Spatial assessment of forest cover and land-use changes in the Hindu-Kush mountain ranges of northern Pakistan

Sami ULLAH[1,5] http://orcid.org/0000-0002-6997-137X; e-mail: sami.ullah@felis.uni-freiburg.de

Muhammad FAROOQ[2] http://orcid.org/0000-0002-9243-744X; e-mail: alfarooq74@yahoo.com

Muhammad SHAFIQUE[3] http://orcid.org/0000-0002-4063-6666; e-mail: shafique08@yahoo.com

Muhammad Afra SIYAB[4] http://orcid.org/0000-0001-7775-4538; e-mail: mafrasiyab@gmail.com

Fazli KAREEM[2] http://orcid.org/0000-0003-2318-8758; e-mail: fazalgis@gmail.com

Matthias DEES[1] http://orcid.org/0000-0002-7220-6222; e-mail: matthias.dees@felis.uni-freiburg.de

1 Chair of Remote Sensing and Landscape Information System, Institute of Forest Sciences, Faculty of Environment and Natural Resources, University of Freiburg, Tennenbacherstraße 4, 79106 Freiburg, Germany

2 Pakistan Space and Upper Atmospheric Research Commission (SUPARCO), Hayatabad, Phase 5, 25124 Peshawar, Pakistan

3 National Centre of Excellence in Geology, University of Peshawar, Khyber Pakhtunkhwa, 25120 Peshawar, Pakistan

4 Office of the World Wildlife Fund (WWF), sector G - 5/2, 4400, Islamabad, Pakistan

5 Department of Forestry, Shaheed Benazir Bhutto University, Sheringal, Dir Upper Khyber Pakhtunkhwa 23004, Pakistan

Citation: Ullah S, Farooq M, Shafique M, et al. (2016) Spatial assessment of forest cover and land-use changes in the Hindu-Kush mountain ranges of northern Pakistan. Journal of Mountain Science 13(7). DOI: 10.1007/s11629-015-3456-3

Abstract: Anthropogenic activities and natural processes are continuously altering the mountainous environment through deforestation, forest degradation and other land-use changes. It is highly important to assess, monitor and forecast forest cover and other land-use changes for the protection and conservation of mountainous environment. The present study deals with the assessment of forest cover and other land-use changes in the mountain ranges of Dir Kohistan in northern Pakistan, using high resolution multi-temporal SPOT-5 satellite images. The SPOT-5 satellite images of years 2004, 2007, 2010 and 2013 were acquired and classified into land-cover units. In addition, forest cover and land-use change detection map was developed using the classified maps of 2004 and 2013. The classified maps were verified through random field samples and Google Earth imagery (Quick birds and SPOT-5). The results showed that during the period 2004 to 2013 the area of forest land decreased by 6.4%, however, area of range land and agriculture land have increased by 22.1% and 2.9%, respectively. Similarly, barren land increased by 1.1%, whereas, area of snow cover/glacier is significantly decreased by 21.3%. The findings from the study will be useful for forestry and landscape planning and can be utilized by the local, provincial and national forest departments; and REDD+ policy makers in Pakistan.

Keywords: Forest cover changes; Land use changes; Remote sensing; Hindu-Kush Mountain regions; SPOT satellite images

Received: 21 January 2015
Revised: 29 April 2015
Accepted: 7 August 2015

Introduction

Accurate and updated information about changes in forest cover and land-use is of significant importance for protection, conservation and sustainable utilization of mountainous environment. Anthropogenic activities are continuously altering the natural rate of exchange of carbon between the atmosphere and the terrestrial biosphere reserved through land-cover changes (Watson et al. 2000). Approximately 8000 years ago, half of the earth's land area (50%) was covered by forest, as compared to currently of 30% (Lambin et al. 2003). Agriculture land has replaced the forests, savanna and steppes in many parts of the world to meet the food demand of the growing human population (Lambin et al. 2003). Continuous and updated information about forest cover and land-use change of an area is of significant important to develop a strategy for the management and sustainable utilization of natural resources. Hence, it is highly important to understand, evaluate and monitor the dynamics of forest cover and land-cover resulting from anthropogenic activities and natural processes including afforestation, reforestation and deforestation (ARD) and other land-use changes.

The Hindu-Kush mountainous ranges in northern Pakistan, has immense potential of natural resources in the form of subtropical Oak forest, subtropical Chir pine forest, dry and moist temperate Coniferous forest, tall snowcapped mountains, pleasant climatic condition, long fluting rivers. Many studies reported that natural resources in northern Pakistan, specifically forest reserves are continuously decreasing due to ever increasing human population, deforestation for cultivation, fuel wood and timber; over grazing, non-scientific collection of medicinal plants, miss management and limitation of accurate and updated knowledge for forest stake holders (Ahmad and Nizami 2015; FAO 2009; Jan et al. 2011; Qamer et al. 2012; Qasim et al. 2011; Shehzad et al. 2014; and Siddiqui et al. 1999). In addition, there is a controversy about the current status of forest cover in the country; according to the Pakistan Forest Institute in Peshawar, the total area under forest in the country is 5.02%, others estimate it is as low as 3.4% and according to the Food and Agricultural Organization (FAO) it is only 2.2% (Khan 2014). Moreover, during the conflict period (2008 to 2009) in Khyber Pakhtunkhwa which was linked to the security situation, several stories and news came into existence about extensive rate of deforestation in northern parts of Pakistan. According to the reports, the timber mafia moved towards the thick forest due to withdrawal of forest guard and the peoples and most of the forest land were clear-felled and were converted into barren land (Bacha 2008). In July and August 2010, Pakistan was hit by an extreme rainfall event, leading to a devastating flood (UNDP 2012). Due to the 2010 flood millions of population have been affected, fertile agriculture land were inundated, livestock were killed and many building were demolished in the study area. One of the causes of flood was the active deforestation in the study area. Therefore, it is highly crucial to assess and quantify forest cover and other land-use changes for clarification, planning and management.

Pakistan has also ratified the Kyoto Protocol and the United Nation Frame Work Convention on Climatic Change (UNFCCC) in the year 2005 (Nizami 2012) and joined UN-REDD in 2011 (UN-REDD 2011). It is estimated that Pakistan will earn $400 million to $4 billion each year for carbon stored in the country's forests (Tribune Express 2013), with condition to develop, a well-established monitoring system for reporting and verification of net release of carbon, due to forest cover and land use changes.

Geographical Information System (GIS) and Satellite Remote Sensing (RS) are frequently and efficiently used to evaluate changes in forest cover and other land-cover units over a given time period at a local and regional scale (Anderson 1976; Atesoglu and Tunay 2010; Coppin and Bauer 2009; Dewan and Yamaguchi 2009; Shalaby and Tateishi 2007). RS provides multi-spectral and multi-temporal data that can be used to evaluate the type, amount and spatial location of land use change while GIS provides a flexible environment for displaying, storing and analyzing digital data necessary for change detection (Wu et al. 2006). Moreover, SPOT satellite images are regularly updated and acquired by Pakistan Space and Upper atmospheric Research Commission (SUPARCO). It is highly crucial to test the potential of GIS and RS and the available remote sensing datasets for continuous planning, monitoring of the natural resources of Pakistan.

The present study deals with the assessment and detection of changes in forest cover and other land-use units in the Sheringal and Pathrak ranges of Dir Kohistan during the period 2004, 2007, 2010 and 2013 using high resolution SPOT-5 satellite imagery with a spatial resolution of 2.5 m. The primary aim of this study is provide baseline information to the forest stakeholder in order to develop a strategy for conservation and sustainable utilization of the mountainous environment. In addition, this study will resolve the issue of uncertainty of statistics about ARD reported by different national and international organizations. Moreover, the study will be helpful to establish the monitoring system for forest cover and other land-use changes.

1 Study Area

The study area cover Sheringal and Pathrak ranges of Dir Kohistan forest division located in the Hindu-Kush mountain regions of northern Pakistan (Figure 1). The total area of the study area is 92,690 hectares (ha). The elevation of study area ranges from 1165 m to 4847 m above sea level. Forest was stratified into subtropical broadleaves Oak forest, temperate coniferous forest and alpine and subalpine regions on the basis of Digital Elevation Model (DEM). The elevation of Subtropical Oak forest ranges from 1165 m to 1833 m (Figure 1) and is composed of plant species i.e. *Quercus incana, Quercus ilex, Quercus simicarpifolia* and *Quercus dilatata*. Coniferous forest ranges from 1833 m elevation to 3833 m (Figure 1) and is composed of plant species i.e. *Cedrus deodara, Abies pindrow, Pinus willichiana, Picea smithiana* and *Pinus gererdiana*. Alpine and subalpine regions are located at elevation ranges from 3833 m to 4847 m (Saddozai 1995) and are mostly range lands dominated by small shrubs and grasses. Major portion of agriculture field's lies in the main valley around the side of rivers as well as

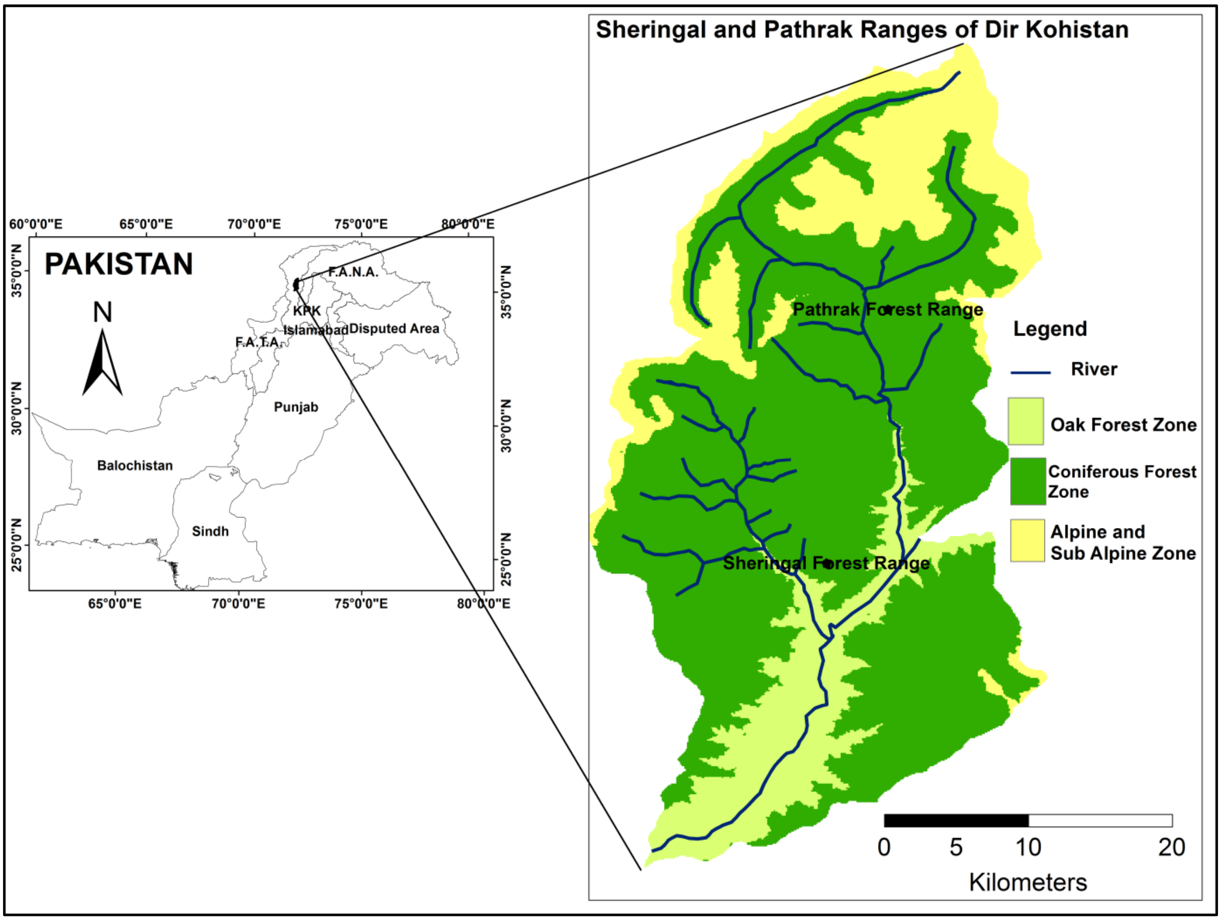

Figure 1 Location map of the study area representing Sheringal and Patrak ranges of Dir Kohistan Forest Division.

in the subtropical Oak forest zone. The study area has a network of five tributaries of Punjkora river in the Sheringal forest range. Glaciers/snow are present round the year on the mountain peaks that provide continuous supply of water to the rivers throughout of the year.

2 Methodology

2.1 Data collection

2.1.1 Remote sensing data

We have used SPOT-5 imagery, acquired in February 2004, October 2007, October 2010 and October 2013. The images were obtained from the Pakistan Space and Upper Atmospheric Research Commission (SUPARCO), the National Space Agency of Pakistan.

2.2.2 Collections of data for training signatures and for ground validation

A number of training signatures were created by taking polygons using GPS in the field representing homogenous area for each land-cover types, while training signatures in inaccessible high altitudinal sites were prepared from SPOT-5 and Digital Globe (Quick birds) based Google imagery. Similarly, for accuracy assessment a total of 297 random sample points were taken. Out of 297 sample points, 60% sample points were taken in the field using GPS representing each land-cover type, while the remaining 40% sample points for high altitudinal inaccessible test sites were taken from Astrium (SPOT-5) and Digital Globe (Quick birds) based Google imagery.

2.2 Image processing for the assessment of forest cover and land-use changes

The SPOT-5 satellite images were provided with 10 meter multispectral band and 2.5 meter panchromatic band and were pan-sharpened into 2.5 m resolution using the resolution merge tool in ERDAS IMAGINE 2014 software. Subsequently, all the scenes of the study area were mosaic together using histogram matching tool in color correction and average at the set overlap function using ERDAS IMAGINE 2014 software. Finally, the polygon of the study area extracted from the mosaic scene using extract by mask tool in ArcMap 10.2. Based on the training signatures the final extracted mosaic pan-sharpened scene of 2004, 2007, 2010, 2013 were classified into forest land, range land, snow cover/glacier, agriculture land, water bodies and barren land using supervised maximum likelihood classification algorithm. In addition, Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) DEM with 30 m spatial resolution was also used for the forest stratification as the forest types of the study area is based upon altitudinal elevation. Finally, the derived land-cover maps were verified and analyzed for forest cover and other land-use changes from 2004-2013.

2.3 Forest cover and land-use dynamics change detection map

Forest cover and land-use dynamic change detection map was developed from the classified images of 2004 and 2013, which give us information about when, where and how many changes in forest cover and other land-cover had been taken place during the period 2004 to 2013. The change detection map was determined using the reclassification and addition tool in ArcMap 10.2. For example the pixels of forest land at 2004 were reclassified as 1 and 10 at 2014. Similarly, the pixels of range land were reclassified as 2 at 2004 and 20 at 2013. After addition of reclassified maps of 2004 and 2013, the resulted pixels were classified either as 11 which mean no change or 12 which mean changing of forest land into range land. This change detection technique was very useful and was analyzed for the land-cover classes.

2.4 Accuracy assessment

For accuracy assessment the random points (297) as discussed above were cross checked with the classified maps. User accuracy and producer accuracy were calculated for each Land Use and Land Change (LULC) classes. Finally Kappa statistics was determined from the observed and expected using the following formula (Stehman 1996).

$$K = \text{observed} - \text{expected} / 1\text{-expected} \qquad (1)$$

3 Results

3.1 Spatial assessment of forest cover and other LULC changes (2004-2013)

The results show that during the period 2004 to 2013 the area of forest land decreased by 6.4%, however, area of range land and agriculture land increased by 22.1% and 2.9% respectively. Similarly, barren land increased by 1.1%, while area of snow cover/glacier is significantly decreased by 21.3%. Area under water bodies were decreased by 0.2% (Table 1).

The spatial distribution of final classified output maps of forest cover and other LULC of the years 2004, 2007, 2010 and 2013 were shown in Figure 2.

3.2. Spatial detection of forest cover and other land-use changes (2004-2013)

The results of forest cover and other land-use change detection map showed that 48.5% of area remained the same where no changes had taken place. The highest changed was noticed in the area of forest land which was converted to range land, however during the same time period some of the area of range land was converted back to forest land in 2013. One of the reasons of change of range land back to forest land is due to the image acquisition. The 2004 SPOT scene was acquired in February, where majority of broadleaves species were devoid of leaves during the winter season. It shows that broadleaves species were classified as a range land instead of forest land in 2004. The result also showed that 3.2% of snow cover land was converted into forest land in 2013. This was also because of the acquisition of 2004 SPOT scene in February, where major portion of forest land was hidden under the snow cover and hence was classified as a snow cover. But in October, 2013, there was no snow cover and hence the forest land which was under snow cover in 2004 was converted back to forest land. In spite of all the above changes forest land was decreased by 6.4% during ten years period from 2004 to 2013. The second highest changed was noticed in the area of snow cover which was converted into range land in 2013. This was also because of the image acquisition scene in February, 2004 where major portion of the range land areas located in alpine areas were hidden under the snow cover, which were converted back to range land in 2013. The conversions of snow cover area (2.4%) into barren land also indicate presence of snow cover in February, 2004 and absence of snow cover in October, 2013. The results of change detection map also showed increased in agriculture land due to conversion of range land, forest land and snow cover. The spatial distribution and details of other minor LULC changes were presented in the Figure 3 and Table 2.

4 Discussion

We have found that during the period 2004 to 2013 the area of forest land decreased by 6.4% with an annual declined rate of 0.6%. According to

Table 1 Forest cover and other Land Use and Land Chang (LULC) dynamics in hectare (ha) and percentage (%) from 2004 to 2013

LULC	2004		2007		2010		2013		LULC change (2004-2013)	
	ha	%	ha	%	ha	%	ha	%	ha	%
Forest land	35080	36.7	32559	34.1	28907	30.3	28946	30.3	-6134	-6.4
Range land	31645	33.1	46773	48.9	52317	54.8	52747	55.2	21102	22.1
Agriculture land	1302	1.4	3190	3.3	4086	4.3	4072	4.3	2770	2.9
Barren land	2652	2.8	6777	7.1	2718	2.8	3758	3.9	1106	1.1
Glacier/snow cover	21408	22.4	579	0.6	3014	3.2	1014	1.1	-20394	-21.3
Water bodies	3458	3.6	2812	2.9	1635	1.7	3286	3.4	-172	-0.2
Others	9	0.0	2864	3.0	2876	3.0	1731	1.8	1722	1.8
Total	95554	100	95554	100	95554	100	95554	100		
Over all accuracy	62.22%		75%		78%		78%			
Kappa coefficient	58%		65%		69%		69%			

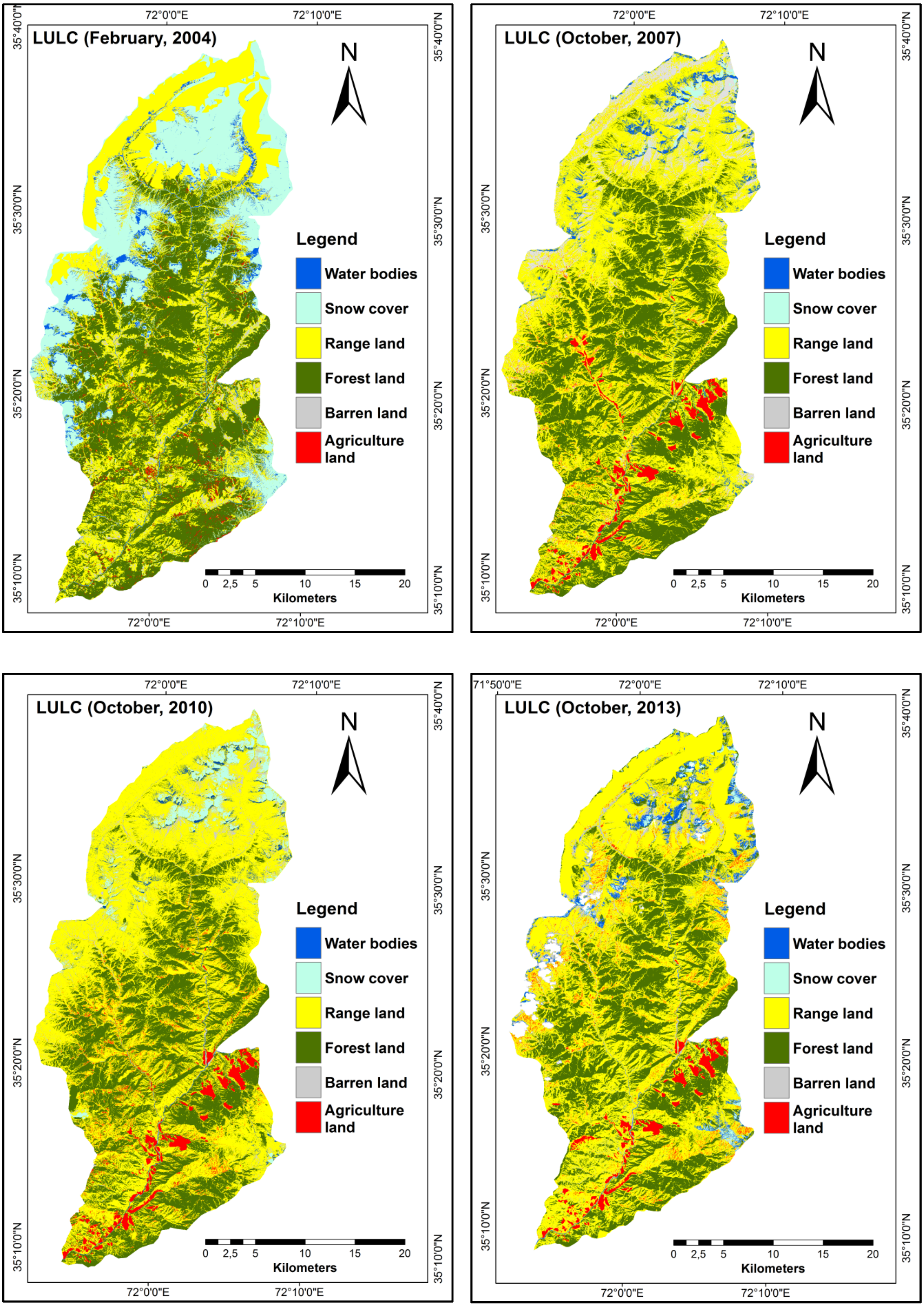

Figure 2 Spatial distributions of LULC of Sheringal and Pathrak ranges of Dir Kohistan at 2004, 2007, 2010 and 2013.

Table 2 Spatial Detection of forest cover and other land-use changes in hectare and percentage (%) in the Sheringal and Pathrak ranges of Dir Kohistan (2004-2013)

Land Use and Land Change	Area (ha)	%	Land Use and Land Chang	Area (ha)	%
No change	46303.4	48.5	Forest land to barren land	262.8	0.3
Range land to Forest land	4046.7	4.2	Range land to barren land	686.0	0.7
Agriculture to Forest land	435.8	0.5	Agriculture land to barren land	14.2	0.0
Barren land to Forest	286.3	0.3	Snow cover to barren land	2293.6	2.4
Snow cover to Forest land	3059.0	3.2	Water bodies to barren land	376.6	0.4
Water bodies to Forest land	631.4	0.7	Forest land to snow cover	4.2	0.0
Forest land to Range land	13327.5	14.0	Range land to snow cover	34.3	0.0
Agriculture land to Range land	720.6	0.8	Agriculture land to snow cover	0.2	0.0
Barren land to Range land	1714.7	1.8	Barren land to snow cover	8.7	0.0
Snow cover to Range land	10696.4	11.2	Water bodies to snow cover	43.8	0.0
Water bodies to Range land	1881.2	2.0	Forest land to water bodies	174.5	0.2
Forest land to Agriculture land	760.1	0.8	Range land to water bodies	310.0	0.3
Range land to Agriculture land	1986.5	2.1	Agriculture land to water bodies	5.6	0.0
Barren land to Agriculture land	421.8	0.4	Barren land to water bodies	39.7	0.0
Snow cover to Agriculture land	655.1	0.7	Snow cover to water bodies	2500.5	2.6
Water bodies to Agriculture land	123.7	0.1	Undefined change due to clouds coverage at 2004	1731.9	1.8
Total	95536.7	100			

change detection map, major decreased in forest land was due to conversion of 14% of forest land to range land, 0.8% to agriculture land, 0.3% to barren land and 0.2% to water bodies. However, during the same period 4.2% of range land, 0.5% of agriculture land, 0.3% of barren land, 0.7% of water bodies and 3.2% of snow cover were converted back to forest land. This indicated that major decreased in forest land is due to conversion of forest land to range land followed by agriculture and barren land. Our results highlights that forest area continuously decreasing due to ever increasing human population and thus the demands for fuel wood, timber, fodder and agriculture land increases which results in over exploitation and conversion of forest resources to range land. In contrast, Food and Agriculture Organization (FAO 2007) reported deforestation rate in Pakistan with annual declined rate of 0.75% per year (FAO 2009) which is slightly higher than our results. National Conservation Strategy (NCS) reported deforestation declined rate of 0.2% of forest cover in the 1980s (FAO 2009). Some other studies also reported declined rate in forest cover in the Himalayan Hindu Kush mountain region of Pakistan. For example, Qasim et al. (2011) reported 30.5% reduction with annual declined rate of 0.78% in forest cover in Kalam region, 49.7% with annual

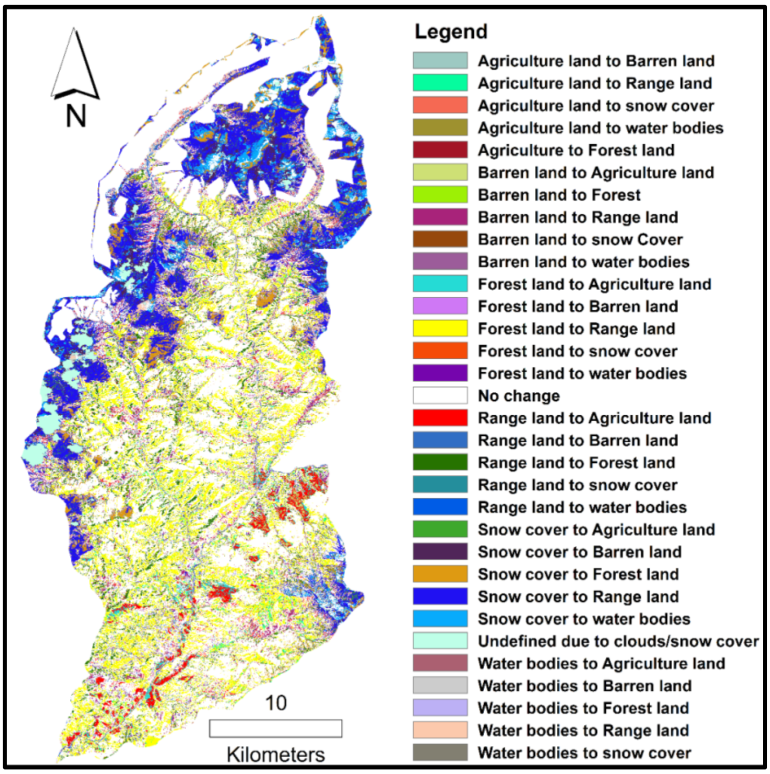

Figure 3 Spatial detection of Forest cover and other land-use changes of Sheringal range of Dir Kohistan (2004-2013).

declined rate of 1.27% in Malam Jaba and 70.9% with annul declined rate of 1.81% in the Barikot regions between 1968 to 2007 in district Swat. Ahmad and Nizami (2015) reported -11.56% reductions in forest cover with annual declined rate of 0.96% from 1999 to 2011 in the Kumrat valley, Hindu Kush mountain regions of Pakistan. Shehzad et al. (2014) reported 0.14% per annum deforestation rate during the 1992-2000 and 0.54% per annum during the period 2000-2009 in dry temperate forest of Chitral valley, northern Pakistan.

Agriculture land was increased from 1.4% to 4.3% with annual increased rate of 0.29%. According to change detection map agriculture land were increased due to conversation of 0.8% of forest land, 2.1% of range land, 0.4% of barren land and 0.7% of snow cover to agriculture land. However, during the same time period 0.5% and 0.8% were converted back to forest land and range lands. Ahmad and Nizami (2015) reported 100% increase in agriculture land with annual increased rate of 8.33% during the period 1999 to 2011 in the Kumrat valley of Dir Kohistan, Pakistan. Qasim et al. (2011) reported 11.4% deforestation caused by agriculture expansion with annual increased rate of 0.29% of agriculture land in Kalam region, 77.6% reduction in forest cover with an annual increased rate of 1.98% of agricultural land expansion in Malam Jaba and 129.9% reduction in forest cover with an annual increased rate of 3.3% of agricultural expansion during a case study of District Swat.

From the year 2004 to 2013 area of range land significantly increased by 22.1%, however, area under snow cover/glacier is significantly decreased by 21.3%. There was almost an equal amount of increased in range land and decreased in snow cover/glacier was observed from 2004 to 2013. The significantly higher rate of glacier/snow cover in the 2004 is due to the image acquisition during the winter season (February, 2004) where abundant amount of snow cover was present in the alpine areas resulting major amount of range lands located in the alpine regions were hidden under the snow cover. From 2007 onward to 2013 there is steady increased in the area of range land. Similarly, Qasim et al. (2011) reported 158.7% increase in range land in Kalam region, 38.18% in Malam Jaba due to conversion of forest land and 22.2% (1968-1990) and 13.22% (1990-2007) increased in range land due to conversion of agriculture land to range land. Ahmad and Nizami (2015) reported 7.64% decreased in total area under rangeland/barren land during the period 1999 to 2011 in a case study of Kumrat valley, Hindu Kush regions of Pakistan.

5 Conclusion and Outlook

The tools of GIS and RS are effectively and efficiently used to map and evaluate forest cover and other land-use change from 2004-2013. The key findings of the study is that forest land is continuously decreasing and range lands as well as agriculture land were increasing that can be attributed to the anthropogenic activities and natural processes. The ongoing deforestations have devastating impacts on the local and regional environment. Therefore, there is an urgent need to continuously monitor the ongoing forest cover and other land-use changes and accordingly develop and implement strategies to minimize the deforestation and assist in sustainable utilization of natural resources.

The study shares valuable information for establishment of well design monitoring system based on GIS and RS technology and for reporting and verification of net release of carbon due to changes in forest cover and other land-use under Kyoto Protocol, UN-REDD+ etc. Since UN-REDD is an initiating phase in Pakistan and this study will be helpful in order to make a baseline information for reporting changes in forest cover and other land use changes. It will also be helpful in resolving the issue of uncertainty about ARD reported by different national and international organization in the study area.

Acknowledgements

I am thankful to Pakistan Space and Upper Atmospheric Research Commission (SUPARCO), for the provision of SPOT satellite images. Moreover, I am highly thankful to national center of excellence in Geology (NCEG), University of Peshawar and Department of Forestry, Shaheed Benazir Bhutto University, Sheringal, Dir Upper for supporting financially this research project.

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