussain et al. (2012) found that the contribution of state forests in providing timber and fuelwood is just 14% and 10% respectively. Another problem affecting the forests of Pakistan is that forest officials are implementing old and obsolete management practices. No proper forest database is developed or maintained and much time is wasted in "useless management activities" (Wani 2002).

VHR satellite images are commonly used in the forestry sector for the extraction of forest parameters, especially in assessing deforestation and forest degradation rates for better management and decision making (Hussin et al. 2014; Huang et al. 2009b). In this study, which used VHR satellite images, a decrease was observed in closed canopies of *Pinus wallichiana* and *Pinus roxburghii*, which led to an increase in the open canopy covers of both *Pinus* species. Due to limitations in spectral layers of SPOT-5 (i.e. 4 bands) and overall occurrence in the study area, separated close canopy of *Pinus* species and broad-leaved species could not be captured. In the mountain territories, shadow and positional accuracy for comparison of land features, using VHR satellite images, are obstacles which can be overcome with sufficient ground knowledge and through alternative ancillary information including topographic sheets and photographs (Asner and Warner 2003; Dare 2005; Ozdemir 2008). The digital elevation model generated from SRTM was found to be superior when compared with the DEM

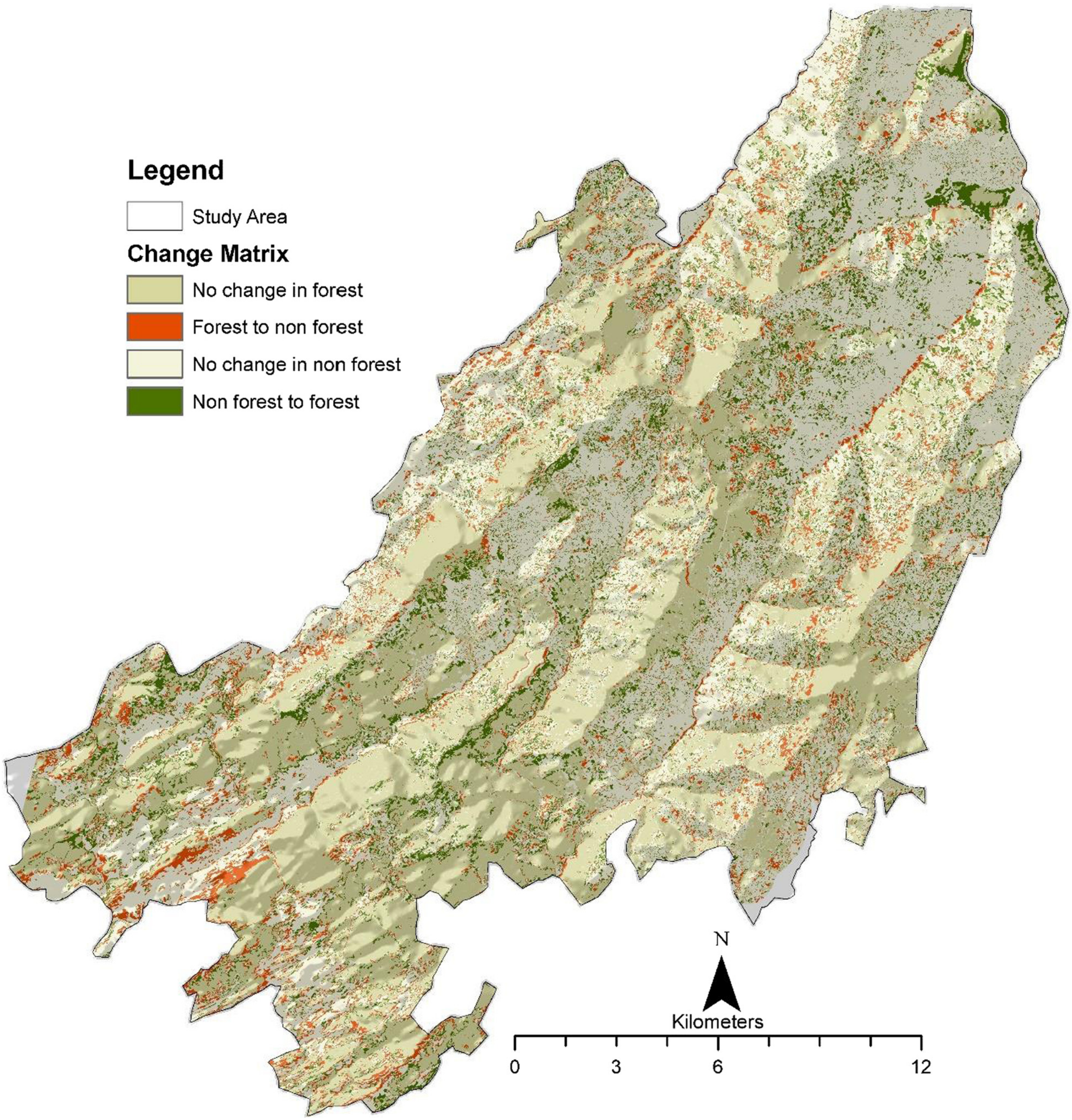

Figure 5 **Forest cover change in two forest management regimes between 2005–2011.**

generated model from other optical data sets like ASTER (Nikolakopoulos et al. 2006). For the selected study area SRTM was acquired in the year 2000. Following the severe earthquake in the central Himalayas of Pakistan, the topography of the area was severely affected. Therefore, DEM generated through ASTER stereo pairs were used in this study.

Good results from high resolution satellite images depend on positional accuracy. If the images were not observed from exactly the same point in space, then they can have different displacements, which could cause misregistration errors. Although positional calibration is a basic element of image analysis data flow, interpreters often face problems due to systematic or unsystematic errors in satellite images. Geometric or ortho-rectification (especially in mountain area) of the satellite images is vital to overcome the distortions related to the sensor (e.g. jitter, view angle effects), satellite (e.g. attitude deviations

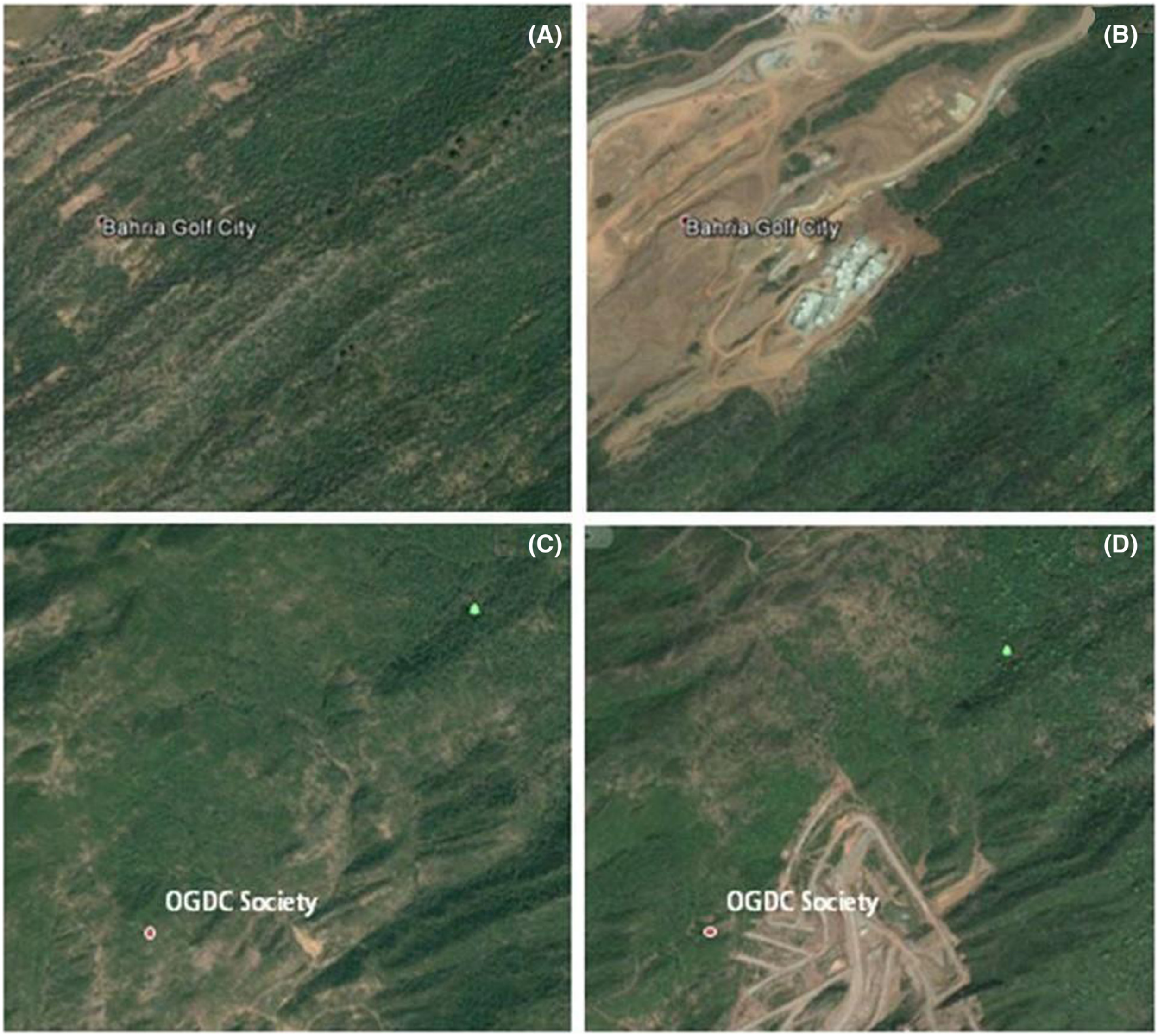

Figure 6 Illegal encroachments in state owned forests as observed from Google Earth. **(A)** Bahria Golf City in 2005 **(B)** Bahria Golf City in 2011 **(C)** OGDC Society in 2005 **(D)** OGDC Society in 2011.

from nominal), and Earth (e.g. rotation, curvature, relief). The study area described here lies in a mountainous region, and topographic effects in terms of the earth's curvature, mountain shadow, and clouds represent major obstacles that need to be taken into account (Itten and Meyer 1993).

Conclusions

This study involves a comparison of two forest ownerships (state and community/private) over five years (2005–2011) using uniform satellite data (SPOT-5) and related methodology, i.e., GEOBIA. The study reveals that state-owned forest is more effective than community/private forest in conserving and managing the forest resource. Pakistan has one of the fastest rates of deforestation in Asia, therefore better management practices, greater awareness, and incentives for the local communities are required. This study may represent an important first step in promoting the Murree area as a model for community mobilization and a showcase for best community/private forest initiatives in Pakistan.

Competing interests

All authors listed have contributed sufficiently to the project to be included as authors, and all those who are qualified to be authors are listed in the author by-line. To the best of our knowledge, no conflict of interest, financial or otherwise, exists. The findings reported stand as scientific study and observations of the authors and do not necessarily reflect the views of World Wide Fund for Nature-Pakistan (WWF-Pakistan) or the International Centre for Integrated Mountain Development (ICIMOD). Geo-Informatics, Hong Kong Polytechnic University, Hung Hom, Hong Kong.

Authors' contributions

NS carried out the data analysis/modelling, US wrote the majority of the text, HG devised the concept of the article, coordinated with all authors and also ensured consistent notations. SRA, IR and SMI were involved in field data collection and analysis. All authors read and approved the final manuscript.

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Author details

[1]World Wide Fund for Nature (WWF), Ferozepur road, Lahore 54600, Pakistan. [2]Institute of Geology, University of the Punjab, Lahore, Pakistan. [3]International Centre for Integrated Mountain Development (ICIMOD), GPO Box 3226, Kathmandu, Nepal. [4]Department of Land Surveying and Geo-Informatics, Hong Kong Polytechnic University, Hung Hom, Hong Kong.

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References

Abbasi O (2011) Tree Slaughter: The Murree Hills Chainsaw Massacre, Connivance of Forest Officials in Illegal Logging Alleged. The Express Tribune, November 30, 2011

Ali Z (2013) Missing the Forest for the Trees. DAWN

Ali J, Benjaminsen TA (2004) Fuelwood, timber and deforestation in the Himalayas. Mt Res Dev 24:312–318

Aplin P, Atkinson PM, Curran PJ (1997) Fine spatial resolution satellite sensors for the next decade. Int J Rem Sens 18(18):3873–3881, doi:10.1080/014311697216694

Ashraf I, Saeed U, Shahzad N, Gill J, Parvez S, Raja A (2014) Delineating Legal Forest Boundaries to Combat Illegal Forest Encroachments: A Case Study in Murree Forest Division, Pakistan. In: Forensic GIS. Springer, pp 263–286. http://link.springer.com/chapter/10.1007%2F978-94-017-8757-4_13

Asner GP, Warner AS (2003) Canopy shadow in IKONOS satellite observations of tropical forests and savannas. Remote Sens Environ 87:521–533

Atje, R, Roesad K (2004) Who Should Own Indonesia's Forests. Review of. Exploring The Links Between Economic Incentives, Property Rights And Sustainable Forest Management. Centre for Strategic and International Studies (CSIS) Working Paper Series: WPE 76.

Atta ur R, Khan A, Collins A, Qazi F (2011) Causes and extent of environmental impacts of landslide hazard in the Himalayan region: a case study of Murree, Pakistan. Nat Hazards 57(2):413–434, doi:10.1007/s11069-010-9621-7

Bengston DN (1994) Changing forest values and ecosystem management. Soc Nat Resour 7(6):515–533, doi:10.1080/08941929409380885

Blaschke T (2010) Object based image analysis for remote sensing. ISPRS J Photogram Rem Sens 65(1):2–16, doi:10.1016/j.isprsjprs.2009.06.004

Blaschke T, Hay GJ, Kelly M, Lang S, Hofmann P, Addink E, Queiroz Feitosa R, van der Meer F, van der Werff H, van Coillie F, Tiede D (2014) Geographic object-based image analysis – towards a new paradigm. ISPRS J Photogram Rem Sens 87:180–191, doi:10.1016/j.isprsjprs.2013.09.014

Boyd DS, Foody GM (2011) An overview of recent remote sensing and GIS based research in ecological informatics. Ecol Informat 6(1):25–36, doi:10.1016/j.ecoinf.2010.07.007

Bukhari A (1997) The Role of NGOs in Promoting Fuel Wood Production in Pakistan. In: National Workshop on Wood Fuel Production and Marketing in Pakistan. RWEDP Report, vol 49

Chawla AY, Pawan K, Uniyal SK, Kumar A, Vats SK, Kumar S, Ahuja PS (2012) Long-term ecological and biodiversity monitoring in the western Himalaya using satellite remote sensing. Curr Sci 102(8):1143–1156

Dare PM (2005) Shadow analysis in high-resolution satellite imagery of urban areas. Photogramm Eng Rem Sens 70(2):169–177

Drăguţ L, Tiede D, Levick SR (2010) ESP: a tool to estimate scale parameter for multiresolution image segmentation of remotely sensed data. I J Geogr Inform Sci 24(6):859–871, doi:10.1080/13658810903174803

FAO (2010) Global Forest Resources. Assessment 2010. Food And Agriculture Organization Of The United Nations, Rome, Italy

Foody MG (2002) Status of land cover classification accuracy assessment. Remote Sens Environ 80:185–201

Giada S, De Groeve T, Ehrlich D, Soille P (2003) Information extraction from very high resolution satellite imagery over Lukole refugee camp, Tanzania. Int J Rem Sens 24(22):4251–4266, doi:10.1080/0143116021000035021

Gilani H, Shrestha HL, Murthy M, Phuntso P, Pradhan S, Bajracharya B, Shrestha B (2015) Decadal land cover change dynamics in Bhutan. J Environ Manage 148:91–100

Hasan L (2001) Analysing Institutional Set-up of Forest Management in Pakistan. Pakistan Institute of Development Economics, Islamabad

Hasan L (2008) An Anatomy of State Failures in Forest Management in Pakistan. In: 23 AGM Papers, Islamabad. Society of Development Economics, Pakistan, pp 1–25

Hay GJ, Castilla G (2008) Geographic Object-Based Image Analysis (GEOBIA): A new name for a new discipline. In: Blaschke T, Lang S, Hay G (eds) Object-Based Image Analysis. Lecture Notes in Geoinformation and Cartography. Springer Berlin, Heidelberg, pp 75–89, doi:10.1007/978-3-540-77058-9_4

Herold M, Liu XH, Clarke KC (2003) Spatial metrics and image texture for mapping urban land use. Photogramm Eng Rem Sens 69(9):991–1001

Huang C, Goward SN, Schleeweis K, Thomas N, Masek JG, Zhu Z (2009a) Dynamics of national forests assessed using the Landsat record: Case studies in eastern United States. Remote Sens Environ 113(7):1430–1442, doi:10.1016/j.rse.2008.06.016

Huang H, Gong P, Cheng X, Clinton N, Li Z (2009b) Improving measurement of forest structural parameters by co-registering of high resolution aerial imagery and low density LiDAR data. Sensors (Basel) 9(3):1541–1558, doi:10.3390/s90301541

Hussain T, Khan GS, Khan SA, Masoo N, Ashfaq M, Sarwer N (2012) Farmers' Agro forestry in Pakistan, Farmers' Role-Trends and Attitudes. Curr Res J Soc Sci 4 (1):29–35

Hussin YA, Gilani H, Leeuwen L, Murthy MSR, Shah R, Baral S, Tsendbazar N-E, Shrestha S, Shah SK, Qamer FM (2014) Evaluation of object-based image analysis techniques on very high-resolution satellite image for biomass estimation in a watershed of hilly forest of Nepal. Appl Geomatics 6(1):59–68, doi:10.1007/s12518-014-0126-z

Irshad M, Khan A, Inoue M, Ashraf M, Sher H (2011) Identifying factors affecting agroforestry system in Swat, Pakistan. Afr J Agr Res 6(11):2586–2593

Itten KI, Meyer P (1993) Geometric and radiometric correction of TM data of mountainous forested areas. IEEE Trans Geosci Rem Sens 31(4):764–770

Kamp U, Growley BJ, Khattak GA, Owen LA (2008) GIS-based landslide susceptibility mapping for the 2005 Kashmir earthquake region. Geomorphology 101(4):631–642, http://www.sciencedirect.com/science/article/pii/S0169555X08000767?np=y

Kamp U, Owen L, Growley B, Khattak G (2010) Back analysis of landslide susceptibility zonation mapping for the 2005 Kashmir earthquake: an assessment of the reliability of susceptibility zoning maps. Nat Hazards 54(1):1–25, doi:10.1007/s11069-009-9451-7

Khan AN (2001) Impact of landslide hazards on housing and related socio-economic characteristics in Murree (Pakistan). Pak Eco Soc Revi 39(1):57–74

Khan J, Muhammad B, Khan MA, Hussain Z, Khattak SU, Bacha N, Ullah F, Lutfullah G, Ali R (2014) Effect of forest fire on the chemical composition of the soil of Margalla Hills of Pakistan. Pak J Weed Sci Res 20(2):213–223

Knorn J, Rabe A, Radeloff VC, Kuemmerle T, Kozak J, Hostert P (2009) Land cover mapping of large areas using chain classification of neighboring Landsat satellite images. Remote Sens Environ 113(5):957–964, doi:10.1016/j.rse.2009.01.010

Kumar U, Kerle N, Punia M, Ramachandra TV (2011) Mining land cover information using multilayer perceptron and decision tree from MODIS data. J Ind Soc Rem Sens 38(4):592–603, doi: 10.1007/s12524-011-0061-y

Laliberte AS, Rango A, Havstad KM, Paris JF, Beck RF, McNeely R, Gonzalez AL (2004) Object-oriented image analysis for mapping shrub encroachment from 1937 to 2003 in southern New Mexico. Remote Sens Environ 93(1–2):198–210, http://www.sciencedirect.com/science/article/pii/S0034425704002147

Mathieu R, Aryal J, Chong AK (2007) Object-based classification of IKONOS imagery for mapping large-scale vegetation communities in urban areas. Sensors 7:2860–2880

McAlpine CA, Rhodes JR, Callaghan JG, Bowen ME, Lunney D, Mitchell DL, Pullar DV, Possingham HP (2006) The importance of forest area and configuration relative to local habitat factors for conserving forest mammals: A case study

of koalas in Queensland, Australia. Bio Conserv 132(2):153–165, http://www.sciencedirect.com/science/article/pii/S0006320706001455
Mollicone D, Achard F, Federici S, Eva HD, Grassi G, Belward A, Raes F, Seufert G, Stibig HJ, Matteucci G, Schulze ED (2007) An incentive mechanism for reducing emissions from conversion of intact and non-intact forests. Clim Change 83:477–493
NIDM (2011) National disaster risk situations in Pakistan. NDMA, Islamabad, Pakistan
Nikolakopoulos KG, Kamaratakis EK, Chrysoulakis N (2006) SRTM vs ASTER elevation products. Comparison for two regions in Crete, Greece. Int J Rem Sens 27(21):4819–4838, doi:10.1080/01431160600835853
Niraula RR, Gilani H, Pokharel BK, Qamer FM (2013) Measuring impacts of community forestry program through repeat photography and satellite remote sensing in the Dolakha district of Nepal. J Environ Manage 126:20–29, doi:10.1016/j.jenvman.2013.04.006
Ozdemir I (2008) Estimating stem volume by tree crown area and tree shadow area extracted from pansharpened Quickbird imagery in open Crimean juniper forests. Int J Rem Sens 29(19):5643–5655, doi:10.1080/01431160802082155
Pu R, Landry S, Yu Q (2011) Object-based urban detailed land cover classification with high spatial resolution IKONOS imagery. Int J Rem Sens 32(12):3285–3308, doi: 10.1080/01431161003745657
Qamer F, Abbas S, Saleem R, Shehzad K, Ali H, Gilani H (2012) Forest cover change assessment in conflict-affected areas of northwest Pakistan: The case of Swat and Shangla districts. J Mt Sci 9(3):297–306, doi:10.1007/s11629-009-2319-1
Quintano C, Cuesta E (2010) Improving satellite image classification by using fractional type convolution filtering. Int J Appl Earth Obs 12(4):298–301, doi:10.1016/j.jag.2010.02.008
Rahman A-u, Khan AN, Collins AE (2013) Analysis of landslide causes and associated damages in the Kashmir Himalayas of Pakistan. Nat Hazards 71(1):803–821, doi:10.1007/s11069-013-0918-1
Santurri L, Aiazzi B, Baronti S, Carlà R (2012) Influence of spatial resolution on pan-sharpening results. In: Geoscience and Remote Sensing Symposium (IGARSS), 2012 IEEE International. IEEE, Munich, Germany, pp 5446–5449
Saura S (2002) Effects of minimum mapping unit on land cover data spatial configuration and composition. Int J Rem Sens 23(22):4853–4880, doi:10.1080/01431160110114493
Scarpa R, Hutchinson WG, Chilton SM, Buongiorno J (2000) Importance of forest attributes in the willingness to pay for recreation: a contingent valuation study of Irish forests. Forest Pol Econ 1(3–4):315–329, doi:http://dx.doi.org/10.1016/S1389-9341(00)00026-5
Shahbaz B, Ali T, Suleri A (2007) A critical analysis of forest policies of Pakistan: implications for sustainable livelihoods. Mitig Adapt Strat Gl 12(4):441–453, doi:10.1007/s11027-006-9050-9
Stathakis D, Vasilakos A (2006) Satellite image classification using granular neural networks. Int J Rem Sens 27(18):3991–4003, doi: 10.1080/01431160600567779
Stehman SV, Czaplewski RL (1998) Design and analysis for thematic map accuracy assessment: fundamental principles. Remote Sens Environ 64:331–344
Thessler S, Sesnie S, Ramos Bendaña ZS, Ruokolainen K, Tomppo E, Finegan B (2008) Using k-nn and discriminant analyses to classify rain forest types in a Landsat TM image over northern Costa Rica. Remote Sens Environ 112(5):2485–2494, doi:10.1016/j.rse.2007.11.015
Townshend JR, Masek JG, Huang C, Vermote EF, Gao F, Channan S, Sexton JO, Feng M, Narasimhan R, Kim D, Song K, Song D, Song XP, Noojipady P, Tan B, Hansen MC, Li M, Wolfe RE (2012) Global characterization and monitoring of forest cover using Landsat data: opportunities and challenges. Int J Digital Earth 5(5):373–397, doi:10.1080/17538947.2012.713190
Vogelmann JE, Xian G, Homer C, Tolk B (2012) Monitoring gradual ecosystem change using Landsat time series analyses: case studies in selected forest and rangeland ecosystems. Remote Sens Environ 122:92–105, doi:10.1016/j.rse.2011.06.027
Wani BA (2002) National Forest Policy Review. Ministry of Environment, Local Government and Rural Development, Islamabad, Pakistan