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An appraisal of population growth and forest cover change in Rawalpindi using NDVI and Linear regression model

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Abstract

Population growth and vegetation cover have an inverse relationship since population growth promotes human activities, urban expansion, land use changes, which consequently result in forest cover change. Decline in forest cover is a major factor behind climate change and a great environmental challenge for the present day world. The present study was an attempt to analyse the change in forest cover led by population growth in Rawalpindi division of Punjab-Pakistan during the last 25 years. The Data for population was obtained from Punjab Bureau of Statistics, Lahore. Landsat satellite images were used to assess the forest cover change temporally for the years 1990, 2000, 2010 and 2015. The normalized difference vegetation index (NDVI) technique was used to monitor the forest cover change and the linear regression was applied to find out the relationship between population growth and forest cover change within the study area. The results reveal that population grew up to 67.4% during 1990 to 2015 and due to this rapid population growth, the south western and south central part of the Rawalpindi division has witnessed great changes in vegetation cover and on overall basis the region is experiencing continual forest degradation especially after year 2010. The results of linear regression also confirm the strong relationship found between population growth and vegetation cover change within the region. The results of the study can help in further advancement for developing workable policies for forest cover conservation and management in the Rawalpindi region.

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Introduction

Human beings-the most important developmental modifiers of the modern world yet regarded as the chief source of change in Nature and sole responsible for environmental degradation as well. The exponential population growth is the main contributor for putting enormous pressure (Mittal, 2013) on the environment in the form of accelerated human activities, urban sprawl, land use changes, and as a result is leading towards alteration of ecosystems, decreased water supplies, depletion of natural resources and forest cover change (Ahmad *et al.,* 2012). Forests are essential for the stability of natural environment and human survival as well as other visceral lives. However, these continuous environment purifiers and home to wild life (Nwakile *et al.*, 2017. Ikehi 2015) are currently greatly endangered owing to unnecessary wood cutting and clearance of forest land for other land uses (Misra *et al.,* 2014).

Pakistan falls in those countries where natural forest resources are scarce due to diversity in topography and dry climatic conditions; however, deforestation and forest degradation rates are very high because of unsustainable anthropogenic activities specifically in the mountainous area. Forests in Pakistan hardly cover an area of 16,440Km² making hardly up to 5% of the total land area of the country (Mehmood *et al.* 2017). Great dependence on Fuel wood (Ali and Benjaminsen, 2004) forest conversion into agricultural and urban land uses are the main reasons behind less forest cover in Pakistan. Rawalpindi division is the most thickly forested part of the Punjab province mainly dominated by coniferous, riverain, scrubs and deciduous forest types. During the last few decades, the region has witnessed rapid population growth and high rate of urbanization triggered by unplanned migration which adversely affected the forest cover over there (Iqbal and Iqbal, 2018).

Knowing the significance of forest protection and need of sustainability, many scholarly researches have been conducted to determine forest cover change by using modern techniques e.g. remote sensing since it provides a synoptic and systematic earth cover view at consistent intervals of time and is very beneficial for land cover assessments and reveals different aspects of biological variations (Kumar, 2011). Vegetation bearing regions can be highlighted through many indices by remote sensing by which Normalized difference vegetation index (NDVI) is the most common flora index extensively used to study forest cover change and to observe the relation in vegetation growth frequency and spectral variability. It is very beneficial to determine the production of green flora as well as to detect vegetation variations and widely applied to assess the vegetation condition and efficiency in diverse ecosystems (Nnaji *et al.,* 2016, Ghebrezgabher, 2016, Gandhi *et al.,* 2015, Jin *et al.,* 2013, Atzberger, 2013, Tan *et al.,* 2010).

Unfortunately, very few researches are available on Rawalpindi who studied the pattern of natural vegetation and temporal changes at smaller scale i.e. either at tehsil or district level. Therefore, due to gap found in literature, the present study was conducted to assess the change that took place in forest cover due to population growth in Rawalpindi division during last 25 years through applying NDVI and further supporting by Linear regression model.

Materials and Methods

Selection of study area

The present study was performed in the Rawalpindi division of Punjab province, Pakistan (Fig. 1). It is situated between 32° 30" to 34° 10" North latitudes and 71° 45" E to 73° 45" East longitudes. The division is bounded from north by Margalla Hills and the Kala-Chitta Ranges, from west by River Indus, from east by River Jhelum while Salt range is present on the southern side. Its total land area is approx. 22,254Km² and general elevation lies between 472-610 meters above mean sea level. Administratively, the division is consisted of 4 districts and 22 tehsils (Fig. 2). Generally, Rawalpindi division experiences intense climate with regional variations from hot to warm summers and mild to cool winters with great annual rainfall diversity ranging between 21 to over

60 inches (Iqbal and Iqbal 2018). It is one of the most populous zones in the province with total population size approx. 89,560,000 and average annual growth rate of 2.17% (GOP, 2015).

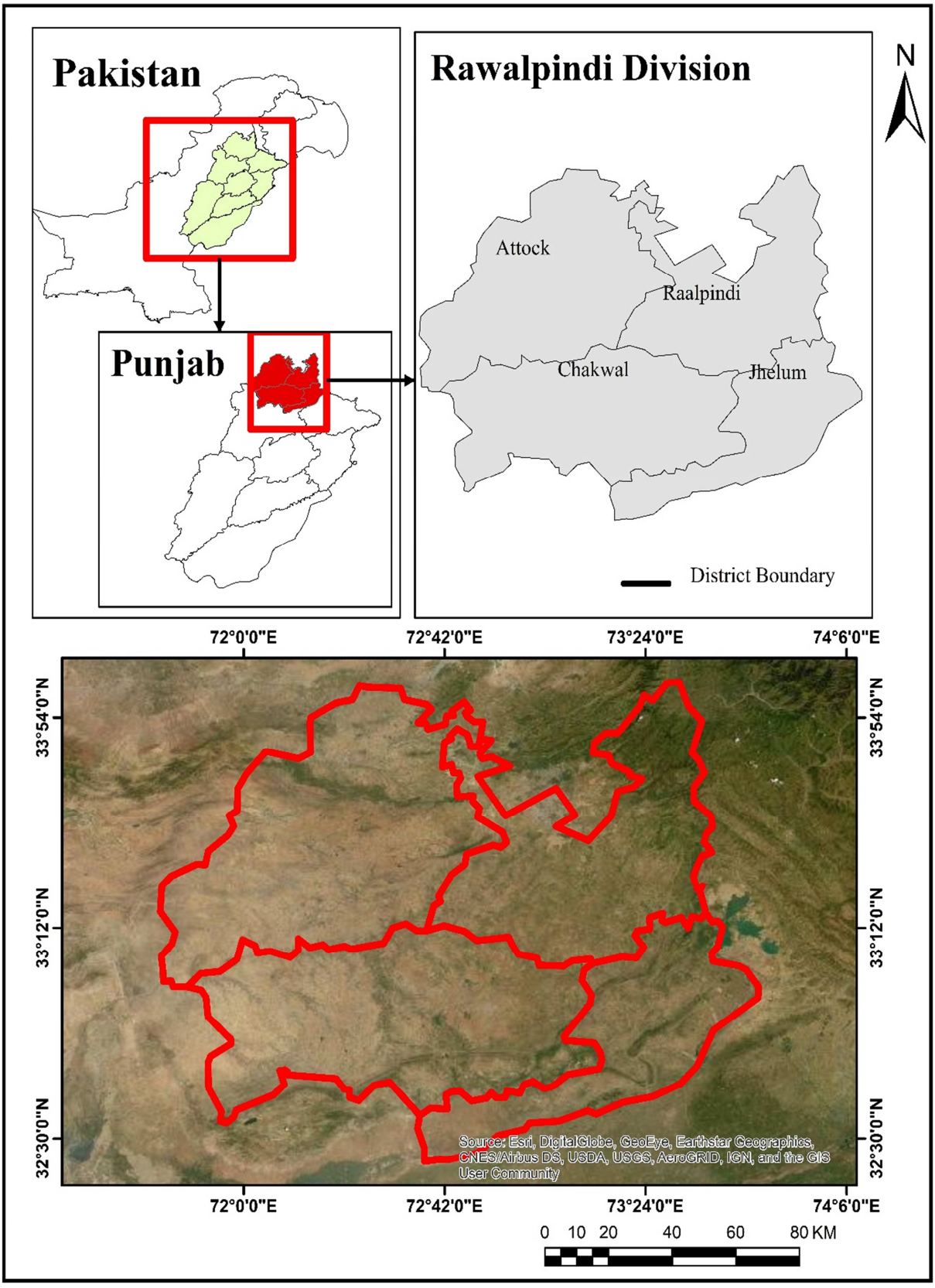

Fig. 1. Rawalpindi Division - The study area.

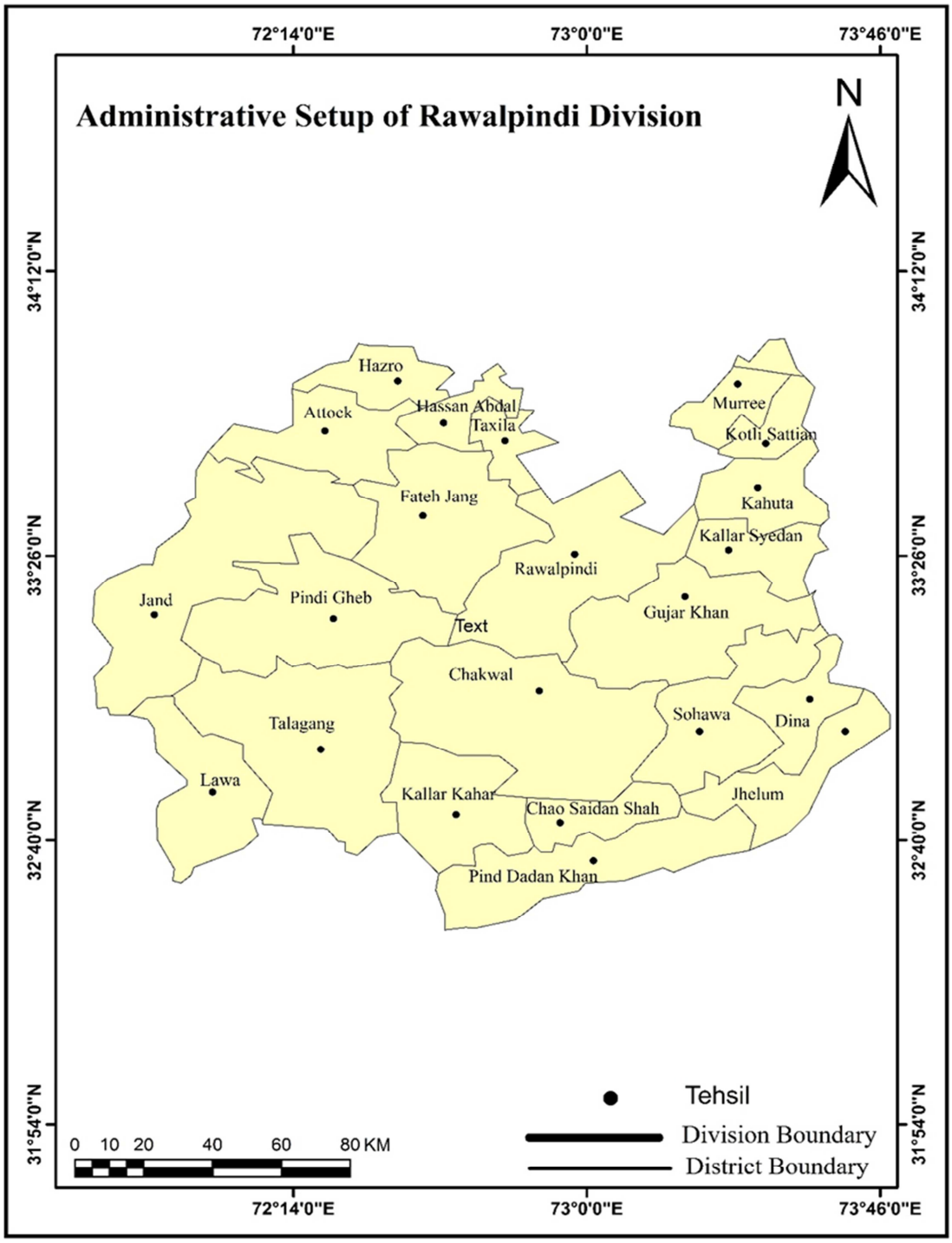

Fig. 2. Administrative units of Rawalpindi Division.

Data collection and data analysis

Keeping in view the nature of research, the present study was an empirical research mainly based on secondary data sources. Firstly, for the assessment of forest cover change 04 Landsat images with 30 and 15 meters resolution were downloaded from Earth Explorer via accessing the website of United States Geological Survey (USGS) for years 1990, 2000, 2010 and 2015 (see Table 1 and Fig. 3). The downloaded images were mosaicked through mosaic tool in ArcGIS 10.5 and were further enhanced to generate NDVI. To calculate NDVI the following equation was used (Meneses-Tovar 2012):

$$NDVI = \frac{NIR-RED}{NIR+RED} \quad (1)$$

Table 1. Characteristics of Satellite images used for NDVI.

Year	Data	Bands	Spatial Resolution (m)	Thermal Resolution (m)	Path/Row	Date of acquisition
1990	TM	1-5&7 6	30 -	- 120	150/36,37 151/37	11-06-1990
2000	ETM+	1-5&7 6 8	30 - -	- 60 15	150/36,37 151/37	14-06-2000
2010	TM	1-5&7 6	30 -	- 120	150/36,37 151/37	18-06-2010
2015	OLI +TIRS	1-8 Pan(9) 10-11	30 15 -	- - 100	150/36,37 151/37	16-06-2015

Source: http://landsat.usgs.gov

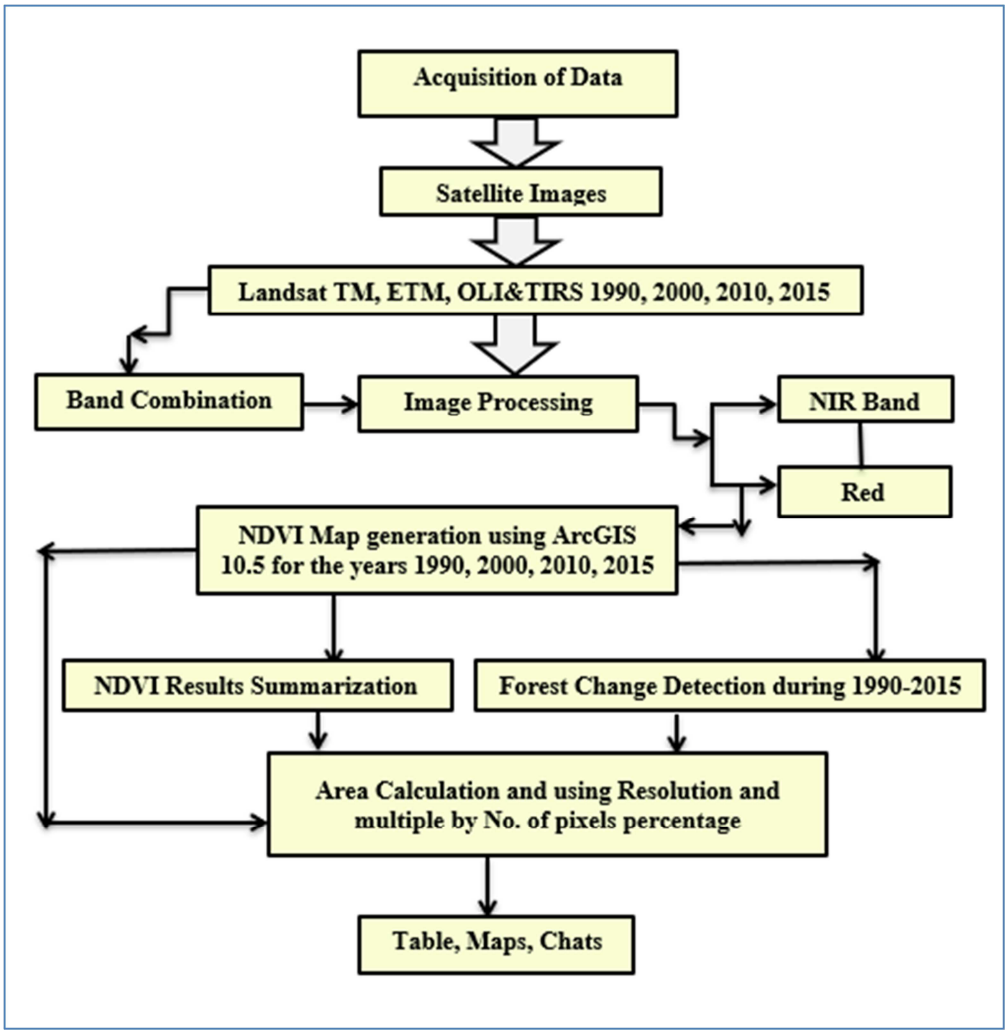

Fig. 3. Methodology used for NDVI.

The procedure was utilized to locate the vegetation cover of the study area and the changes occurred during the reference period by setting the threshold of NDVI image. However, since bands articulate in wavelengths in order of 1µm. Therefore, with assistance of the four visible arrays (middle infrared, visible blue and thermal infrared) other features were extracted and only three observable bands (near infrared, visible green and visible red) were utilized.

Secondly, for analysing population growth within the study area, data was obtained from Punjab Bureau of Statistics, Lahore and were processed in MS Excel 365 and SPSS version 22.

A quantitative thematic map was prepared by using ArcGIS 10.5 to show the tehsil wise growth in population that took place within the region during the last 25 years. Moreover, population percent growth and annual growth rates were also calculated by using the following formula:

$$PR = \frac{(V_{Present} - V_{Past})}{V_{Past}} x\,100 \qquad (2)$$

Where

PR = Present Rate

V Present = Present value (Present Population)

V Past = Past value (Past Population)

And for calculation of annual percent growth rate simply PR was further divided on N = the number of years. Moreover, the population size figures of 5 tehsils for year 1990 were not available so there percent growth rates were not included in the research.

Finally, linear regression analysis was used to estimate the correlation between population growth and forest cover change while taking population growth as independent variable and forest cover as dependent variable. For this purpose, the equation of linear regression was used and described as under:

$$Y = \alpha + \beta x \qquad (3)$$

Where

Y = dependent variable value calculated by linear regression (forest cover change)

α = the coefficient freedom showing y dependent on x.

β = the angle coefficient (slope) of regression line, also reflecting the variation of y variable and x variable increase one unit.

x = the independent variable (Population growth)

Moreover, R2 is the coefficient of determination of the variable y, with respect to change of the variable X. The range for R2 lies within 0 to 1. The greater value of R2 shows the dependency of Y on X and subject to change.

Results and discussion

Forest cover changes during 1990-2015

The present study examined the changes occurred in forest cover due to population growth within the study region in past 25 years through NDVI (Fig. 4).

It can be seen from Fig. 4 that during the year 1990, NDVI values ranged from 0.81 to -0.97. Thickest forest cover dominated by dense green color was found in the northeast part of the division including Murree, Kotli Sattian, Kallar Syedan and Kahuta tehsils. While as moderate forest cover was observed in the southern portion of the study area chiefly in Kallar Kahar, Choa Saidaen Shah and Jhelum Tehsils and some scattered patches of vegetation cover distributed in Fateh Jang, and Attock tehsils. However, very low vegetation was noticed in Lawa, Talagang, Jand and Pindi Gheb tehsils.

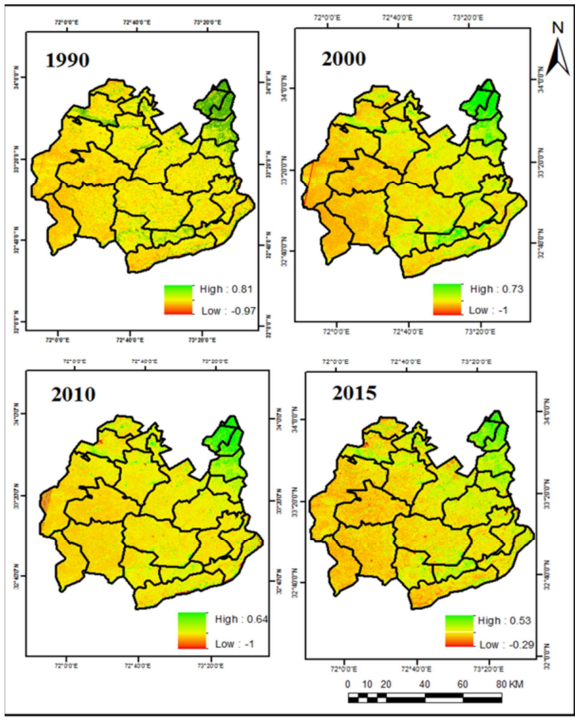

Fig. 4. Forest cover change in Rawalpindi during 1990 to 2015.

In year 2000, the NDVI values were calculated between 0.73 to -1. The lowest NDVI index was found in the western and southwestern parts of the Punjab division. However, the pattern of highest NDVI values was similar to 1990's yet with less color density found in northeast and central-south portions of the region. It can be observed that the overall vegetation cover was lowered within the region, since the lighter green color indicates decreased thickness in vegetation cover.

Furthermore, during the year 2010, the NDVI values ranged between 0.64 to -1 of high and low

class respectively, revealing the overall lowering of vegetation cover within the study area. It is worth mentioning that visible change in forest cover was observed at Kallar Syedan, Choa Saidaen Shah, Jhelum, Kallar Kahar, Attock, Rawalpindi and Fateh Jang tehsils.

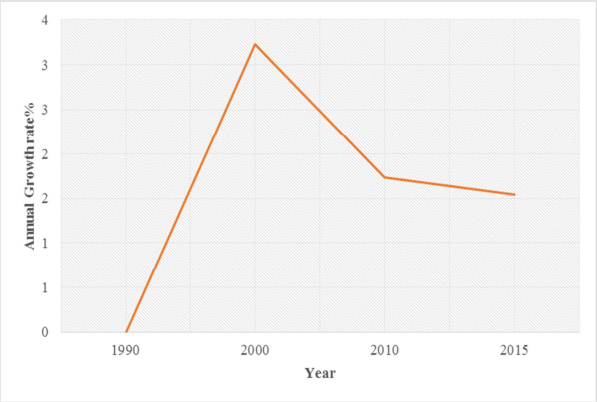

Fig. 5. Annual Growth rate of poulation of Rawalpindi Division.

In year 2015, the NDVI values were calculated between 0.53 and -0.29. Highest values were observed at Murree, Kotli Satian, Kahuta, and to some extent at Choa Saidan Shah. The areas with lowest NDVI values were Jand, Lawa, Pindi Gheb, Talagang and Fateh Jang, Sohawa and Gujar Khan Tehsils.

Population growth in study area from 1990 to 2015

Various scholars focus on overpopulation when they analyse natural resource usage. According to Wilson, "population growth is the raging monster upon the land" (Agrawal, 2012). A remarkable population increase in Rawalpindi division was observed from year 1990 to 2015 (see Table 2). During year 1990, the total population of Rawalpindi division was only 5.35 million which rose up to 7.09 million in year 2000 showing an annual growth rate of 3.23%. While after passing a decade, the population grew up to 8.32 million in year 2010 and registered an annual growth rate of 1.74% (Fig. 5) revealing decreased growth rate yet an increase of 17.36% in the total population size during 2000 to 2010. Finally, in the last reference i.e. year 2015, the population reached up to 8.96 million with an annual growth rate of 1.54%s and an increase of 7.74% in the total population as compared to the previous reference year 2000. It is worth mentioning here that the declined growth rate and less population increase during 2010 to 2015 is mainly due to the five years gap taken because of the limitation of research already mentioned in the previous section. In general, Rawalpindi division showed a growth of 3.61 million people in overall population from 1990 to 2015 with an average growth rate of 2.17%. Furthermore, great regional variations were seen in terms of population percent growth within the study area (Table 3). Highest population percent growth was exhibited by Taxila as its population increased more than 280% during 1990 to 2015. More than 100% increase in population was observed at Jand and Rawalpindi tehsils; hence Pind Dadan Khan, Fateh Jang and Sohawa tehsils recorded more than 50% increase in their population size from 1990 to 2015. Besides, 02 tehsils i.e. Kahuta and Attock experienced a decline of approx. 30% in their population size and Murree tehsil exhibited no change in population in the past 25 years.

Table 2. Population Growth in Rawalpindi Division (1990 to 2015).

Year	Total Population	Decade wise growth (%)	Annual Growth Rate (%)
1990	5,352,000	----	----
2000	7,086,000	32.39	3.23
2010	8,316,000	17.36	1.74
2015	8,960,000	7.74	1.54

Source: Punjab Bureau of Statistics (1990-2015)

However, it was also observed that least increase in percent population was experienced at the tehsils of Pindigheb, Jhelum and Chakwal with not more than 17%. Moreover, due to non-availability of previous data, the percent population increase for Kotli Satian, Dina, Lawa etc. was not calculated. The rank wise position of every tehsil as per 2015 is also mentioned table 3, and the tehsil wise population growth can also be seen in fig. 6.

Table 3. Tehsil wise population growth in Rawalpindi division.

Tehsil	1990	2015	Percent growth (1990-2015)	Rank as per 2015	Tehsil	1990	2015	Percent growth (1990-2015)	Rank as per 2015
Rawalpindi	1613000	3231000	100.31	1	Fateh Jang	178000	279000	56.74	12
Gujar Khan	379000	657000	73.35	2	Murree	275000	275000	0.00	13
Chakwal	564000	626000	10.99	3	Pindigheb	211000	246000	16.59	14
Lawa	0	592000	0.00	4	Dina	0	217000	0.00	15
Talagang	325000	486000	49.54	5	Kallar Syedan	0	210000	0.00	16
Jhelum	405000	461000	13.83	6	Kahuta	288000	203000	-29.51	17
Taxila	116000	441000	280.17	7	Sohawa	128000	195000	52.34	18
Attock	513000	354000	-30.99	8	Hassan Abdal	0	179000	0.00	19
PindDadan khan	213000	338000	58.69	9	Kallar Kahar	0	137000	0.00	20
Hazro	0	323000	0.00	10	Choa Saidan Shah	0	135000	0.00	21
Jand	143000	293000	104.90	11	Kotli Sattian	0	99000	0.00	22

Source: Punjab Bureau of Statistics (1990-2015)

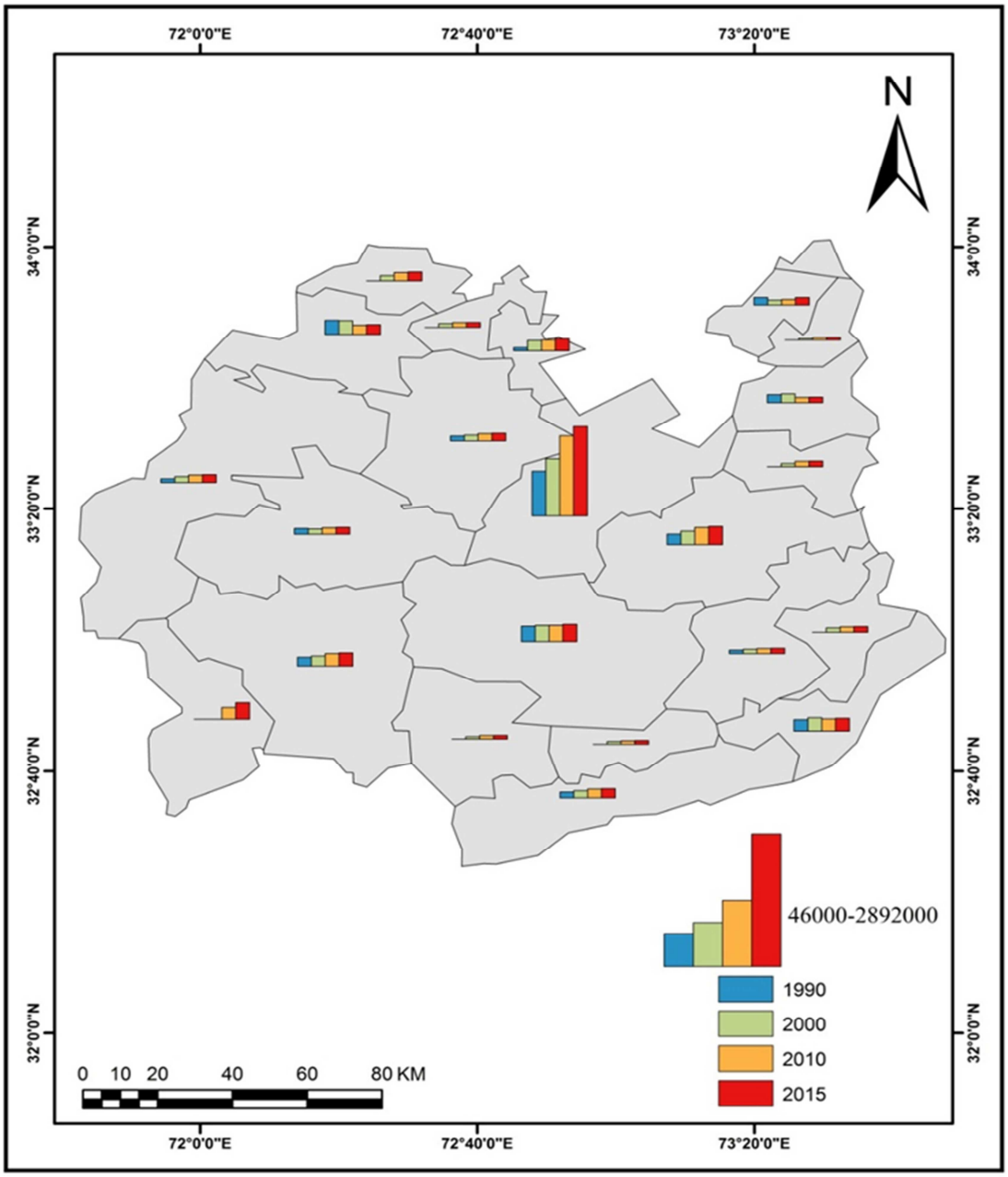

Fig. 6. Tehsil wise population growth in Rawalpindi Division (1990-2015).

Results of Linear Regression

To understand the relationship between population growth and forest cover change linear regression analysis was performed in SPSS (Fig. 7). The results were found very impressive as the value of R^2 was 0.9, indicating strong relationship between the two variables i.e. Population growth (independent variable) and Forest cover change (dependent variable). It is evident that the expansion in densely populated, built-up areas in the division is resulting in forest cover decline in the past 25 years.

Keeping in view, the above mentioned facts it is obvious that growing population size of the study area has resulted in rapid expansion of built-up land due to different factors like growing population, migrations from villages to urban areas, and housing society's developments, education facilities, better job opportunities and provision of better medical amenities, etc. in the study area. These factors are also supported by Arfan (2008) Kamran and Jamil (2008) and Tanvir *et al.* (2006) who concluded that urban growth is increasing in Rawalpindi region at very high rate (Saeed *et al.,* 2011). This bad impact would also lead to climate change and undulation effect would further increase global warming in the forthcoming decades (Siddiqui *et al.,* 2009). The activities, like tree cutting due to intensively household needs and highest market worth (cooking, heating, cooking etc.) forest ailment and futile forest managing etc. are hastening the deforestation rate in watershed part (Naim and Abbasi, 2012; Tanvir *et al.,* 2010).

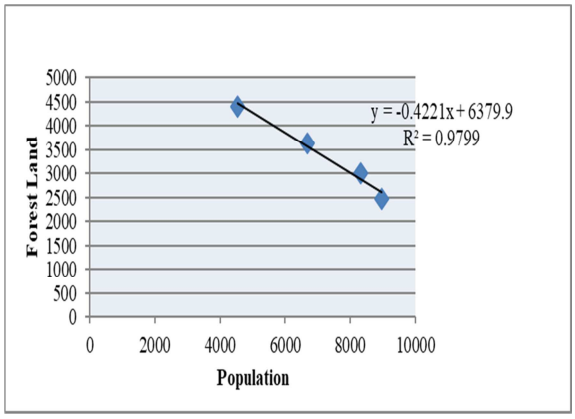

Fig. 7. Relationship between Population Growth and Forest cover.

Conclusions

The present study concludes that Rawalpindi division has witnessed a population growth of nearly 3.61 million people with a percent growth increase of 67.4% from 1990 to 2015 due to natural increase and internal migration patterns. This speedy growth in population instigated expansion in urban settlements, agricultural land and other economic activities like mining and manufacturing all have greatly affected the natural vegetation cover and there is a trend of forest decline particularly after year 2010. This forest cover loss can cause wide and diverse ecological degradation in the division and serious threats for the native biodiversity residing in nearby areas. This problem should be studied to find practical solutions to preserve limited and valuable forestland. The risky zones could be dealt by afforestation and espousing apposite soil-water conservation procedures. Media campaigns and the mass awareness should be launched sporadically for encouraging public to protect the natural reserve heritage of the country. GIS and RS skills can be affectedly used to monitor regular land use land cover alterations and so on.

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Conflict of the Interest

Authors declare no conflict of interest.

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