ASSESSMENT OF AFFORESTATION AND FOREST RESTORATION PROJECT IN DISTRICT BUNER, KHYBER PAKHTUNKHWA, PAKISTAN

By

KHAN ISHFAQ AHMAD

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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DEDICATION

To my beloved and dearest parents, words cannot describe my love towards you and I am grateful to the Almighty Allah for blessing me with parents like you.

To my dear brothers, Mr. Ahmad Ali Khan, Bilal Ahmad Khan, Numan Ahmad Khan, Izaz Ahmad khan, and Aftab Ahmad Khanfor their motivation in these tiresome years.

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I thank you from the core of my heart.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairperson : Mohd Nazre bin Saleh, PhD
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Climate change is one of the biggest issues of this century. Global temperature is continuously increasing and thus affecting the environment. A forest ecosystem is considered one of the most significant ecosystems in combating climate change. As a signatory nation of the Kyoto Protocol, Pakistan is committed to address global warming issues, protecting the existing forest and enhancing the carbon sequestration potential through afforestation, reforestation, and sustainable forest management. To comply with the Bonn Challenge effort, the government of Khyber Pakhtunkhwa, Pakistan, initiated the Billion Tree Afforestation Project (BTAP) which has recently been completed. The major objective of this project was to restore and protect the forest to remove carbon from the atmosphere. Two major methods were followed for forest restoration; enclosure establishment (to promote natural regeneration) and forest plantations. This study investigated the forest restoration sites in District Buner, Khyber Pakhtunkhwa, Pakistan. The study area was divided into two types i.e., enclosures (natural forest) and plantations.15 sites from each forest type (i.e. 15 sites from natural forest and 15 sites from plantations) were selected, covering the whole area for data collection. The data was collected during October, 2020 to December, 2020, following Simple Random Sampling technique. At least 5-12 sample plots of 250 m2 area were laid out in each site to collect data in the field. The survival rate of tree species, , their composition, and their biomass (carbon) in both sites (natural regeneration and plantations) were studied and analyzed. The survival rate of planted seedlings on each plot was then evaluated by counting both live and dead individuals. Through the assessment of survival rate, the success or failure of plantations can be determined. The study revealed that the enclosure (assisted natural regeneration) sites mainly consisted of *Pinus roxburghii*, while plantation sites mostly comprised broadleaved species. *Eucalyptus camaldulensis* was the most planted species with about 77.45% of the total species while Pine species (i.e., *Pinus roxburghii*) proportion was only about 3.19%. The rest of the 19.37% were other broadleaved species. Similarly, the enclosure sites were mainly comprised of *Pinus roxburghii* with about 54.78%, followed by *Dodonaea viscosa* with 12.14%. The overall average density of

the natural forest was recorded as 1384.17 individuals per ha while the mean density of plantation sites was found to be 1131.6 per ha. The density of new regenerations in natural forest is comparatively high and is not established yet. The average survival rate of all plantation sites was about 58.49%where the highest average survival rate was 82.45%while the lowest survival rate of a site was 37.04%. The carbon sequestration potential of *Pinus roxburghii* grown in plantations and enclosures was calculated for the year 2050 while using the growth rates (diameter and height) of the species. The growth data were obtained from the Yield Table of the species prepared by the Pakistan Forest Institute. Different allometric equations were applied to estimate the above-ground biomass of the study area. Using each question, the average above-ground carbon stock of *Pinus roxburghii* in the natural forest was estimated as 9.83 t/ha, 12.67 t/ha, and 12.74 t/ha. The average carbon stock of *Pinus roxburghii* grown in the plantation was estimated as 1.33 t/ha, 1.72 t/ha, and 1.72 t/ha using each equation. All broadleaved species (such as *Eucalyptus camaldulensis, Morus alba, Dalbergia sissoo, Melia azedarach, Cassia fistula*) of the plantation sites have the potential to sequester about 0.5 million tons of CO2 until 2030.

The restoration campaign in the present study area can be considered successful in terms of wood production, reducing pressure on natural forests and carbon sequestration but it may not be effective in terms of biodiversity and resilience. Hence, increasing the proportion of indigenous multiple tree species is suggested to develop a resilient and diverse ecosystem.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Sarjana Sains

PENILAIAN PROJEK PENAMBAKAN DAN PEMULIHAN HUTAN DI DAERAH BUNER, KHYBER PAKHTUNKHWA, PAKISTAN

Oleh

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Perubahan iklim adalah salah satu isu terbesar abad ini kerana suhu global terus meningkat dan mempengaruhi alam sekitar. Ekosistem hutan dianggap salah satu ekosistem yang penting dalam memerangi perubahan iklim. Sebagai negara yang menandatangani *Kyoto Protokol*, Pakistan berkomitmen untuk menangani isu pemanasan suhu global, melindungi hutan sedia ada dan meningkatkan potensi penyerapan karbon melalui penanaman semula hutan, penghutanan semula, dan pengurusan hutan secara berkekalan. Untuk mematuhi Bonn Challenge, kerajaan Khyber Pakhtunkhwa, Pakistan telah memulakan Projek Penanaman Semula Sebillion Pokok, yang selesai baru-baru ini. Objektif utama projek ini adalah untuk memulih dan melindungi hutan bagi menyerap karbon dari atmosfera. Dua kaedah utama diikuti untuk pemulihan hutan; penubuhan berpagar (untuk menggalakan pertumbuhan semulajadi) dan ladang hutan. Kajian ini menilai kawasan pemulihan hutan di Khyber Pakhunkhwa, Buner, Pakistan. Kawasan kajian dibahagikan kepada dua jenis iaitu berpagar (hutan asli) dan ladang. Sebanyak 15 kawasan bagi setiap jenis hutan (15 kawasan untuk hutan asli dan 15 kawasan bagi ladang) dipilih, meliputi semua kawasan bagi kutipan data. Data dikutip pada Oktober – Disember 2020 menggunakan teknik Persampalen Rawak Secara Mudah. Sekurang-kurangnya 5 (lima) plot persampelan bersaiz 250 m^2 ditubuhkan pada setiap kawasan bagi pengumpulan data dilapangan. Kadar kehidupan spesies pokok, komposisi dan biojisim (karbon) di kedua-dua lokasi (regenerasi semulajadi dan ladang) dikaji dan analisa. Kadar kehidupan anak benih yang ditanam di setiap petak kemudian dinilai dengan mengira bilangan individu yang hidup dan mati. Melalui penilaian kadar kehidupan, kejayaan atau kegagalan ladang dapat ditentukan. Kajian menunjukkan bahawa kawasan berpagar (regenerasi semulajadi yang dibantu) terdiri terutamanya dari *Pinus roxburghii*, sementara lokasi ladang terdiri dari spesies berdaun lebar. *Eucalyptus camaldulensis* adalah spesies yang paling banyak ditanam dengan 77.45% dari jumlah keseluruhan spesies, sementara spesies *Pinus roxburghii* hanya sebanyak 3.19%. Selebihnya, 19.37% adalah spesies berdaun lebar yang lain. Lokasi berpagar juga terdiri terutamanya dari *Pinus roxburghii* dengan komposisi sebanyak 54.78%, diikuti oleh *Dodonaea viscosa* dengan 12.14%. Purata bilangan pokok sehektar direkodkan sebanyak 1,384.17 pokok sehektar

manakala ladang sebanyak 1,131.6 pokok sehektar. Bilangan pokok sehektar di hutan asli adalah lebih tinggi dan belum mencapai tahap matang. Purata kadar kehidupan di kawasan ladang adalah sebanyak 58.49%, yang mana kadar kehidupan tertinggi adalah 82.45% dan 37.04% kadar terendah. Potensi penyerapan karbon *Pinus roxburghii* yang ditanam di ladang dan berpagar dianggarkan untuk tahun 2050 menggunakan kadar tumbesaran (diameter dan tinggi) spesies. Data tumbesaran diperolehi dari Jadual Pengeluaran spesies yang disediakan oleh Institut Hutan Pakistan. Persamaan alometrik yang berbeza digunakan untuk menganggarkan biojisim atas tanah di kawasan kajian. Dengan menggunakan setiap persamaan, stok karbon bagi *Pinus roxburghii* di hutan asli dianggarkan berjumlah 9.83 t / ha, 12.67 t / ha, dan 12.74 t / ha. Purata Stok karbon *Pinus roxburghii* yang ditanam di ladang dianggarkan sebanyak 1.33 t / ha, 1.72 t / ha, dan 1.72 t / ha menggunakan persamaan yang sama. Semua spesies berdaun lebar (seperti *Eucalyptus camaldulensis, Morus alba, Dalbergia sissoo, Melia azedarach, Cassia fistula*) dari kawasan ladang berpotensi untuk mengasingkan sejumlah 0.5 juta tan CO_2 sehingga 2030. Kempen pemulihan dalam kajian ini boleh diangap Berjaya dari segi pengeluaran kayu, mengurangkan tekanan terhadap hutan asli dan pengasingan karbon tetapi tidak berkesan dari segi kepelbagaian biodiversiti dan kemandirian hutan. Sehubungan itu, penambahan bilangan spesies pokok tempatan dicadangkan bagi meningkatkan kemandirian hutan dan kepelbagaian ekosistem.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

AGB	Aboveground Biomass
BGB	Belowground Biomass
FAO	Food and Agriculture Organization
IPCC	Intergovernmental Panel on Climate Change
LULC	Land Use/Land Cover
REDD	Reducing Emissions from Deforestation and forest Degradation
BEF	Biomass Expansion Factor
CO2	Carbon dioxide
GFRA	Global Forest Resources Assessment
GHGs	Greenhouse Gases
BTAP	Billion Tree Afforestation Project
UNFCCC	United Nations Framework Convention on Climate Change
CDM	Clean Development Mechanism
WWF-Pak	World Wide Fund for Nature Pakistan
KP	Khyber Pakhtunkhwa
TBTAP	Ten Billion Tree Afforestation Project
TB	Total Biomass
TC	Total Carbon
SDGs	Sustainable Development Goals
SER	Society for Ecological Restoration

CHAPTER 1

INTRODUCTION

1.1 General Background

Forest ecosystems provide various services to humanity in terms of providing timber, fuelwood, fodder, medicinal plants, purification of water, regulating surface temperature, cleaning of air, provision of aesthetic value and helping erosion and flood control. Besides, that they are home to millions of wildlife species, forests store carbon dioxide and give oxygen to humans. Millions of people worldwide depend on forest resources, especially in developing countries.

With time, the world population has increased, resulting in more consumption of unsustainable forest resources. This, ultimately, has been resulting in deforestation and forest degradation. Land-use change from forest to other land use (for example, agriculture land and settlement) causes the emission of carbon dioxide into the atmosphere. Land-use land-cover change (LULC) has contributed about one third of the total carbon emission into the atmosphere (Zhou et al., 2020). Carbon is a greenhouse gas and its excess in the atmosphere leads to a rise in surface temperature. This rising global temperature trend leads to climate change thus affecting rainfall patterns, humidity, and sea level.

"Climate change refers to seasonal changes over a long period of time" (NASA, n.d.). Carbon dioxide and methane, the main contributing gases to global warming, increase in the atmosphere due to industrialization and combustion of fossil fuels (Krapivin et al., 2017). Greenhouse gases, including CO2 and methane emissions, were found to have increased in the 21st century compared to the 1990s (Le Qúéré et al., 2012), despite the struggles to control the emission (Smith, 2016). Climate change may bring benefits for a shorter duration, especially for rain-fed agriculture-dependent but the negative impacts may surpass the positive ones in the long run. Some areas may benefit from an increase in food production due to more rainfall but others may be significantly affected by less precipitation, high temperature, and increased evapotranspiration which may ultimately result in food shortage (Lobell et al., 2011).

Climate change effects are likely to be earliest in tropical regions. According to Tol (2018), the adverse impact of climate change will be significantly higher in developing, hotter and lower-lying countries. Thus, climate change would be a significant issue, especially for developing countries such as Pakistan. The United Nations Intergovernmental Panel on Climate Change (IPCC) recommended that to prevent disastrous and devastating consequences of climate change, we must reduce greenhouse gas emissions to the atmosphere by half by 2030 and completely by 2040 (IPCC, 2018).

Natural systems like glaciers, coral reefs, boreal and tropical forests, polar and alpine ecosystems are susceptible to climate change (McCarthy et al., 2001). However, forests are valued as a valuable tool against global warming as it stores a large amount of carbon dioxide for an extended period. The forest ecosystem is a significant factor in climate change. It acts as a carbon sink and a carbon source via photosynthesis and holds it in biomass and soil organic matter. Forests store more carbon than the carbon present in the atmosphere (Nizami, 2010), likely one trillion tons, double the atmospheric carbon (Ali et al., 2020b). Nevertheless, disturbances such as deforestation, land-use change from forest to other land-use (i.e. agriculture), and forests will become sources and emit carbon into the atmosphere. Therefore, protecting these forests is essential to combat climate change and at the same time, protect biodiversity.

Reducing emissions from deforestation and forest degradation (REDD+) is an initiative to protect the existing forest and enhance forest cover. It's also an awareness program to mitigate climate change by absorbing carbon through the forest ecosystem. The REDD+ program encourages developing countries to strengthen their forest cover in return for carbon credits, boost their economic conditions and change people's priorities from cutting trees to planting them.

Article 2.1 of the Kyoto Protocol has addressed global warming issues and urged the signatory nations to protect the existing forest and enhance the carbon sequestration potential through afforestation, reforestation, and sustainable forest management (Salunkhe et al., 2018; Yavasli, 2012). In this view, 'Bonn Challenge' (2011) has committed to restore 150 million hectares of degraded land by 2020 and 350 million hectares by 2030. In this context, various countries such as China, India, Ethiopia, and Pakistan have started massive afforestation projects to restore the degraded land and enhance the forest cover.

Pakistan is a developing country and has a low forest cover of 5.1% of the total area. 4.51m ha area of total area 87.98 m ha is under forest cover (Ali et al., 2017; Bukhari et al., 2012). Pakistan has diverse ecological zones, divided into various forest types based on altitude and species composition. Local people in Pakistan highly depend on forest resources thus resulting in diminishing the forest cover. Pakistan is listed in the top 10 most vulnerable countries to the effect of climate change.

Pakistan has observed an increase in annual mean temperature of about 0.47^{o} C since 1960 (Gorst et al., 2018). Glaciers are the significant water source for rivers and because of rising temperature, they are receding quickly, resulting in flooding and sea-level rise (Rasul et al., 2012). Consequently, Pakistan is predicted to most likely face a water shortage problem in the future. Severe drought has been seen at the start of this century and heavy floods during the last decade (Fahad & Wang, 2020). Changes in rainfall and snowfall pattern have already been observed in various parts of the country. Similarly, the country has also witnessed changes in the severity and duration of the winter and summer seasons. Because of that, climate change affects the agriculture sector, especially of the less developed and agrarian countries like Pakistan. It was predicted that Pakistan would most likely witness a decline in wheat and rice

production worth billions of dollars by 2050 due to climate change (Khan et al., 2020). In another study, the extreme temperature harms wheat production in Pakistan (Ali et al., 2017). Besides the agriculture sector, climate change could also result in droughts and the extinction of local wildlife species (Hussain et al., 2020).

In order to avoid the destructive effects of climate change and restore the degraded land, the government of Khyber Pakhtunkhwa (KP), Pakistan, initiated a mega afforestation project in the province. This project was started in 2014 and has been completed recently. Agroforestry, farm forestry, roadside and canal-side plantation, plantation on community and private land, and natural regeneration were promoted through this project. The accomplishment of this project was highly appreciated by World Economic Forum, IUCN, and WWF-Pakistan.

1.2 Problem statement and significance of the study

Reforestation and afforestation are the two most common methods, used globally to restore degraded land. Reforestation is the restoration or plantation on degraded forested land, while afforestation is planting new trees on non-forested land (i.e., creating a new forest). Pakistan has completed the world acclaimed 'Billion Tree Afforestation Project' in Khyber Pakhtunkhwa, province, during 2014-2019, significantly increasing the province's forest cover. The primary purpose of this project was to address the challenge of climate change and environmental degradation on the one hand and to increase wood production on the other hand. The project has adopted two main strategies for restoring degraded forests viz: plantations of coniferous and broad-leaved tree species. Secondly, the establishment of closures to control and promote assisted natural regeneration of the existing natural forest. The closure can be regarded as the area which is protected and untouched from outer disturbance.

An early assessment of this project is essential to study the survival rate and growth performance of plantation and natural regeneration. External disturbances such as fire, grazing, grass cuttings are key factors and have a significant role in the success or failure of new plantations and natural regeneration. Plantations mainly include *Eucalyptus camaldulensis, Acacia modesta, Robinia pseudoacacia, Ailanthus altissima,* and *Pinus roxburghii*, while enclosure (natural forest) mainly consists of *Pinus roxburghii, Dodonaea viscosa,* and some proportion of broadleaves species. As one of the primary objectives of this restoration project is to mitigate climate change, it is imperative to estimate the carbon stock potential of this project for both areas. Different techniques are used for carbon stock estimation across the globe; destructive, non-destructive, and remote sensing. Non-destructive is the most common method used worldwide, while the destructive method is particularly used to develop an allometric equation. Remote sensing techniques on the other hand, require field data for validation. Field measurement technique could be grouped in to two categories; destructive and non-destructive methods. Destructive technique is also known as direct method where the trees are filled/harvested and different components like truck, branches, etc. are weighed. This method is considered only for a small area due to its destructive nature. On the other hand, non-destructive technique is the most common method used worldwide where different tree parameters such as diameter at breast

height (dbh), tree height, volume of a tree and wood density are measured for biomass estimation. Allometric equation is considered the most accurate and easy way to estimate carbon stock. However, it required a local developed allometric equation. For reliable carbon stock calculation, it is critical to remember that allometric equation can only be used for the same species under identical ecological conditions. The allometric equation developed for single specie stand can give inaccurate result when used for the mixed-species stand. Therefore, this study will compare different published allometric equations and recommend the appropriate one to estimate carbon stock produced from both areas. Estimating carbon stock is an important factor for successful reforestation projects but has not been given proper attention in Pakistan. The finding of this study will be helpful in identifying a promising strategy for the implementation of new projects. Most importantly, it could be a baseline for future research regarding any changes in forest structure. It will also provide basic information for policymakers and resource managers for the upcoming ecosystem restoration projects.

1.3 Research Objectives

The objectives of this study are:

i. To assess the tree species composition in selected forest restoration projects.

ii. To assess the survival rate and growth performance of *Pinus roxburghii* (Chir Pine) in selected forest plantations and natural regeneration in the district of Buner.

iii. To compare carbon sequestration potential for *Pinus roxburghii* between forest plantations and naturally regenerated forests in the district of Buner.

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