Geospatial analysis of chilghoza forest in Sulaiman Mountainous Range

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Abstract

Pinus gerardiana (chilghoza) is a rare gymnosperm that grows in dry temperate conditions. It is also considered as a precious species because of its medicinal and economical value. Pakistan is a blessed country with chilghoza forests in Khyber Pakhtunkhwa (KPK), Balochistan, Kashmir and Gilgit-Baltistan. This study was carried out to monitor the chilghoza growing in the Sulaiman Mountainous Region of Sherani district Balochistan, in order to detect the health status and land cover changes of chilghoza from the year 1999 to 2019 by using the techniques of Geographical Information System and Remote Sensing. Supervised machine learning algorithm was employed to classify the seven land cover classes and calculate the area cover occupied by each class and also analyzed the shifting pattern of these classes. While Arc Model was built to check the health status. The results revealed that the area about 174 km² was covered by thick chilghoza in the year 1999, but it decreased up to 84.9 km² recorded in the year 2009, and increased again up to 127 km² in the year 2019. On the other hand, sparse chilghoza occupied an area of 77.5 km², 247.7 km² and 139.9 km² in the year 1999, 2009 and 2019, respectively. These results depicted the decrease in chilghoza cover during 1999–2009 year due to overexploitation and gradual increase in land cover of chilghoza after the year 2009 due to the conservation efforts carried by government and non-governmental organizations. Further conservation and protection are required for this species because it is not only a rare species but also an excellent source for economic benefits on local, national and international scales.

Keywords Chilghoza · Endangered species · Health status · LULC · NDVI

1 Introduction

Balochistan is facing various environmental and ecological problems since past few years. These problems are causing disturbances and changes in land cover and in various ecosystems, including forests of the province and is vulnerable to a much higher extent of such disturbances. Sulaiman Mountain Range in Sherani being the habitat of chilghoza forest needs to be addressed and the forest needs to be assessed in order to check its overall health status and to check whether these changes occurring in the province

has which kind of impact on the forest at large scale which only possible by using integrated techniques of Satellite Remote Sensing (SRS) and Geographical Information System (GIS).

Pinus gerardiana (Wallich ex D. Don) was discovered by a British army official Captain Patrick Gerard in nineteenth-century [6]. It is known as chilghoza in Urdu, and its other names are neoza pine and chilghoza pine. It belongs to kingdom Plantae, class Pinopsida, order Pinales, family Pinaceae, genus *Pinus* and species *gerardiana* [2, 3]. The growth of chilghoza trees is very slow and they are found

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at elevation ranging between 1800 and 3350 m [12]. The height of these trees ranges from 10 to 25 m, and they consist of erect branches, flaky bark and needle-like leaves. The recorded age of chilghoza trees generally ranges from 125 to 345 years [8]. Their cones are 10 to 18-cm long and 9 to 11-cm wide in opening condition and almost 40 nuts are present in one cone [21]. Chilghoza trees generally grow in slightly acidic or neutral soils. Moreover, they require dry temperate climatic conditions for growth [1]. As this specie is a gymnosperm, so it has seeds, but no fruit [17]. Additionally, it is an evergreen tree, so it remains green throughout the year, but its cones start to flourish in month of May and June. The cones ripe in month of September and later on turn in to brown color. Then, the harvesters collect them for nuts extraction and sell in the market [18]. According to International Union for Conservation of Nature (IUCN) red list category, it is currently marked under the near threatened category, as its cover has declined and still continuing to decline [11]. Major threats responsible for this decline are ranching, farming of livestock, overgrazing, logging and timber/wood harvesting [20].

Globally, chilghoza forests are only present in East Asia, South East Asia, West Asia and Central Asia [20]. Chilghoza trees make 20% of Pakistan's total forest cover and are found in Khyber Pakhtunkhwa (KPK), Balochistan, Kashmir and Gilgit-Baltistan [19]. These trees in Balochistan are found in Sherani District at Shinghar, Kaisaghar, Torgar (southern continuation of SMR) and Takht-e-Sulaiman (highest peak of SMR). In this region, Oshka is the local name of chilghoza cone and Zarhghozi or Zanghozi is the local name of its nuts [19]. The communities/tribes living in the SMR are distributed between the Sherani tribe living on the both sides of borders known as Largha Sherani in Khyber Pakhtunkhwa and Bargha Sherani in Balochistan. The Bargha Sherani tribe is further distributed between its sub tribes known as Oba Khel, Chual Khel and Hassan Khel. In Sulaiman Range, the major owners of chilghoza forests are Hassan Khel and Oba Khel and in smaller portion owner of chilghoza forest are Chual Khel. According to traditions and customs in Sherani, every person living in the tribe has equal authority or ownership right over all the resources that are available in that area [21]. *Pinus gerardiana* has various ecological benefits, medicinal uses and economical advantages on local, national and international level. Pakistan earns twenty-five billion rupees each year from fifty countries (including China, Middle Eastern countries, USA, European countries) by exporting chilghoza nuts [2, 3, 16]. Furthermore, Pakistan produced 3,200 metric tons of chilghoza nuts during year 2015–2016, 3400 metric tons during year 2016–2017 and 3700 metric tons during year 2017–2018 [2, 3]. Pakistan is contributing 18% chilghoza production at global level [14].

Remote sensing and GIS are very effective as they provide information of LULC at a particular time and location [4]. The present study aimed to detect the health status and LULC changes of the chilghoza forest from the year 1999 to 2019 using GIS and Remote Sensing techniques. The study was carried out in Sherani district of SMR which is situated in Balochistan province, Pakistan. Sherani covers an area of 2800 km² (1100 sq mi). It is located between 29° 29'59.99" N and 65°39'59.99" E. In Sherani District, a very dense and pure cover of chilghoza forest are found in SMR which ranges from 2700 to 3400 m in elevation. This SMR is an extension of Hindu Kush at junction of three provinces that is Balochistan, Punjab and KPK [5].

2 Materials and methods

An extensive survey was carried out and coordinates were recorded via GPS (Model:62 GPS map) for ground truthing. Secondary data comprise three satellite imageries for the month of May with zero cloud cover and guide map were used for the present study. For the study year 1999 and 2009, imageries of Landsat 4–5 Thematic mapper (TM) consist of seven spectral bands and satellite image Landsat-9 operational land imager (OLI) consists of nine bands having 30 m resolution were retrieved from the USGS Glovis. Normalize difference vegetation index was employed to assess the health of chilghoza forest in last twenty years, whereas LULC was assessed by classifying the satellite imageries of last twenty years to check the cover pattern of chilghoza along with olives and other vegetation in the study area. Imageries were preprocessed by performing geometric corrections using WGS-1984 coordinated system in order to set in new space of reference where every pixel gets equivalent XY value in the determined projection system. Then, imageries were subset by creating the area of interest (AOI) layer. Processing of the imageries was performed using the software of ERDAS imagine 11 v. Supervised machine learning algorithm (SMLA) based on maximum likelihood was employed to delineate the seven classes of each image, including thick chilghoza, sparse chilghoza, olives, vegetation, water, barren and mountains. Class was assigned to each pixel that has the highest probability. Classified pixels were compared with the ground truth data in order to assess how much accurate classification has been done in percentage. For this 256, random sample points were selected on each satellite imagery and compared those pointed pixels with reference geo-coordinate values recorded by GPS device and also verified by Google Earth as well. Parameter for distribution was random. After accuracy assessment, ArcGIS (10.2 v) was utilized to vectorize all classified imageries into polygon and generated the land cover maps for the

year 1999, 2009 and 2019. Analyzing the LULC using the emerging field of technology (Remote sensing and GIS) gives a better understanding of the land cover changes and their causative factors [22] because it cover large scale and can also use to compare present time with previous time data. In this regard, moreover, NDVI (Normalized Differentiated Vegetation Index) was applied using raster calculation and health status maps were also generated.

3 Results

3.1 Accuracy assessment of classification

By using error matrices (confusion matrices) for two decades (1999, 2009 & 2019), the percentage of probability assigned to image pixel and accuracy were checked between selected reference pixels and classified pixels. Omission error (OE) was recorded which shown the pixels of one class which actually belongs to another class. Along with this, commission error (CE) was also recorded which shown the pixels belonging to reference class, but failed to classified correctly. The overall accuracy of the classified images of 1999, 2009 and 2019 was 98.83%, 99.61% and 99.61% respectively. Whereas the Kappa Statistics or Kappa Coefficient showed strong accuracy for the classified images that was 0.984 for 1999, 0.995 for 2009 and 0.995 for 2019 (Table 1).

3.2 NDVI results

The NDVI calculations revealed the health status of chilghoza forest shown in Fig. 1. The calculated values of NDVI were ranging between -1 to $+1$, which showed that vegetation < 0.5 VI is poor in health and vegetation having ≥ 0.5 – 1 depicting good health. In the year 1999, NDVI values were ranging 0.23 to 0.58 for dense vegetation, 0.13 to 0.23 for medium vegetation and 0.06 to 0.13 value was recorded for sparse vegetation. Moreover, significantly lesser value (≤ 0) was recorded for the rocks and barren area. On the other hand, health status was improved in the year 2009 marked by NDVI values (0.26–0.60 for dense vegetation, 0.17–0.26 for medium vegetation, 0.10–0.17 for sparse vegetation). Whereas in the year 2019, the observed NDVI values were 0.24–0.49

for dense vegetation, 0.18–0.24 for medium vegetation, 0.14–0.18 for sparse vegetation.

3.3 Land use land cover

The LULC map of year 1999 (Fig. 2a) revealed that the major class was mountain occupying 473.3 km² area, followed by thick chilghoza covered 174 km² area. Moreover, water covered the area about 165.3 km², olive occupied 136 km² and barren had 117.9 km² area. Additionally, sparse chilghoza occupied 77.5 km² and the class of vegetation covered the least area about 33.4 km².

Similarly the major class cover was the mountain occupied the 400.6 km² area in the year 2009 shown in Fig. 2b. whereas sparse chilghoza covered the 247.7 km² area, followed by class of olive which occupied the area about 136.6 km², vegetation occupied 116.9 km² area, barren covered 101.4 km² area, water covered 89.6 km² and thick chilghoza was the least class cover occupied the 84.8 km² area. LULC map in Fig. 2c showed that the major class in the year 2019 was mountain occupied 343.4 km² area. The second major class cover was olive which occupied the 202.4 km² area whereas sparse chilghoza had 139.9 km² area, vegetation had 137.2 km² area, thick chilghoza had 127 km² and water occupied the 122.3 km² area. The least class cover was barren (104.4 km²).

3.4 Land shifting (1999–2009)

Map in Fig. 3 revealed the shifting of cover classes to other classes during the decade (1999–2009). The most prominent and major shifted class was barren cover (86.39 km²) which shifted in to mountain class and most area of mountain class get shifted into vegetation (49.9 km²), while 49.3 km² area of olives class shifted into mountain cover. It has apparent that there has been 51% decline of thick chilghoza, and its 29.55 km² has transformed into sparse chilghoza, while 15.51 km² has transformed into mountain cover. Along with this, other classes like water, barren and mountains were declined up to 45.8%, 14% and 15.4%, respectively. The decrease in water was brought by shifting of 26.53 km² into vegetation cover and 19.90 km² area into mountain. The decrease in barren area occurred mainly due to its transformation of area about 86.39 km² into mountain cover. Whereas the decline in mountains cover was due to the shifting into various classes including 49.9 km² area into vegetation class, 29.65 km² area into water class and 12.79 km² into sparse chilghoza. On the other hand, vegetation and sparse chilghoza experienced extreme increase in 250% and 219% respectively.

Vegetation has increased due to shifting of mountain (49.9 km²) and water class (26.53 km²) into vegetation. On the other hand, sparse chilghoza has been increased in the

Table 1 Overall accuracy and Kappa statistics for classification

Accuracy assessment	Classification years		
	1999	2009	2019
Accuracy (%)	98.83	99.61	99.61
Kappa statistics	0.984	0.995	0.995

Fig. 1 NDVI map showing health status for chilghoza forest in year a. 1999, b.2009, c. 2019

year 2009 due to shifting of various classes like 29.55 km² area of thick chilghoza, 19.13 km² area of olives and 16.52 km² area of vegetation. Olives remained almost same and experienced only 0.4% increase in the year 2009.

3.5 Land shifting (2009–2019)

According to the map shown in Fig. 4, shifting of all classes into other classes has occurred from the year 2009 to 2019

Fig. 2 LULC map showing class cover in year **a** 1999, **b** 2009, **c** 2019

Fig. 3 Map of land classes shifting (1999–2009)

Fig. 4 Map of land classes shifting (2009–2019)

but only the shifting of barren area into thick chilghoza has not taken place. The area of vegetation about 60 km² has shifted into mountain class which marked as the major transformation. After this, the most transformation is of sparse Chilghoza (52 km²) into vegetation. Thick chilghoza cover has shown 49.8% increase due to shifting from the class of sparse chilghoza (42.4 km²) and olives (13 km²). Olives have increased up to 48.2% and the classes contributed to this increase were vegetation (46.2 km²), sparse chilghoza (44.3 km²), mountain (38 km²) and thick chilghoza (12 km²). Vegetation increased up to 17.2% which involved the transformation of 52.1 km² area of sparse chilghoza, 33.2 km² area of olives and 14.12 km² area of mountains into vegetation..

Moreover, water increased up to 36.5% by the shifting of 25.06 km² area of mountains and 14.13 km² area of barren area. Barren land also increased up to 2.96% because 15 km² area of mountains has shifted into the barren class cover. In the year 2019, only sparse chilghoza and mountains were the classes which shown decline which was of 43.5% and 14.3%, respectively. Sparse chilghoza shifted into various classes like 52.1 into vegetation, 44.3 km² into olives and 42.44 km² into thick chilghoza. While mountains experienced the transformation of its 38 km² area into olives, 25.06 km² into water, 24.2 km² into sparse chilghoza and 14.12 km² into vegetation.

4 Discussion

The causes and trends of LULC are dynamic, complex and change over time [13]. These changes in land use and land cover occur due to natural as well as socio-economic factors [22]. In the concerned years of this study (1999–2019), thick chilghoza cover has been changed in the demarcated study area. In the year 1999, thick chilghoza covered the area about 174 km² but decreased up to 84.78 km² in the year 2009 which means it experienced 51% decline. This decline involves the transformation of 29.55 km² area of thick chilghoza into sparse chilghoza cover and 15.51 km² area into mountains. In the year 2019, thick chilghoza gone through 49.8% increase and became 127 km² which involved the shifting of 42.44 km² area of sparse chilghoza and 13 km² of olives into thick chilghoza. This increase represents decreased cutting and reduced burden on the chilghoza trees which occurred due to a number of reasons. One of the reasons is the frequent shifting or migration of people from Sherani District to other areas since past few years, for achieving an urbanized life (having facilities, updated lifestyle, education etc.) [19]. Additionally, Sherani District experiences continuous sunlight especially in summer, so solar panels are good option to replace the forest timber for heating purposes. In this regard, some

NGOs have given solar panels and solar geysers to some of the people. This created awareness in the communities regarding the use of efficient and renewable solar energy and people themselves started to install such things like solar panels, solar geysers and solar stoves in their homes [19].

Moreover, World Wide Fund (WWF) has initiated a conservation project for chilghoza forest in the SMR in the year 1992. During this conservation project, a Jirga (local meeting with elders of the community) was held in which an agreement was decided that cutting of Chilghoza trees would be banned and the only wood permitted to extract would be dry wood. In case of violation of the agreement, 100 US dollars per tree was decided to be charged from the local people [5].

Additionally, incentives were also provided by WWF to the local communities in order to encourage them for the conservation of chilghoza forest. Afterward, the local people started to realize the importance of chilghoza trees when the Pakistani chilghoza nuts got international popularity and large scale export activities of the nuts has started and this resulted in reduction in the over exploitation of chilghoza forest [19]. Sparse chilghoza has shown opposite changes as compared to thick chilghoza. It covered 77.5 km² in the year 1999, 274.66 km² in the year 2009, while in the year 2019 it covered 139.9 km² land area. So in the year 2009, it experienced very prominent increase about 219% as various classes like 29.55 km² area of thick chilghoza, 19.13 km² area of olives and 16.52 km² area of vegetation have shifted into sparse chilghoza. Whereas in the year 2019, it decreased by 43.5% and shifted into various classes like 52.1 km² area into vegetation, 44.3 km² area into olive's cover and 42.44 km² into thick chilghoza. As chilghoza tree is slow growing and generally grows only 12 inches per year in ideal conditions, hence till the year 2009 the trees did not grow fully and did not formed dense canopies and remained sparse [7]. But in the year 2019, those sparse trees continued to grow and converted into fully grown thick chilghoza cover. Cover of olives occupied the area about 136 km² in the year 1999, 136.6 km² area in the year 2009 and 202.4 km² area in the year 2019. This revealed that the class cover of olives shown almost no change in the year 2009. But in year 2019 the olive trees increased up to 48.2% and the classes contributed to this increase include 46.2 km² area of vegetation, 44.3 km² area of sparse chilghoza, 38 km² area of mountains and 12.1 km² area of thick chilghoza. The major reason of this increase was the plantation of new olive trees that started by Government officials including Governor Balochistan [10]. Hence various plantation campaigns were started for the olive production. One of the campaigns was initiated in the year 2018 by Pakistan Agriculture and Research Council (PARC) with the motto of

planting 120,000 olive trees in Balochistan Province [15]. The growing agricultural activities in Sherani District have been resulting in to increased land utilization for agricultural practices. Along with this, the wild plants also keep growing on lower elevations as well as on mountains. Due to these factors, vegetation experienced increasing trend throughout the concerned years (1999–2019) as it had 33.4 km² area in year 1999, 116.9 km² in the year 2009 and 137 km² area in the year 2019. Vegetation increased about 250% as 49.9 km² area of mountains and 26.53 km² area of water were transformed into vegetation. Moreover the transformation of 52.1 km² area of sparse chilghoza, 33.2 km² area of olives and 14.12 km² area of mountains into vegetation resulted into 17.2% increase in vegetation cover in the year 2019.

Water occupied 165.3 km² area in the year 1999, but it was decreased up to 45.8% and left with 89.6 km² area in the year 2009. This decline was brought by shifting of 26.53 km² area of water cover into vegetation cover and 19.90 km² area into mountains. Sherani District experienced more precipitation during the year 2019 as compared to the year 1999 and 2009. This was major reason for the increased water cover in the district and increased water channels overall (on lower and higher elevations) which were previously dried up due to the insufficient precipitation. Hence there was 36.5% increase in water and it occupied 122.3 km² area in the year 2019. This change was brought by the shifting of 25.06 km² area of mountains and 14.13 km² area of barren area.

Changes in the barren class have also appeared as it covered total 117.9 km² land area in the year 1999, but eventually due to its shifting into mountains about 86.39 km², 14% of its area has reduced and the total area occupied by the barren class became 101.4 km² till the year 2009. Conversely, in the year 2019 the barren class increased up to 2.96% and occupied 104.4 km² which was mainly due to the transformation of 15 km² of mountains into barren area. For purpose of land formation for infrastructural development, mountainous regions were exploded with blast [9]. One more reason for conversion of mountains into barren area was the rapid road construction in Sherani District.

It is evident that mountains cover has decreased throughout in the concerned years as they occupied 473.3 km² area in the year 1999, 400.56 km² area in the year 2009 and ultimately further decreased up to 343.4 km² in the year 2019. This decline in mountain cover was due to the planting trees (49.9 km²) on mountains, increased water cover (29.65 km²). The further decline of 14.3% in the year 2019 was brought by the conversion of 38 km² area of mountains into olives cover, 25.06 km² area into water cover, 24.2 km² area into sparse chilghoza and 14.12 km² area into vegetation. This decline has resulted because

of the vegetation growth (mainly wild plants), increasing water channels and growth of trees (chilghoza and olives) on mountains.

5 Conclusion

The results of present geospatial analysis showed that all classes have experienced either increasing or decreasing changes during the years of 1999 to 2019. Chilghoza cover which is the main focus of this study has experienced land changes. Sparse chilghoza cover has increased in the year 2009, but decreased in during the decade of 2009–2019. While thick chilghoza cover has declined in the year 1999 but increased again in the year 2019 due to the conservation initiatives taken place by Government and NGOs in District Sherani. This rare specie still needs further conservation and protection efforts in every place where it exists because it is not only rare but also an excellent source for economic and monetary benefits on the local, national and international scales. Ultimately, by focusing on the protection and growth of chilghoza forests, their status can be improved and can be taken out from the “near-threatened” category of IUCN red list.

Compliance with ethical standards

Conflict of interest The authors have no conflict of interest.

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