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## Assessment of deforestation in sub-tropical forest using spatio-temporal landsat data

## Evaluación de la deforestación en bosques subtropicales utilizando datos de terrenos espacio-temporales

## Avaliação do desmatamento em florestas subtropicais utilizando dados espaço-temporais do terreno

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### ABSTRACT

The present research evaluated spatio-temporal change in the sub-tropical forest of district Malakand through Remote Sensing and GIS techniques. The main objective was to identify different land cover classes and to determine temporal changes in forest cover



in the study area. This study was based on the two different classification techniques for the land cover classification. In this study, four Landsat images were acquired with the interval of 10 years from 1988 to 2018. The maximum likelihood classification and Minimum distance classification was applied on all the four images step by step. The total area of district Malakand was recorded as 975.32 km<sup>2</sup>. Regarding percent wise area coverage Forest covered 22.1 % of the total area while other classes' settlements, agriculture, barren land and water have covered 17.7, 23.3, 33 and 3.9% respectively in 1988. Whereas in 2018, percent wise area coverage forest covered 9.3 % of the total area although other classes settlements, agriculture, barren land and water have covered 33.8, 22.3, 31.8 and 3.7 respectively. The change in forest area over the time was 60.4 km<sup>2</sup> which is equal to 6.2 % during 1998 to 2008 and ultimately overall deforestation was 124.4 km<sup>2</sup> which is equal to 12.7 % loss of forest area lost from 1998 to 2018. Thus, the forest area was changed to settlements and barren lands from 1988 to 2018. Normalized Difference Vegetation Index (NDVI) was calculated for 1988, 1998, 2008 and 2018. Based on NDVI analysis, total deforestation over the time was 166.29 km<sup>2</sup> in last 30 years (1988-2018) with percent deforestation of 43.66 % area lost. The Landsat images have 30 meters resolution and small forest area changes can not detected by Landsat images, thus high-resolution products can detect more deforestation comparatively.

**Keywords:** Deforestation; Spatio-temporal analysis; Landsat, Supervised Classification; NDVI.

## RESUMEN

La presente investigación evaluó el cambio espacio-temporal en el bosque subtropical del distrito de Malakand mediante técnicas de teledetección y SIG. El objetivo principal era identificar las diferentes clases de cobertura del suelo y determinar los cambios temporales de la cobertura forestal en el área de estudio. Este estudio se basó en dos técnicas de clasificación diferentes para la clasificación de la cubierta del suelo. En este estudio, se adquirieron cuatro imágenes Landsat con un intervalo de 10 años desde 1988 hasta 2018. La clasificación de máxima verosimilitud y la clasificación de mínima distancia se aplicaron a las cuatro imágenes paso a paso. La superficie total del distrito de Malakand se registró como 975,32 km<sup>2</sup>. En lo que respecta a la cobertura porcentual de la superficie, el bosque cubrió el 22,1 % de la superficie total, mientras que los asentamientos, la agricultura, las tierras baldías y el agua cubrieron el 17,7, el 23,3, el 33 y el 3,9 % respectivamente en 1988. Durante el año 2018, el bosque cubrió el 9,3 % de la superficie total, así también los asentamientos de otras clases, la agricultura, la tierra estéril y el agua han cubierto el 33,8, 22,3, 31,8 y 3,7 respectivamente. El cambio en la superficie forestal a lo largo del tiempo fue de 60,4 km<sup>2</sup>, lo que equivale a un 6,2 % durante el período 1998-2008 y, en última instancia, la deforestación global fue de 124,4 km<sup>2</sup>, lo que equivale a una pérdida del 12,7 % de la superficie forestal perdida entre 1998 y 2018. Por lo tanto, la superficie forestal se transformó en asentamientos y tierras baldías de 1988 a 2018. Se calculó el índice de vegetación de diferencia normalizada (NDVI) para 1988, 1998, 2008 y 2018. Según el análisis del NDVI, la deforestación total a lo largo del tiempo fue de 166,29 km<sup>2</sup> en los últimos 30 años (1988-2018), con un porcentaje de deforestación del 43,66 % de superficie perdida. Las imágenes Landsat tienen una resolución de 30 metros y los cambios en las áreas forestales pequeñas no pueden ser detectados por las imágenes Landsat, a diferencia



de los productos de alta resolución que pueden detectar más deforestación en comparación.

**Palabras clave:** Deforestación; Análisis espacio-temporal; Landsat, Clasificación supervisada; NDVI.

## RESUMO

A presente pesquisa avaliou a mudança espaço-temporal na floresta subtropical do distrito de Malakand através de técnicas de Sensoriamento Remoto e GIS. O principal objetivo era identificar diferentes classes de cobertura terrestre e determinar as mudanças temporais na cobertura florestal na área de estudo. Este estudo foi baseado nas duas diferentes técnicas de classificação da cobertura do solo. Neste estudo, quatro imagens Landsat foram adquiridas com o intervalo de 10 anos, de 1988 a 2018. A classificação de máxima probabilidade e a classificação de distância mínima foram aplicadas passo a passo em todas as quatro imagens. A área total do distrito de Malakand foi registrada como 975,32 km<sup>2</sup>. Em relação à porcentagem de cobertura de área sábia, a floresta cobriu 22,1 % da área total, enquanto os assentamentos de outras classes, agricultura, terra árida e água cobriram 17,7, 23,3, 33 e 3,9% respectivamente em 1988. Enquanto que em 2018, a porcentagem de cobertura de área razoável abrangia 9,3 % da área total, embora os assentamentos de outras classes, a agricultura, a terra árida e a água tenham coberto 33,8, 22,3, 31,8 e 3,7, respectivamente. A mudança na área florestal ao longo do tempo foi de 60,4 km<sup>2</sup> que é igual a 6,2 % durante 1998 a 2008 e finalmente o desmatamento total foi de 124,4 km<sup>2</sup> que é igual a 12,7% de perda de área de floresta perdida de 1998 a 2018. Assim, a área florestal foi mudada para assentamentos e terras áridas de 1988 a 2018. O Índice de Vegetação com Diferença Normalizada (NDVI) foi calculado para 1988, 1998, 2008 e 2018. Com base na análise do NDVI, o desmatamento total ao longo do tempo foi de 166,29 km<sup>2</sup> nos últimos 30 anos (1988-2018) com percentual de desmatamento de 43,66 % de área perdida. As imagens Landsat têm resolução de 30 metros e pequenas mudanças de área florestal não podem ser detectadas pelas imagens Landsat, assim, produtos de alta resolução podem detectar mais desmatamento comparativamente.

**Palavras-chave:** Desmatamento; Análise espaço-temporal; Landsat; Classificação supervisionada; NDVI.

## INTRODUCTION

Deforestation is the complete clearance of forest vegetation and their substitute by non-forest land cover (Philippe & Karume, 2019; Kemppinen *et al.*, 2020). Forest play important roles in soil nutrient absorption (Nitschke *et al.*, 2017) and worked as carbon sinks because trees absorbing CO<sub>2</sub> and decrease the pressure of global warming on the environment (Zhao *et al.*, 2019). After the industrial revolution, CO<sub>2</sub> concentration in the atmosphere is increasing in a very rapid pace (Ussiri & Lal, 2017). This increasing concentration of CO<sub>2</sub> significantly contributing to global warming and hence causing climate change, increasing frequency and magnitude of floods, droughts, heat wave and pollution etc., thus affects human life (Nda *et al.*, 2018). Forests are also contributing in provision of clean drinking water (Westling *et al.*, 2020), regular water flow and filtering pollutants, enhancing air and water quality (Davies *et al.*, 2017). Direct and indirect are two main drivers which may cause deforestation of different nature including ecological, social pressure, commercial and biophysical factors interacting in complex manner



ultimately results loss of vegetation. Direct drivers of deforestation may be natural as well as anthropogenic. Natural direct drivers may include damage caused by heavy floods, areas burnt by forest fires, infestation or attack by parasites or predators and hurricanes. On the other hand; anthropogenic direct drivers may include clearing of forest for agriculture, breeding of livestock, extraction of commercial timber, excessive logging, fuel wood collection, exploitation of forests for mining activities, infrastructure and construction of dams (Batar *et al.*, 2017; Behera *et al.*, 2019). Indirect drivers are a complex interaction of economic, governance, technological, and demographic activities (Kessy *et al.*, 2016; Tegegne *et al.*, 2016). Indirect causes of deforestation may also include lack of political actions (Carr, 2007), failure of policy and governance (insufficient tenure system, fraud and incorrect public administration), social pressure, military environmental terrorism and adverse impact of climate change (Chakravarty *et al.*, 2012; Sonter *et al.*, 2017).

Remote sensing has been extensively used to know community development, desertification (Kouba *et al.*, 2018) and deforestation (Meshesha *et al.*, 2016). Globally, remote sensing is widely used to monitor the forest cover spatiotemporally to understand forest degradation (Khan *et al.*, 2016) and its impacts on climate, human life and biological diversity (Van der Sande *et al.*, 2017; Yu *et al.*, 2020). Since the launch of Landsat program in 1972, has been widely used for investigating natural resources management such as forest cover mapping (Phiri & Morgenroth, 2017; Wulder *et al.*, 2016). Forest analyses, direction), and spatial pattern of land use change detection can be possible through GIS and remote sensing (Islam *et al.*, 2018; Shawul *et al.*, 2019).

Pakistan has diverse climatic conditions because of which there are different types of forest in the region (Khan *et al.*, 2018). Coniferous forests are is mainly situated in northern areas of Khyber Pukhtunkhwa (KP), northern Punjab, Balochistan and Kashmir (AJK) region. These forests are found at altitudes 1,000 to 4,000 meters above mean sea level (Ali *et al.*, 2018; Ali *et al.*, 2019). In KP, these forests are mainly present in district Dir, Malakand, Swat and Mansehra, while in Punjab it can be found in district Rawalpindi (Bukhari *et al.*, 2019; Ali *et al.*, 2020). Furthermore, these forests provide supply of fuel wood, wildlife, erosion control, flood protection and timber for construction (Qamer *et al.*, 2016; Zeb *et al.*, 2019). In district Malakand, conifer species (*Pinus roxburghii* and *Pinus wallichiana*) of Sub-tropical Chirpine and Ecotone have significant environmental, socioeconomic and biological role. It supports tourism industry, wildlife habitats and has high potential of timber production (Khan & Ullah, 2016). The forest area facing serious challenges like encroachment, lack of land use planning and awareness in the community, deforestation and conversion forest to Barren land (Ali *et al.*, 2017).

Forest cover areas in District Malakand have gone under rapid transformations. However, Billion Tree Afforestation Project (BTAP) is forest conservation programme of Khyber Pakhtunkhwa Provincial Government in Pakistan which has been started in 2014 and completed in 2019. Under BTAP, afforestation activities were conducted in different areas in district Malakand which restored and increased vegetation cover slightly. The present research evaluated spatio-temporal change in the sub-tropical forest of district Malakand through Remote Sensing and GIS techniques. The main objective was to identify different classes of land use, land cover and determine temporal forest cover change (spatial distribution) in the study area.



## MATERIALS AND METHODS

### Study Area

Malakand is bounded on the north by Lower Dir district, on the east by the district of Buner, on the south-east by Mardan district and south-west by Charsadda district and Mohmand Agency. It is also bounded by a range of mountains on the north-east separating it from district Swat and another range of mountains to the west separating it from Bajaur and Mohmand agencies. The soil of Malakand is generally loamy and moist, Stone gravelly, and rock lands and is irrigated by the Swat River, which flows from Swat and joins the river Kabul near Peshawar. The mean annual precipitation of the study area range from 600 to 650 mm which is not enough; therefore, the soil requires artificial irrigation (Khan *et al.*, 2017). The climate here is moderately cold in winters and pleasant in summers. Moreover, the highest temperature (43°C) has been recorded in the month of June and July whereas the lowest temperature (-3°C) may be recorded in winter (in December and January).

Supervised classification of the satellite images of district Malakand and field-based survey were carried out to analyses the forest cover change in study area District Malakand. Remote sensing method used was to analyze forest cover change dynamics in the study area. The maximum likelihood and maximum distance method of supervised classification were examined for all Landsat images (from 1998 to 2018). After the image classification clearly, compared the resulting maps on a pixel-by-pixel basis by means of a change detection matrix. The flowing steps were conducted for procedure of image processing; (1) Data preparation which included correction done in software namely Environment for Visualizing Images (ENVI 5.3) and Sentinel Application Platform (SNAP), (3) Supervised image classification using training data sets taken for forest department, (4) Analysis after classification for forest cover lost during 1998-2018 (5) Preparation of change detection maps. These applications were carried out using ENVI and ArcGIS 10.3 software. For change detection over a period of time temporal satellite imagery were used of same time period and same season. Landsat Satellite images of four times (1988, 1998, 2008 & 2018) were downloaded (<http://glovis.usgs.gov/>).

In order to reduce computation time, different bands of Landsat images were combined and stacking has been done in ENVI 5.3. In Landsat 5 there were seven bands these bands were stacked to make a composite satellite image. A study area was specified using area of interest (AOI) option in the subset interface and subsets were ready after the job status completion. Maximum likelihood technique was used to categorize the pixels. It is a classification system in which unidentified pixels are allocated to classes using outline of likelihood around training areas using the maximum-likelihood statistic. Furthermore, NDVI was determined that ranges from (-1) to (+1); though, no green leaves gives a value near to zero. A value of zero means no flora and near to +1 (0.8 - 0.9) shows the maximum probable density of green leaves. After all the classification of all maps they were reclassified into desired forest cover classes by using reclassification tool in ArcGIS 10, raster calculation option was used to measure the particular area. Images were also be prepared of all the land cover types for each year of the study area.





## RESULTS

This study is based on the two different classification techniques for the land cover classification. In this study we have taken images with the interval of 10 years from 1988 to 2018. Four images of 1988, 1998, 2008 and 2018 were taken and 1<sup>st</sup> those images were preprocessed and all the images are shown in figure 4.1. These images are 1<sup>st</sup> corrected radio metrically and then IAR correction were applied and then Dark Subtraction was applied to able the image for the further processing.

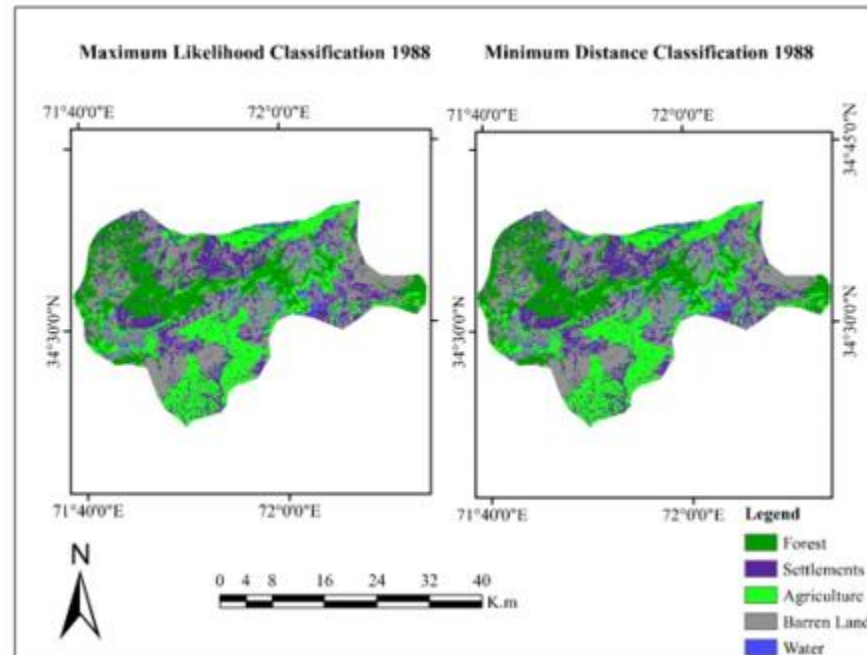
### Supervised Classification

The maximum likelihood classification and minimum distance classification was applied on all the four images step by step. The classified image is shown in Figure 1 and Table 1 described the covered areas and percentages by each class in 1988 Landsat-8. The total area of district Malakand was recorded as 975.32 km<sup>2</sup>. The highest land cover area was Agriculture 227.6 (km<sup>2</sup>) while the lowest area (37.7 km<sup>2</sup>) was covered by water. Forest area was 215.2 km<sup>2</sup> extended over central and northern part of the district. The remaining areas covered by Settlements and Barren Land were 173 km<sup>2</sup> and 321.5 km<sup>2</sup>. Regarding percentage distribution of area, forests covered 22.1 % of the total area while other class settlements, agriculture, barren land and water have covered 17.7, 23.3, 33 and 3.9 respectively.

**Table 1.** - Classes area and percentages of 1988, 1998, 2008 and 2018

	1988		1998		2008		2018	
Class	Area (km <sup>2</sup> )	% age	Area (km <sup>2</sup> )	% age	Area (km <sup>2</sup> )	% age	Area (km <sup>2</sup> )	% age
Forest	215.5	22.1	189.0	19.4	151.6	15.5	91.2	9.3
Settlement	173.0	17.7	215.3	22.1	281.8	28.9	321.9	33.0
Agriculture	227.6	23.3	195.4	19.9	150.6	15.4	217.6	22.3
Barren Land	321.5	33.0	340.4	34.9	355.1	36.4	310.5	31.8
Water	37.7	3.9	35.4	3.6	36.4	3.7	34.1	3.7
Total	975.32	100	975.32	100	975.32	100	975.32	100





**Figure 1.** - Classification classes 1988

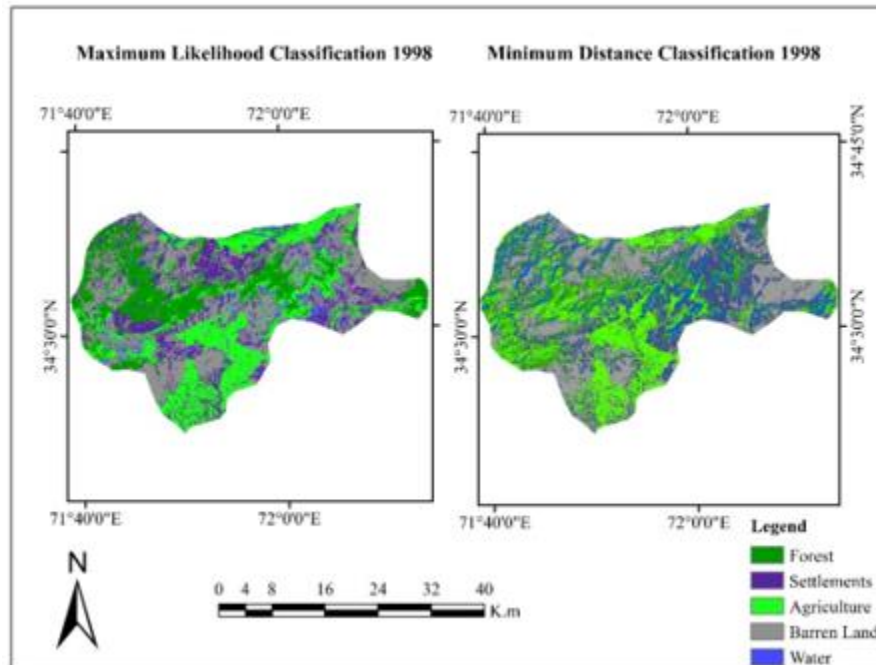
In the classified images of 1998, agriculture covered much area throughout the study area especially near the rivers and northward sides (Figure 2). The highest land cover area was barren lands  $340.4 \text{ km}^2$  while the lowest area  $35.4 \text{ km}^2$  was covered by water. Forest area was  $189 \text{ km}^2$  extended over central and northern part of the district. The remaining areas covered by Settlements and Agriculture were  $215.3 \text{ km}^2$  and  $195.4 \text{ km}^2$ . Regarding percentage distribution of area, forests covered 19.4 % of the total area while other classes settlements, agriculture, barren land and water have covered 22.1, 19.9, 34.9 and 3.7 respectively. The change in forest area over the time was  $26.5 \text{ km}^2$  which is equal to 2.7 percent during 1988 to 1998 (Table 1).

Similarly, in the classified images of 2008, the maximum likelihood classifier shows the high rate of forest as compare to minimum distance classifier (Figure 3). In both images in north direction there is high rate of agriculture area.

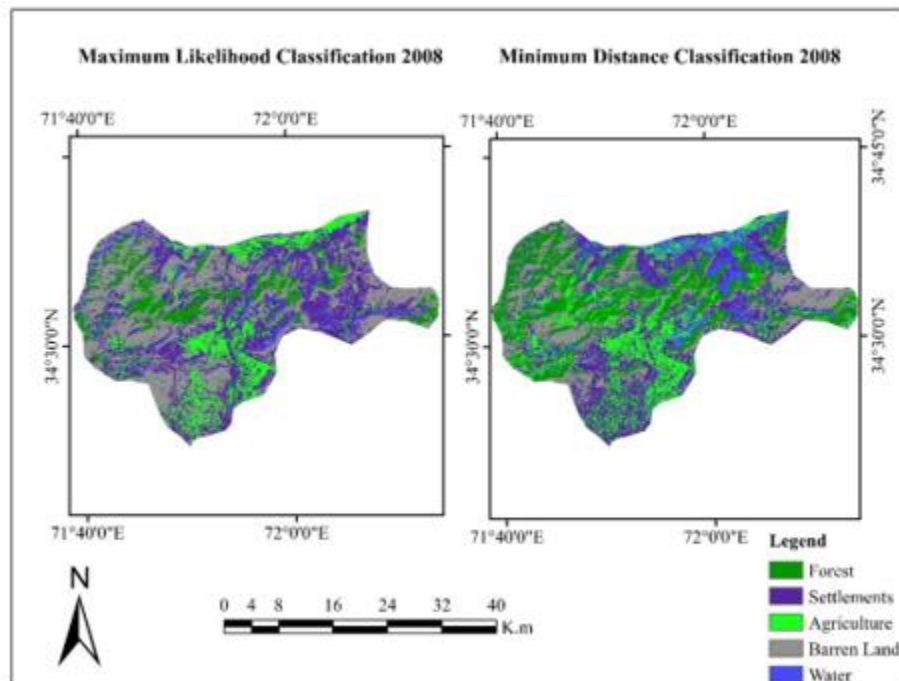
According to Table 1, the highest land cover area was barren lands which covered  $355.1 \text{ km}^2$  indicating increases in the barren area as compared to 1998. The lowest area  $35.4 \text{ km}^2$  was covered by water. Forest area was  $151 \text{ km}^2$  extended over central and northern part of the district. The remaining areas covered by Settlements and Agriculture were  $281.8 \text{ km}^2$  and  $150.4 \text{ km}^2$ . Regarding percent wise area coverage forest covered 15.4 % of the total area while other class settlements, agriculture, barren land and water have covered 28.9, 15.4, 36.4 and 3.7 respectively. The change in forest area over the time was  $37.4 \text{ km}^2$  which is equal to 3.9 percent during 1998 to 2008 while during two decades 1988 to 2008 deforested area was  $64 \text{ km}^2$  which is equal to 6.6 percent of area lost during this period.







**Figure 2. - Classification classes 1998**



**Figure 3. - Classification classes 2008**

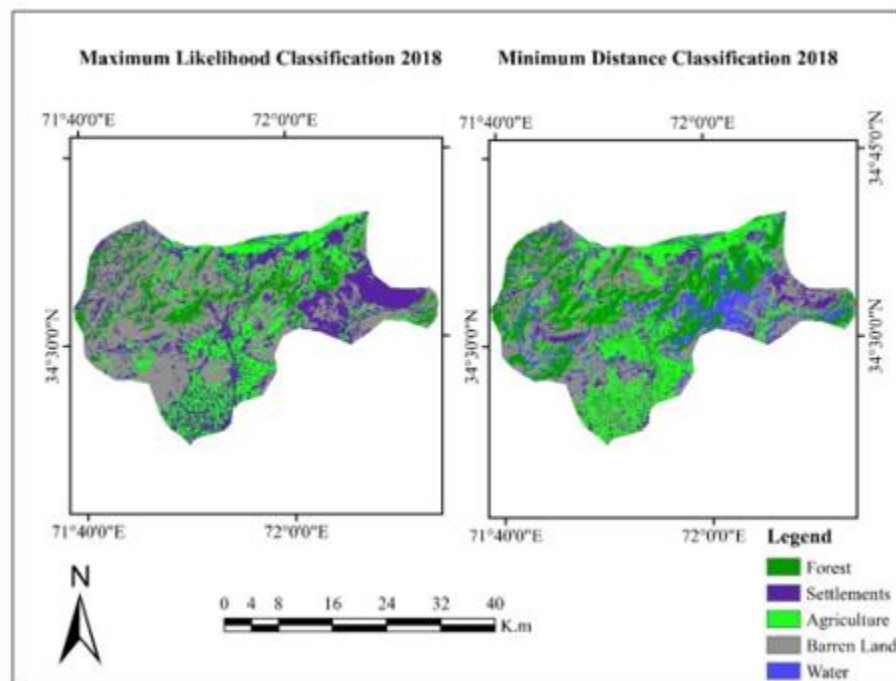
Lastly, in the classified images of 2018 from Landsat-8 image, it can be seen that settlement has increase exponentially during 1998 to 2008 and forest has gradually decreased in this last 10 years (Figure 4). In these classified images the barren land has



been increased and there is drastic decrease in forest area. The barren land is also increased in the area.

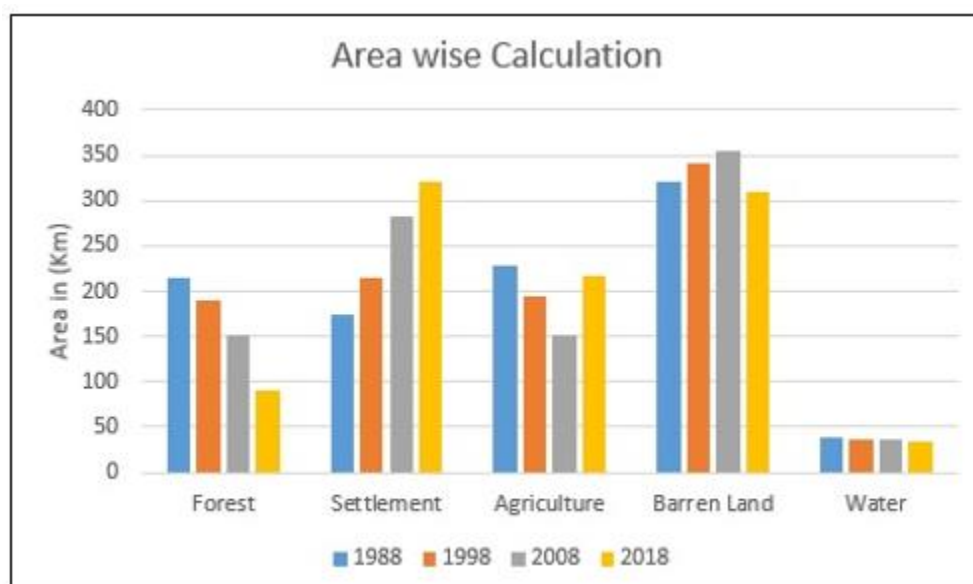
According to Table 1, the highest land cover area was settlements which covered 321.9 km<sup>2</sup> indicating increase in the barren area as compared to 1998. The lowest area 35.4 km<sup>2</sup> was covered by water. Forest area was decreased to 91.2 km<sup>2</sup> extended over central part of the district. The remaining areas covered by barren lands and Agriculture were 310.5 km<sup>2</sup> and 217.6 km<sup>2</sup>. Regarding percent wise area coverage forest covered 9.3 % of the total area while other class settlements, agriculture, barren land and water have covered 33.8, 22.3, 31.8 and 3.7 respectively.

The change in forest area over the time was 60.4 km<sup>2</sup> which is equal to 6.2 percent during 1998 to 2008 while overall deforestation was 124.4 km<sup>2</sup> which is equal to 12.7 percent loss of forest area lost from 1998 to 2018. The area wise chart is shown in the area (Figure 4). We can see that forest is deceased in every decade. On the other hand, the settlement is increased with the passage of time. Thus, the forest area was changed to settlements and barren lands from 1988 to 2018 (Figure 5).



**Figure 4. - Classification classes 2018**





**Figure 5. - Area wise classes during 1988-2018**

### Accuracy assessment

As it is important that the post classified image should be validate. With the help of accuracy assessment both the classifiers were also tested. It is observed that the results of maximum likelihood classifier were more accurate as compare to minimum distance classifier. The accuracy assessment table of maximum likelihood is shown in Table 2. Here from this table we can identify that the overall accuracy from ML classifier was 92.4 % with Kappa coefficient of 0.81. From the minimum distance classifier, the overall accuracy was 87 % and the Kappa coefficient was 0.76. Therefore, from those results and accuracy assessment tables it is proven that Maximum likelihood classifier is best for land cover classification. The table generated from minimum distance classification (Table 3).

**Table 2. - Accuracy assessment table of maximum likelihood**

Classes	Fore st	Settlem ent	Agricult ure	Barr en Land	Wat er	Tot al	Produ cer Accur acy	User Accur acy	Error of Commis sion	Error of Omissi on
<b>Forest</b>	1563	22	14	23	3	1611	96.36	97.02	3.63	2.97
<b>Settlem ent</b>	18	1506	40	116	0	1680	91.60	91.82	8.39	8.17
<b>Agricult ure</b>	24	13	1422	46	3	1508	92.35	94.62	7.65	5.48
<b>Barren Land</b>	41	108	62	1326	7	1482	90.51	89.47	9.48	10.52
<b>Water</b>	0	8	10	0	311	319	96.88	97.49	3.11	2.50



<b>Total</b>	1622	1644	1548	1465	321	660 0
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**Table 3. - Accuracy assessment of maximum distance**

Classes	Fore st	Settlem ent	Agricult ure	Barr en Land	Wat er	Tot al	Produ cer Accur acy	User Accur acy	Error of Commis sion	Error of Omissi on
<b>Forest</b>	1513	22	83	23	3	169 4	96.36	97.02	3.63	2.97
<b>Settlem ent</b>	18	1435	46	116	0	168 6	91.60	91.82	8.39	8.17
<b>Agricult ure</b>	13	44	1304	71	5	143 7	91.64	88.27	8.36	11.73
<b>Barren Land</b>	41	108	109	1226	7	159 1	90.51	89.47	9.48	10.52
<b>Water</b>	0	8	6	0	311	325	96.88	97.49	3.11	2.50
<b>Total</b>	1622	1644	1548	1465	321	660 0				

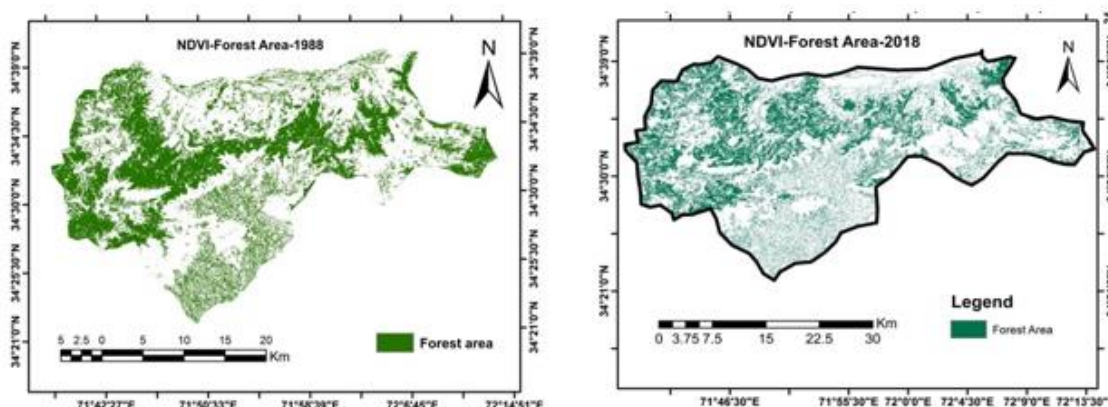
## NDVI Analysis

Normalized Difference Vegetation Index (NDVI) was calculated for 1988, 1998, 2008 and 2018 (Table 4). NDVI outputs computed from Landsat images of study area for the year 1998 and 2018 have been shown in Figure 6. Regarding forest cover analysis through NDVI, normally some higher NDVI values were in same range for agriculture areas and forest areas. These forest areas values are bit lower than NDVI in 2018 and 2008. These agriculture-based values were kept in consideration. According to Table 4, 1988 the NDVI based forest area was 380.79 km<sup>2</sup> which is equal to 423110 pixel value of Landsat-5 image while the area id reduced to 327.89 km<sup>2</sup> in 1998. Further deforestation was evident from 2008 and 2018 NDVI which showed forest areas as 255.57 km<sup>2</sup> and 214.50 km<sup>2</sup> respectively. The area changes for the base year 1988 were; deforestation from 1988 to 1998 was 52.90 km<sup>2</sup>, next from 1998 to 2008 the deforestation was 72.32 km<sup>2</sup> and lastly from 2008 to 2018 forest area has been reduced 41.06 km<sup>2</sup>. Regarding percent change with the base year 1988, the percent changes were; 13.89 % for 1988-1998, 22.05 for 1998-2008 and 16.06% for 2008-2018. Total deforestation over the time was 166.29 km<sup>2</sup> in last 30 years (1988-2018) with percent deforestation of 43.66 % area lost.



**Table 4. - Temporal Analysis of NDVI analysis (1988-2018)**

Year	1988	1998	2008	2018
NDVI Pixel	423 110	364 330	283 970	238 338
Area in m <sup>2</sup>	380 799 000	327 897 000	255 573 000	214 504 200
Area in km <sup>2</sup>	380.79	327.89	255.57	214.50
Area Change	Base year	52.90	72.32	41.06
Percent Change	Base year	13.89%	22.05%	16.06%
Deforestation (1988-2018)	380.79-214.5= 166.2948 km <sup>2</sup>			
Percent Deforestation (1988-2018)	214.5/380.79 *100 = 56.330 (forest area left) 100 - 56.33 = 43.66			

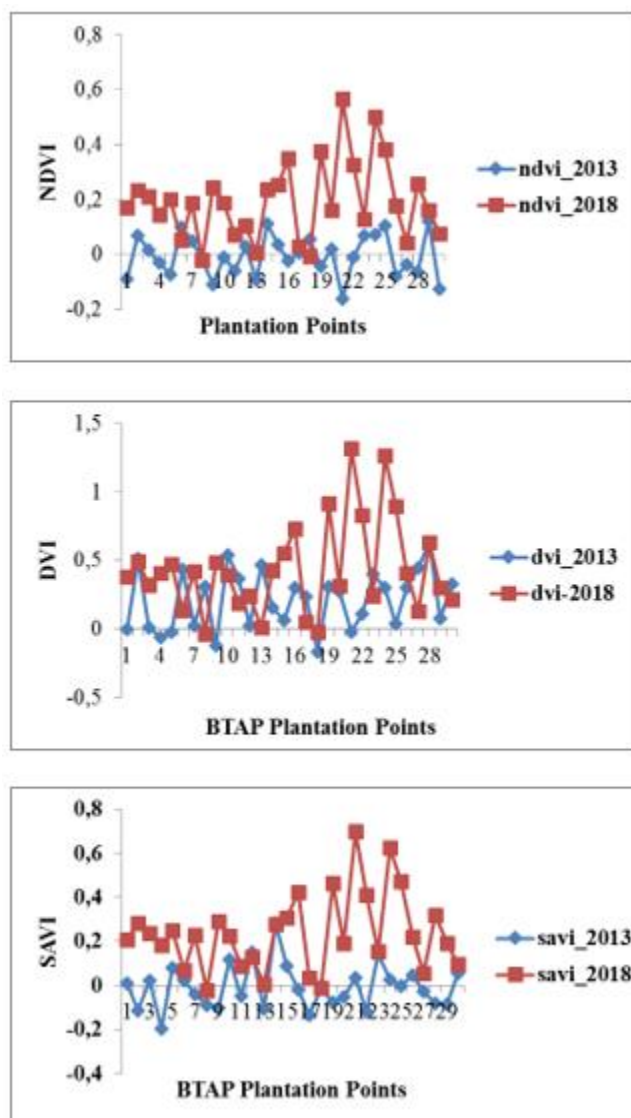


**Figure 6. - Normalized Difference Vegetation Index 1988 and 2018**

### Plantation under afforestation project in district Malakand

Under Billion Tree Afforestation Project (BTAP), provincial forest department has planted thousands of native plants over a large-area in district Malakand. There are about 29 plantation areas in the study area and the increase in forest due to BTAP intervention has been assessed through vegetation indices. Ratio Vegetation Index (RVI) is ratio between Near Infrared and Red portion of the spectrum because of its importance in photosynthesis. The range of RVI is form 0 to infinity, less than zero shows vegetation while higher values shows vegetation less areas. Soil Adjusted Vegetation Index SAVI overcome the soil interference in the reflectance values by considering the soil factor, that's why can SAVI can used in combination to NDVI. SAVI has same range similar NDVI. The DVI also consider slope of the soil line and weigh Near Infrared to differentiate vegetation areas from non-vegetated areas. The values range from negative to positive values, vegetation are expressed by positive values. Plantations shape file created via ArcGIS 10.3 was overlaid on corresponding vegetation indices of both all acquired images. The masked pixels values were extracted for all the indices and were arranged properly into excel sheets. Result of all vegetation indices showed significant increase in vegetation cover due to plantation program in the study área (Figure 7).





**Figure 7. - NDVI, DVI and SAVI for BTAP Plantation Points**

## DISCUSSION

Forests has significant environmental, socioeconomic and biological role but forest area in Pakistan facing serious challenges like encroachment, lack of land use planning and awareness in the community, deforestation and conversion forest to Barren land. Forest cover areas in District Malakand have gone under rapid transformations. *Mahboob et al., (2016)* reported from their studied of land-use changes in Islamabad that urbanization has increased between 1975 and 2010 from 50km<sup>2</sup> to 332km<sup>2</sup>, which has ultimately resulted in alarming reduction of forest area from 465km<sup>2</sup> to 145km<sup>2</sup> including Margalla Hills National Park. Similarly, *Batool and Kanwal Javaid (2018)* used Landsat-7 and Landsat-8 to discover the land-use changes in Margalla Hills National Parks, Islamabad





between 2000 and 2008. They identified 13 % deforestation with 2 % increase in construction.

Mitchell *et al.*, (2014) stated that Pakistan has greater rural area where people mostly count on natural resources. Furthermore, there are numerous forest product-based industries relying on forest. Forests offer different ecosystem services for the local people. Though, developmental activities attract more tourists to these forests but it greatly effects and disturb the forest ecosystem (Sheday *et al.*, 2019). Siyal *et al.* (2016) studied the spatial and temporal difference in the forest cover of the Pai forest in Sindh using land surface temperature using optical and thermal Landsat satellite data (1987-2014). The study showed 15 % of deforestation in thin forest in just 5 years (1987-1992) while 26 % increase was recorded in thick forest cover in a span of about 21 years (1992-2013). It was analyzed that most of forested area has been cleared in 1992.

Rashid & Iqbal, (2018) studied forest cover dynamics during 1990- 2016 using Landsat images along Karakoram Highway. The forest cover change maps of the five land-use based classified study area (forest, vegetation, urban, open land and snow cover) detect 26% decline in the forest cover in duration of 26 years. Urban expansion and vegetation replacement was reported as the main cause of forest cover declination. In this context, various studies concluded that rapid urban expansion and agricultural encouragement are the two main factors causing forest cover reduction (Gilani *et al.*, 2015; Sajjad *et al.*, 2015; Qamer *et al.*, 2016; Khalid *et al.*, 2016; Kundu, 2017). Additionally, illegal logging is also an element of forest degradation in developing countries (Khalid *et al.*, 2016; Qamer *et al.*, 2016). In this context, the pressure of local community on these forests for wood consumption it is projected that the forest of Malakand and Hazara may no longer exist by the year 2027. Rangelands, agriculture and plantations fulfill about 21 % of the total needs. But the supply gap of 8.8 million m<sup>3</sup> by 2027 is expected to reach out to 13.6 million m<sup>3</sup> by 2050 (Rashid & Iqbal, 2018).

Due to land use changes and expansion in urban areas, increases in forest degradation occur in Abbottabad to Besham in Khyber Pakhtunkhwa. Changing these lands into pastures, parkland and agricultural vegetation increase the aesthetic value but are vulnerable to intense grazing and ultimately cause degradation. Local community demand for wood is another factor of forest degradation (Fischer *et al.*, 2010; Ali *et al.*, 2006; Rashid & Iqbal, 2018).

Kausar *et al.*, (2016) used Landsat images detect LULC change due to the enhanced activities of ecotourism during 1998-2010. The study reported that the Built-up area have increased by 11.73 %, reserve forest by 8.11% while grassland and dense natural forest decreases by 7.50 and 12.37 % respectively. Similarly, Urooj and Ahmad, (2019) conducted spatio-temporal analysis of ecological changes around wetland in AJK. The study revealed remarkable increase in built-up area, while reduction in water body, vegetation and barren area was observed from 1992 to 2013. In another study, researchers concluded that rapid increasing in the agricultural land area is one main cause of forest decline (Qasim *et al.*, 2011). Tang *et al.*, (2005) stated that main drivers behind forest decline were urban development and settlements. Similarly, Awasthi *et al.*, (2002) and Twumasi & Merem, (2006) described the trend of forest declining in the watershed area around the world. Moreover, Landsat images have 30 meters resolution and small forest area changes can not detected by Landsat images, thus high resolution images can detect more deforestation comparatively. Spot-5/6/7 and Worldview 2/3 can implement for detailed deforestation. Fusion of Sentinel-2, Sentinel-1 and SAR/Radar



imagery can enhanced the results. Results can be compared with Global 1km Lidar Forest Canopy Height maps and Global Forest Cover Change 2000-2017 datasets.

## CONCLUSION

This study was based on the two different classification techniques for the land cover classification. In this study have taken images with the interval of 10 years from 1988 to 2018. The maximum likelihood classification and minimum distance classification were applied on all Landsat images.

The total area of district Malakand was recorded as 975.32 km<sup>2</sup>. Regarding percent wise area coverage Forest covered 22.1 % of the total area while other classes' settlements, agriculture, barren land and water have covered 17.7, 23.3, 33 and 3.9 respectively in 1988. Whereas in 2018, percent wise area coverage forest covered 9.3 % of the total area while other classes settlements, agriculture, barren land and water have covered 33.8, 22.3, 31.8 and 3.7 respectively.

The change in forest area over the time was 60.4 km<sup>2</sup> which is equal to 6.2 percent during 1998 to 2008 while overall deforestation was 124.4 km<sup>2</sup> which is equal to 12.7 percent loss of forest area lost from 1998 to 2018. The forest area was changed to settlements and barren lands from 1988 to 2018. Normalized Difference Vegetation Index (NDVI) was calculated for the three decades (1988- 2018) and results showed total deforestation of 166.29 km<sup>2</sup> with percent deforestation of 43.66 % area lost.

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**Conflict of interests:**

The authors declare not to have any interest conflicts.

**Authors' contribution:**

**Syed Hassan Raza:** Literature search and review, instrument making, instrument application, compilation of information resulting from the instruments applied, statistic analysis, preparation of tables, graphs and images, database preparation.

**Muhammad Irfan Ashraf:** Conception of the idea, instrument application, compilation of information resulting from the instruments applied.

**Areeba Binte Imran:** Conception of the idea, general advice on the topic addressed, drafting of the original (first version), review and final version of the article, article correction.

**Ishfaq Ahmad Khan:** Compilation of information resulting from the instruments applied, statistic analysis, preparation of tables, graphs and images.

**Syed Ghayoor Ali Shah:** Conception of the idea, literature search and review, database preparation, general advice on the topic addressed.





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