Research Article

Current Status and Stand Structure of Riverine Forests of Sukkur, Sindh

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Abstract | A study was conducted to assess the current status, structure, and growing stock of riverine forests in Sukkur District. Data was collected from 751 sample plots laid out in different forest areas through a systematic random sampling design using a grid of 500 m x 500 m. It was found that the Riverine forests of Sukkur are highly degraded, and only 28% of the forest cover exists. Species diversity is quite low as only 7 different species were recorded during the field measurements. *Tamarix dioca* has dominated the growing stock with a 41% share in the total trees, followed by *Acacia nilotica* and *Prosopis cineraria,* each having a 27% share in the growing stock. The average stocking was estimated at 90 trees per ha, which is quite low compared to a well-stocked riverine forest or plantation. The average diameter at breast height (DBH) was recorded as 12.49 cm, and the average tree height was estimated as 6.78 m. The average canopy cover is 30% in the area. The total growing stock in the landscape was estimated as 51,978 m^3. The average growing stock was determined as 7.94 m^3 per ha. The growing stock level in riverine forests in the study area is far lower than that of the normal riverine forest. The study recommends adopting effective measures for the rehabilitation of these forests. These measures may include control of open grazing and cutting of trees through community participation and restoration of landscape through artificial regeneration techniques such as through sowing and planting. Preparation and implementation of forest management is also required to ensure sustainable forest management in the area.

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Introduction

Forests are important natural resources which provide many valuable goods and services. Forests play a critical role in supporting local economies and are pivotal for global efforts in combating climate change, preserving biodiversity, and improving environmental conditions. They stand as the most vital carbon reservoir on land, offering carbon sequestration as a fundamental ecological service (Kumar *et al.*, 2019). Given their essential contribution to mitigating climate change, the significance of forests has enormously heightened. They serve dual roles by absorbing carbon dioxide and potentially releasing it upon deforestation (Brown, 2002). Therefore, safeguarding forests is imperative in

the fight against climate change.

Assessing and managing forests, along with quantifying various ecosystem services, necessitate detailed data on the composition of forest stands. A forest stand, usually the basic unit of forest management, is identified as a continuous mass of trees that are relatively homogeneous in terms of age distribution, species composition and structural form, situated on a site of consistent quality, making it a distinct entity (Nyland, 2007; Helms, 1998). The configuration of a stand encompasses the spatial and chronological arrangement of trees and flora within the stand. This arrangement is characterized by various attributes such as species diversity, the vertical and horizontal spatial arrangement, and dimensions of both living and dead flora, including aspects like crown volume, leaf surface area, and stem basal area (Oliver and Larson, 1996). Their structural and species diversity significantly influences the utility of forests for both consumptive and non-consumptive purposes.

Pakistan encounters a notable shortfall in forested areas, with forests spanning just 5% of its land. Among its total land area of 87.98 million hectares, merely 4.51 million hectares are forested (Bukhari *et al*., 2012). Within Pakistan, Sindh stands out as one of the provinces with minimal forest coverage, having just 660,584 hectares (4.6%) under forests, which includes 183,835 hectares of riverine forests. These riverine forests not only provide the local populace with essential resources such as fodder, honey, fuelwood, timber, and tannin but also are crucial habitats for species like the Hog deer, Fishing cat, Wild boar, and Foxes, along with various small mammals (WWF, 2007). Additionally, they act as carbon sinks and offer protection against the impacts of floods. The Sukkur Forest Division encompasses an area of 50,294.4 hectares across three civil districts: Sukkur (26,257.4 hectares), Shikarpur (12,275 hectares), and Ghotki (11,762 hectares) (Wagan and Domki, 2000).

The Sustainable Forest Management (SFM) initiative, a collaborative effort by the Ministry of Climate Change (MoCC), the Global Environment Facility (GEF), and the United Nations Development Programme (UNDP), was executed across selected regions in Punjab, Sindh, and Khyber Pakhtunkhwa between 2017 and 2021. Its principal aim was to foster the practice of sustainable management within the Western Himalayan Temperate Coniferous forests, Sub-tropical broad-leaved evergreen thorn forests, and Riverine forests across Pakistan. This endeavour targeted the enhancement of biodiversity conservation, climate change mitigation, and the preservation of forest ecosystem services (UNDP, 2016). The riverine forests in the Sukkur area were among the six chosen landscapes for the deployment of the SFM project, aimed at augmenting the governance of these woodlands. Prior to this project, there was an absence of comprehensive data regarding the current conditions and structural composition of these forests, essential for evaluating their capability to offer ecosystem services. Consequently, a detailed investigation was carried out within the framework of the Sustainable Forest Management Project to evaluate the present condition, structural integrity, and biomass of the riverine forests in the Sukkur District.

Materials and Methods

The riverine forests situated alongside the Indus River in Sukkur District span the latitudinal range of 27.81118 to 27.92718 and the longitudinal range of 68.7813 to 69.0511. In the period from January to March 2018, a comprehensive field investigation was executed within these forests. For data collection, a systematic random sampling approach was employed. This method facilitated the establishment of 751 sample plots, which were methodically positioned across the riverine forests of Sukkur, as delineated on geo-referenced maps utilizing a 500 x 500 meter grid (Figure 1). For the collection of data within each plot, a circular area with a 17.84-meter radius was defined. High-resolution imagery from Google Earth was analyzed through visual interpretation to assess the current state of the forest. The distribution sample plots in different forest areas are given in Table 1.

Table 1: *Distribution of sample pots in different Forest strata.*

Forest area	Forest area (ha)	Number of sample plots
Bindi Dhareja	2,941	127
Keti Abad	4,585	339
Keti Shah	7,346	97
Keti Shahu	4,512	132
Kadrapur	857	10
Shahpur	5,500	46
Total	25,741	751

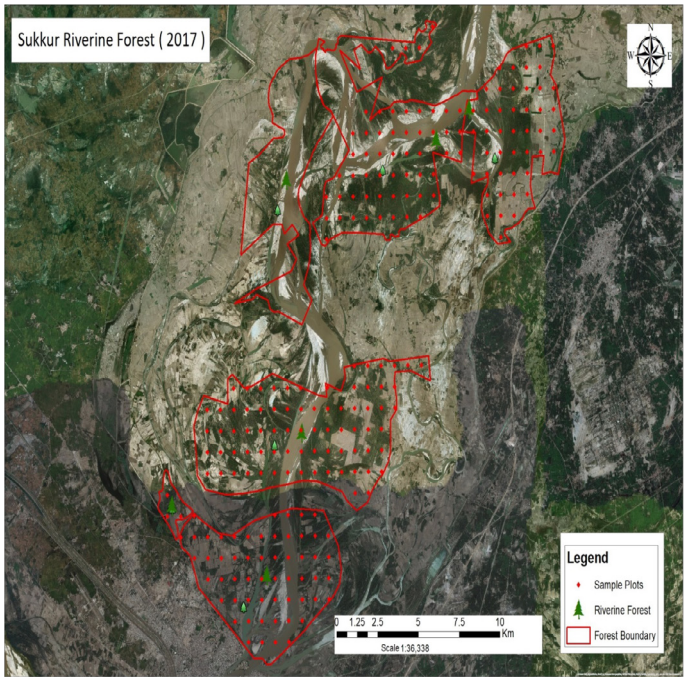

Figure 1: *Location of sample plots.*

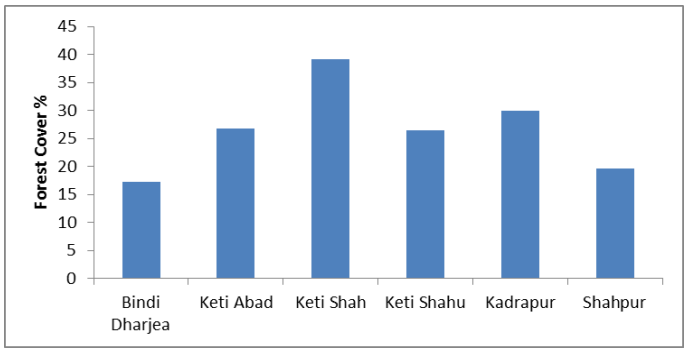

Figure 2: *Existing forest cover in different forest areas.*

Results and Discussion

Existing forest cover

The assessment of the current forest coverage within the study zone utilized visual analysis of ultra-high-resolution satellite imagery provided by Google Earth. This examination revealed that a mere 28% of the original forest cover persists, albeit in a significantly deteriorated state. The remaining 72% of what was once forest land has been repurposed for agricultural activities or transformed into various other types of land use. Of the total area of 25,741 hectares, only 7,147 hectares currently possess a canopy coverage exceeding 10%. Within this context, Keti Shah exhibits the most substantial forest cover at 39%, with Kadrapur at 30% and Ketiabad at 27% following in succession. Detailed coverage statistics for each forest area are compiled in Table 2 and Figure 2 The findings underscore the acute vulnerability of the riverine forests, which are facing critical challenges due to diminished water flow in the Indus River and encroachments by affluent landowners. This scenario corroborates the observations documented by Naisr and Akbar (2012) and Amanullah and Ahmed (2015), who have reported similar pressures on these ecosystems.

Table 2: *Estimates of forest cover in different forest areas.*

Forest area	Forest area as per working plan (ha)	Existing forest cover (ha)	Existing forest cover (%)
Bindi Dharjea	2941	509	17.31
Keti Abad	4585	1231	26.85
Keti Shah	7346	2878	39.18
Keti Shahu	4512	1196	26.51
Kadrapur	857	257	29.99
Shahpur	5500	1076	19.56
Total	25,741	7,147	27.76

Growing stock composition

In the course of field data collection, an inventory identified 3,086 individual trees spanning 7 distinct species. According to the data presented in Figure 3, *Tamarix dioca* constitutes the predominant species within the stock, accounting for 41% of the total tree population. This is closely followed by *Acacia nilotica* and *Prosopis cineraria*, each comprising 27% of the overall stock. *Populus euphratica* holds a 2% share of the tree population. Conversely, Ziziphus, Eucalyptus, and *Prosopis juliflora* each represent a 1% fraction of the total.

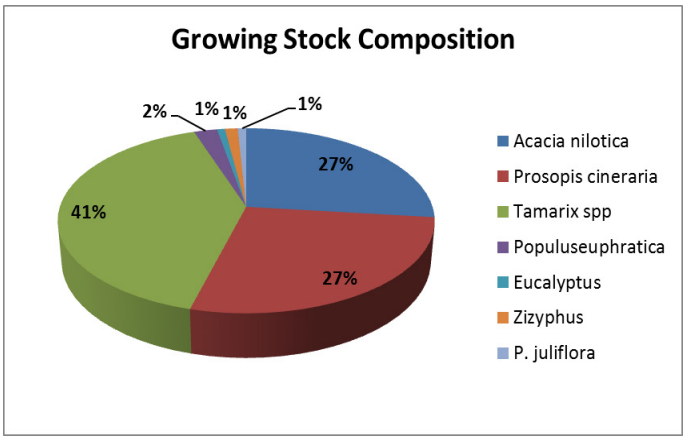

Figure 3: *Growing stock composition in different forest areas.*

The composition of the growing stock within the riverine forests of the project area reflects significant degradation in species diversity. The inventory revealed the presence of merely seven tree species, among

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which *Tamarix dioca* emerges as the predominant species, typically marking the initial succession stages in riverine environments. Notably, traditional riverine species such as *Acacia nilotica* and *Prosopis cineraria* are positioned second in the stock hierarchy. Moreover, *Populus euphratica*, a crucial component of the riverine ecosystem, is now critically endangered, constituting just 2% of the growing stock. This pattern of species distribution and the evident threat to biodiversity mirror the observations previously documented by Amanullah and Ahmad (2015).

Acacia nilotica stands out as the tree species with the highest economic worth owing to its timber, yet there has been a notable shift towards its replacement by alternative species. The distribution of Acacia nilotica is notably concentrated in Kadrapur, where it commands an 88% proportion of the total tree count. Conversely, in Keti Abad and Bhindi Dhareja, its prevalence is reduced to 44% and 40%, respectively.

Tree stocking/density

The mean density of the tree population was calculated to be 90 trees per hectare, significantly below the benchmark of 1,062 trees per hectare established for a well-stocked or typical riverine forest (Hafeez, 1973). Within the scope of the study, Keti Shah exhibited the greatest density at 114 trees per hectare, closely followed by Ketiabad with 113 trees per hectare. Kadrapur presented the sparsest density, with a mere 63 trees per hectare. Comprehensive details regarding tree density across different sites are provided in Table 3.

Table 3: *Tree stocking/density.*

Area	Tree stocking/Density
Keti Shah	114
Keti Abad	113
Bindi Dhareja	107
Keti Shahu	78
Shahpur	66
Kadrapur	63
Average	90

The condition of tree stocking reveals extensive degradation of the forests, primarily due to indiscriminate logging, a phenomenon corroborated by observations made during field surveys. The stocking levels have declined drastically, and regeneration rates are minimal, largely as a result of unrestricted grazing. Given the current low stocking levels, the forests are underperforming in terms of yielding optimal outputs of timber and fuelwood, as well as in their capacity to sequester significant quantities of carbon dioxide. Nonetheless, considerable potential exists for the rehabilitation and restoration of these forests, contingent upon the implementation of effective management and administrative strategies.

Stand structure

Inventory findings elucidate that the entirety of the riverine forests predominantly exists in the pole crop phase, characterized by trees with a diameter of less than 30 cm. The average diameter at breast height (DBH) was measured at 12.49 cm, while the mean height of trees was determined to be 6.78 meters. A striking 97% of the tree population possesses a diameter below 30 cm. Larger trees exceeding 30 cm in diameter are exceptionally rare, observed only within the Bhindi Dhareja and Keti Shah forests, with the remainder of the forest areas markedly deficient in larger trees. The average canopy coverage across these forests is noted to be 30% (Table 4). These observations unequivocally signal the profound degradation of the riverine forests, underscored by the extensive removal of large trees. Consequently, there is an imperative necessity for the conservation of the surviving tree population within these landscapes.

Table 4: *Stand structure in different forest areas.*

Area	Mean DBH (cm)	Mean height (m)	Average canopy cover %
Keti Shah	10.12	6.23	32
Keti Abad	10.66	6.10	32
Bindi Dhareja	12.18	7.71	33
Keti Shahu	11.89	6.05	31
Shahpur	15.69	6.57	26
Kadrapur	14.38	8.04	24
Average	12.49	6.78	29.67

Growing stock

The cumulative growing stock within the examined landscape has been quantified at 51,978 cubic meters, with an average stock density of 7.94 cubic meters per hectare. Among the regions assessed, Bhindi Dhareja exhibited the highest stock density at 10.24 cubic meters per hectare, followed by Kadrapur at 9.05 cubic meters per hectare and Keti Shah at 8.53 cubic meters per hectare. Comprehensive specifics regarding the growing stock are enumerated

in Table 5. When compared to the benchmark density of 29 cubic meters per hectare typical for riverine forests, the current stock levels are markedly lower. This discrepancy underscores the extensive degradation faced by these forests, largely attributed to overharvesting and unregulated grazing activities (Ali *et al*., 2018).

Table 5: *Aboveground carbon stocks in different forest areas.*

Area	Volume/ha (m^3)	Existing forest area (ha)	Total growing stock (m^3)
Keti Shahu	8.53	1,196	10,202
Keti Abad	7.27	1,231	8,949
Keti Shah	6.54	2,878	18,822
Shahpur	6.01	1,076	6,467
Bindi Dhareja	10.24	509	5,212
Kadrapur	9.05	257	2,326
Average	7.94	7,147	51,978

Conclusion and Recommendations

The Sukkur riverine forests are in a state of significant degradation. Current assessment indicates that a mere 28% of the original forest cover remains, with the vast majority, 72%, being repurposed for agriculture, grazing, or other uses. The diversity of species within these forests is alarmingly low, with only seven species identified during the field survey. Dominating the remaining flora, *Tamarix dioca*, represents 41% of the growing stock, while *Acacia nilotica* and *Prosopis cineraria* each account for 27%. *Populus euphratica* constitutes a minor 2%, and Zizyphus, Eucalyptus, and *Prosopis juliflora* each hold a mere 1%.

Tree density in these areas averages 90 trees per hectare, substantially lower than that of a well stocked forest. The majority of these forests are characterized by young, slender trees with diameters under 30 cm. The average tree diameter at breast height is 12.49 cm, and the average height is 6.78 m, with 97% of trees falling below the 30 cm diameter mark. The canopy cover averages at 30%. The total estimated growing stock is 51,978 cubic meters, translating to an average of 7.94 cubic meters per hectare, significantly below the normal for riverine forests.

Immediate actions are imperative to curb the ongoing degradation of the Sukkur riverine forests. Key strategies should include regulating open grazing, curbing illegal tree felling, and fostering community involvement and social organization for effective enforcement. Additionally, artificial regeneration techniques such as sowing and planting are advocated to restore these degraded lands. The development and execution of a comprehensive forest management plan is critical for achieving sustainable forest management in the region.

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Novelty Statement

Riverine forests of Sindh are the most productive forests in Southern Pakistan which are subjected to a very high degree of degradation. However, no research has been conducted in the past to assess the stand structure, species composition and growing stock in these valuable forest type. This study is the first attempt to collect quantitative data on the status of river forests in Sukkur, Sindh.

Author's Contribution

Anwar Ali: Conceived the idea and designed the study.
Muhammad Ayaz Khan: Provided financial and technical support for data collection in the field.
Muhammad Atif Majeed: Drafting of paper and review of literature.
Nowsherwan Zarif: Drafting analysis and revision of manuscript.

Conflict of interest
The authors have declared no conflict of interest.

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