Assessing Carbon Sequestration Potential of Selected Woody Tree Species Growing in Hattar Industrial Estate, Haripur, Pakistan

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Abstract

Climatic change and global warming is a burning issue across the globe as the earth temperature raises up to 4 °C due to greenhouse gases. Pollution from industries contributing greenhouse gases (GHGs) includes CO_2, CFCs, CH_4, N_2O, etc., which absorb the infrared light, and increase temperature of the earth. Carbon is considered to be most important casual factor for global warming that can be reduced by the terrestrial ecosystem budget. The sub-tropical broadleaved tree species in Pakistan are the main constituents of the terrestrial ecosystems, playing a vital role in the global carbon cycle. The present study was designed to calculate carbon stocking capacity from five industrial sites in Hattar Industrial Estate (HIE) Haripur. Over all, three woody plant species namely *Eucalyptus cameldulensis, Populus nigra* and *Melia azedarachta* were selected to calculate carbon stocking potential by non-destructive method using allometric equations. Carbon stocking potential of selected trees species was calculated through biomass data called from field inventory. Our results showed that *Eucalyptus cameldulensis* has high above ground, below ground and total biomass stocking i.e. 2.14 tonnes of carbon followed by *Populus nigra* (0.99 tonnes)and *Melia azedarachta* (0.115 tonnes). These findings revealed that *E. cameldulensis* has great potential to utilize and store atmospheric carbon. We concluded from our results, that the potential of carbon capturing and storage of the area can be increased on extensive managements of high biomass carbon density through proper scientific methods.

Keywords: Biomass Carbon, *Eucalyptus camaldulensis,* Industrial zone, Pakistan.

Introduction

Global warming is the extreme dreadful shocks of the recent periods (Salvatore *et al.*, 2017). Since past three eras, pollution from industries contributing greenhouse gases (GHGs) as CO_2, CFCs, CH4, N_2O, etc., which absorb the infrared light, and increase temperature of our earth (IPCC 2007; Montagnini and Nair 2004; Ajani and Shams 2016). Greenhouse gases once produced, remain stuck in surrounding for hundreds of years. Carbon is considered to be most important casual factor for global warming (Kerr, 2007; Franzluebbers *et al.*, 2017; Jones *et al.*, 2017). Some anthropogenic activities like deforestation, agriculture and livestock production, burning of fossil fuels increase in earth temperature (IPCC 2007; Kiran and Kinnary 2011), Chavan and Rasal (2011), Weber (2013), Ajani and Shams 2016). The increased concentration of carbon release in the atmosphere is one of today's most important interests and referred in Kyoto Protocol (Stewart and Hessami, 2005).Transportation and industrial sources account for more than 80% of anthropogenic CO_2 emissions worldwide. Carbon dioxide levels have been shown to have risen as a result of increasing industrial activity. According to NASA reports 2018, the amount of CO_2 has been reached to 408ppm in the atmosphere.

With many protective carbon reduction methods, the trees are considered to be most efficient and cost effective method to reduce carbon from atmosphere. Carbon sequestration is defined as the extraction or removal of CO2 present in the atmosphere (Lal, 2008). Terrestrial ecosystem are considered one of the best and most vital constituents for the storage of atmospheric carbon. Additionally, forest ecosystems have the potential to store and sink a high amount of atmospheric carbon because of their longevity and woody nature (Ali et al., 2019). Globally, the carbon is kept in a wide range of various stocks. The natural existing stocks are present such as the atmosphere, oceans, terrestrial system and fossil fuel deposits. It has been observed that carbon in terrestrial system is sequestered in sediments, wetlands, rocks, swamps, forests, grasslands, forest soil, and agricultural land (Song *et al.,* 2017). It has been estimated that approximately two thirds of the terrestrial carbon of the globe, excluding the carbon sequestered in the sediments and rocks, is sequestered by the standing trees, woody plants, forests, under-story plants, forest debris, leaves and the soil of forests.

Moreover, there also exist some artificial or non-natural sinks for stock of carbon. For example, wood products which are long-lived and the wastes, dumps which constitute a separate carbon stock created by humans. Over several decades, with the increase in the harvest of global timber and manufacturing of the wooden products, the carbon stocks are probably increasing as the carbon is being sequestered wooden products and waste dumps are also expanding. The stock which take up the carbon is known as a "sink" and the "source" is the one which is responsible for releasing carbon. Changes in flow and shifts of carbon from one stock to another, over the period of time such as, shift from the external atmosphere to the forest, are exhibited as the carbon "fluxes" (Froelich *et al.,* 2015). Carbon may also be transferred from one of its original stock to another with time. Burning of fossil fuel are responsible for the shifts of fossils carbon deposits in to the atmospheric stock (Amin et al., 2022). Physical processes and human activities also convert gradually the atmospheric carbon into the ocean stock. The growth in biological potential also involves the carbon shifting from one stock to another.

As the plant species fix the atmospheric carbon in their tissues, cell as it grows, thereby transforming the atmospheric carbon to the biotic system. The concentration of the carbon stored in any of the stock may be large, in comparison to its initial stock or fluxes, and may be small or zero. The old plants or forest, experiencing no or little growth, would possess this character. The fluxes may be significant but the stock may be small. Young and the fast-growing trees tend to have this potential. The grasses and agricultural crops also act as a sink but the sequestering of carbon by them is limited, because of their limited accumulation of biomass and short life accumulations (Sundarapandian *et al.*, 2013). The role of human in the management of carbon is increasing and is crucial with the increase in awareness regarding use of woody plants and their potential in carbon sequestration.

Plants are the major components which are involved in storing carbon as long as the plants live, regarding their biomass (Ali et al., 2022). Biomass becomes a component of the food chain once a plant dies, and hence enters the soil as soil carbon. The re-emission of carbon into the external atmosphere caused by biomass incineration enters the carbon cycle (Khan et al., 2018). The role of plants in sequestration of carbon is now clearly understood and offer the great potential for the management of sink. Many plants and some of the crops, having short span of life and involved in releasing their carbon at the end of season, the forest plants biomass are responsible for accumulating carbon over longer period of time i.e. decades. Additionally, the potential of carbon accumulation in plants can be increased by forestation leading to high possibility of carbon sequestration and increase it significantly additional carbon sequestration in short spans.

Nowadays the trees are being managed for wildlife, timber, recreation but sequester of carbon must be managed as a by-product. The current study was designed to know the potential of carbon sequestration in selected woody tree species. This first attempt will provide a baseline for forest management in the region, including forest resource utilization and carbon management.

Materials and methods

Study area

The study area selected for collection of sample was Hattar industrial estate which consist of almost 44 union councils, situated in district Haripur, Khyber Pakhtunkhwa, Pakistan. It is located in the south of Haripur, The Industrial Estate Hattar which is the exact area in which research was conducted is situated at Kot Najeebullah at a distance of 16 kilometers. The total area consists of 4.18 km^2 (1,032 acres) of land. There are found approximately more than four thousand operational and industrial units including food industry, beverage processing units, textile, paper printing, crockery, chemical, publishing, cement, rubber, and leather and carpets products industries.

The Major woody in the studied area are *Pinus roxburghii* (Chir Pine), *Dalbergia sissoo* (Shisham), *Acacia modesta* (Phuali), *Azedarachta indica* (Neem), *Melia azedarach* (Bakhin), *Bombax ceiba* (Simal), *Juglans regia* (Walnut), *Callistemon acuminatus* (Bottle brush), *Platanus orientalis* (Chinar), *Populus nigra* (Poplar), *Eucalyptus camaldulensis* (Eucalyptus).

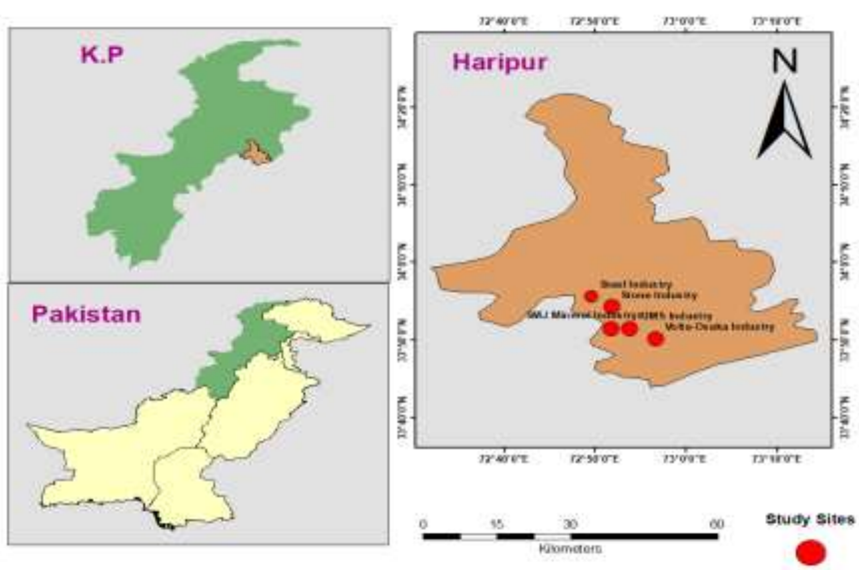

Figure 1 Map of research area

Determination of carbon sequestration

Within Hattar industrial estate, we selected three tree species from five plots for the determination of carbon sequestration potential. The selection of the tree species was purely based on its frequent occurrence in the sampled plots. The selected plants species were *Eucalyptus camaldulensis* (Eucalyptus), *Populus nigra* (Populus) and *Melia azedarach* (Bakain).

Field work to calculate carbon sequestration

Within each sample plot selected woody trees were counted and measured. The measurement regarding amount of carbon were carried out on the basis of standing biomass of woody trees. A non-destructive method for estimation of biomass was used to measure the height (Haga altimeter) and diameter of trees (Tree calliper).

Biomass and carbon stock calculation

The data regarding diameter and height was analysed using MS excel version 2013. Diameters of all trees were measured in field but height was computed only for randomly selected sample trees. Recorded diameter and height was used in the given Allometric equations calculate above ground tree biomass (AGTB). Belowground biomass was calculated by using root-shoot ratios available in literature (Cairns et al., 1997; IPCC, 2006). Generally belowground biomass was taken 25% of the aboveground biomass. Belowground biomass was converted to carbon by multiplying with carbon fraction which is 0.47.

Allometric equations

Eucalyptus camaldulensis (Eucalyptus) $0.023(D^2H)^{0.9985}$ (Ali, 2017)

Melia azedarach (Bakhin) $0.0286(DBH)^{2.163} \times H^{0.74}$ (Lin, 2008)

Poplus nigra (poplar) $0.0194(D^2H)^{0.9669}$ (Anwer Ali, 2018)

Tree biomass was converted to carbon by multiplying it by the carbon fraction, which for all species is 0.47 (IPCC, 2006).

Total biomass

Following method was used to calculate carbon stock.

Total biomass was the sum of their above and below ground biomasses then, carbon stock was transformed by multiplying it by 0.47.

Total biomass = AGB + BGB

Total biomass × 0.47

Estimation of CO_2 equivalents

Carbon stocks were converted to CO_2 equivalents by multiplying with 3.66 (the ratio of carbon atoms in CO_2 molecular weight). This determines full amount of carbon dioxide sequestered.

RESULTS AND DISCUSSION

BIOMASS ESTIMATION OF SELECTED WOODY TREES

Biomass of selected tree species are shown in table 1 and figure 1.1. It was observed that *Eucalyptus cameldulensis* has highest above ground biomass, below ground biomass and total standing biomass of 1.319 t ha^{-1} followed by *Populus nigra* 0.575 t ha^{-1} and least biomass was observed in *Melia azedarachta* of 0.066 t ha^{-1}.

Table 1: Aboveground (AGB), belowground (BGB) and total biomass (TB) of selected tree species^{-1}

S. No	Species	AGB (t tree^{-1})	BGB (t tree^{-1})	TB (t tree^{-1})
1	*Eucalyptus cameldulensis*	1.047	0.272	1.319
2	*Melia azedarachta*	0.053	0.013	0.066
3	*Populus nigra*	0.456	0.118	0.575

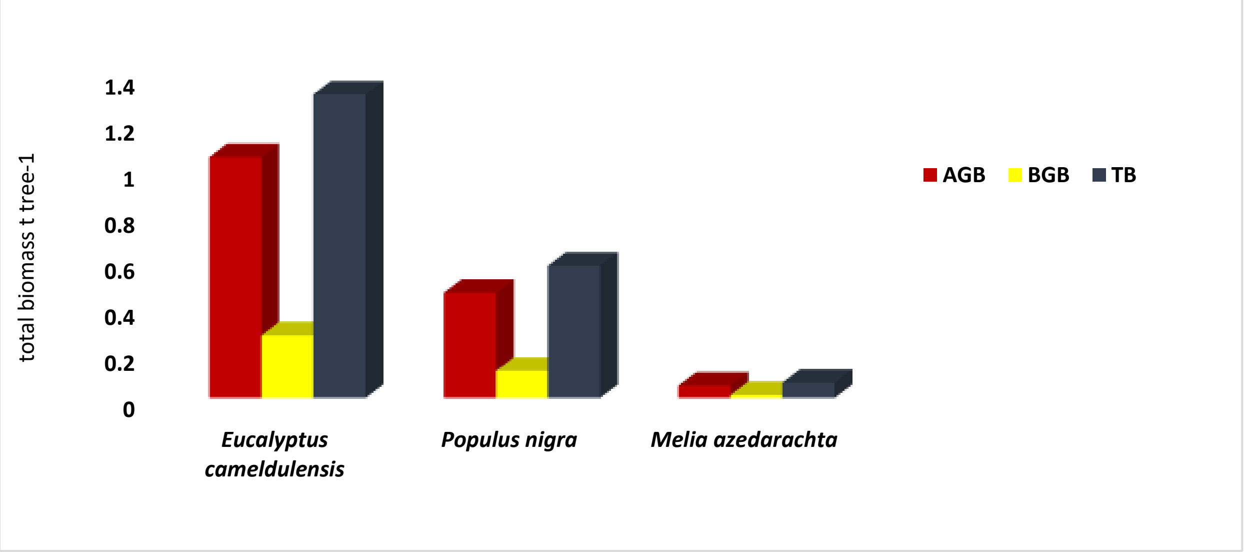

Figure 1.1: Total biomass of selected tree species

CARBON STOCKING POTENTIAL OF DIFFERENT TREE SPECIES

Eucalyptus cameldulensis having greater biomass absorbs 2.145 tonnes of carbon followed by *Populus nigra* absorbing 0.99 tonnes and *Melia azedarachta* absorbing 0.115 tonnes of carbon.

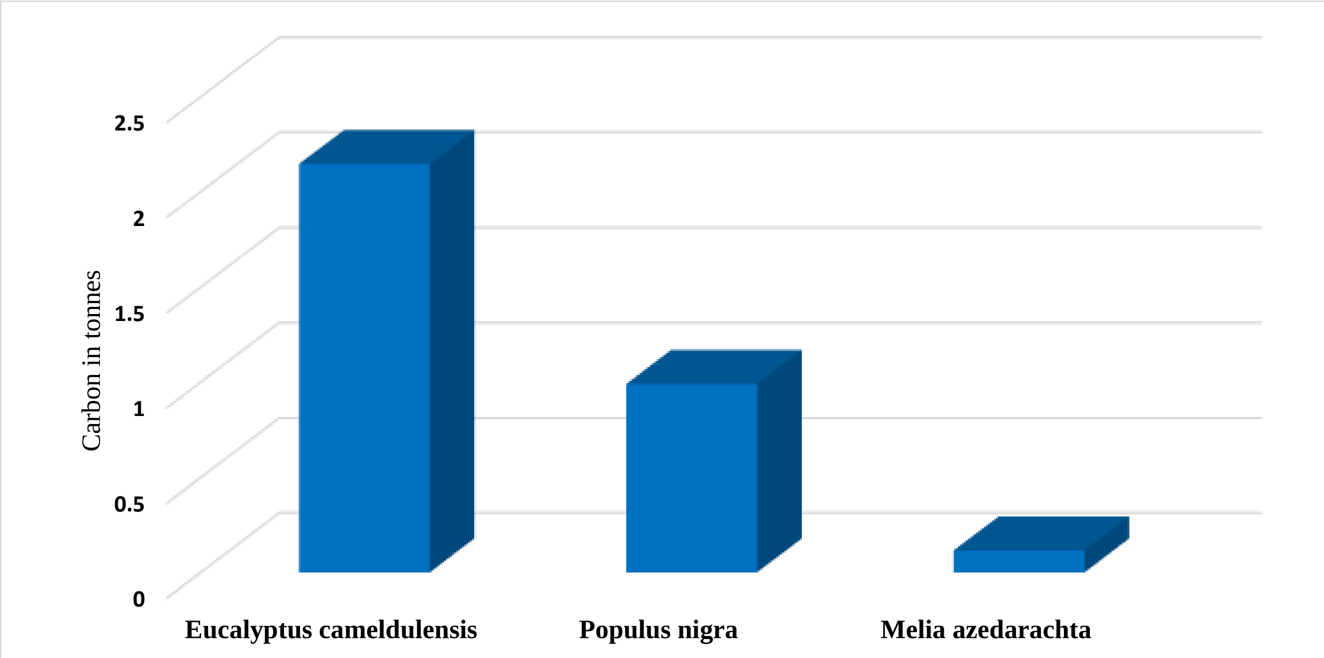

Figure 2: Carbon stocking potential of different tree species

DISCUSSION

Many studies have been emphasized on the importance of growing plants and their role in carbon sequestration which is well known and reported (Farrelly *et al.*, 2013; Tiwari & Singh, 1987), nevertheless not many studies have been conducted to address the potential of industrial trees or the higher plants grown in industrial areas and their role in carbon sequestration. In this study the selected plants *Eucalyptus cameldulensis, Melia azedarachta* and *Populus nigra* were analyzed for their carbon sequestration potential found in different industrial areas. Carbon sequestration is a process or phenomenon which involves the CO_2 storage and the preservance of many other forms of carbon leading towards mitigation of global warming. The plants capture CO_2 is from the outer atmosphere and store in them in the form of cellulose. According to (Erickson *et al.*, 2015) plants are the vehicle to address the effects of carbon, as well as address the problems arise due to emission of fossil fuels. Carbon sequestration is also involved in diminishing the increase in greenhouse gases to the biosphere which are emitted due to anthropogenic activities, burning of fossil fuels, pollution, automobiles and industrial contamination. Forests and tress play a vital role in global cycle of carbon Lake 2010. Along with forest, tress present in urban and industrial areas are also important in preserving and maintaining environment. Since the introduction of carbon as commodity to change climate, estimation of carbon sequestration has become important and expanded along with the estimation of biomass which is also important. The assessment of biomass is important (Ali et al., 2019; Zheng *et al*., 2004). As estimation of biomass is a significant indicator of carbon sequestration because it provides information of functional as well as attributes of trees due to the fact that approximately more than 50% of dry biomass consist of carbon (Cannell, 1995; Kulkarni, 2018; Losi *et al*., 2003; Montagu *et al*., 2005; Rafdinal *et al*., 2021; Richter *et al*., 1995). The assessment of biomass illustrates the concentration of carbon sequestered by trees. Our results showed that eucalyptus has the highest above ground biomass, below ground biomass and total standing biomass followed by *Populus nigra* and *Melia azedarachta* (Figure 1.1) so biomass estimation is the first step in sequestration of carbon by trees so highest amount of carbon sequestration was found in *Eucalyptus cameldulensis* followed by *Populus nigra* and lowest in *Melia azedarachta* which is due to the fact that biomass as well as carbon accumulation depend on the species of tree, properties of site, spacing, climatic conditions, class and distribution of tree (Pussinen *et al*., 2002; Vucetich *et al*., 2000). The highest carbon sequestration in *Eucalyptus cameldulensis* (Figure 4.14) and *Populus* found in our study is supported by the fact that Eucalyptus and poplar are one of the fast-growing species, and are meeting the high demands of fuel and wood industry in comparison to other plant species. The Biomass production of both these plants was high as compared to *Melia azedarachta* playing an important role in carbon sequestration of industrial areas. Below-ground biomass, above-ground biomass, litter, dead wood, soil and organic matter are the basic pools of carbon in natural ecosystem (Kindermann *et al*., 2008; Takahashi *et al*., 2010; Vashum & Jayakumar, 2012). The increasing emission of carbon is major concerns of whole world (Chavan & Rasal, 2010; Ali and Khan, 2022) so the higher plants with high biomass and fast growth are involved in carbon sequestration which is the most cost-effective method to mitigate of global warming and climatic alterations.

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