MAPPING OF HALOPHYTES AND CHANGE DETECTION ANALYSIS OF KARACHI COAST USING GIS AND REMOTE SENSING

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ABSTRACT

Vegetation of the coastline plays a crucial part, as plants are the stabilizer of sand dunes that anticipate the disintegration of coast. The natural vegetation at the coast devastatingly reduces, because of the urban sprawling and overutilization of land resources. The assessment of vegetation through Geographical Information System and Remote Sensing (GIS and RS) at the coastal areas of Karachi has not been deeply studied yet. The main aim of the study was to mapped the identified halophytes (salt tolerant plants) based on ground survey through Nikon Coolpix built-in GPS camera and Change Detection (CD) analysis of the study area from of Landsat images from 1989-2018 by using NDVI. Approximately, thirty different species has been identified through geo-tagged images. The obtained results revealed that the CD analysis confirmed that the remarkable variation observed in vegetation distribution, which might be depends largely upon the amount of downpour. Moreover, the study area of 1989 was 133.78 km2 which coverage vegetative proportion about 12.58 km2, while increased up to 141.3 km^2 in 2018 and vegetation coverage increases by 15.4km^2. Overall, the vegetation coverage was observed highest 21.7km^2 during 1994. Prominently mangroves increase at the mouth of Liyari River which was the major source of sewerage water, directly dumped into Arabian Sea. It's not easy to detect halophytes through Landsat images (30m resolution), Hyperspectral data is mandatory for the study of halophytes as most of them are grasses, herbs and shrubs.

KEYWORDS: Change detection, halophytes, Geographic Information System (GIS), Remote Sensing (RS), Normalized Difference Vegetation Index (NDVI).

INTRODUCTION

Coastal areas of the Karachi are the most profitable and negligible zones. Utmost coastal area is land filled by sea reclamation at the cost of removal of mangroves for the accommodation of elite society, recreation and for the construction of port. Though its beneficial for the urban economy but the removal of wild vegetation (salt tolerant plants, even survive on air moisture) causes many problems, from urban heat to disturbance of biodiversity of the coastal area. Halophytes (salt tolerance plant) at the coasts of DHA and Clifton bulldozed occasionally but at the coasts of Hawks bay and Sandspit, mangroves and other halophytes are thriving although anthropogenic activity is at the peak. Globally population of the world is flourishing, human intervention is immensely expanding and creating environment unbearable for the living things as numerous plants species and other creatures are forcefully terminated at the disturbing proportion (Cho *et al.,* 2021). Major causes of land degradation are human interventions such as mining, cutting of forest for fuel, decline of agriculture areas and removal of the wild plants for the advancement. Major threats to natural vegetation are urban development, agricultural activities and climate change can be recognized but their extent is unknown by the environmentalists (Eppink *et al*., 2004; MacKay *et al.,* 2009). Eco-physiological constraints are crucial issues of the environmental land degradation (Thomas, 1997). Influence of human activities and disparities of the climate in the arid and semi-arid regions are the leading source of degradation of land (Ahmad, 2002; Kertész, 2009). Halophytes are salt resisting plants capable to reproduce and thrive harsh saline environment and great indicator of salinity (Radyukina *et al.,* 2007; Flowers *et al.,* 2010). Salt tolerant plants have the capability to lower the water table, survive water logging conditions, saline land and barrage areas, but obtained lower production than healthier soil (Barrett-Lennard, 2002; Vermue *et al.,* 2013; Bui, 2013). Salt enormously effects the generative development of halophytes and it upsurges the production because of plants hormones, nutrition, and regulation of floral genes that can be transfer to the crops for saline agriculture (Yuan *et al.,* 2019). There are almost 2,200 halophytes (Menzel and Lieth, 1999) in Pakistan around 19% of the flora are halophytes, only minute data is available (Alam and Ali, 2010).

According to Gibbons *et al.* (2006) identification and mapping of natural vegetation is a chief problem for the management of conservation and biodiversity. Conventionally, landscape mapping through ground true thing is time taken and affluent. In this respect, remote sensing is better solution for the mapping of natural vegetation (Xie *et al.,* 2008). In the former study (Lu *et al.,* 2004) stated that the degradation of Earth’s surface can be monitor through satellite and airborne images which can relate correlations between anthropogenic and environmental spectacles, hereafter natural resource can be benefited. Remotely sensed data provide comprehensive and accurate details within range for the mapping and classification of vegetation. According to Foody (2002) stated that Land Cover (LC) is vital variable that effects enormously and associated with the physical and human environment. Furthermore, the LC change is the utmost variable of the changes in globe which greatly affect the ecological and environmental system is linked with the change in climate López *et al.* (2020). Evaluation and mapping of land cover is the fundamental part of application of remote sensing data (King, 2002). Al-Bakri *et al.* (2011) mapped the medicinal plants through GIS layers of aspects, slope and altitude. Ghobadi *et al.* (2012) observed a reduction of wetland area in order to conserve the biodiversity and ecosystem monitored through the Landsat data in cooperated with GIS. Ground data unified with GIS layers to identify the hotspots of conservative area of medicinal plants. Roy *et al.* (2015) developed map of India through remote sensing to show the type of vegetation in terms of existence, habitation and their distribution incorporated with the past 100 years temperature, rainfall and elevation ranges.

Singh (1989) defines change detection as it is a technique that can easily detect the changes in any area at different time scale, so that advances of ecosystems can effortlessly identify at topographical and time-based scales through different satellite images. It is obligatory to recognize the nature of the changes than to recognize the change, as in the terrestrial ecosystem changes can be illustrated scientifically and constantly through remote sensing (Coppin *et al*., 2004; Coops *et al*., 2006). In the study of remote sensing data change detection is a significant component of developments. Anderson (1977) and Aplin (2004) focuses on the exactness and likelihood of the image analysis application. Fisher *et al.,* (2005) emphasis that the through remote sensing techniques, land-cover changes can be detected disparities on the Earth's surface. Furthermore, vegetation indices such as NDVI (Normalized Difference Vegetation Index) and PCA (Principle Component Analysis) can perform better for the analysis of change detection (Ward *et al.,* 2000; Deng *et al.,* 2008). For the monitoring of vegetation use of NDVI was frequent. Malo and Nicholson (1990) revealed that at canopy level of the plant NDVI is interconnected to confrontation and transmission of water vapors. Wessels *et al.* (2004) demonstrate that the occurrence of photo-synthetically active radiation can uniquely be characterizes by NDVI as it can

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easily capture the obvious divergence among the red visible wavelengths and strong reflectance in the NIR (Near Infra-Red) wavelengths. Mambo and Archer (2007) revealed that normalized difference vegetation index has been extensively used for the recognition and monitoring of the variations in environment, it is the spectral vegetation index that can easily evaluate the moisture content of soil and vegetation. Meneses-Tovar (2011) mentioned that the health of the vegetation can be specified by NDVI, with the degradation of vegetation in the ecosystem, with the decrease of reflectance NDVI also decreases. It is essentially recognized as the tool to monitor the land degradation of the land and is interlinked with the growth, environmental conditions and vegetation parameters (Huang *et al.,* 2010). Al-Usmani (2018) investigated the LC changes of mangroves in India through RS and GIS. López *et al.* (2020) assessed the different indicators of changes in landscape and evaluate the Land Cover and land use in mixed-use protected area of Ecuador. Therefore, the main objective of this present work was to elucidate the mapping of halophytes (salt tolerant plants) at the coast and documented through GIS and Remote Sensing at Karachi.

MATERIAL AND METHODS

Study area

The mega city Karachi has been considered the prime and extensive metropolis of Pakistan. It is among the globe fastest developing city situated along the shoreline of Arabian Sea (24° 51`36" N and 67° 00` 36" E; Figure 1). Karachi is Pakistan's major economical hub and export processing zone having two principal docks, the Bin Qasim Port and KPT. Coastal area of Karachi, is carefully chosen as the study area. Karachi have extensive period of drought and rainfall is scarce as it causes pressure on the vegetation of the land. Throughout the year weather is parched in Karachi with minute precipitation which is less than 220 mm annually. Climate and oceanography of the coasts are meticulous by the periodic changes in the Arabian Sea. Spell of rainfall is very low in Karachi cause of aridity. *Halopyrum mucurunatum, suaeda fruticosa* is common at the coast of Clifton and DHA whereas mangroves *avecina marina*, *salvadora persica*, *Arthrocnemum macrostachyum* are common near the coast of Hawkesbay. Discrepancy on coast and inland has been observed in the environment of the study area. Karachi endures an extensive hot summer from March-October, but rainy season winds bring sensible heat in July and August (Figure 2).

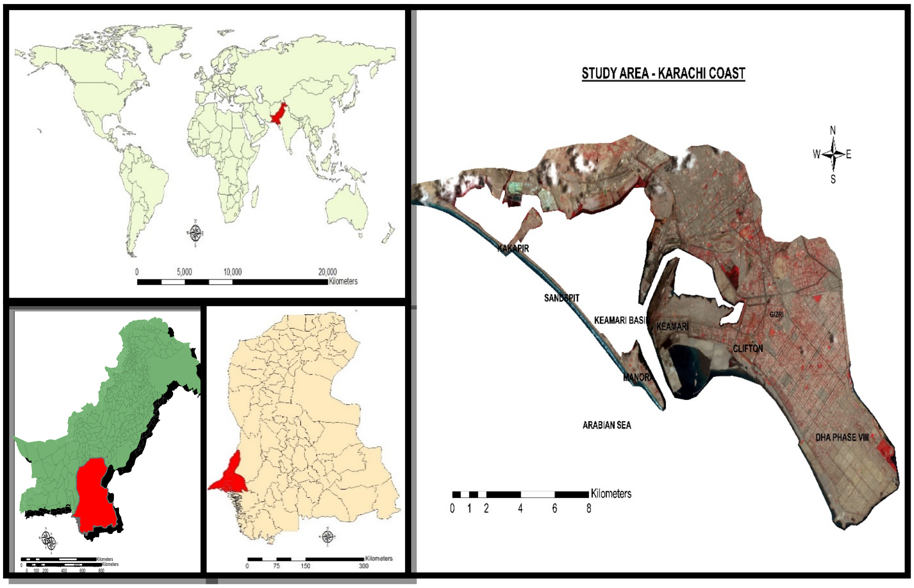

Fig. 1: The geographical map representing the study area of Karachi.

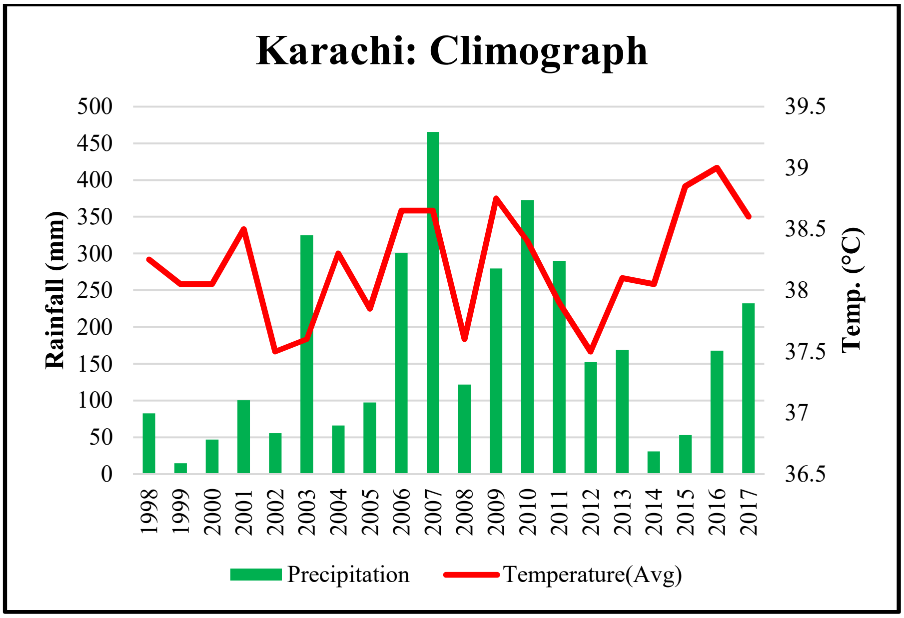

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Fig. 2: Climograph of Karachi showing average temperature and rainfall.

Methodology

The series of Landsat data has been used as Landsat MSS, Landsat TM, and Landsat ETM+ acquired in the year 1989, 1994, 1999, 2004, 2009, 2014 and 2018 respectively (Table1). In remote sensing, Landsat data been used in different application of coast (Ritchie *et al.,* 1990; Munday and Alföldi, 1979). Multispectral data is capable of observing and measuring the biophysical characteristics of habitats of coast whereas multi-temporal is capable of tracking changes over the time scale (Colwell 1983; Wang and Moskovits, 2001). Natural vegetation is often manipulating in the study area, tried to get as many halophytes as possible at and near coast. Plant samples were taken via surveying of dissimilar stands as per the accessibility of chosen species (Figure 3). Furthermore, different species of halophytes are enlisted and geotagged through Nikon Coolpix camera at the beaches of Clifton, Sandspit and Hawkesbay.

Table 1: Acquisition dates of satellite images.

NO.	Acquisition Dates	Sensor
1	31-Dec-1989	Landsat 5_TM
2	29-Dec-1994	Landsat-5_TM
3	11-Dec-1999	Landsat-5_TM
4	30-Nov-2004	Landsat-7_ETM
5	30-Dec-2009	Landsat-7_ETM
6	12-Dec-2014	Landsat-8_OLI/TIRS
7	15-Dec-2018	Landsat-8_OLI/TIRS

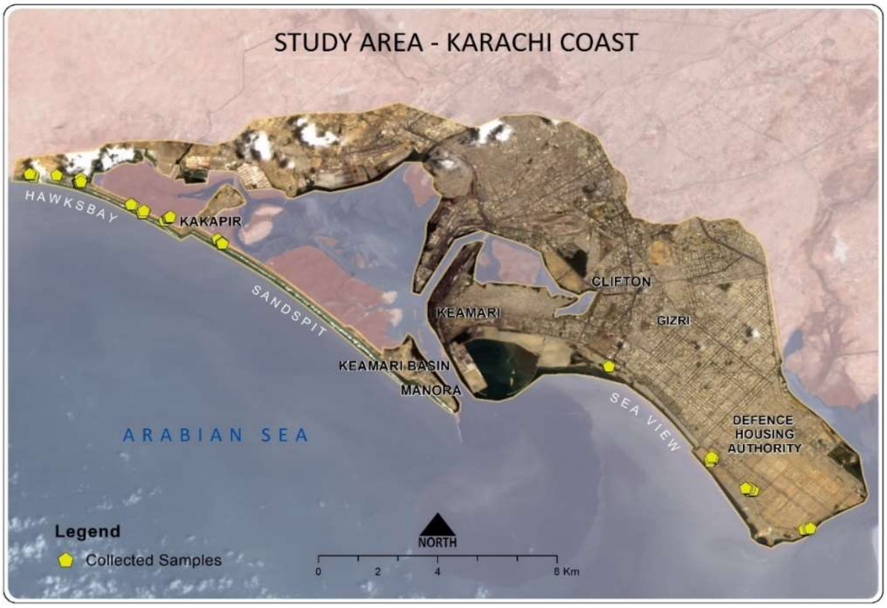

Fig. 3: Part of Coastal areas of Karachi with Distribution of Halophytes shows the location where the different halophytes species have been identified.

Landsat images have been downloaded from the website of Earth explorer (USGS). All the images acquired from 1989 till 2018.Area of Interest (AOI) of all the imageries were clipped through ArcGIS-10.3.1, NDVI being measured by using raster calculator via the equation,

NDVI=(NIR-Red) /(NIR+Red)

Where, band-4 indicated NIR and red denoted the band-3 of landsat-5 and 7, whereas NIR represented band-5 and red denoted the band-4 of landsat-8. The value of the NDVI ranges was detected from -1.0 to 1.0. In addition, the results of NDVI levels from -1.0 to 0 characterize non-vegetative structures as barren land, built-up area and water body. On the other hand, the NDVI level was greater than 0 which show vegetation coverage.

RESULTS AND DISCUSSION

This present study integrated the ground surveys and GIS to map halophytic plants in the study area. Furthermost, the research specified that, remote sensing and GIS data, provides effective approaches for comprehensive mapping and analysis of vegetation data attained from ground investigations (Table 2) and (Figure 4). Likewise, Khan and Qaiser (2006) assessed the characteristics, distribution and potential economic usages of salt tolerant species in Pakistan. Ali (2008) reported a significance of flora with special location to Pakistan. Mehmood *et al.* (2015) found that the total of 331 vascular plant genotypes belonging to 246 genera and 101 families. These comprise 12 genotypes of Pteridophytes, 6 gymnosperms and 313 Angiosperms.

In the former study, Pithawalla and Martin-Kaye (1946) revealed that the Arabian Sea is situated at the South, sand-mounds, mudflats and mangrove swamps at the Eastern Shoreline consistent with the inlets and creeks of Indus Delta. Karachi Development Authority (KDA, 2000) separated the shoreline into six habitats Karachi coast was categorized in 3 segments physico-graphically, Western coast, Southern shoreline and Southeastern coast. Western coast covers rigid conglomerate and shale cliffs from Cape Monze to Bulleji, whereas sandy beaches of Manora, Sandspit and Hawks Bay lie from Buleji to west of the Manora breakwater. At the Cape Monze, *suaeda fruticosa* was dominant and *salvadora persica*, *halopyrum mucronatum*, *aerva javanica, calotropis procera, arthrocnemum indicum, Limonium stocksii, urochondrasetulose* and *fagonia indica*, are common species whereas, at the Hawkesbay *prosopis juliflora* is invasive species. Furthermore, at the backwater, *avicenna marina* was prominent. Keamari, Korangi Creek, and beaches of DHA and Clifton lies at the Southern shoreline of Karachi. From Korangi to Clifton the landscapes of beaches of DHA and Clifton are extremely reformed due to restoration of the sea-by-sea reclamation.

Table 2: Spatial distribution of halophytes.

	Species	Family	Longitude	Latitude
1	*Acacia nilotica*	Mimosaceae	67.6310	24.5470
2	*Aeluropus lagopoides*	Poaceae	67.0178	24.8082
3	*Aerva javanica*	Amaranthaceae	67.0695	24.7640
4	*Arthrocnemummacro stachyum*	Amaranthaceae	66.9072	24.8436
5	*Atriplex stocksii*	Amaranthaceae	67.0694	24.7637

6	*Avicennia marina*	Avicenniaceae	66.9189	24.8361
7	*Calotropis procera*	Asclepediaceae	66.9108	24.8405
8	*Cassia italica*	Caesalpiniaceae	67.0871	24.7511
9	*Cistanche tubulosa*	Orobanchaceae	66.8833	24.8528
10	*Cressa cretica*	Convolvulaceae	67.0698	24.7643
11	*Convolvulus arvensis*	Convolvulaceae	66.8538	24.8619
12	*Cyperus conglomeratus*	Cyperaceae	66.8678	24.8597
13	*Fagonia indica*	Zygophyllaceae	67.0697	24.7641
14	*Halopyrum mucronatum*	Poaceae	67.0271	24.8025
15	*Heliotropium aucheri*	Boraginaceae	67.0589	24.7736
16	*Indigofera hebipetala*	Fabaceae	66.9107	24.8407
17	*Ipomoea pes-caprae*	Convolvulaceae	66.8868	24.8502
18	*Limonium stocksii*	Plumbaginaceae	66.8528	24.8621
19	*Lotus garcini*	Papilionaceae	66.9107	24.8406
20	*Paspalum pasploides*	Poaceae	67.0178	24.8082
21	*Prosopis juliflora*	Mimosaceae	66.5358	24.5042
22	*Salsola imbricata*	Amaranthaceae	67.0701	24.7643
23	*Salvadora persica*	Salvadoraceae	66.8945	24.8487
24	*Serna incana*	Malvaceae	67.0592	24.7728
25	*Sporobolus tremulus*	Poaceae	66.9106	24.8408
26	*Suaeda fruticosa*	Amaranthaceae	67.0078	24.8116
27	*Tamarix indica*	Tamaricaceae	67.0868	24.7512
28	*Tribulus terrestris*	Zygophyllaceae	67.0699	24.7638
29	*Urochondra setulosa*	Poaceae	66.8529	24.8620
30	*Zygophyllum simplex*	Zygophyllaceae	67.0585	24.7734

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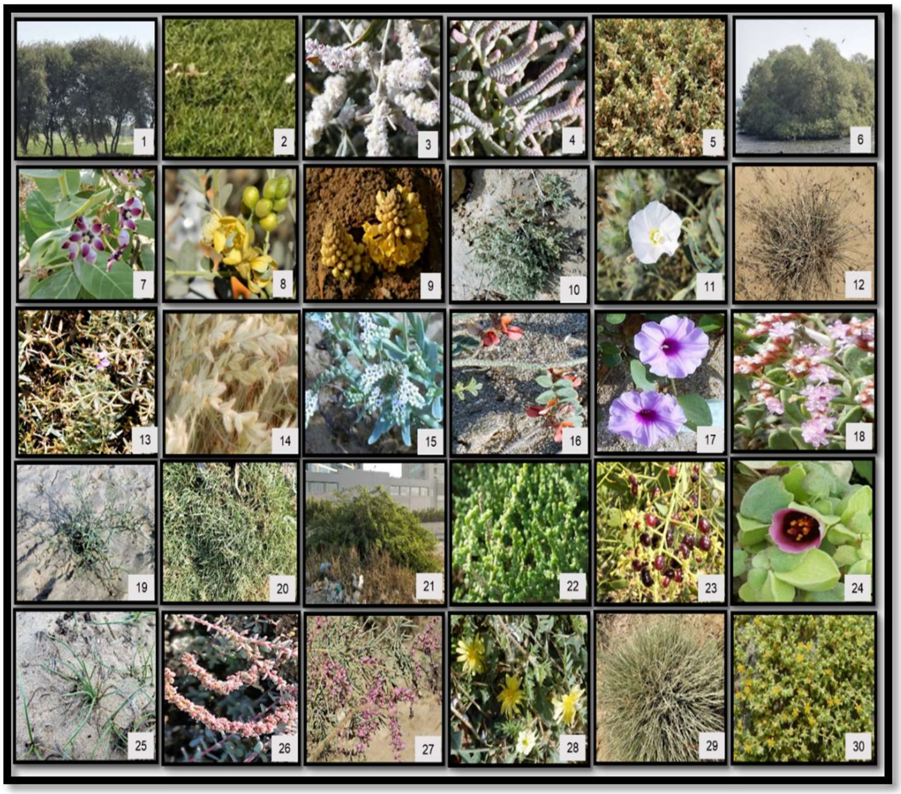

Fig. 4: Diversity of halophyte plants in the study area.

1.Acacia nilotica, 2. Aeluropus lagopoides, 3. Aerva javanica, 4. Arthrocnemum macrostachyum, 5. Atriplex stocksii, 6. Avicennia marina, 7. Calotropis procera, 8. Cassia italica, 9. Cistanche tubulosa, 10. Cressa cretica, 11. Convolvulus arvensis, 12. Cyperus conglomeratus, 13. Fagonia indica, 14. Halopyrum mucronatum, 15. Heliotropium aucheri, 16. Indigofera hebipetala, 17. Ipomoea pes-caprae, 18. Limonium stocksii, 19. Lotus garcinia, 20. Paspalum pasploides, 21. Prosopis juliflora, 22. Salsola imbricate, 23. Salvadora persica, 24. Serna incana, 25. Sporobolus tremulus, 26. Suaeda fruticose, 27. Tamarix indica, 28. Tribulus terrestris, 29. Urochondra setulosa, and *30. Zygophyllum simplex.*

In respect with Clifton beach which may viewing dark-grey silt with minute flakes of mica-mineral in nature. Approximately 60% of the DHA, with shifting sand-dunes and average to coarse sand bar deposits. Near the coast, *suaeda fruticosa* and *halopyrum mucronatum* were observed through survey, whereas, *salvadora* *persica, atriplex stocksii, salsola imbricata, tribulus terristris* and *zygophyllum simplex* were found communal in this region. Few traces of *avicennia marina* are seen near DHA. The Southeastern Karachi coast encompasses Khuddi and Korangi Creek. It comprises four islands: Bundal, Khuddi, Buddo and Miran Island. The Eastern shore comprises mudflats, which are associated by a network of creeks of the Indus Delta, dominated and protected by the mangrove’s species *avicennia marina*. *Tamarix aphylla*, *aeluropus lagopoides, cressa cretica, salvadora persica*, are the common salt tolerant in the shoreline. Wide-ranging of ecology and biodiversity are seen in the study area. Pernetta (1993) emphasis that disparities in the physical features are the main reason of biodiversity stress, as sea level rises, climatic change, increase in salinity, erosion of beaches due to wind and tides and sediments dumping from the river. According to WWF (2005) numerous plant and animal species vanishes, due to anthropogenic activities like pollution, development projects without considering ecology unplanned interventions of human-being as, contamination, environmental uproar and utilization of numerous genotypes and species of animals reportedly disappeared Enright *et al.* (2005).

It’s not possible to detect halophytes through landsat images (30m resolution) as their canopy is not large, in order to detect halophytes, hyperspectral image is necessary. Change detection analysis shows overall vegetation in the study area, only mangroves are prominent at the coast. Change Detection revealed that in 1989 value of NDVI is high 0.56 as vegetation distribution in the Chinna Creek is higher than other years whereas covers of mangroves are visible at the southeast corner of Defence, total study area is 133.78 km2during 1989, out of that vegetation coverage is 12.58 km2. During 1994 values of Normalized Difference Vegetation Index is 0.59, mangroves have been reduced in Chinna Creek as the area reclaimed by the Karachi Port Trust (KPT) housing Scheme at Mai Kolachi in the name of projects of development, however, in the Southeastern part of the Defence mangroves disappears, because the area is land filled, at the Liyari river`s mouth mangroves are thriving. In 1994 the vegetative area increases to 21.7 km^2. During 1999 the value of Normalized Difference Vegetation Index is 0.53 Western and Southeastern side of DHA prolonged with land filled whereas mangroves thrive again at the Southeastern part of DHA.

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During 1999 vegetation coverage continuously decreases to 13.8 km^2. Cyclone 2A hit the coast of Sindh (Category-3) in May 1999. JTWC (Joint Typhoon Warning Center) reported that it has been observed 4th devastated hurricane of Arabian Sea. In 2004 vegetative area is 13.9 km^2 almost same as 1999.Value of NDVI is 0.36 vegetation at the river Liyari's mouth increases prominently during 2004. In October 2004, cyclone Onill, hit the coastal areas with the wind speed of 65 miles per hour with heavy downpour at the coasts of Sindh, while Karachi receives more than 35mm as shown in (Fig 2). In 2009 vegetation coverage of the study area increase to 18.6 km^2 as in July torrential rain fall flooded Karachi with average precipitation 279.9mm, Cyclone Phyan in November advances with gusty winds in Karachi. The floods are the result of the heaviest rains in the region in thirty years. The value of NDVI was 0.62 observed higher as compare to other years (Figure 5).

In addition, EMMAR Crescent Bay is well-known in 2009 at the South-western shoreline of DHA, vegetation was found nearly high in this year. Meanwhile, the vegetation coverage gradually decreases in 2014 i.e., 14.5 km^2 and 2018 it is 15.4 km^2 respectively, although entire area of the study area increases from 141.4 km^2 to 143.2 km^2 (Table 3) and (Figure 6).

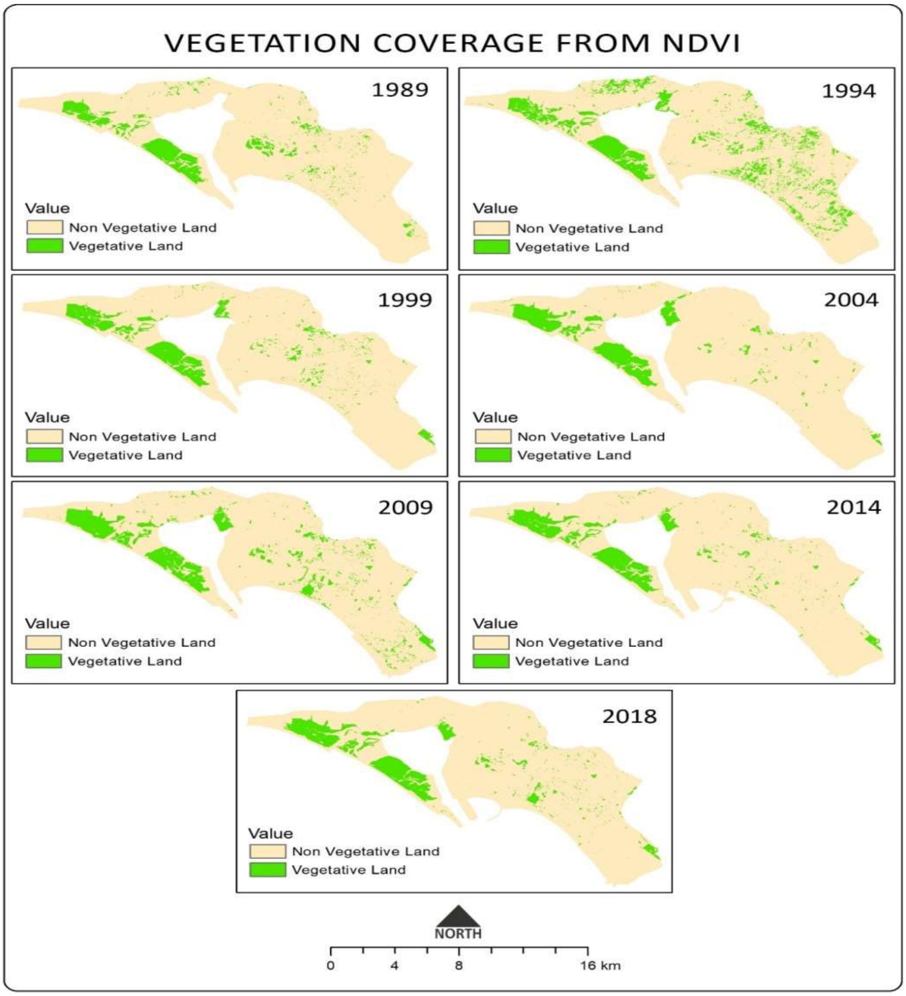

Fig. 5: Temporal distribution of vegetation coverage through NDVI.

Table 3: Vegetation coverage of study area.

Year	Vegetative	Non vegetative	Total Area (km2)
1989	12.58	121.2	133.78
1994	21.7	114.5	136.2
1999	13.8	124	137.8
2004	13.9	124.8	138.7
2009	18.6	120.6	139.2
2014	14.5	126.9	141.4
2018	15.4	127.8	143.2

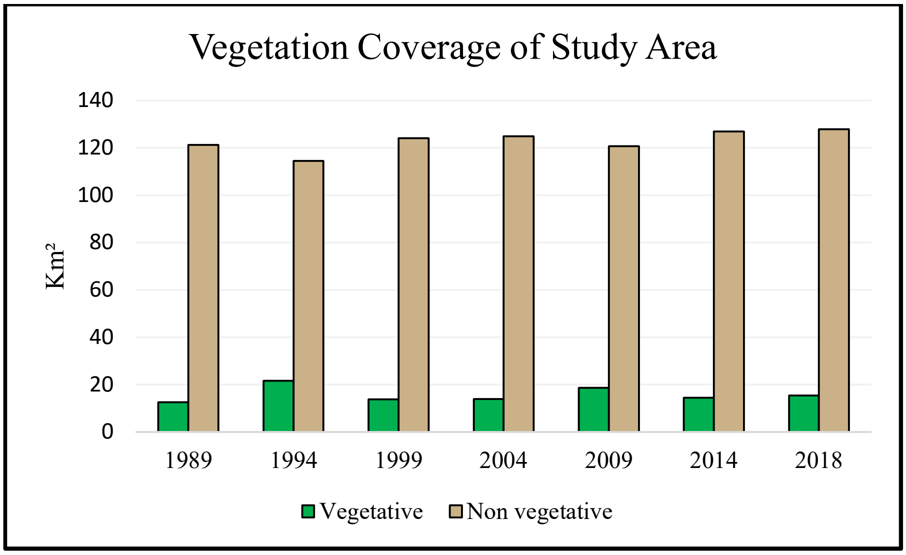

Fig. 6: Vegetation coverage of the study area.

As cyclones are not common in Arabian Sea, NASA earth observatory was in October 2014 perceive Cyclone Nilofer (category-4) reached at coastal areas cause of tropical depression. Value of NDVI in 2014 was 0.39. During 2014 intensification of Keamari Jetty and old Clifton beach was prominent as the sea reclamation is more in that area cause of development of Pak-China Port. Value of NDVI was 0.40 in 2018. General, vegetation increases since 1989, though mangroves are decreasing because of the anthropogenic activities like cutting of trees for fuel and clearing areas for the development projects and increase of salinity due to less fresh water reaches at the sea from the rivers. On the other hand, this study revealed that mangroves increase due to direct dumping of sewerage water appears to be key basis of fresh water and nutrients into the estuaries, the mangroves thrive at the Liyari river's mouth.

Clifton and Defence area were nearly 14.03 km^2 in 1955 while in 2006 it increased to 5.57 km^2, now the DHA and Clifton area was 19.6 km^2 (Kazmi and Mehdi, 2008). Also, Yasmeen (2014) mentioned that exploitation of Karachi coastal area is not a natural process rather intervention of mankind. Most of the sites were close to the shoreline of Defence and Clifton are reclaimed for recreational, residential as well as commercial activities. Residential project of EMMAR Crescent Bay totally built on the landfilled area. According to Geologists and experts reported that all the reclaimed construction areas are highly prone to tremors (Ramkumar, 2009; Welegedara *et al*., 2020). The earthquake of October 2005 may only jolt the Clifton and Defence areas of Karachi henceforth and subsequently increased the vulnerability of the area. While, studying vegetation change, potential use of remote sensing can be seen. Large thicket of vegetation was identified by Landsat images.

CONCLUSION

The purpose of present study was to identify and allocate the vegetation species at the coast and Change Detection analysis revealed that an increase and/or decrease of vegetation of the area depend largely on the amount of rainfall and period of drought. Remarkable change of vegetation from 1989 till 2018 has been observed. In order to study on halophytes species Hyperspectral data is necessary as species are shrubs, herbs and grasses. It seems that concerns authorities are not much interested on the environmental degradation of the coast. Reclamation of the sea can increase the susceptibility of the Defence and Clifton areas. Most of the vegetation of surveyed area near Clifton and DHA has been bulldozed in the name of development, for the construction of elite class societies as halophytes considered as useless wild plants.

ACKNOWLEDGEMENT

Thanks to Muhammad Irfan from Department of Geography for his support.

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