RESEARCH PAPER

Application of satellite remote sensing in forest change detection and its environmental impacts in district Abbottabad, Pakistan

Zaib un Nisa[1, 2], Kamran Mir[2, 3]*, Hina Fatimah[1], Syeda Maleeha Batool[2], Sanaullah[2], Salman Atif[2] and Muhammad Arshad Awan[3]

[1]Department of Biology and Environmental Sciences, Allama Iqbal Open University, Islamabad, Pakistan
[2]Institute of Geographical Information Systems (IGIS-SCEE), NUST, Islamabad, Pakistan
[3]Department of Computer Sciences, Allama Iqbal Open University, Islamabad, Pakistan

*Corresponding author: Kamran Mir (kamran.mir@aiou.edu.pk)

Key Message: Forest plays a significant role in the ecosystem balance and climate of a country. This study reveals that forest change can be effectively evaluated using Satellite Remote Sensing and GIS tools and this process can be automated using GIS functionalities.

ABSTRACT: Decline of natural resources poses significant impact on society directly or indirectly. Change in the forest area can affect the climate and economy of a society. This study highlights the effect of forest increase on surface temperature conditions of Abbottabad. The scope of this study covers the forest change detection of district Abbottabad (Pakistan) using Landsat 5 TM data over the period of 9 years (2000 and 2009) and its subsequent impact on land surface temperature. A Python (Programming) based tool was developed to automate this change detection procedure. Results indicate that almost 1% of the forest area (from 13% to 12% of total land area) has undergone deforestation in 9 years, however vegetation has increased 36% in 2009, 51.6% decline in the past 2000 vegetation cover which is an indication of substantial deforestation. A significant change in land surface temperature of Abbottabad was observed by 9^0 fall in maximum and -10^0 fall in minimum temperature, that deciphers cooler conditions. Study concludes that change in climate is not solely dependent on deforestation but also GIS automated assessment of forest change detection is possible in GIS via python tool. This tool can speed up the process of forest change detection and assessment in Pakistan.

Keywords: Automated change detection, Deforestation, GIS, Remote sensing, Precipitation, Land surface temperature

How to cite this article:

Nisa, Z., Mir, K., Fatimah, H., Batool, S., Sanaullah, Atif, S., & Awan, M. (2018). Application of satellite remote sensing in forest change detection and its environmental impacts in district Abbottabad, Pakistan. *Journal of Pure and Applied Agriculture*, *3*(1), 49-62.

INTRODUCTION

Forests are very significant for a sustainable human life; they have a fundamental role in land ecosystem. They provide the basis for organic carbon production and water cycle (Thompson et al., 2011). It is one of the major carbon reserves in global carbon cycle but now-a-days it is at the verge of rapid decline by deforestation and degradation (Myers, 1989). Deforestation is the conversion of forest land into non forest land, or it can be regarded as a decrease in canopy cover or carbon density by a given amount or sequence of thresholds (Intergovernmental Panel on Climate Change [IPCC], 2000). It is the long-term or permanent removal of forest cover and conversion to a non-forested land use (Lund, 2015). Forests are directly linked with climate thus can be related with economy of a region (Shimelis, 2017). They are under immense pressure of climate variability. Amisah et al. (2009) observed the decrease in precipitation and rise in ambient temperature by the increase in deforestation rate. Deforestation in urban environment is also threatening to carbon stock and resulting in CO_2-methane emissions in the atmosphere, which in turn altering the radiative balance between earth atmosphere systems (Dickinson & Kennedy, 1992). It also reduces evapotranspiration in plants, minimizes cloud formation and downwind precipitation, and thereby weakens the hydrological cycle (Shukla et al. 1990; Miller & Cotter, 2013; Zaccheaus, 2014). It is imperative to monitor the land cover changes by natural and anthropogenic sources, where remote sensing is playing a significant role in providing extensive temporal coverage to detect areal changes.

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. It involves the ability to quantify temporal effects using multi-temporal data sets.

Change detection is useful in such diverse applications as land use change analysis, monitoring of shifting cultivation, assessment of deforestation, study of changes in vegetation phenology, seasonal changes in pasture production, damage assessment, crop stress detection, disaster monitoring, snow melt measurements, day-night analysis of thermal characteristics and other environmental changes (Acharjee et al., 2012; Wojtowicz et al., 2016). Remote sensing change detection studies reveal differences in past, present and future trends that helps policy makers in setting resource managerial priorities.

Jhonnerie et al. (2014) detected change in mangrove forests using Landsat imageries for years 1996 - 2013 and found 197.2 ha loss of mangrove cover caused by anthropogenic factors. Landsat data was also used for spatio-temporal analysis of Pathri Reserve Forest, resultant change detection matrix showed drastic transformation of forest reserve into agricultural land (Freddy et al., 2014). Kumari et al. (2014) used five year span (2005 – 2010) to detect land use land cover change in Poba Reserve Forest that also transformed into agricultural land. Change in open evergreen forest ratio was observed as result of extensive deforestation in the region. But in most of the developing countries, deforestation is directly linked with population growth and indirectly to agricultural expansion (Allen & Barnes, 1985). Besides areal extent, forest health can be measured by calculating leaf area index using LiDAR information that gives better result than that of sensor based Normalized difference vegetation index (NDVI) (Zheng & Moskal, 2009). Forest change detection using multi-date satellite imagery requires understanding of how to adjust applications with change detection methods (Coppin & Bauer, 1996). As far as the scope of this study is concerned, it only covers the forest change detection technique and methodology based on remote sensing tools.

Pakistan has 2.5% forest cover area which has been rapidly declining. Pakistan has one of the highest rates of deforestation in Asia (Food and Agriculture Organization [FAO], 2009). On the other hand, the land area of forests in Pakistan is 4.23 million ha, which is 5.3% of its total land area (Agricultural Statistics of Pakistan, 2011). This is far less than that of the threshold value of 25% (a minimum level set by experts to meet the ecological balance) of total land area that should be covered by forests. This study is meant to find out the level of change in forestation in district Abbottabad over the time span of nine years. District Abbottabad is situated in North Western Frontier region of Pakistan and administratively fall under the KPK province. This district has undergone a great change in land use over the last ten to fifteen years especially after earth quack 2005 in Pakistan. An attempt has also been made to check the cascading effects of change in forestation on the surface temperature of the target area.

The classification process of forest change detection has been sequentially integrated in a single tool with the help of python scripting. The specialty of the python tool is to get two input images of different times and to give the immediate output as forest change detection between the input images of area of interest (AOI). The tool so developed can be considered as an added extension in the software toolbox for Forest Change Detection (FCD) in any part of the globe.

METHODOLOGY

Data acquisition and preprocessing

Landsat 5 TM images of district Abbottabad located at path # 150 and row # 36 were obtained from *glovis.usgs.gov* for the period 21 May, 2000 and 14 May, 2009 (Fig. 1). Although both the images were obtained on same projection system i.e. WGS-84_UTM_Zone_43N but both were not aligned with each other. So image to image registration was carried out before classifying the images. After image registration, the desired AOI scene was extracted using ArcGIS "Extract by mask" tool keeping the shapefile for district Abbottabad as Mask. Top of the Atmosphere (ToA) reflectance of band 4, 3, 2 was calculated using QGIS extension RS & GIS. Same tool was used for extraction of land surface temperature from thermal infrared (IR) band 6.

Brightness temperature from Landsat thermal band IR (band 6) was calculated using Planck's equation (Sobrino et al., 2004).

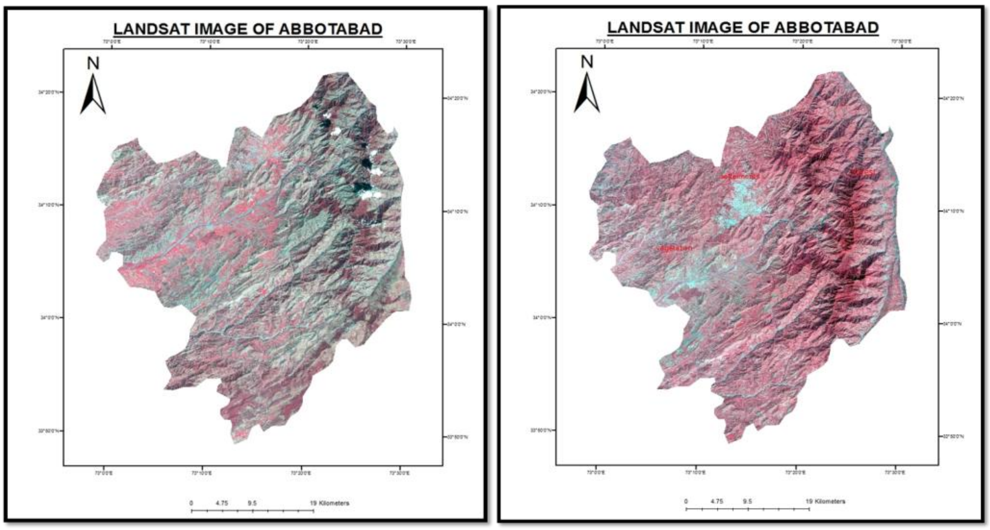
$$\text{Brightness temperature}_{(61,\,62)} = k2/(\ln(k1/L(\pi)+1)) \qquad (1)$$

Where L (π) is radiance, $k2 = C2/\pi$, $k1 = C1/\pi$, $C1 = 1.19104356 \times 10^{-16}$, $C2 = 1.4387685 \times 10^{-16}$, π is band specific central wavelength of sensor.

QGIS tool converts brightness temperature values from kelvin into degree centigrade. Landsat images were classified into 5 classes (tree, vegetation, bare land, water and settlements) using maximum likelihood classifier in Arc map. Brief methodology flow chart is given in Fig. 2. NDVI is calculated from reflectance values in red (band 3) and near infrared (band 4) channels. Threshold over greater than equal to 0.5 NDVI is considered as thick forest canopy cover. This area is further analyzed to estimate change in the forest cover by subtracting forest cover in 2009 from forest cover in 2000.

Python tool development

The whole process of change detection in forestation in the study area was integrated into a single toolbox (Fig. 3). Python Scripting was used to create the tool box which took two images of the study area, and signature files as inputs and performed maximum likelihood classification on both images with computation of change in forest by analyzing each pixel value that gave results in percentage and area in square kilometer unit (Python source-code is available at Annex-A).



Landsat TM image of Abbottabad, 2000 Landsat TM image of Abbottabad, 2009

Fig. 1 Landsat TM Image of Abbottabad during the years 2000 and 2009

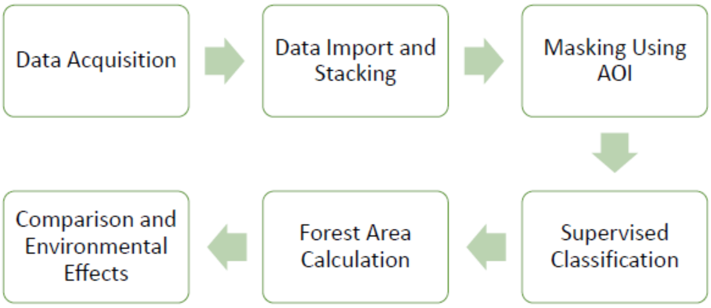
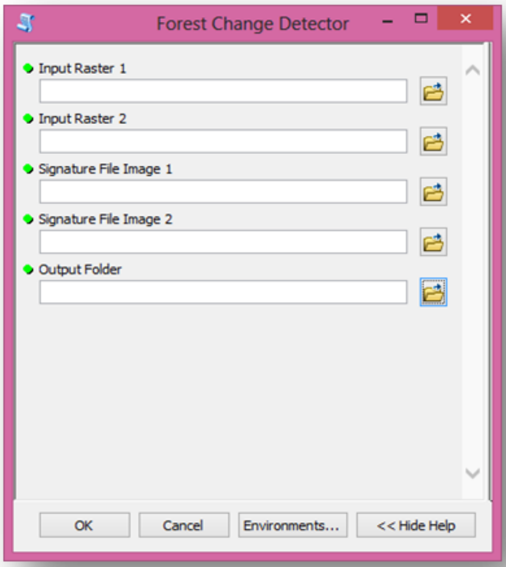


Fig. 2 Methodology Flow-Chart



Forest Change Detector

Fig. 3 Forest Change Detector has been published online on ESRI resource website and it is available for free download

RESULTS AND DISCUSSION

Analysis of change using land use maps

GIS and remote sensing are being extensively used for resource measuring and monitoring (Lambing, 1997; Rogan et al., 2002). Deforestation in northern highlands of Pakistan is attributed to population growth, illegal timber logging and massive consumption of fuel wood (Fischer et al., 2010). The images of the study area were classified for quantitative analysis of data for the years 2000 and 2009. Five major classes including forest, vegetation, settlements, water and bare land were created.

As evident from Fig. 4 and Fig. 5, land use from 2000 to 2009 has been exclusively altered in the nine years. Increase in the settlements and vegetative cover, while decrease in the bare land of 2009 can be seen in Fig. 5. In 1998, it was decided to improve the forest area by starting the practicing plantation scheme. Forests and vegetation were extensively increased with increase in the built up land. People from 2005 earthquake effected areas were migrated to Abbottabad which was also hit by earthquake but the damages were not as severe as they were in other earthquake hit areas that put population pressure over the city. The increment in settlements or urban land is obvious from the land use map. Raza et al. (2012) also reported 2005 Earthquake as a major factor for forest conversion into urban settlements and extensive vegetative land was exploited for the commercial use. We can also see that from 2000 to 2009 there is a continuous increase in vegetative cover that decreased the bare land that deciphers the forest and bare land conversions into agriculture land.

Although agricultural land conversion into forest increases soil organic content in the soil (Liu et al., 2011) but such practices can undermine the capacity of ecosystems to sustain food production and forest resources (Foley et al., 2005). The total area of district Abbottabad is 1756 square kilometers. Tree cover of the total district area was chosen to estimate change as shown in Table 1. Almost 1% of the area has undergone deforestation in the duration of nine years. The graph shown below is describing the area wise change in tree cover from 2000 to 2009 (Fig. 6).

NDVI change in year 2000 and 2009

Another change detection technique was applied to verify 1% decline in tree class. For this purpose, thick canopy area (NDVI > = 0.5) was delineated after NDVI calculation. Vegetation area of the total district area in 2009 was estimated as shown in Table 2. Strong reflectance of vegetation in red and near infrared channel is exploited for forest cover estimation. NDVI values above 0.3 are estimated indication of green areas and low ratio below 0.2 indicates non-vegetative land. Threshold over 0.5 is depicting thick vegetation covering all forest reserves and agricultural land (Fig. 7).

In 2009, forest cover has increased as well as vegetation increase has been observed at entire green belt and areas where new settlements were formed. People began plantation at the periphery of forest reserves and much of the barren land have been covered with trees apparently. But in the change detection map, decrease in the tree cover is greater than that of increase (Fig. 8). About 51.6% area under tree cover in 2000 has been lost but on the other side, 36% of forest cover has been increased (Table 2). Decline in the forest cover is at the periphery of the forest reserves, which indicates forests at the verge of decline. More efforts are needed to protect canopy around forest reserves. Increase in the vegetation cover can be the result of conversion of forest into agricultural lands. Thus area wise change in the forest cover is evident from analyzed maps, but further study is needed to map cropland area in the Abottabad. Overall decrease in forest cover of Pakistan based on twenty years remote sensing data has been reported (Qamer et al., 2016). But how much forest has been converted into agricultural land is still not known.

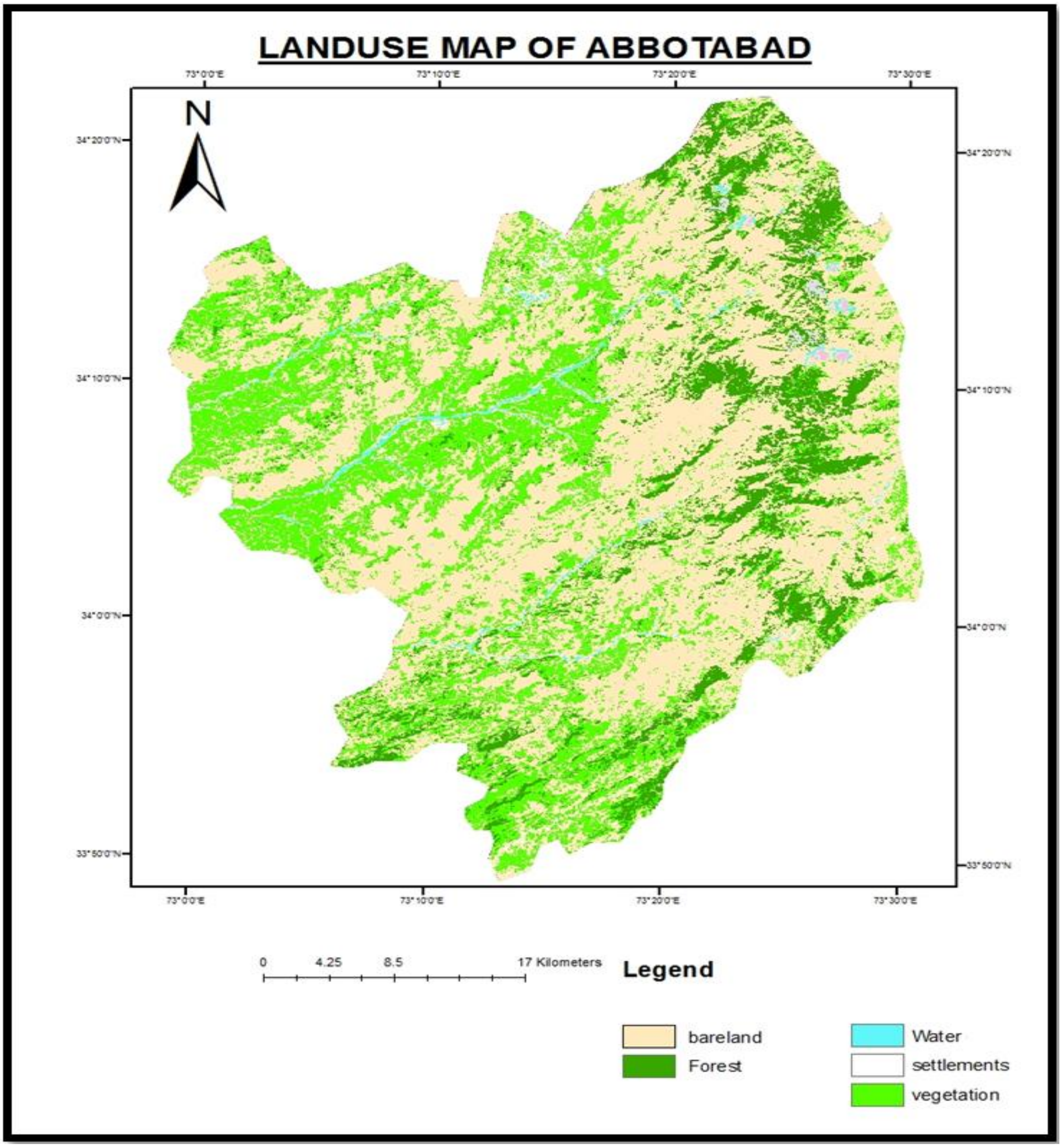


Fig. 4 Land use map of Abbottabad during the year 2000

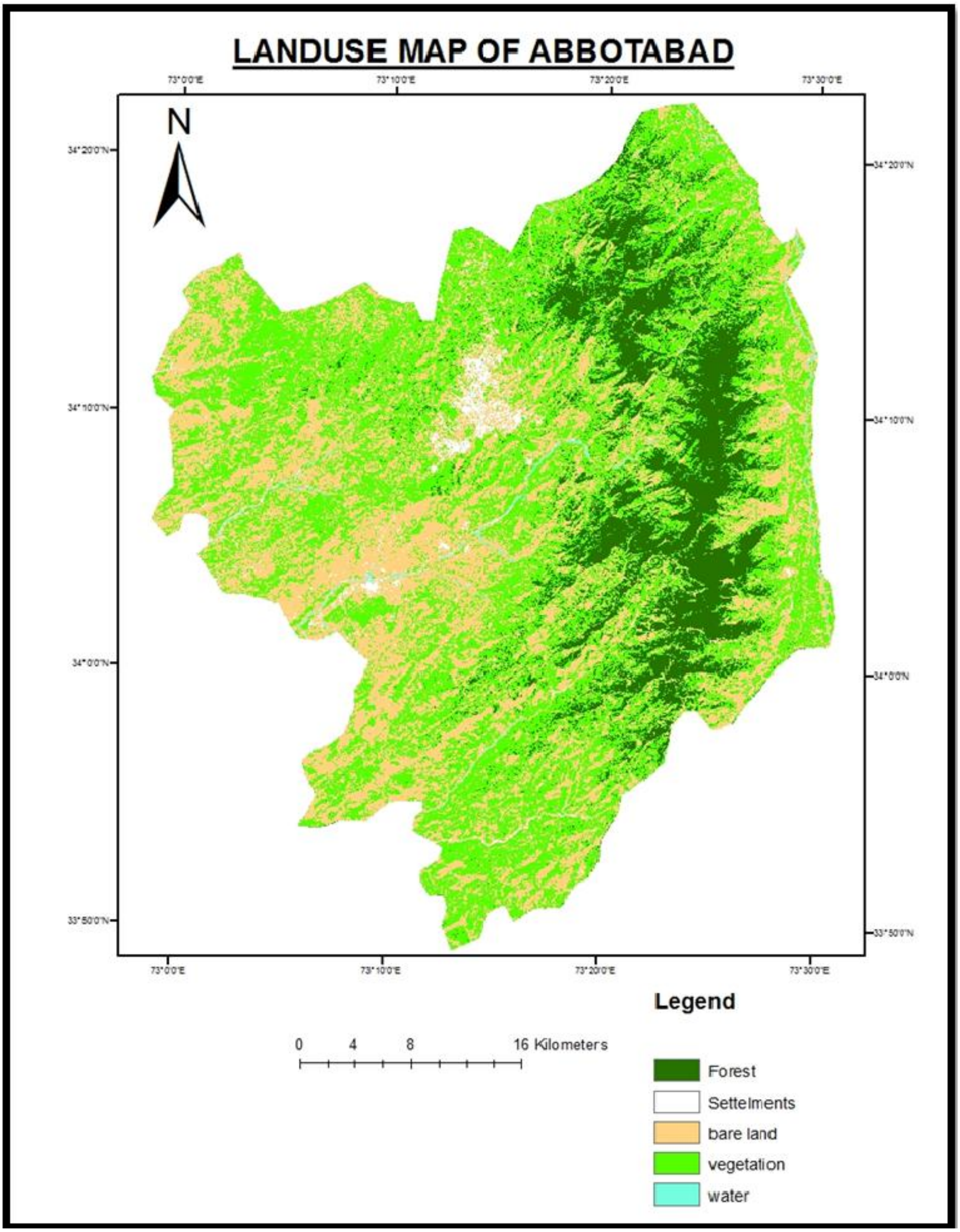


Fig. 5 Land use map of Abbottabad during the year 2009

Table 1 Percentage area of tree cover in the year 2000 and 2009

Year	Pixel count	Area in square meter	Area in square kilometer	Area in percentage
2000	234960	211464000	211.464	12.0423
2009	217697	195927300	195.9273	11.1575

Table 2 Vegetation cover change estimation from 2000 to the year 2009

Vegetation cover change	Pixels count	Area	Change (%)
Increase	91823	82640700	36%
No difference	4146	3731400	1.6%
Decrease	130948	117853200	51.6%

(Total vegetation cover in year 2000 = 22, 81, 70,700 square kilometer)

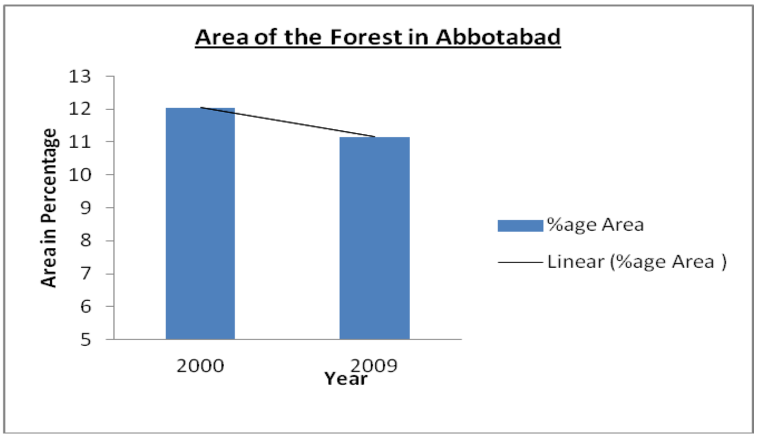


Fig. 6 Graph showing decrease in tree cover in 2009

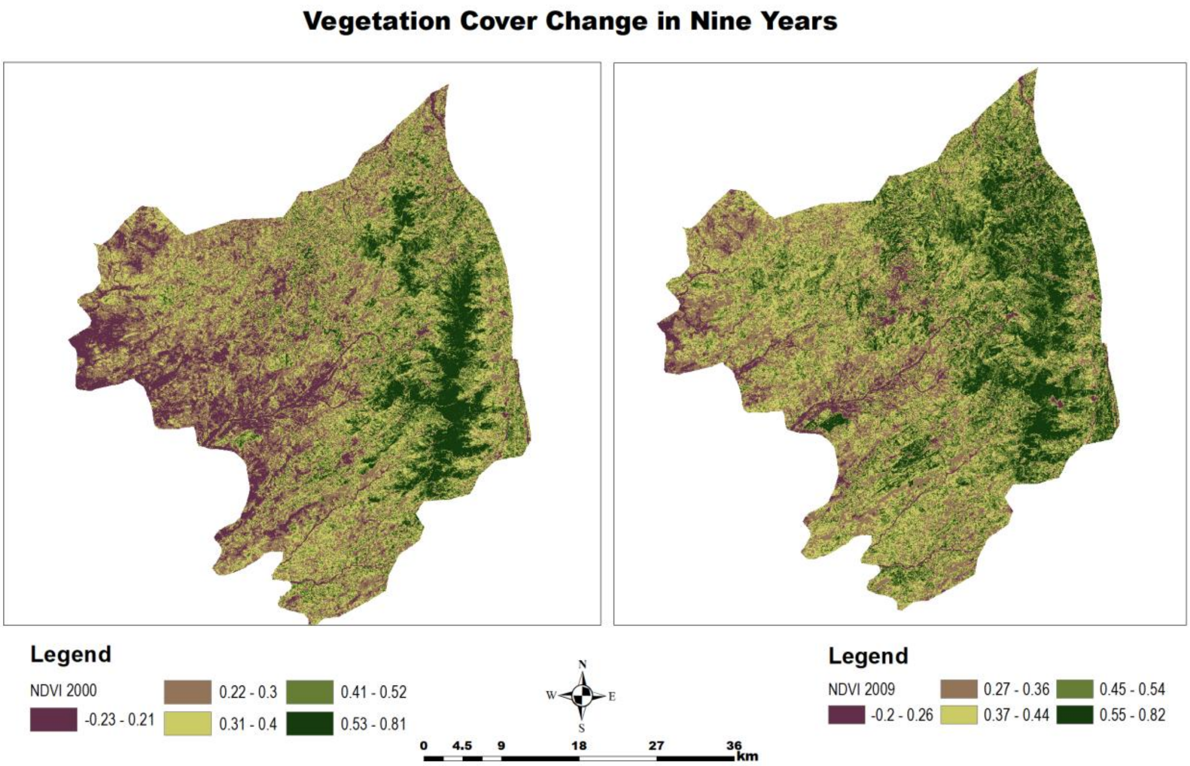


Fig. 7 NDVI maps of year 2000 and 2009

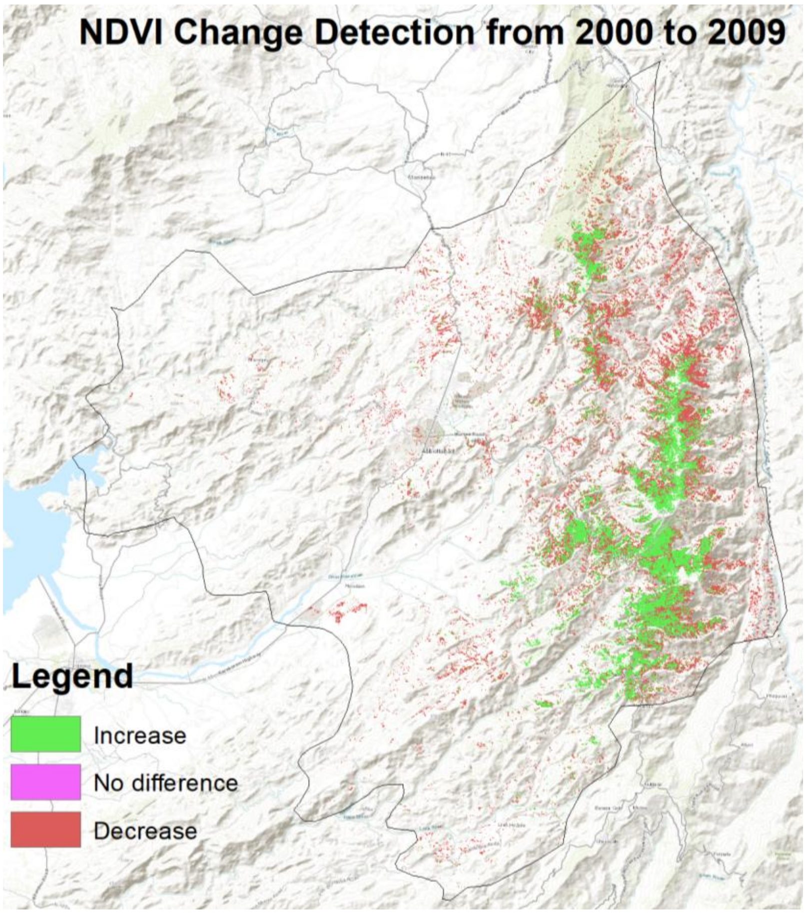


Fig. 8 NDVI change detection map

Impacts of forest cover change on land

District Abbottabad has very pleasant climatic conditions. It is a heart of tourism, and people from all parts of the country visit this area to enjoy its weather and beauty. People prefer to settle in this area because of its weather which also contributes to population increase. Humans are always accused for causing land use change. Human activities that alter the land use are agriculture, livestock, urbanization, deforestation, construction, and development etc. These have some serious implications for sustainable development, climate, and livelihood systems. Recent study revealed that neither population nor poverty alone brings land cover change, it is local as well as national market policies that drive land use change (Lambin et al., 2001). The change in forestation and human developments in the area affects the environment of that area in many ways like land erosion, changes in temperature and precipitation etc. Effect of forestation change over land surface temperature was observed using GIS and remote sensing techniques.

Landsat thermal IR band was used to estimate the land surface temperature (LST) of the area in year 2000 and 2009. Land surface temperature has strong negative correlation with vegetation cover and surface temperature variations that affect the social life attributed with changing vegetation cover (Jenerette et al., 2007). Shift in the pattern of land surface temperature can be attributed to afforestation due to increase in forest conservation efforts and increase in urban settlements, which converted bare land into forest cover. With the passage of time, the maximum surface temperature has been significantly reduced from 53 ^{0}C to 44.6 ^{0}C and the minimum temperature is reduced from 18 ^{0}C to -9 ^{0}C (Fig. 9). This contrasting difference in the LST emphasizes further study on other climatic parameters that govern the climate of a region. Forest has strong influence on the hydrological cycle and its contribution in the hydrological cycle with evapotranspiration is significant. Based on this fact, significant increase in the forest cover has overall pleasant impact on the surface conditions.

Further research is needed in the analysis of environmental and meteorological parameters to clearly assess the reasoning behind this contrasting change in land surface temperature over Abottabad district. However, the main focus of the study was to provide a tool for an automated forest change detection which has been published on esri website and freely available to user community. Its graphical user interface (GUI) deciphers two different dates' raster files with classes that can be incorporated in the tool, and it will give change in percentage for each class as output (Fig. 10). Fig. 11 is the proof of its successful operation. Fig. 12 is indicating a change in tree cover from 221 to 195 square kilometers. This tool can also be customized for other change detection studies.

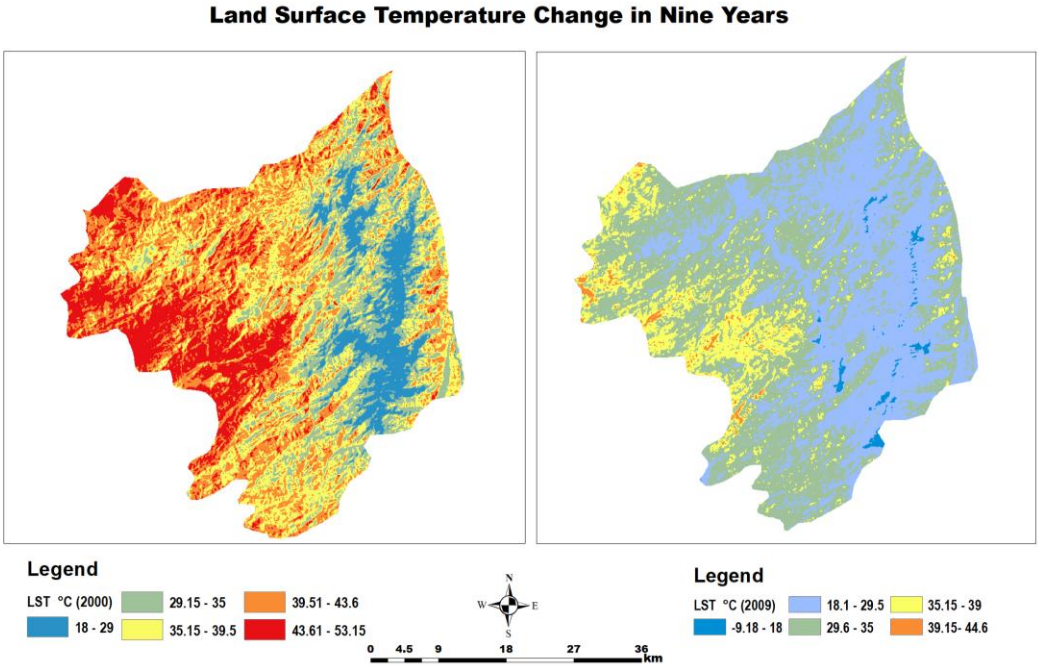


Fig. 9 Change in land surface temperature in Abbottabad during year 2000 and 2009

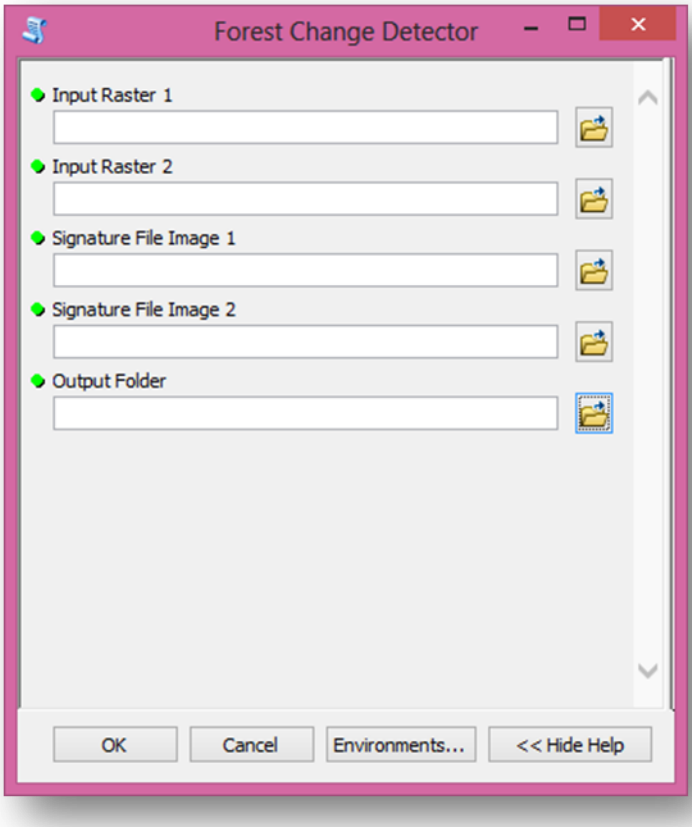


Fig. 10 Forest Change Detector GUI

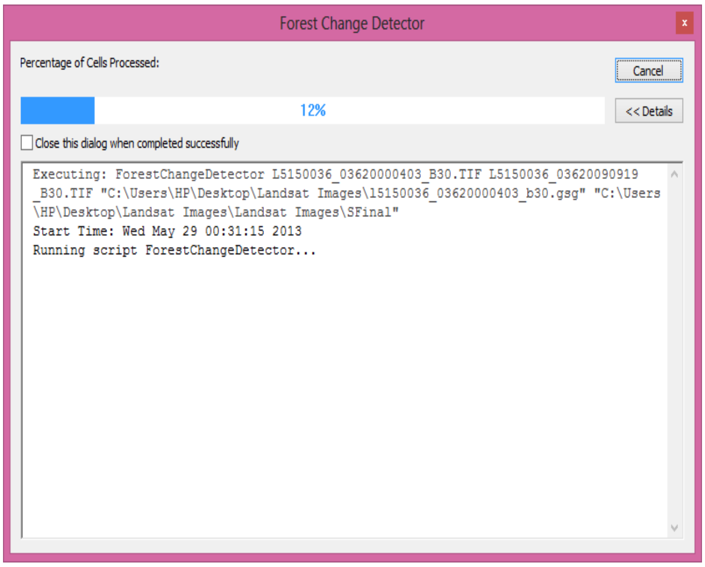


Fig. 11 Forest Change Detector Processing

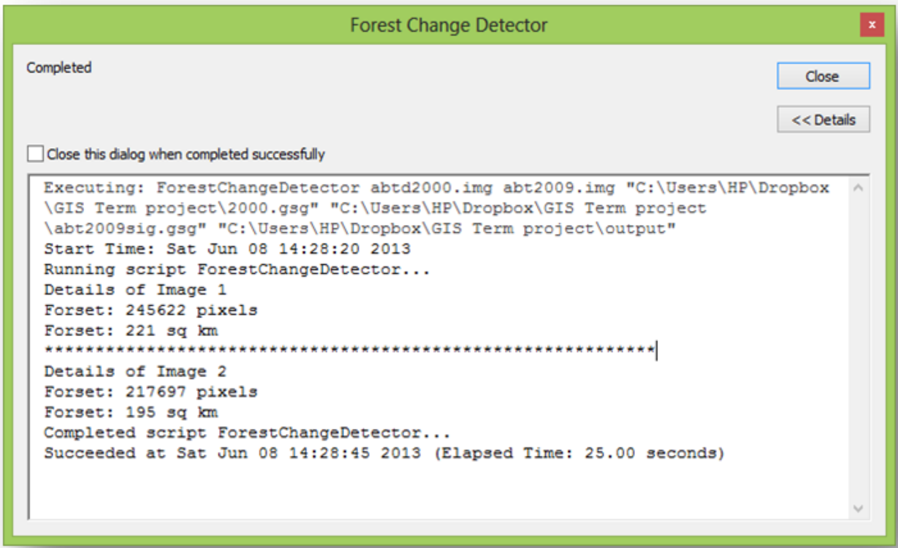


Fig. 12 Output of Forest Change Detector Toolbox

CONCLUSION

Spatial Decision Support System (SDSS) developed as a toolbox for ArcGIS that is very helpful tool to evaluate the forest change in two Landsat images of any area. The results computed through the tool box are compared with the results found through manual calculations and satisfactorily much similar results were obtained. Change in the forested area was analyzed and studied based on remotely sensed data and GIS during years 2000 and 2009 in the district Abbottabad. The region has undergone a clear land-use change due to various anthropogenic and natural factors. Our results have shown that during our study period, the forested area has decreased, while vegetation and settlements have increased. Influence of land cover-land use change over environment was analyzed and the results show that the surface temperature over the years has been reduced significantly. It is noticed that the change in climate is not solely dependent on deforestation. Further research is needed in the estimation of forest cover conversion into agricultural fields and variations in the local climate. The study has provided information regarding change in forestation and its impacts over climate and the developed tool will help us for the assessment of forested areas in all over the world.

Author Contribution Statement: Kamran Mir generated the idea and handled all the programming and technical details whereas Zaib un Nisa, Syeda Maleeha Batool, Sanaullah and Salman Atif performed GIS related tasks and contributed in writing the results. Hina Fatima and Muhammad Arshad Awan improved the literature review and conclusions.

Conflict of Interest: The authors declare that they have no conflict of interest.

Acknowledgements: Authors gratefully acknowledge the US Geological Survey (USGS) for free access to Landsat data. We also acknowledge the use of TRMM data from NASA- Precipitation Measurement Missions. We are very grateful to Pakistan Meteorological Department for sharing Kakul station data for temperature. Also, we acknowledge the anonymous reviewers whose suggestions helped in improving the quality of research.

REFERENCES

Acharjee, S., Changmai, M., Bhattacharjee, S., & Mahanta, J. (2012). Forest cover change detection using remote sensing and GIS – A study of Jorhat and Golaghat district, Assam. *International Journal of Environment and Resource*, *1*(2), 45-49.

Allen, J. C., & Barnes, D. F. (1985). The causes of deforestation in developing countries. *Annals of the Association of American Geographers*, *75*(2), 163-184.

Agricultural Statistics of Pakistan. (2010-11). Government of Pakistan. Ministry of Food, Agriculture and Livestock (Economic Wing). Islamabad. Retrieved from http://www.pbs.gov.pk/content/agricultural-statistics-pakistan-2010-11.

Amisah, S., Gyampoh, A. B., Sarfo-Mensah, P., & Quagrainie, K. K. (2009). Livelihood trends in response to climate change in forest fringe communities of the Offin Basin in Ghana. *Journal of Applied Sciences and Environmental Management*, *13*(2), 5-15

Coppin, P. R., & Bauer, M. E. (1996). Digital change detection in forest ecosystems with remote sensing imagery. *Remote Sensing Reviews*, *13*, 207-234.

Dickinson, R. E., & Kennedy, P. (1992). Impacts on regional climate of Amazon deforestation. *Geophysical Research Letters*, *19*(19), 1947-1950.

Food and Agriculture Organization (FAO). (2009). *APFSOS-Pakistan forestry outlook study II.* IGF office, Ministry of Environment, Government of Pakistan, Bangkok. Retrieved from http://www.fao.org/docrep/014/am623e/am623e00.pdf.

Fischer, K. M., Khan, M. H., Gandapur, A. K., Rao, A. L., Zarif, R. M., & Marwat, H. (2010). *Study on timber harvesting ban in NWFP, Pakistan*. Intercooperation Head Office: Berne, Switzerland.

Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., & Helkowski, J. H. (2005). Global consequences of land use. *Science*, *309*(5734), 570-574.

Freddy, A. J., Tennyson, S., Samraj, D. A., & Roy, A. (2014). Land use land cover change detection using remote sensing and geographical information system in Pathri Reserve Forest, Uttarakhand, India. In P.P. Mathur (Ed.), *Contemporary Topics in Life Sciences* (pp. 353-365). India: Narendra Publishing House.

Intergovernmental Panel on Climate Change (IPCC). (2000). *IPCC special report on land use, land-use change and forestry*. Retrieved from https://www.grida.no/publications/76.

Jenerette, G. D., Harlan, S. L., Brazel, A., Jones, N., Larsen, L., & Stefanov, W. L. (2007). Regional relationships between surface temperature, vegetation, and human settlement in a rapidly urbanizing ecosystem. *Landscape Ecology*, *22*(3), 353-365.

Jhonnerie, R., Siregar, V. P., Nababan, B., Prasetyo, L. B., & Wouthuyzen, S. (2014). Mangrove coverage change detection using landsat imageries based on hybrid classification in Kembung River, Bengkalis Island, Riau province. *Jurnal Ilmu dan Teknologi Kelautan Tropis*, *6*(2), 491-506.

Kumari, M., Das, A., Sharma, R., & Saikia, S. (2014). Change detection analysis using multi temporal satellite data of Poba reserve forest, Assam and Arunachal Pradesh. *International Journal of Geomatics and Geosciences*, *4*(3), 517-525.

Lambing, E. F. (1997). Modeling and monitoring land cover change processes in tropical regions. *Progress in Physical Geography*, *2*, 375-393.

Lambin, E. F., Turner, B. L., Geist, H. J., Agbola, S. B., Angelsen, A., Bruce, J. W., Coomes, O. T., Dirzo, R., Fischer, G., Folke, C., George, P. S., Homewood, K., Imbernon, J., Leemans, R., Li, X., Moran, E. F., Mortimore, M., Ramakrishnan, P. S., Richards, J. F., Skanes, H., Steffen, W., Stone, G. D., Svedin, U., Veldkamp, T. A., Vogel, C., & Xu, J. (2001). The causes of land-use and land-cover change: Moving beyond the myths. *Global Environmental Change*, *11*, 261-269.

Liu, Y. Q., Wang, F., Ke, G. Q., Wang, Y. Y., Guo, S. M., & Fan, C. F. (2011). Effects of converting cultivated land into forest land on the characteristics of soil organic carbon in limestone mountain area in Ruichang, Jiangxi. *Ying Yong Sheng Tai Xue Bao*, *22*(4), 885-90.

Lund, H. G. (2015). *Definitions of forest, deforestation, afforestation, and reforestation*. Report prepared for IUFRO. Gainesville, VA: Forest Information Services. Misc. pagination.

Miller, C., & Cotter, J. (2013). *An Impending Storm: Impacts of deforestation on weather patterns and agriculture*. Amsterdam, The Netherlands: Greenpeace International Ottho Heldringstraat

Myers, N. (1989). The future of forests. In: L. Friday & R. Laskey (Eds.), *The Fragile Environment: The Darwin College Lectures,* (pp. 22-40). Cambridge, England: Cambridge University Press.

Qamer, F., Shehzad, K., Abbas, S., Murthy, M. S. R., Xi, C., Gilani, H., & Bajracharya, B. (2016). Mapping deforestation and forest degradation patterns in Western Himalaya, Pakistan. *Remote Sensing*, *8*(5), 1-17.

Raza, A., Raja, I. A., & Raza, S. (2012). Land-use change analysis of district Abbottabad, Pakistan: Taking advantage of GIS and remote sensing analysis. *Science Vision*, *18*(1-2), 43-49.

Rogan, J., Franklin, J., & Roberts, D. A. (2002) A Comparison of methods for monitoring multi-temporal vegetation change using thematic mapper imagery. *Remote Sensing of Environment*, *80*, 143-156.

Shimelis, A. (2017). Effect of forest cover on climate with implications for agriculture, animal husbandry and water provisions. *Ethiopian Journal of Environmental Studies and Management*, *10*(1), 101-111.

Shukla, J., Nobre, C., & Sellers, P. (1990). Amazon deforestation and climate change. *Science*, *247*(4948), 1322-1325.

Sobrino, J. A., Jimenez-Munoz, J. C., & Paolini, L. (2004). Land surface temperature retrieval from LANDSAT TM 5. *Remote Sensing of Environment*, *90*(4), 434-440.

Thompson, I. D., Okabe, K., Tylianakis, J. M., Kumar, P., Brockerhoff, E. G., Schellhorn, N. A., Parrotta, J. A., & Nasi, R. (2011). Forest biodiversity and the delivery of ecosystem goods and services: Translating science into policy. *BioScience, 61*(12), 972-981.

Wojtowicz, M., Wojtowicz, A., & Piekarczyk, J. (2016). Application of remote sensing methods in agriculture. *Communications in Biometry and Crop Science*, *11*(1), 31–50.

Zaccheaus, O. O. (2014). The effects and linkages of deforestation and temperature on climate change in Nigeria. *Global Journal of Science Frontier Research: H Environment & Earth Science*, *14*(6), 8-18.

Zheng, G., & Moskal, L. M. (2009). Retrieving leaf area index (LAI) using remote sensing: Theories, methods and sensors. *Sensors*, *9*(4), 2719-2745.

Annex – A
Source Code of Python Toolbox

```
# Import system modules
importarcpy
importnumpy
fromarcpy import env
from arcpy.sa import *

#Setting Up Environment to overwrite output if file already exist
arcpy.env.overwriteOutput = True
# Set local variables
inRaster1 = arcpy.GetParameterAsText(0)
inRaster2 = arcpy.GetParameterAsText(1)
sigFile1 = arcpy.GetParameterAsText(2)
sigFile2 = arcpy.GetParameterAsText(3)
outfolder = arcpy.GetParameterAsText(4)
probThreshold = "0.0"
aPrioriWeight = "EQUAL"
aPrioriFile = ""

# Check out the ArcGIS Spatial Analyst extension license
arcpy.CheckOutExtension("Spatial")

# Execute the maximum likelihood classification
mlcOut1 = MLClassify(inRaster1, sigFile1, probThreshold, aPrioriWeight, aPrioriFile)
mlcOut2 = MLClassify(inRaster2, sigFile2, probThreshold, aPrioriWeight, aPrioriFile)

# Saving the output
out1 = outfolder + "\output1.tif"
out2 = outfolder + "\output2.tif"
mlcOut1.save(out1)
mlcOut2.save(out2)

#Calculating Forest area in image 1
forest=0
other=0
nullvalues=0
rstArray = arcpy.RasterToNumPyArray(out1)
rows, cols = rstArray.shape # Return the rows, columns
for rowNum in xrange(rows): # Loop through the rows
for colNum in xrange(cols): # Loop through the row's columns
value = rstArray.item(rowNum, colNum) # Get the value at the cell
if value==1:
forest=forest+value
else:
other=other+value
forestarea=forest*30*30/1000000
arcpy.AddMessage("Details of Image 1")
arcpy.AddMessage("Forset: " + str(forest) + " pixels")
arcpy.AddMessage("Forset: " + str(forestarea) + " sq km")

#Calculating Forest percentage in image 2
forest=0
rstArray = arcpy.RasterToNumPyArray(out2)
rows, cols = rstArray.shape # Return the rows, columns
for rowNum in xrange(rows): # Loop through the rows
for colNum in xrange(cols): # Loop through the row's columns
value = rstArray.item(rowNum, colNum) # Get the value at the cell
if value==1:
```

```
forest=forest+value
else:
other=other+value
forestarea=forest*30*30/1000000
arcpy.AddMessage("Details of Image 2")
arcpy.AddMessage("Forset: " + str(forest) + " pixels")
arcpy.AddMessage("Forset: " + str(forestarea) + " sq km")
```