**Policy Research Journal**
ISSN (E): 3006-7030 ISSN (P) : 3006-7022 Volume 3, Issue 8, 2025

# IMPACTS OF MASS AFFORESTATION PROJECT ON IMPROVING ECOSYSTEM SERVICES IN DISTRICT SWAT

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**DOI:** https://doi.org/10.5281/zenodo.18094011

**Keywords**

**Article History**
*Received: 08 May, 2025*
*Accepted: 14 July, 2025*
*Published: 08 August, 2025*

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**Abstract**

*The study was conducted to assess and quantify the impacts of a mass afforestation project in district Swat. For this purpose, two sites of the same afforestation project were selected for analysis. The first forestland was situated near Shin village having an area of 218 hectares and the other near Fatehpur village, which is about 70 hectares. The total number of plant species identified in the first forestland was 43, while only 35 plant species were identified in the later one. The average densities and percent frequencies of medicinal herbs were a bit higher for Shin forestland than the Fatehpur forest site. Two of the important medicinal herbs namely Asparagus adscendens and Mentha longifolia were completely vanished from the Fatehpur forest site. The Fatehpur forestland is relatively close to local population as compared to the Shin forestland. Hence, there is an increased medicinal plant collection and livestock grazing at the Fatehpur site. The stream discharge for two streams, one each at both the study sites were calculated before and after rainfall on various occasions from April to September in 2024. Average increase in the discharge rate of Stream I having its watershed located in the Shin forestland with comparatively dense vegetation cover was 0.094 $m^3/S$. Whereas, Stream II having its catchments in the relatively scattered forest cover in the Fatehpur region, showed greater increase in the average discharge rates after rainfall i.e. 1.27 $m^3/S$. Similarly, the average sediment load in stream I before and after rainfall was found to be 126 and 164 mg/L, respectively. In stream II the sediment load was again a little higher than stream I, on average 147 and 212 mg/L before and after rainfall, respectively. Finally, the research also estimates the amount of carbon sequestration potential of the two study sites. The total amount of carbon sequestrated by these forestlands is about 87,500 metric tons with a potential of sinking more than three hundred thousand tons of $CO_2$.*

## 1. Introduction

One of the Earth's most diverse and important natural resources include forests. Forestlands provide a wide range of ecosystem services that are crucial for both the environment and human well-being. These ecosystem services can broadly be categorized into; provisioning and regulatory or supporting services (Mengist et al., 2020; Alamgir et al., 2016). Forests provide habitats for a wide variety of flora and fauna. Forestlands are home to a significant proportion of the Earth's terrestrial plants and animals. They offer various macro and microhabitats, inhabiting everything from large mammals to very small insects and microorganisms. The complex nature of these forestlands ranging from forest floor to the canopy creates several niches. This structural diversity allows a wide variety of species to coexist without directly competing for food and shelter.

As an ecosystem regulator, forestlands play a vital role in the hydrological cycle by absorbing and storing rainwater, reducing the risk of floods, and maintaining groundwater levels. They also help in filtering pollutants from water bodies, which can then be used for domestic, agriculture, and industrial purposes. Forest covers also help in limiting soil erosion. Tree roots stabilize soil, reduces the risk of soil erosion and major landslides. Forestlands are crucial in regulating the climate of a region. The trees act as carbon sinks, absorbs carbon dioxide from the atmosphere and help mitigate climate change. They also influence local and global climate patterns by affecting rainfall and temperature (Baskent, 2021; Bozena & Jadwiga 2018; Lee et al., 2012).

Forests are also a source of timber, fuel wood, medicinal plants and may provide wild fruits to the surrounding human populations. Most of these goods and services are traditionally viewed as free benefits to humankind or ‘public goods’. The absence of ownership leads these public goods and services to be utilized at unsustainable levels (Zokaib & Nasir, 2011).

The total area covered by forestlands on the earth is about 3,870 million hectares, 95 percent of these forests are natural while the remaining 5 percent are plantations. 27 percent of the world’s total forests are in Europe, Latin America and the Caribbean keeps 25 percent, Asia and the Pacific region have 19 percent, 17 percent are in the Africa and the remaining 12 percent are found in the North America (FAO, 2001). Forestlands in Pakistan cover an area of 4.606 million hectares that is about 5.7 percent (MoCC, 2021) of the total area of the country. In the Khyber Pakhtunkhwa province, the percentage of the forestland is much higher covering about 17 % of the total area of the province (Wani et al., 2004).

In the last decade of the 20th century, the world lost about 14.6 million ha. of forests every year and these forest lands were converted in to agricultural or urban areas. Although 5.2 million ha of forests were added per year in that period through natural forest expansion, reforestation and plantations still the net loss is 9.6 million ha of forests per year (FAO, 2001). During the first decade of the 21st Century, due to forest degradation and deforestation, we lost about 13 million ha. of forests (equals to the size of Greece) each year. Keeping the same pace, around 170 million ha of additional deforestation will occur by 2030. According to World Wide Fund for Nature (WWF, 2017), each day a forestland equal to the size of a football ground is still being destroyed every second. The observed annual deforestation has been estimated at about 15,000 hectares in average. The annual deforestation rate has been estimated increasing from 0.11 percent to 0.39 percent. Total accumulated deforestation reaching over 178,000 hectares over the entire period of 2004-2016 (Ministry of Climate Change, 2016). According to the National Disaster Management Authority Pakistan's economy is losing around 3.5 million USD a day (1.3 billion USD per year) because of environmental degradation. The floods between 2010 and 2014 alone have resulted in monetary losses of over USD 18 billion, affecting the lives of 38.12 million people directly, with 3.5 million people losing their homes and more than 10.5 million acres of the crop destroyed. According to World Bank’s (2022) Pakistan: County climate and development report; the total cost of environmental degradation is about 6% of the GDP or about PKR 365 billion per year. These costs fall disproportionately on the poor.

As an important global sinks of carbon, as mentioned earlier, trees play a vital role in maintaining the Earth's climate and help mitigating global warming through carbon sequestration. Sequestration activities help controlling global warming by enhancing carbon storage soils and trees, and by minimizing the emissions of greenhouse gases like $CO_2$, methane ($CH_4$) and nitrous oxide ($N_2O$). Trees absorb $CO_2$ during photosynthesis and release $O_2$ into the atmosphere in return like human lungs absorbing $CO_2$ from the blood and infusing it with $O_2$. Hence, forestlands are often called as the "Lungs of the Earth" (Zubair et al., 2022).

There are two important links between trees and climate change. Firstly, trees play a vital role in maintaining the temperature on the surface of earth and regulate weather patterns by storing and sinking large quantities of water and carbon. By cutting forests at the current rate, we are accelerating the impact of climate change already induced by fossil fuels burning. Secondly, climate change is affecting up to two-thirds of existing forestlands, thereby aggravating deforestation and its associated problems. As a result, the world is losing 14.6 million ha of natural forests every year (Khan, et al., 2016).

Deforestation causes considerable release of $CO_2$ in to the atmosphere. Over the last 100 years, deforestation is responsible for an estimated 30% of the atmospheric build-up of $CO_2$. Reducing deforestation is therefore an effective way to reduce emissions of greenhouse gases caused by anthropogenic activities. Vegetation cover also plays a vital role in the protection and management of watersheds. It has been observed that although runoff and sediment yield from a watershed may depend upon season and rainfall intensity but vegetation cover in a watershed plays key role in the control and management of sediment generation and runoff (Zokaib and Naser, 2011).

### 1.1 Problem Statement

Keeping in view that only 5.7 percent of the area is covered with forests we can say that Pakistan is a poor country in terms of its forest resources (MoCC, 2021). Furthermore, the annual deforestation rate in the country is 4.6 percent, which is the 2nd highest in the world. Because of this high rate of deforestation, a great loss of ecological services provided by forestlands has also been observed in national context (Shaheen and Sharukh, 2009). Not only trees in the forestlands of Pakistan are being cut ruthlessly for timber and fuel requirements but the pastures and rangelands of the country are also over exploited (Ahmed et al., 2015). Nomadic grazing and medicinal plants collection has induced a great pressure on the pastures and rangelands in northern districts of Khyber Pakhtunkhwa (Shahbaz et al., 2011).

In response to deforestation a series of mass plantation projects, most of which were supported by international donors, had been initiated in the last few decades in the different regions of Khyber Pakhtunkhwa Province. The basic objective of these interventions was to mitigate the problems created due to deforestation, by involving local people to plant trees and protect catchment areas.

Mass plantations have a number of benefits, both in long term and in short term. Apart from being attractive aesthetically, forests remove and store carbon from the atmosphere, reduce the downward flow of heavy rain and minimize the risk of flooding, improve air quality and reduce the urban heat effect by reflecting sunlight and providing shade. To raise awareness, motivate and mobilize communities and sensitize policy makers towards mass plantation, it is an urgent need to quantify and assess the carbon sequestration of existing mass plantations, its contribution to watershed management and biodiversity improvement.

### 1.2 Objectives

The overall aim of this study is to assess the impacts of mass afforestation projects; to quantify their carbon sequestration value, enhanced watershed values and role in biodiversity conservation through habitat improvement. The specific objectives are:

- To evaluate the impacts of selected mass forestation project in enhancing biodiversity and carbon sequestration
- To assess the effects of the forestation project on watershed improvement in the selected site

In order to achieve the above objectives, aim the study analyses a mass afforestation site at northern Khyber Pakhtunkhwa in Swat district i.e., Fatehpur watershed plantation. The details of the study area are described in section 3.

### 1.3 Scope of the Study

A number of projects regarding conservation of natural resources have been initiated throughout the world by various governmental and non-governmental organizations working on nature and environment. Though, conservation of natural resources and forestlands in particular have always remained a challenge specially in developing countries like Pakistan, still success has been achieved by different agencies up to some extent. The purpose of this study is to identify and evaluate the impacts of such conservation projects on the environmental services of a forestland. The outcomes of this study may determine the difference between the environmental services of a treated and untreated forest area. To some extent, this study may also be fruitful for organizations (donors) working on conservation of natural resources to know the value of conservation efforts in a forestland. Hence, they may be encouraged to invest further. Lastly, the results of the research work should be helpful for future researchers to assess the ecosystem services of forests.

## 2. Literature Review

This section critically examines the literature on the importance of ecosystem services of forestlands. The section begins with the review of past and current literature on the biodiversity conservation service of the forestlands. The following section explores the research work carried on analysing the role of forests in managing watersheds and regulating the water flows in and out of the catchment areas. Section 3.3 reviews literature on soil erosion and the role of vegetation cover in soil conservation. The final section of the section analyses the literature on carbon sequestration and the role of forestlands in climate change mitigation.

### 2.1 Biodiversity Conservation

Biodiversity or Biological diversity has been defined as;

"The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems." (Convention on Biological Diversity, Rio, 1992).

Despite the extremely significant contributions of forests to the conservation of earth's biodiversity, they currently face different and sometimes contradicting challenges (Xofis et al., 2023). The uncontrolled conversion of forests into agricultural lands, observed throughout the world is associated with socio-economic challenges during the 20th century, provides an opportunity for degraded or even lost forests to recover and reoccupy their pre-human areas. This may result in a significant increase in forest cover and a decrease in forest fragmentation, with positive consequences for biodiversity conservation, as is proved with the recent increase in the distribution and abundance of Europe's emblematic carnivores (Otero et al., (2018). Furthermore, increased forest cover has been reported to contribute significantly to increased biomass and carbon stock, with positive consequences for mitigating climate change (Silver et al., 2015). The increases in forest cover, however, may also lead to an increased degree of landscape homogeneity, with negative impacts on local biodiversity and species that require a mosaic of forested and open areas to cover their needs in terms of food and protection.

Sher and Al-yemeni (2011) studied the ecological diversity and economic importance of plant species in the coniferous forest of Swat, Pakistan. The basic objective of the study was to find out the phyto-sociology of the area with special reference to economically important medicinal plant species and their conservation status. While some depend on agriculture, most of the people of the region depend on the available forest resources like fodder for their livestock and medicinal plants for their income generation. Livestock grazing, tree cutting for timber and fuel wood, and ruthless medicinal plant collection exert enormous pressure on the forests and ultimately causes environmental degradation in the area. Other reasons causing this degradation include, poverty, lack of jobs, over population and lack of scientific skill for medicinal plant collection. During the study 90 important plant species consumed by the residents of the region for different purposes were examined. As some of these plants are sold on good prices in the markets, thus they are collected in large numbers not only by the local people but by the outsiders as well. This large-scale collection of medicinal and other valuable plants has posed a threat to the survival of some of these species. Medicinal plants like *Podophyllum hexandrum* and *Berginia ciliata* which were once very common in the forests of Swat but are now confined to a very few small patches. This is only because of the extra ordinary use of these plants over the past few decades. It has been observed during the course of the study that there is no check on the collection of these medicinal plants and are collected in large volumes therefore, causing loss to plant diversity as well as damaging natural habitats of the wild animals. At the moment, apparently there is no efficient mechanism to control the harvesting of forest resources therefore rate of consumption is much higher than the rate of regeneration. Another finding of the study was that most of people involved in the collection and trade of these economically important plant species are unskilled. They do not have knowledge of scientific methods and can even uproot the whole plant even if only the leaves of the plants are valuable. The reproduction rate of these economically valuable plant species has also been badly damaged by the over consumption, forest degradation and deforestation, livestock grazing, urbanization and ruthless collection of these plants in the study area. Finally, the study concludes that some of these plant species are at risk of extinction and may soon disappear from the mountains of the region, if proper conservation measures are not adopted.

The conservation of genetic diversity and resources is of crucial importance for bio-diversity conservation, especially under conditions of climate change, which transforms habitats across the globe. Chertov et al., (2021) studied the genetic diversity and population structure of *Larix sibirica* in the Ural Mountain ranges in Russia. They concluded that the currently observed differentiations between the populations need to be preserved by maintaining non-fragmented populations and preventing the geographical isolation of existing populations. In the same region, another study was conducted by Sboeva et al., in 2022. The study showed a limited genetic diversity in *Pius silvestris*, which is explained by the biogeography of the established populations. A similar study by Gong et al., (2022) on *Cinnamomum camphora* in East Asia revealed significant differences in genetic diversity among populations and moderate differentiation between populations. They pointed out the need of enhancing gene flow to reverse the negative effects of genetic drift and reducing the risk of genetic diversity reduction. Significant differences in the within-population genetic diversity, and high differentiations between populations, were observed by Huanget al. (2022) in different populations of *Camellia chekiangoleosa*. They recommend the adoption of appropriate management measures to maintain the diversity in the high-diversity populations and increase the gene exchange in the low-diversity populations to restore genetic diversity.

Wasiolka and Blam (2011) carried out a comparative study to find out the impacts of protection from livestock grazing on the biodiversity of a savanna habitat. For this purpose, the researchers analyzed plant and reptiles species diversity in a protected park and adjacent non protected farmland within the same savanna habitat in the southern Kalahari, South Africa. The data collected from the two sides showed that the species diversity of grasses and shrubs was very high in the protected park as compared to the non-protected farmland. The vegetation cover was also much denser in the park in comparison of the farmland. Along with the species richness, only few small patches were affected by the shrub encroachment in the park, though because of heavy grazing encroachment of shrubs is a very common problem in most the savanna ecosystems of the world. The diversity in reptile species was also fairly high in the protected park. On the other hand, typical signs of degradation caused by livestock grazing were observed in the farmland. This degradation was characterized by; vegetation covers not dense enough, low grasses diversity, high proportions of annual and perennial shrubs and quite enough pieces of barren land. This huge difference in the two study areas can easily be described by the difference in the feeding behavior of wild ungulates present in the protected park and the livestock (mostly sheep) in the farmland. While the ungulates also consume the woody plants along with grasses, the sheeps only eat herbs and perennial grasses. Moreover, the variety of ungulates present in the protected park and their capability to consume wide range of plant species results in balanced and sustainable habitat. This huge distinction in the characteristics of vegetation covers in the protected park and non protected farmland negatively affects the abundance and diversity of reptiles. Reptiles prey, the arthropods populations are found to be declining because of heavy grazing and low vegetation cover in the open farmland. In addition, because of the scarcity of grasses which are considered as refuge for reptiles, the predation risks for reptiles are also very high in the unprotected farmlands.

Climate and global changes result in significant land use changes and habitat alterations, with subsequent alterations in species' current and future geographical distributions, as well as in their physiological responses. Zhang et al. (2021), studied four alpine Rhododendron species, revealed a significant expected shrinkage in their geographical distribution as a result of climate change, as well as an expected movement of species to different bio-geographical regions. A significant expected decrease in the currently suitable habitats for *Swietenia macrophylla* (mahogany) was reported under different climate change scenarios by Herrera-Feijoo et al. (2023). At the same time, currently unsuitable areas may become suitable in the future, which demonstrates the dynamic nature of any conservation measures, including the designation of protected areas. Climatic patterns affect a number of physiological responses of species, including flowering and fruiting. Dagnachew et al. (2023) point out the need for a better understanding of the relationships between climatic variables and species physiological responses, which vary considerably between species, in order to develop an effective conservation scheme for species of high ecological and economical importance.

Hence, the recent and past literature highlights that deforestation, driven by agriculture, logging, and urbanization, is a primary threat to forest biodiversity. Habitat fragmentation further exacerbates the loss of species by isolating populations and reducing genetic diversity.

### 2.2 Watershed Management

A watershed is an area of land that channels rainfall and snowmelt into streams, rivers, lakes, and aquifers. Forestlands play a crucial role in watershed management by contributing to the regulation, protection, and quality of water resources and also plays a vital role in maintaining the health and functionality of the catchment area.

Khan and Irshad (2018) studied the impacts of forest protection in the upstream watershed on the quality and quantity of water in the downstream areas of moist temperate forest of Himalaya region of Pakistan. To determine the impacts of protection two zones were selected one protected forest and the other Guzara forests. The discharge rates at the watersheds of Zone II were very high compared to that of Zone I. Following the same pattern the average amount of sediments in the streams of Zone I was only 89 mg/L much less than that of Zone II which was 206 mg/L. Similarly, the infiltration capacity of soils of Zone II was much less than that of Zone I.

J. D. Cheng et al (2002) carried out a study to analyse the role of forests in regulating the flow of water from watersheds to the downstream areas in Taiwan. Taiwan is one of the very few countries facing every year challenges like hazardous floods, debris flow and landslides throughout the country. This is mainly because the terrains are very steep, soil is quite fragile, precipitation rates and intensity is high and earthquake occurs quite frequently in the country. More than half of the land of the country is covered with forests so it is important to find out the potential of forests in reducing the frequency and intensity of these natural hazards, but this study was basically about the influence of forest cover, in the watersheds of the country, in decreasing soil erosion and regulation of stream flow. The results of the study concluded that forests in the watersheds of the country are having a positive role in regulating normal downstream water flows and reducing the risks of floods. The rainfall intensity in Taiwan is very high and usually surpasses 100 mm/h but due to the evapo-transpiration loss caused by the vegetation cover in the watersheds the overland flow is very low on the fragile forest soils. Forests are also reducing the erosion rates, in the watersheds by sheltering the land surfaces from direct rainfall effect and in the downstream regions by retarding the water flow. As mentioned, soils of the country are quite susceptible towards erosion and high intensity precipitations can easily flow away these soils but the roots of trees keep intact these fragile soils and protect them from being eroded by rainfall water. Drinking water quality is currently a rising issue in the country and forests are playing a good role in enhancing the quality of water by reducing the sediment loads, filtering the pollutants and stabilizing temperatures of water in the streams. The study also found that rapid urbanization in some of the forested watersheds can increase the frequency and intensity of floods because the infiltration capacity of the soil is decreasing and the peak flows are continuously increasing.

Host Weyerhaeuser et al (2005) analyzed the impacts on the local community and their response to forest rehabilitation and conservation programmes in Yunnan province of northwest China. The Sloping Land Conversion Programme of China was designed to incorporate developments of local people in the watershed restoration project. The project was aimed to minimize soil erosion and decrease runoff in to the river systems. For this purpose, tree plantation has been done on large scale. Farmers voluntarily participated in the plantation programme and were allowed to choose the land they are willing to select for plantation. The villagers were only given the task of planting trees on large hectares of land. As a result, although the overall forest cover has been increased but the watershed areas which were susceptible towards erosion were not restored and thus the real objective of the project was compromised. Another loop hole in the project was the selection of tree species for plantation. Because the project demanded the plantation of such trees, which not only control erosion but also be useful in the development of livelihood of the locals. But the study revealed that the local staff of the forest department fails to suggest particular tree species that meet the needs of local farmers and also good in the soil erosion control.

The literature suggests that forestlands are integral to watershed management by ensuring the quantity and quality of water resources, protecting against natural disasters, and supporting the overall health of ecosystems. Sustainable management of forests within watersheds is essential for the long-term provision of such ecosystem services.

### 2.3 Erosion control and soil conservation

Soil erosion control is one of the key ecosystem services provided by forestlands. This service is crucial for maintaining soil health, preserving land productivity, and protecting water quality.

Zokaib and Nasir (2011) showed the relationship between land uses and its impacts on soil erosion and runoff. For this purpose, the Hilkot watershed which drains into the Terbella dam has been extensively studied. To observe runoff and soil loss the watershed area has been divided in to four experimental plots; pasture, forested, agriculture and degraded lands. The data was collected for seven years from 1999 to 2005. Results showed that soil erosion and runoff varies with the variation in land use type, season and intensity of precipitation but vegetation cover plays a major role in controlling soil erosion and decreasing sediment load in the downstream water. The data reveal that soil loss through erosion and runoff was highest in the degraded lands while, because of good vegetative cover, comparatively lower soil erosion and runoff was recorded in the forested and pasture lands. Therefore, to control soil erosion and runoff and to utilize the runoff water in a better way the vegetative cover must be improved and plantation should be done in the degraded lands of the Hilkot watershed.

Ilan Stavi et al (2008) studied the impacts of livestock grazing on the characteristics of soil in the shrubs of northern Israel. Soil samples were taken in growing season and in the dry season from both north and south facing hillside in the shrub and intershrub areas. These samples were then analysed to determine concentration of moisture, carbon content, concentration of calcium carbonate and bulk density. The results recommended that generalization of the impacts of grazing on soil properties of the whole study area is not possible because no such impacts were observed. Instead, the effects of grazing should be studied on very fine spatial scales of the individual vegetation type. Broadly, grazing had the maximum impact on the soil of the least covered trampling routes, while, no considerable effect had been found on the soil characteristics of the densely covered patches of shrubs.

Depending on the composition, structure and configuration that they have in catchments, land use can accelerate and/or mitigate soil erosion. One of the most important ecosystem services provided by different forestlands is mitigation of soil erosion, and this also affects soil ecosystem services (Rendon et al., 2020). A study Xiong et al., (2019) comparing soil erosions associated with land use and climate type showed that bare lands can be considered as the land cover with the highest rate of soil erosion. Agriculture lands have the second-highest rate of soil erosion, while forestlands are the land cover with the lowest rate of soil erosion. The rate of soil erosion in orchards in grasslands, and in shrublands fall between the rates for bare lands and for forests, and can be arranged in descending order. Forest cover, both natural and artificial, is one of the most important land covers for providing protection against soil erosion (Borelli et al., 2017).

Toit et al., (2009) studied the physical impacts of sheep grazing on the soil characteristics of the Nama Karoo rangelands in South Africa. The research was carried out in a research station of Agricultural Department of eastern Cape Province. The data was collected from eight, 1 ha each, fenced sample sites having same aspect and similar slope. Three different types of sheeps were allowed to graze in different sample sites for same period of time. The infiltration rate was determined in each sample site before and after the grazing. It was found that the infiltration rates were considerably low after grazing than before grazing in most of the sample sites. This decrease in the infiltration rate can be attributed to the soil compaction caused by the grazing and trampling of the sheeps. Because when the compaction of the soil increases the penetration of water in to the soil decreases, thus we observe low infiltration rates in compact soil as compared to relatively loose soils. Ultimately the moisture content of the soil decreases and same was observed during the study that the water content in the soils significantly decreased after grazing. The particle size of the soils did not show any regular pattern that can be related to grazing but in some samples a decrease in the silt component was observed after grazing while in other samples a significant decrease in the clay was found.

King (2007) presented the importance of *Aloe secundiflora* shrubs in the restoration of degraded rangelands in Kenya. Excessive grazing in some of the semi-arid regions of the country has badly damaged the rangelands. It is essential to restore the degraded rangelands because the pastoralists of these areas greatly depend upon these rangelands for their livelihood. Different means can be used for the restoration of such degraded lands, one of which is using a facilitator plant species. A facilitator plant can play a very useful role by surviving in such harsh environmental conditions where other plants may not be able to survive and establish. In this case, the ability of *Aloe secundiflora* shrub as a facilitator plant in the degraded rangelands was examined. One meter sample quadrates were taken in the degraded rangelands to analyze the soil characteristic and vegetation cover. Among these randomly selected samples, some encompass *Aloe secundiflora* shrub, some surrounds *Maerua decumbens* shrub while the rest were shrub less samples. It was found that vegetation cover was maximum around the *Aloe* foci, minimum around the shrub less foci and intermediate around *M. decumbens*. Similarly, species richness was also highest around the *Aloe* foci and surprisingly better in the shrub less samples than in the samples around *M. decumbens*. When the percentage of litter present in the top soils under the samples was calculated it was found that the litter is present in highest amounts in the soils where *Aloe* shrub was present. Thus, high vegetation cover and better species diversity around and good litter percentage in the soil beneath the *Aloe* shrub prove the hypothesis that it is a good facilitator plant species and can be best used as potential tool to restore the degraded rangelands in any arid and semi-arid region of the world.

When addressing soil erosion and the soil erosion regulation ecosystem service, it is necessary to take into account other exogenous and endogenous factors that affect the soil erosion process and thus change the quality and the quantity of the soil erosion mitigation ecosystem service.

### 2.4 Carbon sequestration and Climate change mitigation

Carbon sequestration refers to the process of capturing and storing atmospheric carbon dioxide ($CO_2$). It is a critical strategy for mitigating climate change, as it helps reduce the concentration of greenhouse gases in the atmosphere. Climate change has been considered as one of the great threats to human existence on earth. Due to fossil fuel burning and deforestation, concentration of atmospheric $CO_2$ has increased from 280 mg/L at preindustrial revolution to 394 mg/L presently (Peñuelas et al. 2013). As a result, average global surface temperature is increasing at an unprecedented rate. These changes as well as changes in precipitation, nitrogen deposition are likely to have significant effects on tree growth and forest dynamics, and eventually, carbon accumulation in forest ecosystems (Zuidema et al. 2013). Understanding the accumulated impacts of these climate changes (e.g., global warming, elevated $CO_2$, precipitation change, and nitrogen deposition) is crucial for predicting ecosystem carbon dynamics in forest ecosystems.

Climate change affects forest ecosystem carbon cycling both directly and indirectly (Hui and Luo 2004). Whether forest ecosystems sequestrate more carbon in to ecosystems (carbon sinks) or release more carbon from ecosystems (carbon sources) depends on the net ecosystem carbon exchange, the difference between gross ecosystem primary productivity and ecosystem respiration. When climate change stimulates photosynthesis process by elevated atmospheric CO2 or improved growing conditions (i.e., warmer temperatures, more favourable moisture balance, improved nutrient availability, or decreased pollutants such as tropospheric Ozone or decreases plant or microbial respiration process as a result of altered chemical or physical composition of the plants and soil organic matter, the ecosystems act as carbon sinks (Field et al. 2007). Otherwise, the converse processes can make ecosystems act as carbon sources. Many experimental and modelling studies have been conducted in order to better understand the potential effects of global warming, elevated atmospheric $CO_2$, and changing precipitation regimes on these forest ecosystem processes.

The effects of rising atmospheric $CO_2$ concentrations on carbon sequestration in forest ecosystems have been studied for decades. In the early years, researchers used closed chambers such as glasshouse and growth chamber to grow tree seedling or small trees in pots under control and elevated $CO_2$ levels. These studies were criticized as glasshouse and growth chamber cannot really mimic the real-world environment, thus generated responses that are different to these under natural conditions. Open-top chambers provide natural light and precipitation for trees to grow but may modify air and soil temperature inside the chambers. More recently, trees have been exposed to elevated $CO_2$ using free-air $CO_2$ enrichment (FACE) technology, which allows the fumigation of intact forest ecosystems with air enriched in CO2 in large-diameter plots without walls (Norby et al. 2005; Drakeet al. 2011).

Experimental studies provide direct evidences of increased vegetation carbon accumulation and ecosystem productivity in forest ecosystems under elevated CO2. The enhancement of aboveground

biomass for trees under elevated $CO_2$ range from % to 50 %, with the higher values observed in young trees and little to no response observed in the few experiments conducted to date in mature natural forests (de Graaff et al. 2006). For the belowground biomass, the maximum increases by elevated $CO_2$ can exceed 50 %, hence usually resulting in lower shoot: root ratio (de Graaff et al. 2006). Early results from an open-air $CO_2$ enrichment experiment in a young North Carolina forest also showed increased ecosystem net primary productivity during the first 2 years of exposure, but later findings indicated that this productivity declined with time (Finzi et al. 2002). Planting new forests (afforestation) and restoring degraded forests (reforestation) are effective strategies for enhancing carbon sequestration and contributing to climate change mitigation. These practices are often included in national and global climate strategies, such as the Paris Agreement. Protecting existing forests from deforestation and degradation is crucial for maintaining their carbon sequestration capacity. Conservation efforts help preserve the carbon already stored in forests and prevent additional $CO_2$ emissions.
In summary, the current and recent past literature highlights that carbon sequestration and climate change control are vital ecosystem services provided by forestlands. Through these services, forests help mitigate the effects of climate change, support biodiversity, and contribute to the resilience of ecosystems and human communities. Sustainable forest management is essential to maximize these benefits and ensure forests continue to play their role in combating climate change.

## 3. Materials and Methods

The field work for the study was conducted from April to September in 2024. Study plan was prepared and general information about the area was collected before starting the data collection part of the research. The details of various methodologies used for different parameters are explained in this section.

### 3.1 Study Area- Fatehpur Watershed Plantation in Swat Forest Division

Fatehpur is one of the sixty five union councils in District Swat. According to the census conducted in 2018, the UC has more than 5000 households and a total population was around 42,000. Plantation wise and climatically the area fall in the sub-tropical Chir Pine zone. Therefore the most common and dominant specie is Chir pine.

#### 3.1.1 Forest Cover

The mountains of the area have dense cover of coniferous as well as broad leaved trees that fulfil the domestic requirements for timber, fuel wood and fodder. Forest cover of the valley is divided in upper and lower zones. In lower zone the dominant species include *Pinus roxburghii* (Chir Pine), *Cedrus deodara* (Deodar/Diar), *Pinus wallichiana* (Blue Pine, Kail), *Picea smithiana* (Spruce), *Abies pindrow* (Fir, Palutar), *Quercus incana* (Rin), *Quercus dialtetae* (Oak), *Aesculus indica* (Horse-chestnut, Bankhor). In the upper zone there are some pockets of deciduous broad-leaved species edaphically conditioned in both zones of the area.

#### 3.1.2 Grasslands

Those areas which have rough patches of grasses and scattered tree crops and can be used by local community for grazing and fuel wood purposes may be termed as grass land or range areas. In Fatehpur, the downhill sides are used for the purpose of grazing that result in irregular utilization of palatable and non-palatable species. Livestock grazing is one of the major land uses and most of the areas are subjected to high pressure of grazing. The pattern of local grazing is irregular and beyond the carrying capacity of the rangeland which results in obvious decline in the productivity of the land. These rangelands are usually communally owned or have been divided into sections/khels. They play a vital role in promoting the economic status and meeting fuel demand of the settlements. Unlike entire areas some grasslands are properly protected for controlled grazing and sustainability of fodder production. Natural grass species found are

*Cynodon dactylon* (khabal), *Chrysopogon monticola* (spin wakhay), *Cymbopogan juwarensis* (sargharay), *Andropogon gayanus*. In some spots of the valley the traditional system of land rent (Qalang) is also established for utilizing range land.

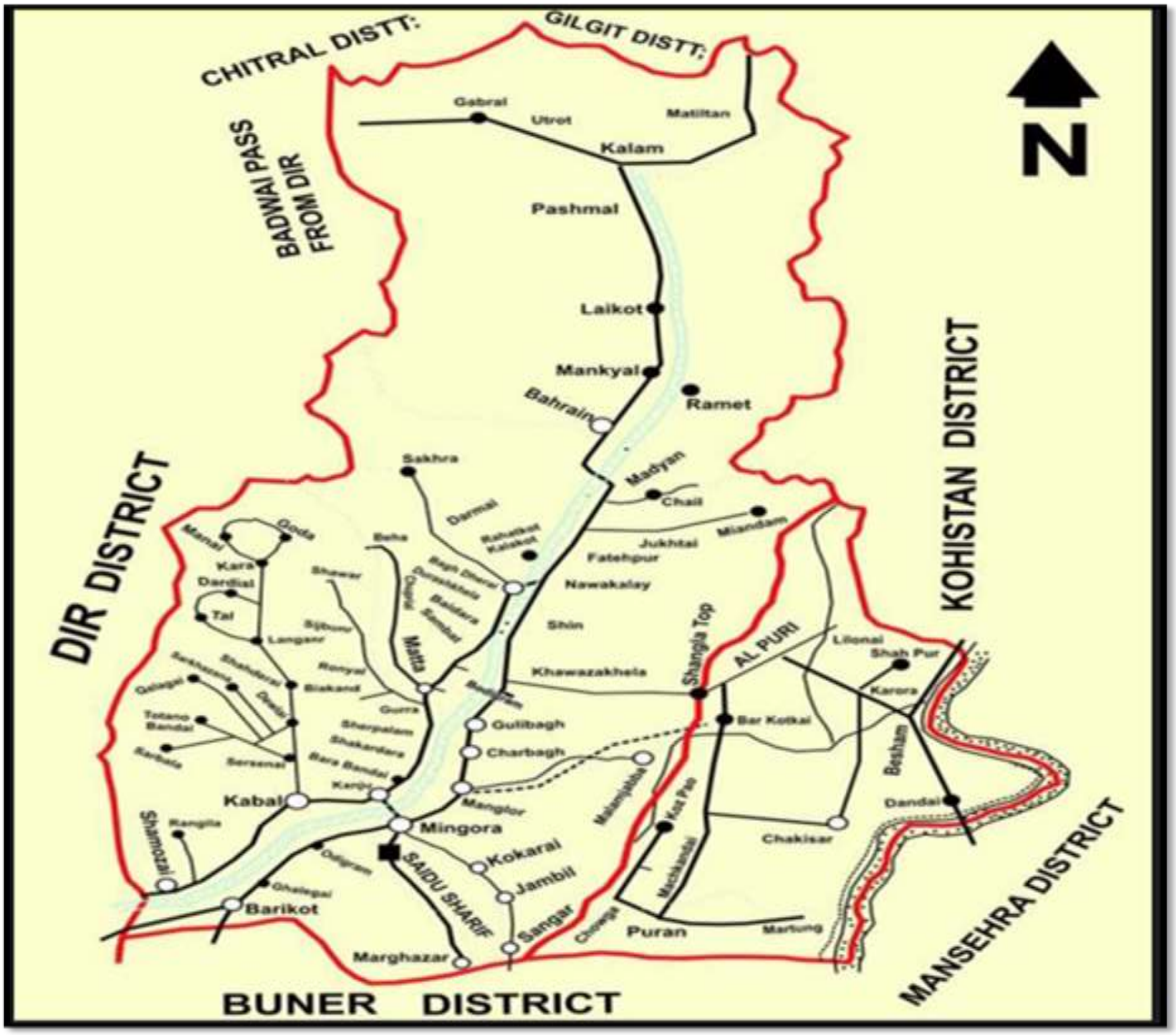



**Figure 3.1: District Swat Map**

### 3.1.3 Agricultural Landuse

Like other areas of Swat district, people of Fatehpur valley raise different seasonal crops and vegetation on their fields. In the valley, though some of the fields are totally dependent on rain water but most of the agriculture land is either near to settlement areas or along the bank of rivers and streams. Majority of the owners cultivate their fields themselves while some have given their land on rent or share based agreement. The crops cultivated on these agricultural lands including wheat, maize, barley etc. when harvested are used domestically as well as sold in the nearby market for commercial purpose resulting impressive socio-economic growth of local population.

### 3.1.4 Fruit Trees / Orchards

Walnut *(Juglans rigea),* Amlok (*Diospyrus kaki),* Black Persimmon (*Diospyrus lotus),* Grapes, Pears, Unab and Apple are the major marketable fruits. About half of the population has 5-6 trees of walnut and amlok per household. The first three are produced on a large scale while rest of the fruit plants are grown for personal use or sold on small scale at Madyan (Swat) local market.

### 3.1.5 Vegetables

Since 1990s vegetables like French bean, Peas, Potato and Turnip were introduced and from then onwards grown on large scale. Other vegetables grown in the valley include Chilly, Cauliflower, Cabbage, Radish and *Brassica compestris* (saag).

### 3.1.6 Water Resources

Being a forest area, the valley contains sufficient number of springs and perennial streams which flow throughout the year fulfilling domestic and irrigation requirements. In some areas due to steep slopes water channels are used for generating power and electricity on small scale through mini hydro power stations and also operating water flour mills. River is the main source of water in the entire area. There are a number of perennial streams and springs in the area, which feed the main river. These fresh springs and streams provide a better environment to aquatic fauna.

## 3.2 Plant Species Identification in the Study Area

The forestland selected for this study constitutes a mass plantation which was carried out under the flagship Watershed Management Project in 1982. The project was implemented by Khyber Pakhtunkhwa (the then NWFP) Forest Department. In the mass plantation project, the most frequent species planted included Chir Pine (*Pinus roxburghii)*. This was followed by *Melia azedarach and Robinia pseudoacacia*. For this research, two sites of the mass plantation project are taken. The first site is near Shin village with total area of 218 hectares and second one is near Fatehpur village, with a total area about 70 hectares.

For the assessment of biodiversity a Line Transact Survey (Sher & Al-Yemini, 2011; Lee at al., 2012) technique was applied. Line transect walk accompanied by the experts was carried out in the study site to ascertain the maximum number of plant species available in both of the forestlands. Once the identification of species along the transect line completed for both the study sites, it was followed by species richness assessment.

## 3.3 Density and Frequency of Plant Species

Plant species data can be collected by two methods systematic or random sampling. A systematic sampling technique assures unbiased data collection and produce results in close approximation to the true features of the vegetation. Hence, systematic sampling method was adopted in the study to have precise information about plant species diversity in the study area. Systematic sampling needs a properly defined sample design. This means the size of each sample (quadrate) and the distance between two samples should be specified. For trees, the plots were approached along the transect walking upstream on a track and from their lower positions, across the slopes on rows. During the field survey, data on various parameters have been collected, within a radius of 17.84 m circular plot all trees Diameter at Breast Height (DBH) have been kept for measurement.

To find out density and frequency of herbaceous plants, the size of the quadrate used in the study was one square meter. The first sample in at each forestland was taken randomly along the transect line and the following quadrates were laid out after every 200 meters. A total of 30 quadrates were taken in each forestland to collect information regarding the ten important selected species. With the limited resources and time constrains it was not possible to find out density and frequency of each and every plant species present in the study area. Therefore, to assess the comparison in the densities and frequencies of various plant species in both the forestlands, only limited plant species were selected.

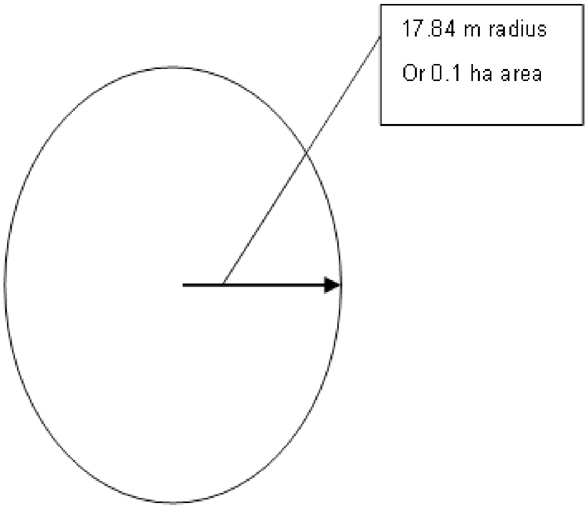



**Figure 3.2 Sample plot design**

**Figure 3.3 Data collection in sample plot**

Density is simply the total number of plants of a particular species present in an area. The number of plants of each of the selected individual species was calculated in all of the quadrates. Finally, all the plants of given species were added upon and divided by the number of quadrates, thus the average densities for the particular plant species were calculated for both of the forestlands. The selected plant species include ecologically important medicinal herbs.

Frequency means the distribution of a specific plant species in a given area. If plants of a particular species occur in patches it can have high density but the frequency should be quite low. This shows a non-uniform distribution of the particular plant species in the given area and any indiscriminate harvest can endanger the existence of the species on the site. Frequencies of the selected herbaceous species were calculated and were tabulated in percentage.

**3.5 Species Diversity**

Species diversity is often regarded as species richness, that is simply count the number of species present in the stand but in fact diversity equally depends upon species evenness along with species richness (Asif, 2001). Species evenness means density and frequency of the different species present in the area under investigation. So high species diversity demands for a good number of species equally distributed in an area. These dual concepts of species richness and evenness can be better illustrated with the help of figure 3.1.

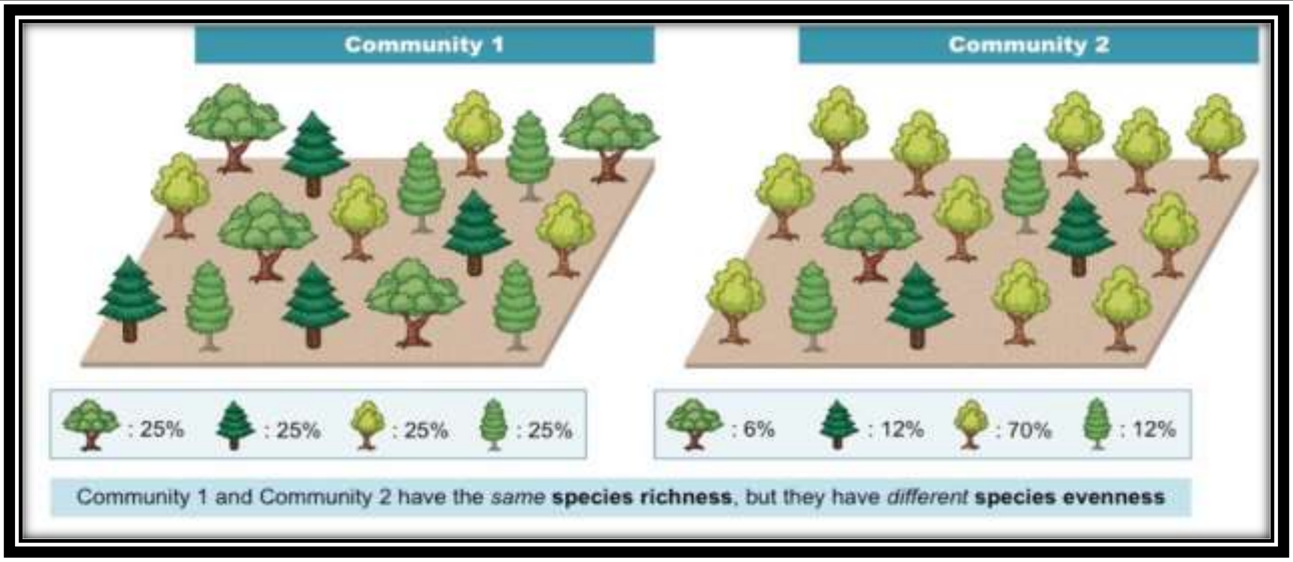



**Figure 3.4 Species Richness and Evenness**

The given figure consists of two communities both composed of same number of species, so species richness is same for both the communities. But community 2 is clearly dominated by one species making 70 percent of the community and the rest of the three species collectively compose only 30 percent of the whole community. In contrast to community 2, community 1 has all the four species in equal number and these species are also almost evenly distributed in the given area. Therefore, we can conclude that comparatively, community 1 is more diverse in than community 2.

### 3.6 Diversity Indices

A diversity index is a mathematical tool to quantify the diversity of species in a community. It actually provides important information about the density and frequency of various species in a community. The ability of diversity indices to measure species abundance and distribution often attracts ecologists to understand community structure and composition. Shannon diversity index and Shannon evenness index are used in this study to compare species density and frequency in the two mentioned study areas.

**Shannon Diversity and Evenness Indices**

The formula for calculating Shannon diversity index $H$ is;

$$H = -\sum Pi \ ln\, Pi \qquad (1)$$

Where;

$P_i$ = the proportional abundance of *i*th species = $n_i$ / N

$n_i$ = number of individuals of the *i*th species

$N$ = Sum total of all individuals of all species

*ln* = Natural logarithm

The formula for calculating Shannon evenness index $E$ is;

$$E = \frac{H}{ln\, S} \qquad (2)$$

Where;

$H$ = Shannon diversity index

*ln* = Natural logarithm

$S$ = Number of total species

Shannon evenness or equitability index gives value from 0 to 1, with 1 being complete evenness and 0 with no evenness. To compare the diversities of two different data sets a "t-test" was carried out.

### 3.7 Collection of water and soil samples for Watershed assessment

To assess the impact of mass plantation on watershed improvement, soil sample were collected to determine the infiltration capacity of soil. For comparative assessment, soil sample from adjacent area having same topography and slope were also collected. Total of 10 soil samples were collected from both mass plantation area (5 samples) and adjacent barren land (5 samples). Similarly, to find out the sediment load for assessing water quality, runoff water samples were taken at the outlet of both mass plantation area and adjacent site.

**Sediment Load**

Water samples were collected from the study area and GPS readings were recorded at each site of the sample collection. The samples were then brought to the laboratory to determine the sediment yield. To determine sediment yield, 100 mm water were taken from each sample. The water samples were then filtered through a filter paper of known weight. The oven dry filter paper was weighed along with the sediments. The difference between initial weight of filter paper and oven dry filter paper should be the weight of sediment in parts per million (mg/L).

**Quantity of Water in Streams (Stream Discharge)**

To find out the impact of vegetation on the change, before and after rain, in the quantity of water in the streams at both the forests sites Manning's equation was applied.

$$Q = CAI \left\{\frac{HR^{0.67} \times S^{0.5}}{n}\right\} \quad (3)$$

Where;

Q = Quantity of water in $m^3$/sec

CAI = Cross Sectional Area of the stream in $m^2$

HR = Hydraulic Radius in meters

S = Slope in percentage

n = Manning's roughness coefficient

And,

$$HR = \frac{CAI}{WP} = \frac{Cross\ Sectional\ Area}{Wetted\ Perimeter} \quad (4)$$

To evaluate the cross-sectional area width of the stream was measured and then depth of the stream at several intervals was measured. The product of width and average depth was determined as cross-sectional area. Slope in percentage was calculated with the help of clinometer, while the coefficient value was taken from Mannings roughness coefficient table. Using the equation the discharge rates were gauged for two streams, one each at conserved and open forestland.

In order to have a neutral approach the data was recorded before and after the rainfall (within four hours of rain). The actual aim of this parameter of the study was to find out the amount of change in the quantity of water in a stream before and after rainfall therefore, an average difference in the values of water quantity before and after rainfall was also calculated and then a comparison was made between the streams of the two study sites.

**3.8 Assessing the carbon sequestration potential**

Besides the socio-economic importance of mass plantation and its environmental benefits in biodiversity conservation, soil fertility and soil stabilization the plantations play a significant role as an atmospheric carbon sink. The carbon sequestration potential of these plantations is substantial but it has not been sufficiently recognized. Different forest types have different rates of carbon sequestration. The amount of carbon sequesters in any land-use system depends on available carbon in standing biomass, soil carbon and carbon in other woody products. Biomass is a direct indicator of carbon content, as carbon makes up a significant portion of plant material. Allometric equations (Aabeyir et al., 2020; Abebe et. al., 2021) were therefore be used to estimate the total carbon stored in the forest. The total biomass content for carbon sequestration is often divided into aboveground biomass (AGB) and belowground biomass (BGB). The equation for calculating the total carbon content for each component is as follows:

Aboveground Biomass Carbon Content (AGBCC):

$$AGBCC = AGBD \times Carbon\ Fraction \quad (5)$$

Where:

AGBCC is the above ground biomass carbon content.

AGBD is the above ground biomass density, representing the total dry mass of aboveground living organisms (e.g., trees, shrubs) per hectare.

Carbon Fraction is the fraction of aboveground biomass that is carbon.

Belowground Biomass Carbon Content (BGBCC):

$$BGBCC = BGBD \times Carbon\ Fraction \quad (6)$$

Where:

BGBCC is the below ground biomass carbon content.

BGBD is the below ground biomass density, representing the total dry mass of belowground living organisms (e.g., roots) per hectare.

Carbon Fraction is the fraction of belowground biomass that is carbon.

The total biomass carbon content (Total BCC) is the sum of aboveground and belowground carbon content:

$$Total\ BCC = AGBCC + BGBCC \quad (7)$$

Biomass is the total biomass of the plant or forest stand, including aboveground and belowground biomass. The biomass were estimated by measuring the diameter, height, and wood density of a sample of trees. This can be measured in various units, such as metric tons or kilograms of dry biomass. Carbon Content is the fraction of biomass that consists of carbon. The carbon content varies depending on the type of vegetation, but a commonly used approximation is around 50% by weight.

Forests also contain other vegetation such as shrubs, bushes, and grasses. The amount of carbon stored in these plants were estimated using standard biomass equations. The Intergovernmental Panel on Climate Change (IPCC) default values were adopted for carbon fraction and ratio of below ground biomass to aboveground biomass (IPCC, 2006; 2019).

### 3.9 Data Processing and Storage

Data was recorded in tally sheets during fieldwork. The data collected from field survey went through validation process, after validation, it was stored in the MS Excel sheet. The digitalized data was further validated to minimize possible errors before submitting for final compilation and analysis. After three ways of validation processes, the final data was considered for calculation of final results. A computer-aided data analysis (CADA) programme i.e. SPSS was used for the LSD (Least Significant Difference) for two-way ANOVA f-test to generate the value of significance at the 95% confidence interval. The processed data is be presented in the form tables and figures and critically analysed in the following section.

## 4. Results and Discussion

This section represents and assess the data collected for this study. The assessment is based on the quantitative data collected in the field and the results drawn from the analysis of the samples at the laboratory. The results of the two studied sites i.e. one, near Shin village having an area of 218 hectares and other near Fatehpur village, which is about 70 hectares are also compared and discussed in this section.

### 4.1 Occurrence of Plant Species

Species occurrence means, the species available in a particular area. The current study was mainly concerned with the plant species in the area. Hence, only plant species in both study sites were identified. For this purpose, a line transect walk was carried out in the study area guided by experts to ascertain the maximum number of plant species available in both the forestlands. A total of 43 plant species were identified in the Shin Village site, while the number of plant species identified in the other Fatehpur site was 35. These plant species founded in each forestland are listed in table 4.1 and 4.2 respectively.

**Table 4.1 Plant Species Identified at Shin Village Forestland**

| S. No | Scientific Name | S. No | Scientific Name | S. No | Scientific Name |
|---|---|---|---|---|---|
| 1 | *Pinus roxburghii* | 16 | *Pinus wallichiana* | 31 | *Viola serpens* |
| 2 | *Robinia pseudoacacia* | 17 | *Picea smithiana* | 32 | *Viola biflora* |

| | | | | | |
|---|---|---|---|---|---|
| 3 | *Melia azedarach* | 18 | *Paeonia emodi* | 33 | *Vibernum grandiflorum* |
| 4 | *Celtis australis* | 19 | *Otostagia limbate* | 34 | *Artimisia vulgaris* |
| 5 | *Cedrus deodara* | 20 | *Myrsine Africana* | 35 | *Valeriana jatamansi* |
| 6 | *Bistorta ampilexicaulis* | 21 | *Adiantum venustum* | 36 | *Taxus buccata* |
| 7 | *Bergenia ciliate* | 22 | *Indigofera heterantha* | 37 | *Swartia elata* |
| 8 | *Berberis lyceum* | 23 | *Hypericum perforatum* | 38 | *Solanum nigrum* |
| 9 | *Avena sativa* | 24 | *Geranium wallichianum* | 39 | *Sambacus wightina* |
| 10 | *Asparagus adscendens* | 25 | *Fragaria vesica* | 40 | *Mentha longifolia* |
| 11 | *Abies pindrow* | 26 | *Ficus palmate* | 41 | *Plantago major* |
| 12 | *Cannabis sativa* | 27 | *Fagonia arabica* | 42 | *Plantago lanceolata* |
| 13 | *Quercus dialatata* | 28 | *Diospyros lotus* | 43 | *Podophyllum emodi* |
| 14 | *Aesculus indica* | 29 | *Cynodon dactylon* | | |
| 15 | *Allium sativum* | 30 | *Corydalis govaniana* | | |

**Table 4.2 Plant Species Identified at Fatehpur Forestland**

| S. No | Scientific Name | S. No | Scientific Name | S. No | Scientific Name |
|---|---|---|---|---|---|
| 1 | *Robinia pseudoacacia* | 13 | *Plantago major* | 25 | *Picea smithiana* |
| 2 | *Pinus roxburghii* | 14 | *Cedrus deodara* | 26 | *Paeonia emodi* |
| 3 | *Melia azedarach* | 15 | *Plantago lanceolata* | 27 | *Pinus wallichiana* |
| 4 | *Bistorta ampilexicaulis* | 16 | *Diospyros lotus* | 28 | *Viola serpens* |
| 5 | *Bergenia ciliate* | 17 | *Indigofera heterantha* | 29 | *Otostagia limbate* |
| 6 | *Berberis lyceum* | 18 | *Hypericum heterantha* | 30 | *Valeriana jatamansi* |
| 7 | *Artimisia vulgaris* | 19 | *Geranium wallichianum* | 31 | *Valeriana wallichi* |
| 8 | *Arisaema jacquemontii* | 20 | *Fragaria vesica* | 32 | *Taxus buccata* |
| 9 | *Aesculus indica* | 21 | *Cynoglossum lanceolatum* | 33 | *Solanum nigrum* |
| 10 | *Adiantum venustum* | 22 | *Cynodon dactylon* | 34 | *Quercus dialatata* |
| 11 | *Acorus calamus* | 23 | *Corydalis govaniana* | 35 | *Podophyllum emodi* |
| 12 | *Abies pindrow* | 24 | *Cannabis sativa* | | |

### 4.2 Density of the Selected Tree Species

Density and frequency of selected plant species found in both of forestlands were cautiously measured. As explained in section 3 due to the time constrains and inadequate resources only a limited number of trees and herbs species were selected for this parameter. The tree species selected included *Pinus roxburghii, Robinia pseudoacacia, Melia azedarach, Cedrus deodara.*

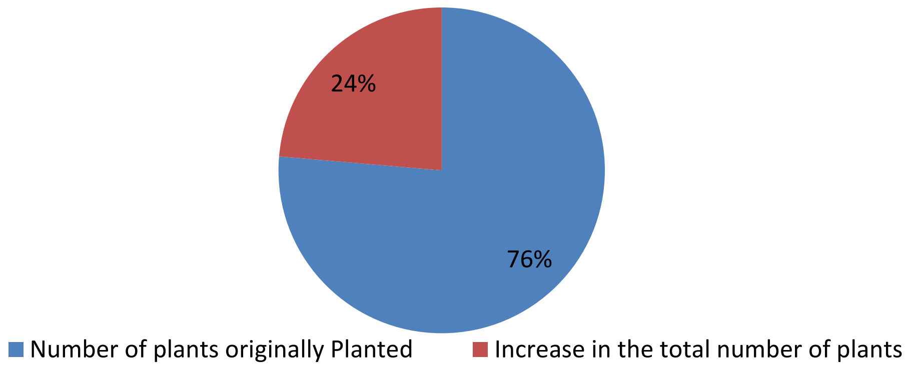
**Table 4.3 Trees species composition in both Forestlands**

| Species | Shin Village Forestland (218 ha) | | Fatehpur Forestland (70.2 ha) | |
|---|---|---|---|---|
| | No of Plants | %age | No of Plants | %age |
| *Pinus roxburghii* (Chir) | 187,220 | 86.6 | 58,563 | 82.4 |

| | | | | |
|---|---|---|---|---|
| *Robinia pseudoacacia* | 19,356 | 9.0 | 6,965 | 9.8 |
| *Melia azedarach (Bakine)* | 9,569 | 4.4 | 5,544 | 7.8 |
| **Total** | **216,145** | **100** | **71,072** | **100** |

Analysing the percentage distribution by species, the most abundant species found in was *Pinus roxburghii*, where it is responsible for the formation of 84.5 % of the total plantation collectively in both the forestlands followed by *R. pseudoacacia* (9.4%) and *M. azedarach* (6.15%).

**Figure 4.1 Percent increase in number of selected tree species**




According to the reports by the Khyber Pakhtunkhwa Forest Department a total of around 224,000 have been planted altogether with about 800 plants per hectare (10 x 10 feet spacing). Presently 287,217 number of plants were estimated during this study i.e. about 994 plants per hectare. This 24.25% increase to number of plants is direct contribution of the mass plantation programme to the biodiversity enhancement and carbon sequestration.

**4.3 Densities of selected herb species**

The important medicinal herbs selected for this study includes *Cannabis sativa*, *Viola serpens*, *Indigofera heterantha*, *Adiantum venustum*, *Mentha longifolia*, *Valeriana wallichii*, *Asparagus adscendens*, *Plantago major*, *Solanum nigrum*, and *Bergenia ciliata*. The average densities (per square meter and per hectare) of the selected herb species are given in table 4.4.

**Table 4.4 Densities of the selected herb species in both the Forestlands**

| S. No | Botanical Name | Shin Village Site | | Fatehpur Site | |
|---|---|---|---|---|---|
| | | Per $m^2$ | Per ha | Per $m^2$ | Per ha |
| 1 | *Adiantum venustum* | 3.025 | 30250 | 2.048 | 20480 |
| 2 | *Asparagus adscendens* | 1.001 | 10010 | 0.000 | 0 |
| 3 | *Bergenia ciliata* | 0.523 | 5230 | 0.340 | 3400 |
| 4 | *Cannabis sativa* | 3.033 | 30333 | 2.600 | 26000 |
| 5 | *Indigofera heterantha* | 1.245 | 12450 | 0.833 | 8300 |
| 6 | *Mentha longifolia* | 0.633 | 6333 | 0.000 | 0 |
| 7 | *Plantago major* | 0.700 | 7000 | 0.357 | 3570 |
| 8 | *Solanum nigrum* | 1.900 | 19000 | 2.670 | 26700 |
| 9 | *Valeriana wallichii* | 0.000 | 0 | 0.433 | 4330 |
| 10 | *Viola serpens* | 1.633 | 16330 | 0.800 | 8000 |

**Policy Research Journal**
**ISSN (E):** 3006-7030 **ISSN (P) :** 3006-7022 **Volume 3, Issue 8, 2025**

It is evident from the table that densities of the most herb species are quite higher in the Shin forestland as compared to the Fatehpur forest area. This clear difference in the densities of plant species can be attributed to the difference in location of the two forestlands. The Fatehpur forestland is relatively close to local population as compared to the Shin forestland. Hence, there is an increased medicinal plant collection and livestock grazing at the Fatehpur site. Most of these herbs are used for various medicinal purposes and thus have high values in the local and distant markets. Therefore, wherever these plants are accessible to the local people they ruthlessly collect these herbs and sell them in the markets. The other plausible reason of the decrease in the selected herb species could be unrestricted grazing. Fuel wood collection and at times forest fires could also decrease the density of valuable medicinal herbs.

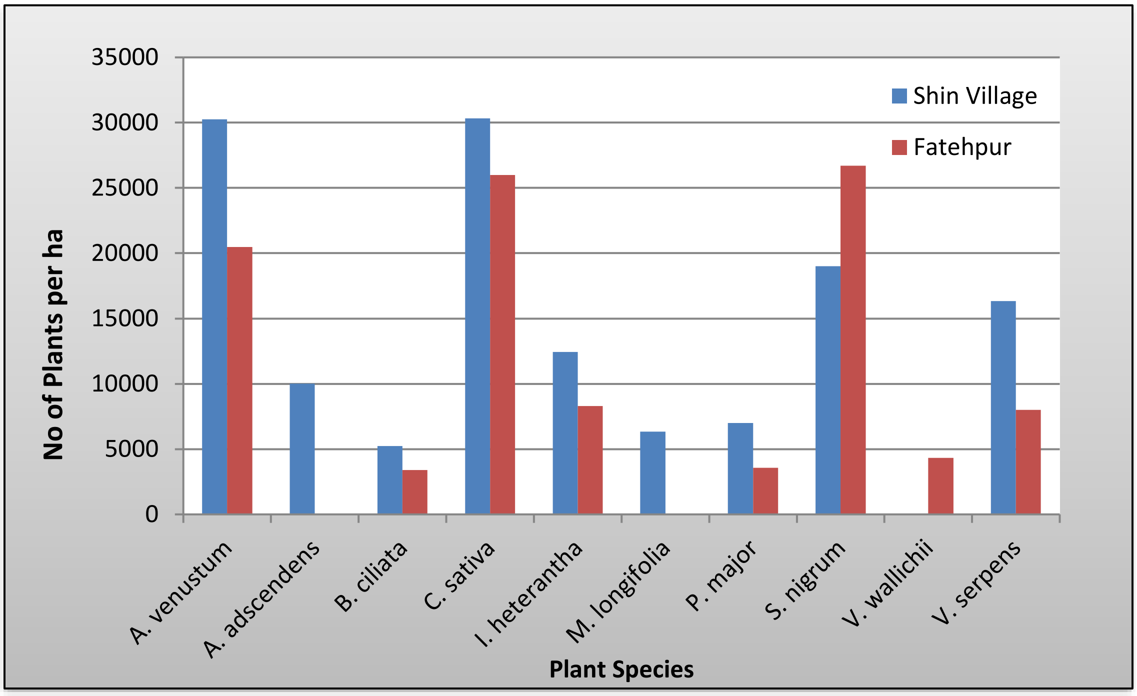



**Figure 4.2 Densities of the target herb species in both of the study sites**

The data shows that *A. adscendens* and *M. longifolia* are non-existent in the second study site. *A. adscendens* is used to enhance and digestion and is also used as a remedy to treat diarrhoea. Likewise, *M. longifolia* is vastly used as spice or as flavouring additive in various foods and sauces. It is also used to treat coughs, colds and inflammatory diseases. The densities of *B. ciliata* and *P. major* were also very low in both the study sites. *B. ciliata* is known to be useful in controlling diabetes, thus regarded as a valuable medicinal herb; therefore it has been ruthlessly uprooted by local and visiting stockers. Similarly *P. major* has a medicinal value in providing relief from itching and swelling due to bee stings or insect bites (Islam et al, 2002). The unchecked uprooting of these medicinal herbs has casted a threat to their existence in the studied forestlands. Another important medicinal herb *V. wallichii* was found in very low quantity in the Fatehpur site and non-existent in the Shin forestland. *V. wallochii* is largely used as antibacterial and antifungal medicines and also used to treat mental illnesses like depression, anxiety and insomnia.

### 4.4 Frequency of the Selected Herb Species

Frequency assesses the distribution of the plant species in a particular area. If a certain species is uniformly distributed in the whole land, the frequency will be high and frequency will be low if the distribution of that particular specie is uneven. Hence, if the plant species occur in patches it may have high density but low frequency as explained in section 3.5 of the thesis. Percentage frequencies of the important herbs in both the study sites are represented in table 4.5.

**Table 4.5 Frequency of the Selected Species in both the Forestlands**

| S. No | Botanical Name | Percentage Frequencies | |
|---|---|---|---|
| | | Shin Village Site | Fatehpur Site |
| 1 | *Adiantum venustum* | 87 | 67 |
| 2 | *Asparagus adscendens* | 43 | 0 |
| 3 | *Bergenia ciliate* | 37 | 25 |
| 4 | *Cannabis sativa* | 92 | 78 |
| 5 | *Indigofera heterantha* | 72 | 65 |
| 6 | *Mentha longifolia* | 35 | 25 |
| 7 | *Plantago major* | 67 | 0 |
| 8 | *Solanum nigrum* | 66 | 30 |
| 9 | *Valeriana wallichii* | 0 | 44 |
| 10 | *Viola serpens* | 20 | 55 |

Like the densities in the two forestlands, a difference in the frequencies of selected herb species has been observed. The study revealed that some of the species like *A. vensutum*, *C. sativa* and *I. heterantha* are evenly distributed in both the forestlands. While, the presence of species like *B. ciliata* and *M. longifolia* was uneven and were restricted to few patches only. *P. major* and *A. adscendens* were relatively equally distributed in Shin village forestland and but completely vanished from the Fatehpur site. Likewise, *V. wallichii* was moderately found in the selected quadrates in the Fatehpur site but was not cited in the Shin village forestland. The results also shows that plants having good densities can still have poor frequencies if they are not uniformly distributed and found in patches in a region.

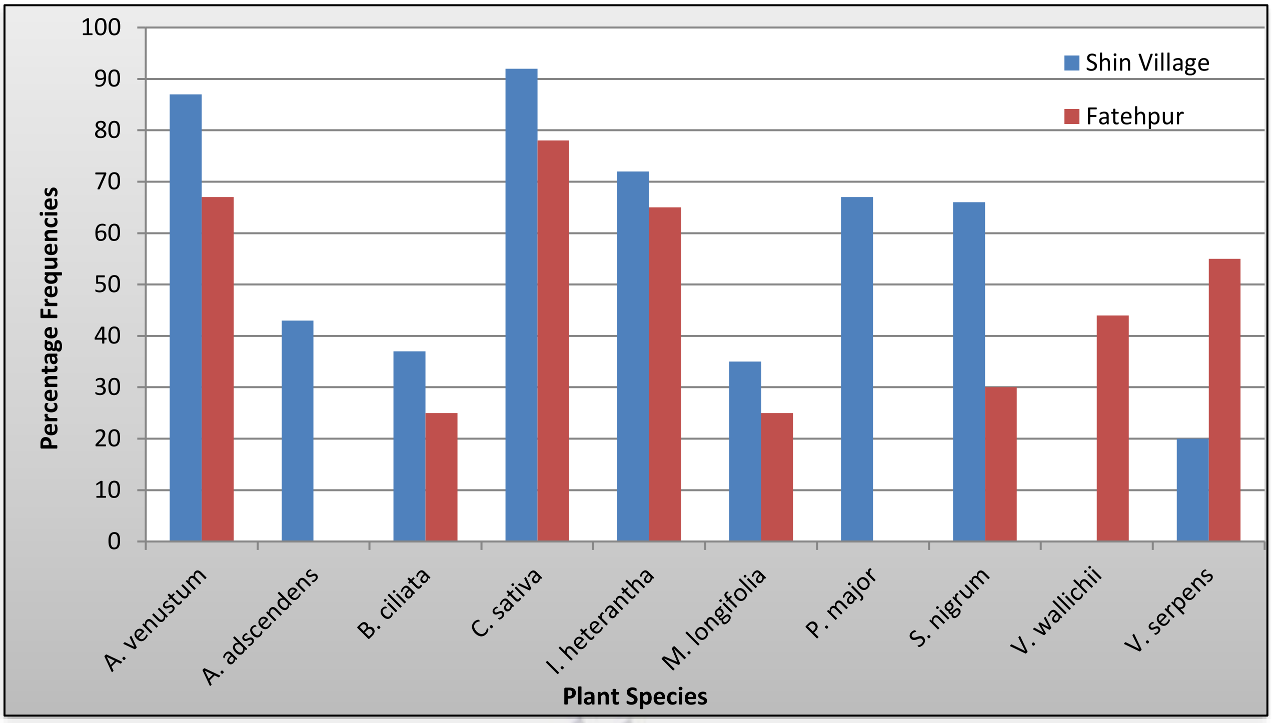



**Figure 4.3** **Per cent frequencies of the target herb species in both the study sites**

### 4.5 Diversity and Evenness Indices

Shannon evenness and diversity indices are applied on the data collected from both the study sites. Application of Shannon equations on the collected data can further elaborate the diversity and evenness in the two forestlands. In both the sites, the individual plants of the selected herb species in each sample quadrate were added upon and the resultant figures were used to calculate Shannon diversity and evenness indices for both sites.

To find out Shannon diversity and evenness indices, the first step of the process is to draw a table describing the values for "$P_i$" "$P_i \ln P_i$" and "$P_i(\ln P_i)^2$", see table 4.6 and table 4.7 for details. To compare and contrast the diversities in the two forestlands a "t-test" is carried out.

**Table 4.6** **Diversity and Evenness Indices for Shin Forestland**

| S. No | Species | No. of Individuals | $P_i$ | $P_i \ln P_i$ | $P_i (\ln P_i)^2$ |
|---|---|---|---|---|---|
| 1 | *Adiantum venustum* | 84 | 0.218182 | -0.33217 | 0.505698 |
| 2 | *Asparagus adscendens* | 30 | 0.077922 | -0.19886 | 0.507502 |
| 3 | *Bergenia ciliate* | 17 | 0.044156 | -0.13777 | 0.429839 |
| 4 | *Cannabis sativa* | 87 | 0.225974 | -0.3361 | 0.499892 |
| 5 | *Indigofera heterantha* | 33 | 0.085714 | -0.21058 | 0.517333 |
| 6 | *Mentha longifolia* | 18 | 0.046753 | -0.1432 | 0.438601 |
| 7 | *Plantago major* | 20 | 0.051948 | -0.15364 | 0.454383 |
| 8 | *Solanum nigrum* | 51 | 0.132468 | -0.26777 | 0.541279 |
| 9 | *Valeriana wallichii* | 0 | 0 | 0 | 0 |
| 10 | *Viola serpens* | 45 | 0.116883 | -0.2509 | 0.538575 |
| **Total** | | **385** | **1.0000** | **-2.03098** | **4.433102** |

Number of Species S = 9
Total Number of individuals of all species N = 385
Now,

$$H_1 = -\sum Pi \;\; ln\, Pi$$
$$= -(-2.03098)$$
$$= 2.031$$

$$E_1 = \frac{H_1}{ln\, S}$$
$$E_1 = 0.924$$

$$\text{Var } H_1 = \frac{\sum pi\,(\ln pi)^2 - (\sum pi\, \ln pi)^2}{N} - \frac{S-1}{(2\,N)^2}$$
$$= \frac{4.4331 - (-2.0309)^2}{385} - \frac{9-1}{(2\times385)^2}$$
$$= \mathbf{0.00079}$$

**Table 4.7 Diversity and Evenness Indices for Fatehpur Forestland**

| S. No | Species | No. of Individuals | $P_i$ | $P_i\, ln\, P_i$ | $P_i\,(ln\, P_i)^2$ |
|---|---|---|---|---|---|
| 1 | *Adiantum venustum* | 58 | 0.218868 | -0.33252 | 0.505198 |
| 2 | *Asparagus adscendens* | 0 | 0 | 0 | 0 |
| 3 | *Bergenia ciliate* | 14 | 0.05283 | -0.15536 | 0.456852 |
| 4 | *Cannabis sativa* | 65 | 0.245283 | -0.34471 | 0.484431 |
| 5 | *Indigofera heterantha* | 25 | 0.09434 | -0.22272 | 0.525814 |
| 6 | *Mentha longifolia* | 0 | 0 | 0 | 0 |
| 7 | *Plantago major* | 10 | 0.037736 | -0.12367 | 0.405271 |
| 8 | *Solanum nigrum* | 58 | 0.218868 | -0.33252 | 0.505198 |
| 9 | *Valeriana wallichii* | 12 | 0.045283 | -0.14014 | 0.433718 |
| 10 | *Viola serpens* | 23 | 0.086792 | -0.21214 | 0.518523 |
| Total | | **265** | **1.0000** | **-1.86378** | **3.83500** |

Number of Species S = 8
Total Number of individuals of all species N = 265
Now,

$$H_2 = -\sum Pi \;\; ln\, Pi$$
$$= -(-1.8638)$$
$$= 1.864$$

$$E_2 = \frac{H_2}{ln\, S}$$
$$E_2 = \mathbf{0.8964}$$

$$\text{Var } H_2 = \frac{\sum pi\,(\ln pi)^2 - (\sum pi\, \ln pi)^2}{N} - \frac{S-1}{(2\,N)^2}$$
$$= \frac{3.83500 - (-1.86378)^2}{265} - \frac{8-1}{(2\times265)^2}$$
$$= \mathbf{0.00134}$$

With the help of "t-test" we can compare the diversities of the two study sites. The formula for t-test is;

$$t = \frac{H_1 - H_2}{(\sqrt{(varH_1 + var\, H_2)}}$$

$$t = \frac{2.031 - 1.864}{(\sqrt{(0.00079+0.00134)}}$$

$$t = 3.6186$$

$t_{95}$= 2.262 $t_{99}$= 2.821

The above calculations reveal that the values of evenness and diversity indices are comparatively high in the Shin forestland than the Fatehpur plantation. This suggest that former site is not only diverse as compare to the later one but the various herb species are also uniformly distributed throughout in Shin plantation site. The resultant value of "t" (3.6186) is greater than the both t-value at 95% and 99% confidence level. This demonstrates that the two plantations are relatively different in terms of diversity of selected herbaceous plant species.

### 4.6 Stream discharge rates at the two forestlands

To find out the rate of discharge in the streams of both forestland, one stream from each study site were examined. The stream discharge for the two streams were calculated before and after rainfall on various occasions from April to September in 2024. The resultant values of rates of discharge in the two streams examined in different seasons are given in table 4.8. It should be noted that Stream I represents the stream at Shin Forest site and Stream II represents the stream at the Fatehpur forestland.

**Table 4.8 Stream discharge rates at both the Forestlands**

| Month/Year | Shin Forestland Stream Discharge Rate ($m^3/S$) | | | Fatehpur Forestland Stream Discharge Rate ($m^3/S$) | | |
|---|---|---|---|---|---|---|
| | Before Rain | After Rain | Difference | Before Rain | After Rain | Difference |
| **April, 2024** | 0.083 | 0.097 | 0.014 | 0.046 | 0.078 | 0.028 |
| **June, 2024** | 1.675 | 1.928 | 0.253 | 1.256 | 1.582 | 0.326 |
| **September, 2024** | 0.056 | 0.071 | 0.015 | 0.039 | 0.065 | 0.026 |
| **Average** | 0.605 | 0.699 | **0.094** | 0.447 | 0.575 | **0.127** |

The data reveals that the average difference in the discharge rates i.e. before and after rainfall of the stream in the Fatehpur forest was a bit higher than the stream in the Shin Forest site. The watersheds of the stream I were located at an area having relatively dense vegetation; on the other hand, stream II being feed by watershed of the Fatehpur site with relatively scarce vegetation. It shows that the denser vegetation at any catchment area help increases evapotranspiration rates and also enhances infiltration and percolation rates as the water takes more time to flow through such watersheds and thus comparatively less change in the water discharge, before after rainfall, can be observed. On the contrast a watershed with vegetation that is uneven have less evaporation rates and high discharge rates, particularly after precipitation.

### 4.7 Sediment yield in the streams of the two forestlands

A comparative analysis of the sediment yield in the streams of the Shin Village forestland and Fatehpur forestland was carried out. The data reveals that there is a close relationship between the density of vegetation in the catchment area of a stream and the amount of sediment load (eroded particles) in any water flowing stream. The subsequent values of concentration of sediments in the streams before and after rainfall in various months of the study year are given in table 4.9.

**Table 4.9 Sediments load at both the Forestlands**

| Month/Year | Shin Forest Sediments Load in the Stream (mg/L) | | | Fatehpur Forest Sediments Load in Stream (mg/L) | | |
|---|---|---|---|---|---|---|
| | B. Rain | A. Rain | Increase | B. Rain | A. Rain | Increase |
| **April, 2024** | 120 | 144 | 24 | 119 | 154 | 35 |
| **June, 2024** | 147 | 212 | 65 | 180 | 285 | 105 |
| **September, 2024** | 112 | 137 | 25 | 142 | 198 | 56 |
| **Average** | 126.33 | 164.33 | 38 | 147 | 212.33 | **65.33** |

Stream I, which is located in the Shin Forest area having comparatively better vegetation on its catchments have low levels of sediments before rainfall with relatively low amount of increase in sediments load after the rainfall in various seasons of the year. Whereas, stream II situated in the Fatehpur forestland have relatively sparse vegetation on its watersheds. Hence, Stream II have generally higher concentration of sediments as compare to stream I before rainfall. In addition to that, the increase in sediment load on stream II after rainfall was very high in comparison to stream I. The average increase in the sediment load after rainfall in stream II was 44 % a bit higher than that of stream I which was 30 %.

The maximum sediment load in both the streams was recorded in the month of June during the monsoon season after a heavy rainfall. However, yet the increase in the sediment load in stream of Shin forestland was merely 65 mg/L compared to 105 mg/L increase in the sediment load of stream in the Fatehpur forestland. This shows that vegetation has an inverse effect on concentration of sediments in the streams. If the density of vegetation in the catchment area of a stream is high, the sediment load will be less and vice versa. Therefore, we can conclude that plantation in the upstream watersheds helps in filtering the water and controlling the erosion, hence provide clean water to the downstream regions.

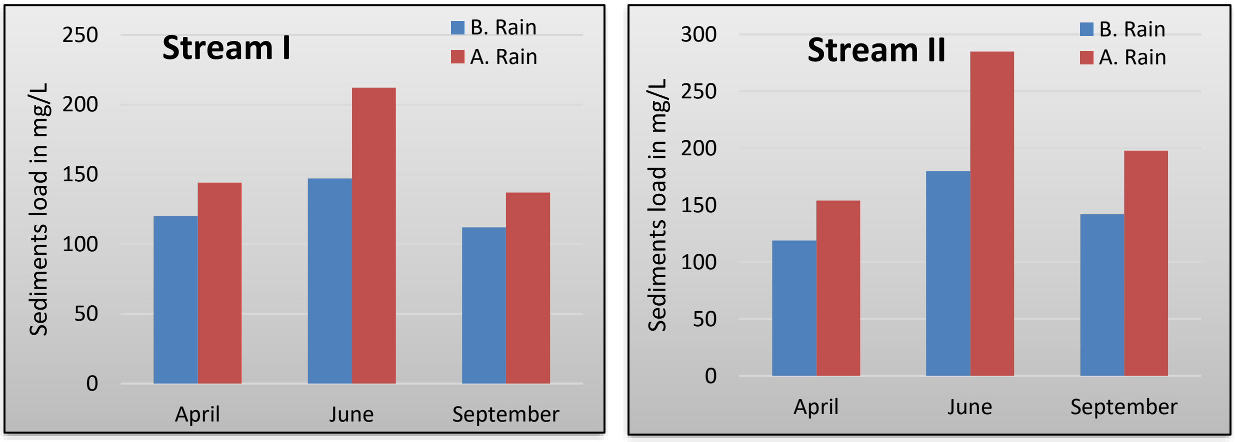



**Figure 4.4 Sediments load before and after rainfall in both the Streams**

### 4.8 Growing stock at both sites of the plantation

The total volume of trees at Shin Watershed Plantation was estimated to be 182,778 cubic meters, of which 175,566 $m^3$ is Chir Pine, 4,506 $m^3$ is Robinia and the remaining 2,706 $m^3$ is Bakine. Likewise, the estimated weight of standing trees in Shin forestland was 108,600 Metric-Tons. The detailed species wise volume ($m^3$) and weight (Metric-tons) of the existing stock of plantation in the Shin forestland is given in table 4.10.

**Table 4.10 Available Stock at Shin Forestland by volume and weight**

| S.No | Species | Number of Trees | %age | Volume (m3) | Weight in M-Ton |
|---|---|---|---|---|---|
| 1 | *Pinus roxburghii* (Chir) | 187,220 | 86.6 | 175,566 | 104,680 |
| 2 | *Robinia pseudoacacia* | 19,356 | 9.0 | 4,506 | 2,820 |
| 3 | *Melia azedarach* (Bakine) | 9,569 | 4.4 | 2,706 | 1,100 |
| **Total** | | **216,145** | **100** | **182,778** | **108,600** |

The total volume of trees at Fatehpur forestland was calculated to be 61,677 cubic meters. Clearly, the highest amount by volume was found to be *P. roxburghii* with 49,270 $m^3$, followed by *R. pseudocacia with* 6,506 $m^3$. The remaining 5,901 $m^3$ was M. *azedarach*. Like Shin forestland, the estimated weight of standing trees in Fatehpur forestland was also calculated in Metric-Tons. The detailed species wise volume ($m^3$) and weight (Metric-tons) of the existing stock of plantation in the Fatehpur forestland is described in table 4.11.

**Table 4.11 Available Stock at Fatehpur Forestland by volume and weight**

| S.No | Species | Number of Trees | %age | Volume (m3) | Weight in M-Ton |
|---|---|---|---|---|---|
| 1 | *Pinus roxburghii* (Chir) | 58,563 | 82.4 | 49,270 | 35,660 |
| 2 | *Robinia pseudoacacia* | 6,965 | 9.8 | 6,506 | 3,220 |
| 3 | *Melia azedarach* (Bakine) | 5,544 | 7.8 | 5,901 | 1,370 |
| **Total** | | **71,072** | **100** | **61,677** | **40,250** |

### 4.9 Carbon Sequestration by both the forestlands

Along with the environmental benefits i.e. biodiversity conservation, soil fertility and soil stabilization, and socio-economic benefits, such mass plantations can play a significant role as a natural sink for atmospheric carbon. The carbon sequestration potential of such mass tree plantations is substantial but it has not been sufficiently acknowledged or even recognized. The amount of carbon sequestered in any land ecosystem depends on the available carbon in standing biomass, soil carbon and carbon in the products derived from woody vegetation. The Intergovernmental Panel on Climate Change (IPCC) default values have been adopted for carbon fraction and ratio of belowground biomass to aboveground biomass. The average carbon fraction found was 0.47 for the available stock and 0.25 of belowground biomass to aboveground biomass.

**Table 4.12 Estimation of Carbon Stock in both of the plantations collectively**

| Total Weight of trees Metric Tons | Average Carbon Fraction | Above Ground Carbon in Metric Tons | Below Ground Fraction | Below Ground Carbon in Metric Tons | Total Carbon (Above + Below) in Metric Tons |
|---|---|---|---|---|---|
| 148,850 | 0.47 | 69,960 | 0.25 | 17,490 | 87,450 |

The total estimated carbon, above ground and below ground, collectively in both the forestlands accounts for 87,450 Metric-tons. Out of this total carbon stock, the above ground carbon contributes 69,960 tons while below ground estimates around 17,500 tons (Table 4.12). We can also convert the carbon values to carbon dioxide by multiplying carbon value with 3.67. This is because one unit of Carbon can produce 3.67 units of $CO_2$ when fully oxidized. Hence the above plantation collectively sequestrates about 320,942 metric tons of carbon dioxide.

## 5. Conclusion and Recommendations

### 5.1 Conclusion

The overall conclusion of the study is that mass afforestation projects have enormous environmental benefits. They not only help in biodiversity conservation, enhancing soil fertility and soil stabilization, controlling downstream erosion but such plantations can also play a significant role in sinking greenhouse gases like carbon dioxide.

A slight difference was observed in the diversity, density and frequency of plant species of the Shin forestland as compared to the Fatehpur forestland. A total of 43 plant species were identified in the Shin Village plantation as compared to 35 at the other study site. Similarly, the estimated values for average density and frequency of medicinal herbs were a bit higher for Shin forestland than the Fatehpur forest site. This relative difference in the densities and frequencies of plant species can be attributed to the difference in location of the two forestlands. The Fatehpur forestland is relatively close to local population as compared to the Shin forestland.

It has also been deducted that the density of vegetation in upstream catchment areas plays an important role in maintaining the quality and quantity of water in the downstream regions. For example, Stream I located in the Shin forestland with comparatively dense vegetation cover showed less changes in the discharge rates after rainfall. While, clear variations were observed, after rainfall in most seasons, in the discharge rates of stream II having its catchments in the relatively scattered forest cover in the Fatehpur region. Similarly, difference in the sediment loads of the two streams was also observed; with stream II having higher values than that of stream I. This means that vegetation not only act as regulator to the flow of water but also act as a filter and provide clean water to the downstream areas.

Finally, the amount of carbon sequestration potential of these mass afforestation projects is significant and needs further attention. The total amount of carbon sequestrated by these two forestlands is about 87,500 metric tons. The amount of carbon sequestration in any ecosystem depends upon the available standing vegetation, soil carbon and carbon in the woody products derived from such vegetations.

### 5.2 Recommendations

Keeping in view the value of the environmental services provided by these two forestlands, the study recommends the following.

- Such afforestation projects must continue in different parts of the country, especially Khyber Pakhtunkhwa.
- To protect and enhance the environmental services of these forestlands, there should be certain checks on grazing. The owners

of the forests should be given some incentives so that they do not lease their lands for nomadic grazing.

- However, if grazing cannot be completely stopped, then there should be a rotation policy so that different sections of a forest can be grazed alternately.
- Training sessions should be arranged for the medicinal plant collectors. Thus, they can have proper knowledge and skill of collecting medicinal herbs and do not ruthlessly uproot every herb.
- Alternative energy sources like biogas plants should be introduced to decrease consumption of fuel wood, and ultimately conserve forests.
- If a forestland is very much degraded, it should be completely fenced, and banned for all sorts of anthropogenic activities before taking any restoration measures.
- Globally practiced environmental conservation methods like Payment for Environmental Services (PES) schemes should be introduced in the study area to conserve forest resources. And proper laws must be developed for PES so that forest resources must not be consumed as free goods.
- Provide alternative livelihood activities to the local people to decrease pressure on forest resources. Like fish farming, nursery raising, off season vegetables, skill development training
- The concerned NGOs should arrange meetings with the religious leaders of the area and ask them to speak about the importance of vegetation and other natural resources in their *Khutbas*.
- Large scale environmental awareness programmes must be initiated in the study area, including delivering lectures on environmental issues in schools and other educational institutions.

**References**

Aabeyir, R., Adu-Bredu, S., Agyare, W.A. (2020). Allometric models for estimating aboveground biomass in the tropical woodlands of Ghana, West Africa. For. *Ecosyst.* 7, 41, 1-23.

Abebe, S., Minale, A.S., Teketay, D. et al. (2021). Biomass, carbon stock and sequestration potential of Oxytenanthera abyssinica forests in Lower Beles River Basin, Northwestern Ethiopia. *Carbon Balance Manage* 16, 29-42.

Adnan, S.M. 2002. Assessment and Documentation of the non timber forest flora as livelihood source for the local community in Swat, NWFP–Pakistan (case study of Miandam valley). WWF-Pakistan

Ahmed, K., Shahbaz, M., Qasim, A., & Long, W. (2015). The linkages between deforestation, energy and growth for environmental degradation in Pakistan. *Ecological Indicators*, *49*, 95-103.

Akber, K.F., Ahmed. Z., Shad. M. A., Ansari, T. M. 2000. The ecological study of roadside vegetation and soils in Sahiwal District. *Online Journal of Biological Sciences* 3 (7), 627-634.

Alamgir, M., Turton, S, M., Macgregor, C. J., Pert, L. P. 2016. Assessing regulating and provisioning ecosystem services in a contrasting tropical forest landscape. *Ecological Indicators*, 64, 319-334.

Ali, T., Ahmad, M., Shahbaz, B., Suleri, A. 2007. Impacts of participatory forest management on financial assets of rural communities in Northwest Pakistan. Ecological Economics, 63, 588-593.

Başkent, E. Z. (2021). Assessment and valuation of key ecosystem services provided by two forest ecosystems in Turkey. *Journal of Environmental Management*, 285,

Bonham, C.D. (1989). Measurements for terrestrial vegetation. *John Wiley & Sons*, New York, NY. pp 199-264.

Borrelli, P., Robinson, D.A., Fleischer, L.R., Lugato, E., Ballabio, C., Alewell, C., Meusburger, K., Modugno, S., Schütt, B., Ferro, V. 2017. An assessment of the global impact of 21st century land use change on soil erosion. *Nat. Community*, 8, 1–13.

Bożena, K., Jadwiga S. (2018). Forest ecosystem services – assessment methods. *Folia Forestalia Polonica*, 60, 248-260.

Cheng, J. D., Lin, L. L., Lu, H. S. 2002. Influences of forests on water flows from headwater watersheds in Taiwan. *Forest ecology and management*, 165, 11-18.

Chertov, N.; Vasilyeva, Y.; Zhulanov, A.; Nechaeva, Y.; Boronnikova, S.; Kalendar, R (2021). Genetic Structure and Geographical Differentiation of Larix sibirica Ledeb. in the Urals. *Forests*, 12, 1401-1418.

Cox, W.G.1997. Laboratory manual of general ecology. *WMC Brown Co. Dubuque*, Iowa USA.

Dagnachew, S.; Teketay, D.; Demissew, S.; Awas, T.; Lemessa, D (2023). The Effects of Monthly Rainfall and Temperature on Flowering and Fruiting Intensities Vary within and among Selected Woody Species in Northwestern Ethiopia. *Forests, 14*, 541-557.

DCR, 1998. District Census Report of Swat by statistics Division Government of Pakistan August, 1999.

FAO (2001). *Global Forest Resource Assessment 2000 main report 2001*. FAO Forestry Paper 140. Rome.

FAO, Global Forest Resource Assessment 2000. main report 2001. FAO Forestry Paper 140. Rome.

Gong, X.; Yang, A.; Wu, Z.; Chen, C.; Li, H.; Liu, Q.; Yu, F.; Zhong, Y (2021). Employing Genome-Wide SNP Discovery to Characterizethe Genetic Diversity in Cinnamomum camphora Using Genotyping by Sequencing. *Forests*, 12, 1511-1526.

Gracia, R. R., Celaya, R., Gracia, K. 2012. Goat grazing, its interactions with other herbivores and biodiversity conservation issues. Small Ruminant Research, 107, 49-64.

Hanstad, K. M., Peters, D, P, C., Skaggs, R. 2007. Ecological service to and from the rangelands of the United States. *Ecological Economics*, 64, 261-268.

Hania, A., Bushra, T., Shahzad, M., Mehmood, S., Batool, H., Naeem, K. (2020). Spatiotemporal Analysis of Land Use / Land Cover in Swat, Pakistan Using Supervised Classification in Remote Sensing: 2000 to 2015. *International Journal of Economic and Environmental Geology*. 11. 69-74.

Herrera-Feijoo, R.J.; Torres, B.; López-Tobar, R.; Tipán-Torres, C.; Toulkeridis, T.; Heredia-R, M.; Mateo, R.G (2023). Modelling ClimaticallySuitable Areas for Mahogany (Swietenia macrophylla King) and Their Shifts across Neotropics: The Role of Protected Areas. *Forests*, 14, 385-398.

Huang, B.; Wang, Z.; Huang, J.; Li, X.; Zhu, H.; Wen, Q.; Xu, L. (2022). Population Genetic Structure Analysis Reveals Significant Genetic Differentiation of the Endemic Species Camellia chekiangoleosa Hu with a Narrow Geographic Range. *Forests*, 13, 234-239.

IPCC (2006). Guidelines for national greenhouse gas inventories. *Prepared by the National Greenhouse Gas Inventories Programme.* Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K, editors. Published: IGES, Japan.

IPCC (2019). *Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Agriculture, Forestry and Other Land Use*. Published: IGES, Japan.

Irshad, S., Khan, S. 2012. Impacts of protection in water quality, quantity and soil of Himalayan moist temperate forests of Galliyat. Science, technology and development, 31 (2), 91-98.

Khan, H. A. 1995. Working plan for protected forests of Bahrain Tehsil, Swat District. Khyber Pakhtunkhwa Forest Department, Peshawar.

Khan, M. A., Khan, J. A., Ali, Z., Ahmad, I., & Ahmad, M. N. (2016). The challenge of climate change and policy response in Pakistan. *Environmental Earth Sciences*, *75*, 1-16.

Khan, S.R., Khan, S.R. 2009. Assessing poverty-deforestation links: Evidence from Swat, Pakistan. Ecological Economics, 68, 2607-2618.

King, E. G. 2008. Facilitative effects of Aloe secundiflora shrubs in degraded semi-arid rangelands in Kenya. Journal of arid environments, 72, 358-369.

Knight, D. H., A distance method for constructing forest profile diagrams and obtaining structural data. Trop Ecol., 1963, 4, 89-94.

Lee, H. d., Smith, C., Herbohn, J., Harrison, S. 2012. More than just trees: Assessing reforestation success in tropical developing countries. *Journal of rural studies*, 28, 5-19.

Lee, S., Allsopp, N. 2007. Namaquland: Understanding vegetation change using biophysical manipulations. Journal of arid environments, 70, 755-766.

Louhaichi, M., Ghassali, F., Salkini, A. K., Petersen, S. L. 2012. Effects of sheep grazing on rangeland plant communities: Case study of landscape depression within Syrian arid steppes. *Journal of arid environments*, 79, 101-106.

Mahr, M. A. 2001. Comparision of plant diversity in reserved and guzara forest. A case study in Muree Hills. *Pakistan Forest Institute*, 41-54.

Mengist, W., Soromessa, T. & Feyisa, G.L. 2020. A global view of regulatory ecosystem services: existed knowledge, trends, and research gaps. *Ecol Process* 9, 2-14.

MoCC 2016. *Annual Report, National Disaster Management Authority*. Ministry of Climate Change, Government of Pakistan.

Ministry of Climate Change 2020. *National Forest Monitoring System – Measuring, Reporting and Verification. Final report.* Ministry of Climate Change, Islamabad, Pakistan.

McElwee, P.D. 2012. Payments for environmental services as neoliberal market-based forest conservation in Vietnam: Panacea or problem. Geoforum, 43, 412-426.

Nautiyal, S., Kaechele, H. 2007. Adverse impacts of pasture abandonment in Himalayan protected areas: Testing the efficiency of a natural resource management plan. Environmental impact assessment review, 27, 109-125.

Otero, I.; Marull, J.; Tello, E.; Diana, G.L.; Pons, M.; Coll, F.; Martí Boada, M (2015). Land abandonment, landscape, and biodiversity: Questioning the restorative character of the forest transition in the Mediterranean. *Ecological Society*, 20, 7-25.

Parkes, J., Henzell, R., Pickles, G., 1996. Managing Vertebrate Pests: Feral Goats. Australian Government Publishing Service, Canberra.

Peñuelas J, Sardans J, Estiarte M et al., (2013). Evidence of current impact of climate change on life: a walk from genes to the biosphere. *Glob Chang Biol,* 19, 2303–2338.

Qasim, M., Hubacek, K., Termansen, M., Khan, A. 2011. Spatial and temporal dynamics of land use pattern in District Swat, Hindu Kush Himalayan region of Pakistan. Applied Geography, 31, 820-828.

Rendon, P.; Steinhoff-Knopp, B.; Saggau, P.; Burkhard, B (2020). Assessment of the relationships between agroecosystem condition and the ecosystem service soil erosion regulation in Northern Germany.

Sagar, R., & Singh, J. S. (2006). Tree density, basal area and species diversity in a disturbed dry tropical forest of northern India: implications for conservation. *Environmental Conservation*, *33*(3), 256–262.

Sboeva, Y.; Chertov, N.; Nechaeva, Y.; Valeeva, A.; Boronnikova, S.; Kalendar, R (2022). Genetic Diversity, Structure, and

Differentiation of Pinus sylvestris L. Populations in the East European Plain and the Middle Urals. *Forests,* 13, 1798-1811.

Shahbaz, B., Ali, T. and Suleri, A.Q. 2011. Dilemmas and challenges in forest conservation and development interventions: Case of Northwest Pakistan. Forest Policy and Economics, 13, 473-478.

Sher, H., Al-yemeni, M. 2011. Economically and ecologically important plant communities in high altitude coniferous forest of Malam Jabba, Swat, Pakistan. Saudi Journal of Biological Sciences, 18, 53-61.

Sierra, R., Russman, E. 2006. On the efficiency of environmental services payments: A forest conservation assessment in the Osa Peninsula, Costa Rica. Ecological Economics, 59, 131-141.

Silver, W.L.; Osterag, R.; Lugo, A.E (2000). The potential for carbon sequestration through reforestation of abandoned tropical agricultural and pasture lands. *Restor. Ecol.*, 8, 394–407.

Soussan, J., Shrestha, B.K., Uprety, L.P. 1995. The social Dynamics of Deforestation. A case study from Nepal. The parthenon publishing group limited, London.

Stavi, I., Ungar, E. D.,2008. Lavee, H., Sarah, P. Grazing-induced spatial variability of soil bulk density and content of moisture, organic carbon and calcium carbonate in a semi-arid rangeland. Catena, 75, 288-296.

Toit, G. N., Snyman, H. A., Malan, P. J. 2009. Physical impacts of grazing by sheep on soil parameters in the Nama Karoo subshrubs/grass rangeland of South Africa. Journal of arid environments, 73, 804-810.

Wani, B. A., & Shah, H. (2004). *Forestry Statistics of Pakistan*. Pakistan Forest Institute. 1-40.

Wasiolka, B., Blaum, N. 2011. Comparing biodiversity between protected savanna and adjacent non-protected farmland in the southern Kalahari. Journal of arid environments, 75, 836-841.

Weyerhaeuser, H., Wikes., Kahrl, F. 2005. Local impacts and responses to regional forest conservation and rehabilitation programs in China's northwest Yunnan province. Agricultural systems, 85, 234-253.

World Bank Group. (2022). *Pakistan: Country Climate and Development Report*. World Bank Publications.

WWF, (2017). *Third Party Monitoring of Billion Tree Afforestation Project, Phase-II*. World Wide Fund for Nature Pakistan.

Xiong, M.; Sun, R.; Chen, L (2019). A global comparison of soil erosion associated with land use and climate type. *Geoderma,* 343, 31–39.

Xofis P., Kefalas, G., Poirazidis, K (2023). Biodiversity and conservation of forests. *Forests*, 14, 1871-1876.

Zhang, J.-H.; Li, K.-J.; Liu, X.-F.; Yang, L.; Shen, S (2021). Interspecific Variance of Suitable Habitat Changes for Four Alpine Rhododendron Species under Climate Change: Implications for Their Reintroductions. *Forests*, 12, 1520-1531.

Zokaib, S., & Naser, G. (2011). Impacts of land uses on runoff and soil erosion. A case study in Hilkot watershed, Pakistan. *International Journal of Sediment Research*, 26, 343-352.

Zokaib, S., Naser, G. 2011. Impacts of land uses on runoff and soil erosion. A case study in Hilkot watershed, Pakistan. International Journal of Sediment Research, 26, 343-352.

Zubair, M., Yasin, G., Qazlbash, S. K., Ul Haq, A., Jamil, A., Yaseen, M., & Guo, W. (2022). Carbon Sequestration by Native Tree Species around the Industrial Areas of Southern Punjab, Pakistan. *Land*, *11*(9), 1577.

Zuidema PA, Baker PJ, Groenendijk P et al., (2013). Tropical forests and global change: filling knowledge gaps. *Trends Plant Sci*, 18, 413–419.