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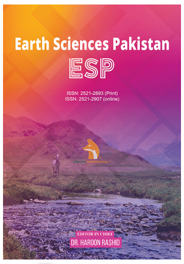

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RESEARCH ARTICLE

MAPPING OF SPATIO-TEMPORAL LANDUSE AND LAND SURFACE TEMPERATURE USING SATELLITE DATA- A CASE STUDY OF SUKKUR-KOTRI INDUS REACH

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ABSTRACT

The riparian zone is an ecological corridor for the rivers, forests, and lakes where the transition of water occurs between flora, fauna, and alluvial soil. It functions as a barrier to protect the riparian cities from floods, a retainer to hold the sediments transported in the water body, and a purifier in an order to adsorb the harmful dissolved solids present in the river flow. At some rivers, where the riparian zone has been degraded, the natural vegetation is observed to be under-functioning, consequently decreasing the water quality. The anthropogenic activities on river beds e.g agriculture are a reason for riparian degradation. In this study, the riparian zone of River Indus's reach between the Sukkur and Kotri barrages is observed to identify the varying land covers and land temperature ranges due to agricultural invasion that could threaten the river ecosystem and sustainability. In a low flood period, less moisture on the river bed facilitates the detection of mature Rabi crops through the Landsat satellite. Acquired Imageries were classified for natural vegetation and agricultural area using the Visible bands. Land Surface Temperature (LST) was calculated from the pixels of the Thermal band. The images for 1999, 2003, 2010, 2015, 2018, and 2019 for February were utilized for the processing. Results demonstrated that in 1999, the 45.4% area of the Sukkur-Kotri reach was under the natural vegetation cover and decreased up to 14.2% area in 2019. In 1999, 22.5% of the reach area was under agricultural farming and increased up to 60% of the area in 2019. Analysis of surface temperature demonstrated that the areas having high temperatures are under natural vegetation cover, which is being reduced. And the areas having low temperatures are under agricultural farming, which is being increased inside the riparian zone.

KEYWORDS

Indus River, Riparian Vegetation, Forest, Remote Sensing, Hybridized Classification, Land Surface Temperature.

1. INTRODUCTION

Riparian zones are known as ecological corridors that embrace the soil-water transition zone. These riparian forests and wilderness conserve the biodiversity, fertile alluvial soil, and hydro-morphological dynamics of the river. The hotspots of these forests are present along the banks of the rivers and inside river beds, contributing to the economy and natural resources of the region. In Pakistan, most of the forests exist along the Indus River and are visible along the longitudinal riparian reaches up to the Indus Delta. These forests are recognized for their historical worth as wildlife reservation, river channel conservation, and bank protection from flood since their presence dated back to the dynasties of local rulers (Nawaz, 2008).

The preservation of these riparian zones was also associated with the local's interests and benefits e.g. for entertainment purposes. The dispersion of the riparian forests started to occur simultaneously with the downfall of responsible rulers and regional dynasties. Initially, the local feudal take over the land and used these "katcho areas" for their agricultural and food-related interest and benefits (Budhani and Gazdar, 2011). The regulations for the Land Rules declared the riparian zone of the Indus River as the government property, though these forests are neither guarded by the land management officials, nor any strict actions are taken by the government for their protection.

It has been a common practice by the farmers of the surrounding areas to approach the river bed during the low flood and use the riparian space for agricultural purposes. The fertility of the alluvial soil brings the bumper crop profit for the farmer without much land preparation efforts. This type of land-use follows the deterioration of the naturally occurring wild vegetation and the alluvial regime of the river (Khatoon, 2008). The removal of natural vegetation by the farmers follows the abandoning of land for an entire season and hard-panned after the harvesting of crops. It hinders the growth of natural riparian forest trees of high economic value

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and decreases the flood-carrying capacity of the soil for the coming wave of flood in the Kharif season, respectively (Inam et al., 2008).

The reduction of the riparian plants on the river site has lowered the sediment holding capacity of the riparian zone that purifies river water from silt and harmful dissolved solids. Riparian deforestation has converted millions of acres of native grasslands, riverine forests, prairie, and wetlands into croplands. Whereas, the crop-free bare land could not stop the flooding and endangers the farmers' property inside the riparian as well as in the surrounding areas (Budhani and Gazdar, 2011). The applied fertilizers to the crops during cultivation eventually lead to the downstream river's water pollution and quality deterioration. These anthropogenic actions lead to an unsustainable future for the river ecosystem.

In the Sindh province of Pakistan, the original riparian forests that were famous for containing the eclectic species of flora and fauna have now turned into meager savannahs. This scenario affects the ecosystem of a river and its geomorphology in form of unsuccessful vegetation growth (González del Tánago et al., 2016). According to a group researcher, the political bias among provinces is identified as a menace for the country's natural resources depletion (Siddiqui et al., 2004). This study is an effort to find out the scientific evidence of the anthropogenic activities that cause a massive decrease in the natural forests. Instead of stating the wood requirements, water diversions, upstream river damming, and extensive animal grazing as the root cause of riparian deforestation, the study focuses on the increasing agricultural activities in riparian areas.

The research is carried out using remote sensing principles to find out the Spatio-temporal variations of natural vegetation and agriculture between Sukkur-Kotri Indus reach from 1999 to 2019. According the research and analysis for the natural resources are made globally using satellite technology with an updated Spatio-temporal resolution (Anderson et al., 2017). The advanced geo-spatial tools and techniques are applied to the area of interest to find out the hydrological, climatological, and agricultural patterns at different periods. Further problems like surface temperature are increasing day by day, where the temperature in thickly vegetative reach, e.g., forest, used to be fairly less in the past (Abbasi et al., 2012; Anbumozhi et al., 2005).

2. Material and Methods

2.1 Study Area

The study area is a reach of Indus River, from Sukkur Barrage (at 27.677872° N 68.845286°E) up to Kotri Barrage (at 25.442943°N 68.317469°E) in Sindh province. The total length of the reach is 478.603 km. The total area of the riparian zone is 3954.53 km^2 (approximately 4000 km^2) along the reach bounded by the levees, and the width is about three to four kilometers. The mean annual rainfall lies between 175 and 100mm, for the lower Indus region. The weather conditions are dry in winter and very hot in summer. The temperature for the area is higher than 40 °C. The riparian area between Sukkur and Kotri barrage is shown in Figure 1.

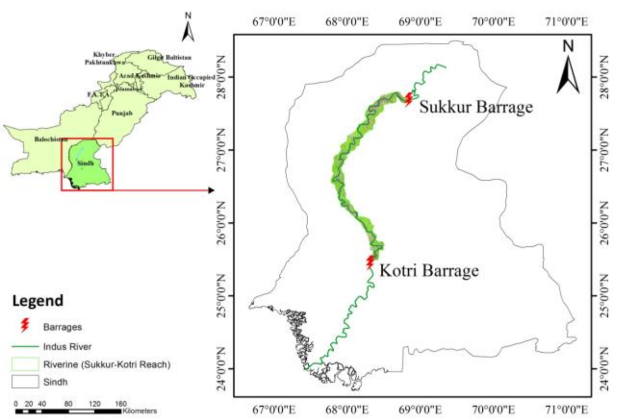

Figure 1: Study Area Map

2.2 Data Collection

The satellite imageries were downloaded from the USGS Earth Explorer website (https://earthexplorer.usgs.gov/). From 1999 to 2019, six years were selected and their images were downloaded from available versions of satellite e.g. Landsat 5, 7, and 8. These satellites have coverage of the study area in 2 tiles for the longitudinal reach of the river and spatial resolution of 30*30 km. From the year 2011 to the present, the data for Landsat 7 is faulty due to scan line error, and Landsat 5 was used as an alternative. The month of February was taken into account for this research as the river flow is minimum, the Rabi crop is at the maturity stage and efficiently detectable by the satellite sensor. The imageries with cloud cover greater than 20% in February were replaced by the March imageries.

2.2.1 *Satellite Data Types*

The satellite data was available at different levels of processing. The Visible bands from Level-2 were processed to get the land use-land cover change. The Thermal bands from Level-1 were processed to detect the Land Surface Temperature (LST) information (Sekertekin and Bonafoni, 2020).

2.3 Methodology

The flowchart of methodology used in this study is shown in Figure 2.

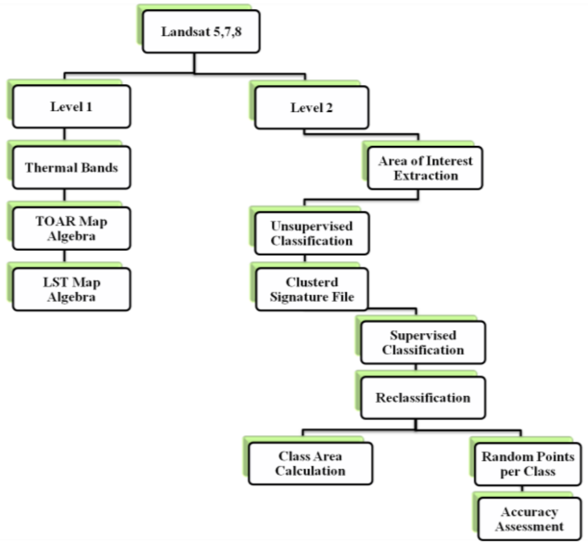

Figure 2: Methodology

2.3.1 *Level-2 Visible Band Processing*

The hybridized technique of Classification using ArcMap 10.1 was applied to imageries of Landsat 5, 7, and 8. In an unsupervised classification process, the Iso-cluster tool was run for 15 iterations and the imagery was classified in 25 random classes (Hazarika et al., 2015). The signature file of these classes was generated, based on which the Maximum Likelihood classification tool was applied. For Reclassification, the reference signatures for different objects in the imagery were determined using Google Earth Pro and different band visualization. The agriculture patches in the imagery were identified using the NIR band. The natural vegetation was identified by understanding the spectral signature curve for different categories like shrubs, trees, and savannah, shown in Figure 3. To identify the objects, classified imagery was swapped with real imagery, in response to which 25 classes were reduced to 4 classes. These were finally converted to polygons and areas for required classes were determined using pixels.

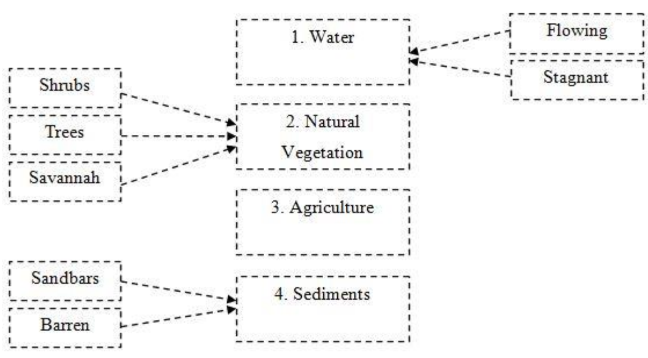

Figure 3: Classification Scheme

2.3.2 *Accuracy Assessment of Classified Images*

For the assessment of the classification, the random points generated from the hybridized classification imagery were used as sample points. The technique of Stratified random sampling was followed and a total of 120 points were generated, 30 for each stratum. The Confusion matrix was generated after the interpretation of 30 random points per class of water, soil, natural vegetation, and agriculture. Kappa coefficient was calculated from the confusion matrix to find the accuracy of research (Jensen, 2015).

2.3.3 *Level-1 Thermal Band Processing*

The thermal bands of the imageries were downloaded with the metadata files. The Map Algebra tool was used in GIS and calculation of spectral radiance of Top of Atmosphere (TOAr) was done. The spectral radiance was further converted into the Land Surface Temperature (LST) using the calculation from and the temperature layer was calculated in Kelvin, later converted in Degree Celsius (Sekertekin and Bonafoni, 2020). The temperature range for each stratum was identified by random point sampling and the graphical trend was generated.

3. Results

3.1 Trend for Forest Cover in Comparison with Agriculture

The classified imageries of six selected years 1999 to 2019 are shown in Figure 4 and the percent areas are shown in Table 1. Natural Vegetation was continuously decreasing in an area where agriculture was increasing for time as shown in Figure 5. A group researcher concluded that the natural vegetation was replaced by agriculture farming (Habibullah Abbasi et al., 2011). This temporal variation explained the visual effect of anthropogenic land-use conversion on the study area. Due to the vast stretches of riparian areas between Sukkur and Kotri barrage, the ground-truth surveys could not be performed. Alternatively, the accuracy assessment was performed for all imageries using the Google Truth technique. The historical imagery datasets were evaluated from Google Earth Pro against the stratified sample points for each class. The Kappa coefficient for six imageries was calculated as 0.88, 0.92, 0.93, 0.91, 0.89 and 0.91 respectively.

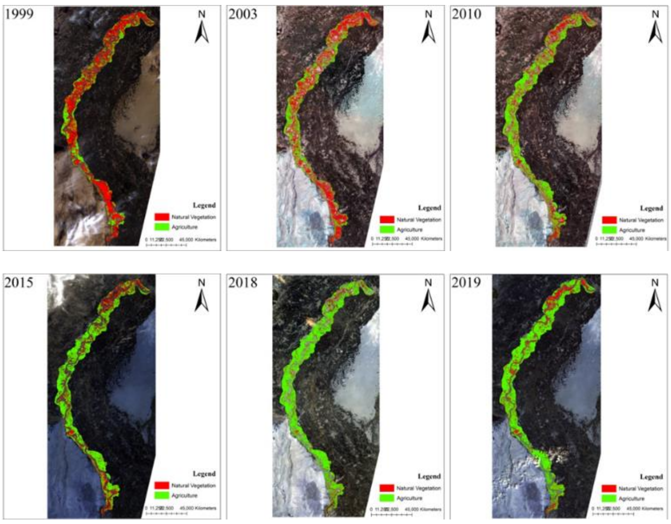

Figure 4: Spatio-temporal change in the Riparian reach of Indus River

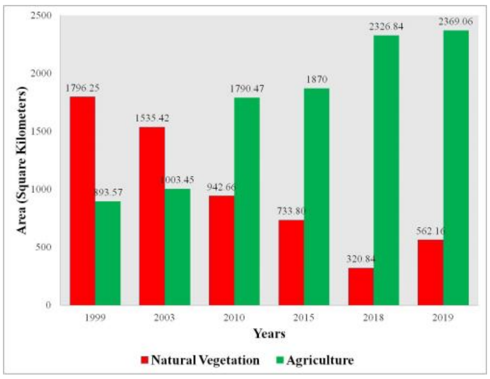

Figure 5: Temporal Variation between Natural Vegetation and Agriculture

Table 1: Percentage Area inside the Riparian Zone		
Years	**Natural Vegetation Percentage**	**Agriculture Area Percentage**
1999	45.42%	22.60%
2003	38.83%	25.37%
2010	23.84%	45.28%
2015	18.56%	47.29%
2018	8.11%	58.84%
2019	14.22%	59.91%

3.2 Land Surface Temperature Trend for LULC

In Figure 6, the Land Surface Temperature (LST) for natural vegetation and agriculture are shown for the riparian reach. From 1999 to 2010, The trend for is increasing also verified by (Abbasi et al., 2012). But, the temperature in 2015 and 2019 seems to be affected due to the presence of smog or clouds. LST is a radiation-based temperature in which the atmospheric path radiance is seen as an error. These errors could be the cloud, smog, and moisture droplets suspended in the atmosphere. On the other hand, the difference in temperature values of agriculture and vegetation is evident. The natural vegetation had some degrees higher LST than Agricultural fields. An average difference of 2.953 °C was estimated between the LST of natural vegetation and agriculture.

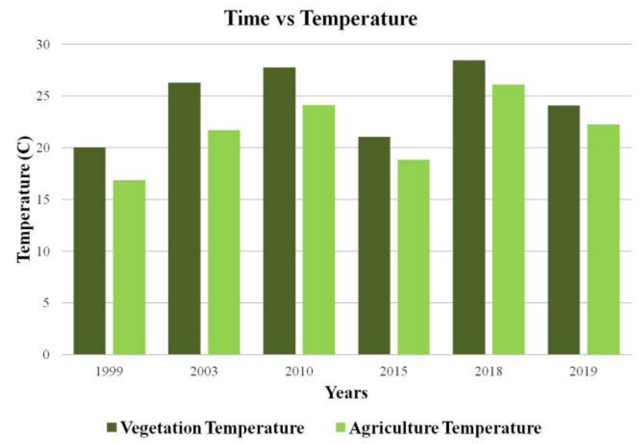

Figure 6: Temporal Variation in LST between Natural Vegetation and Agriculture

In Figure 7, the temperature for Water and Sedimentation is shown for the riparian reach. The sediments have some degrees higher LST than water. The average difference of 6.727 °C was estimated between the LST of sediments and water.

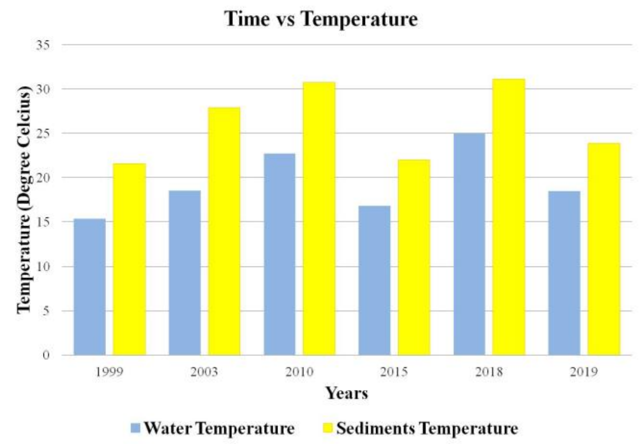

Figure 7: Temporal Variations in LST between Water and Sediments

Due to the irregular climate conditions for February, the LST was not determined precisely from 2010 onwards. It has been observed that the water area had the lowest value of LST in the riparian environment, where the area exposed to sediments had the highest value for LST. The agricultural area has fewer LST values than the area enclosed by natural vegetation. The same trend of temperature was observed in riparian areas upstream of Sukkur Barrage and Downstream of Kotri Barrage (Fund, 2008). The results are also consistent with the higher temperature for barren land than the crop cover (Siyal et al., 2017).

4. Conclusion

The conversion of natural vegetation cover into the agricultural area for maximizing food production is being practiced by agricultural communities inside the riparian forests all over the world. The Spatio-temporal decrease in natural vegetation within the Indus River reach, for a period of 1999 to 2019 concluded that the ecological integrity of the riparian ecosystem is under threat. The temporal increase of agricultural area in the riparian zone is a challenge for Wildlife and Land Regulatory Authorities in terms of ecosystem maintenance for the flora and fauna. The status of Land Surface Temperature (LST) of the riparian reach discloses the temporal decline of temperate areas due to the removal of natural vegetation in the winter season. The agricultural areas are expanding temporally with less LST than the temperature in natural vegetation. It has been recommended for future studies to take into account the high-resolution reference data to identify the crops with high demand being harvested in the riparian area. The researchers should design a strategy to use the riparian zones beneficially and sustainably and also provide alternative ways to maintain the demand for identified crops.

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