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SHORT COMMUNICATION

Spatiotemporal Analysis of Land Use / Land Cover in Swat, Pakistan Using Supervised Classification in Remote Sensing: 2000 to 2015

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Introduction

Changes in land use and land cover affect the social, economic and natural aspects of any area. Mostly land use and land cover (LULC) changes are the result of population growth and human activities in the form of urban agglomerations and industrialization etc. Physical factors like soil structure and type, slope condition, topography are main aspects. Land use change defines the historical pattern that how people used that specific land which depends on the availability of resources and economic conditions. LULC changes may trigger the detrimental effects like increase in natural hazard events and changes in climatic patterns. Climatic pattern directly affects the precipitation, groundwater recharge, the amount of evapotranspiration and runoff generation. On regional and local scale, LULC change is a far-reaching issue because environment and climate condition depend on it.

Globally, LULC is the major indicator of the environment's changes such as deforestation lead to environmental variations. Owing to this, there have been drastic changes in climatic patterns during last three decades. Remote sensing data and satellite images are useful for LULC change detection with respect to time and cost (Sarma et al., 2001). Land use mentions human activities and different use of land e.g. built up area, agricultural land and wildlife management area etc. Land cover includes natural cover e.g. natural vegetation, rock, water bodies (river, lake), soil, snow, forest and others.

With population growth and human activities, great pressure is being placed on arable land, water, energy, and biological resources to provide an adequate supply of food, while maintaining the integrity of our ecosystem. Land use changes are taking place due to rapid urbanization, changes in river regimes, effects of shifting cultivation, spread of erosion and desertification. Land use change is directly related to hydrological cycle (Sreenivasulu and Bhaskar, 2010) and, any change in land use and shifting cultivation is the major cause for large scale changes in associated ecosystem (Chakraborty, 2009).

LULC change detection type analysis provides valuable information that efficiently demonstrates changing pattern with respect to time, space and impacts on environment. In last few years, remote sensing technique has been used for LULC mapping. Satellite remote sensing (SRS) acquires information about the Earth's surface, subsurface and atmosphere remotely from sensors on satellites is an important component of observation of LULC (Yang, et al., 2013). The use of satellites allows the observation of states and processes of the atmosphere, land and ocean at several spatio-temporal scales. It is one of the most efficient approaches for monitoring land cover (Homer et al., 2007) and its changes through time over a variety of spatial scales (Bontemps, et al., 2011).

This study was conducted to understand the LULC changes in Swat district resulted by human activities during 2000 to 2015. This area is known as the forest land, but with the passage of time, the forest cover has been reduced and built up area is increased. These aggressive human activities have influenced this district and changed the land use and land cover pattern which has direct impact on environment.

Study Area

Swat valley is located in Khyber Pakhtunkhwa (KP) province of Pakistan (Fig. 1). Geographically, the centre of the watershed of the Swat river is located at 35° north latitude and 72.30° of east longitude covering an administrative area of 5392 Sq. Km (FAO, 2016).

Swat is bounded by Chitral, upper Dir and lower Dir from the western side, Gilgit-Baltistan from the northern side and Kohistan, Buner and Shangla from

eastern and south eastern sides (Fig 1). Most of the Gilgit Baltistan region and some northern parts of KP province including Swat, receive significant amount of solid precipitation in the form of snow. With the rise in temperature, the melt water from the seasonal snow, provides significant contribution to the river flow and formation of many small and large lakes which are abundant in the mountainous regions (Ghauri et al., 2018; Qaisar et al., 2019). Administratively, Swat is a district in KP which ascends to Hindu Kush. The major cities of Swat are Saidu Sharif and Mingora (Ahmad et al., 2015).

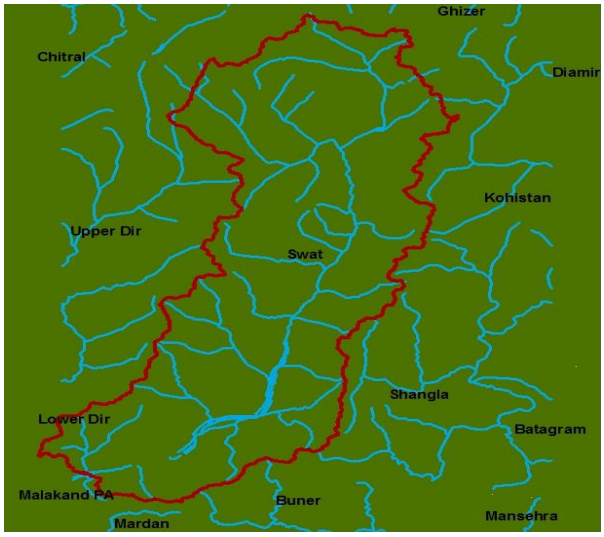

Fig. 1 Swat watershed with associated streams (Inset: location of the study area).

Materials and Methods

In this study, the forest and other land cover areas have been extracted from the Landsat imageries (Table 1).

Table 1 Landsat datasets.

Landsat	Date	Path	Row
Landsat 4-5 TM	27 Oct, 2000	151	35
Landsat 4-5 TM	11 Oct, 2000	151	36
Landsat 4-5 TM	22 Oct, 2004	151	35
Landsat 4-5 TM	22 Oct, 2004	151	36
Landsat 7 ETM	07 Oct, 2010	151	35
Landsat 7 ETM	07 Oct, 2010	151	36
Landsat 8 OLI/TIRS	13 Oct, 2015	151	35
Landsat 8 OLI/TIRS	29 Oct, 2015	151	36

The methodology includes the geo-referencing and sub-setting of imagery. Sub-setting is made to trim AOI from entire tile of the imagery. Classification and rectification of each subset is the most familiar method to evaluate forest changes (Rawat and Kumar, 2015).

There are several types of classifications such as supervised, unsupervised (partially supervised), object-based classification, machine learning classification, fuzzy classification, regression tree analysis and fuzzy-spectral mixture analysis. Supervised-classification technique was adopted for the extraction of classes. The training areas enabling supervised classification were provided to the software. Satellite images were classified as per the requirement. A quality control test was performed to check the random classes manually for the correct assignment of the classes.

The image classifier acts as a discriminator which discriminates a particular class in favor of others. Mathematically, where $m(c_k , x)$ is discriminator function, relating feature vector x and class c_k. Where

$$k=1,\ldots,L$$

Here $m(c_k ,x)$ as $m_k (x)$ is the symbol for simplicity

During the classification procedure of multiclass scenario, the discriminators va1ue is high for a particular class, whereas varies in other classes.

$$m_k(x)>m_l(x),$$

where

$$l = 1,\ldots,L,$$

and

$$l \neq k \text{ and } x \in c_k$$

Considering a two-class scenario, the discriminator's va1ue is positive for first class, and is negative for the second class respectively.

$$m(x)> 0 \; x\in c_1$$

where

$$m(x)< 0 \; x\in c_2$$

Several recent scientific articles (Lu et al., 2004; Younes et al., 2019) among others, have highlighted the importance of landuse change detection for better analyzing the mutual associations of anthropogenic processes and expected response of the nature for efficient decision making.

Results and Discussion

The classification results from the Landsat multi-temporal imagery suggest that the forest cover has reduced from 1473 sq km to 1086 sq km in 15 years duration due to increase in settlements. However, the classification results for snow, show higher area under snow initially and then a sharp decrease in 2015. This can be associated with the seasonal variations. Figure 6 indicates the similar levels of snow cover over the 10 years period from 2000 to 2010. The water bodies increased to a great extent i.e. 11 to 25%. The classification results for Swat (Fig 2-5) and after the classification of all images into 5x land cover classes, the quantifications over the last 15 years from 2000 to 2015 have been extracted (Table 2, Fig. 6).

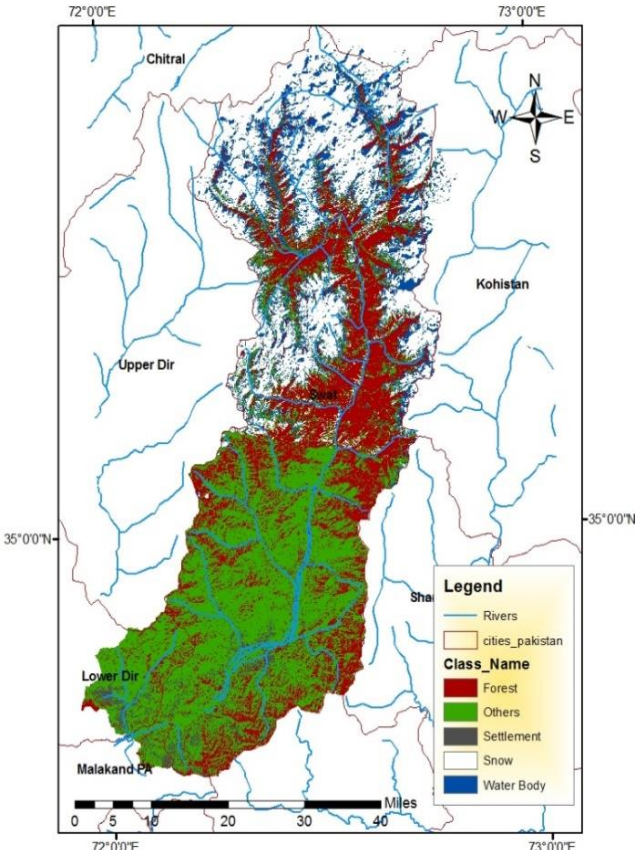

Fig. 2 Land cover map of Swat (2000).

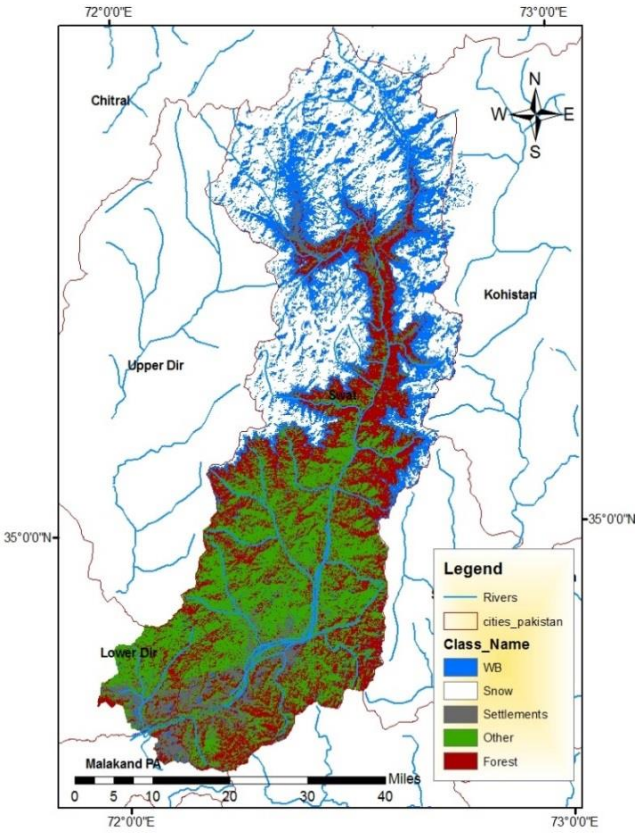

Fig. 3Land cover map of Swat (2005).

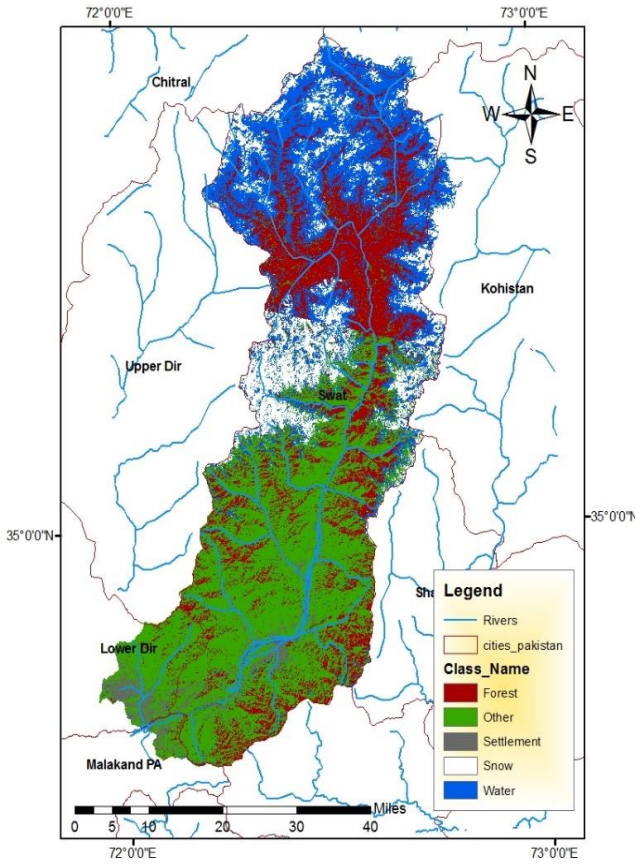

Fig. 4 Land cover map of Swat (2010).

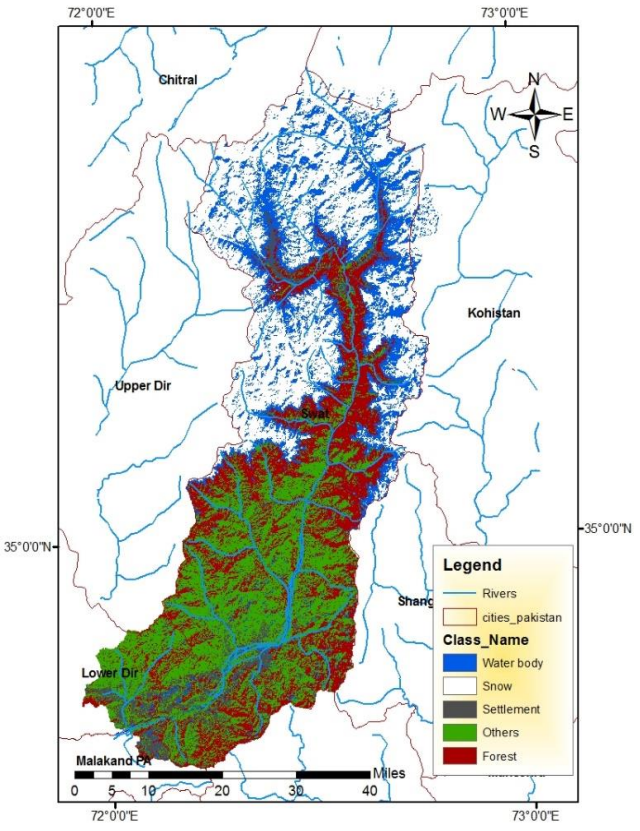

Fig. 5 Land cover map of Swat (2015).

Table 2 Trend of land use based on different parameters from year 2000 to 2015.

Landuse / Year	2000	2005	2010	2015
Forest	1473.07	1235.40	1167.93	1086.05
Snow	1375.45	1638.90	1554.58	620.22
Water Body	623.10	1067.90	1155.66	1441.31
Settlements	163.50	271.72	370.41	2192.59
Others	2117.60	1532.24	1497.58	406.41
Sum	5752.72	5746.16	5746.16	5746.58

In order to assess the accuracy of the results of Landsat based classification, the results have been compared with the Swat section of Land Cover Atlas of Pakistan (Fig. 6). This atlas has been compiled by the FAO and SUPARCO (available from FAO) and used very high-resolution SPOT imagery at 5m spatial resolution from year 2010 early monsoon season. The detailed international classification scheme of FAO known as Land Cover Classification System (LCCS) has been used for the extraction of land cover types.

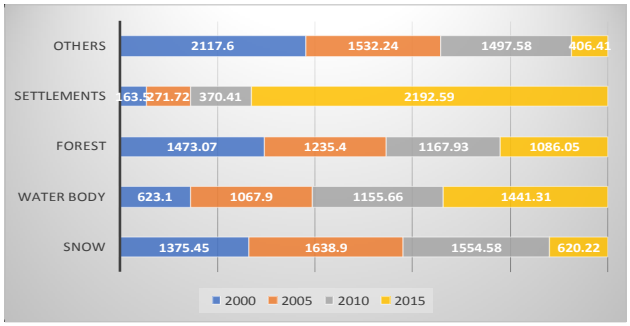

Fig. 6 Landuse in Swat watershed (2000-2015).

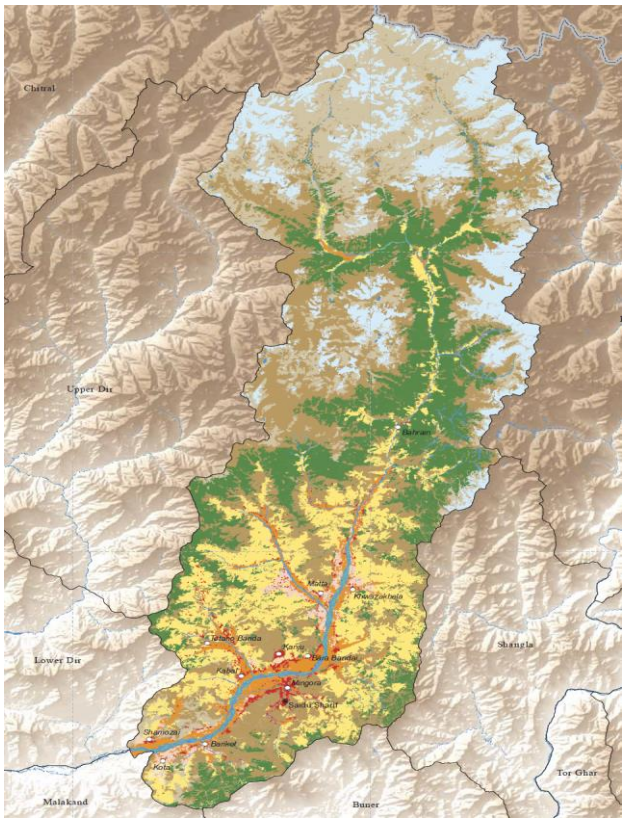

Fig. 7 Land cover map of Swat (FAO, 2016).

The map consists of 13 land cover classes (Fig. 7, Table 3).

Table 3. Distribution of land cover in Swat (FAO, 2016).

Legend	km²	%
Orchards	49.64	0.9
Crop Irrigated	5.99	0.1
Crop Marginal and Irrigated Saline	0.00	0.0
Crop in Flood Plain	170.78	3.2
Crop Rainfed	758.34	14.1
Forest - Natural Trees and Mangroves	1,171.22	21.7
Natural Vegetation in Wet Areas	62.26	1.2
Range Lands - Natural Shrubs and Herbs	1,429.09	26.5
Built-up	77.31	1.4
Bare Areas	0.00	0.0
Bare Areas with Sparse Natural Vegetation	1,015.03	18.8
Wet Areas	38.45	0.7
Snow and Glaciers	613.84	11.4
Grand Total	**5,391.95**	

Conclusion

Swat is a beautiful valley with splendid landscapes thus receiving many tourists. Notable land use types in the Swat region are forests, snowy areas and water bodies. In the last 20 years, the forest cover and rangelands have decreased significantly. This may be associated with the massive wood cutting activities in the region. Like other cities, the Swat district has also seen an abrupt increase in the settlements associated with the increase of population in the region. The trend indicates a greater risk of further decline of forest / crop / vegetation area in the future.

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