

Review Article

Environmental Importance of Mulberry: A Review

ABSTRACT

Mulberry is a woody, deciduous tree that is economically important. It is regarded as a distinctive plant on the planet due to its widespread geographical distribution across continents, ability to be cultivated in various forms, multiple uses of leaf foliage and positive impact in environmental safety approaches such as ecorestoration of degraded lands, bioremediation of polluted sites, water conservation, soil erosion prevention, and enhancement of air quality through carbon sequestration. Mulberry has a robust root system. Mulberry root systems can significantly improve soil shear strength and anti-erosive capacity. Mulberry plantations are extremely effective in suppressing sand storms and conserving water and soil. This paper reviews the environmental importance of mulberry.

Keywords: Mulberry, environment; carbon sequestration; heavy metals; soil erosion

INTRODUCTION

Plants play a vital role in maintaining a healthy environment. Prior to the arrival of humans, the world was protected and had a high level of biodiversity with little disturbance [1]. However, since the nineteenth century, due to increasing urbanisation and rising human population, enormous amounts of non-biodegradable solid trash, liquid chemicals, and hazardous gases have been discharged into the environment from our houses, cars, and factories [2]. Human activities over the last two centuries have resulted in the emergence of contemporary global issues such as climate change, greenhouse effect, environmental protection and safety, depletion of natural energy resources, and a sustainable environment for future generations [3]. Climate change is one of the most important environmental issues confronting humanity today. Recent climate change has been ascribed to a significant increase in GHG emissions, mainly carbon dioxide (CO₂), caused by human activity. According to available data, CO₂ concentrations have risen from 280 parts per million by volume (ppmv) to 402.2 ppmv since the 1750s [4], owing primarily to the use of fossil fuels and large-scale deforestation. This scenario necessitates a paradigm shift in crop selection in order to counteract the effects of climate change. Phytoremediation is an environmentally friendly and promising technology that uses plants to absorb, transport, degrade, or detoxify heavy metals and hazardous chemical compounds [5]. It is a relatively new technology that is seen as unique, efficient, and cost-

effective, and beneficial to the environment with widespread acceptance. One of the goals of current agricultural development is low-carbon agriculture. Farmers are increasingly choosing for alternative farming methods that are more profitable and resilient to an unexpected weather pattern as climate change continues to wreak havoc on agriculture.

Mulberry, which belongs to the genus *Morus* of the family Moraceae and has about 36 varieties, is a hardy plant that may be found worldwide in practically all sorts of agroclimates from tropical to temperate. They are found all across the world, from the tropics to the subarctic, and at altitudes ranging from sea level to 4000 m [6; 7]. Mulberry trees may grow naturally at temperatures ranging from 40°C to -40°C, precipitation of 300 mm or more, and soil pH values in the 4.5 to 9 range [8]. It is regarded as a unique plant on this planet due to its widespread geographical distribution across continents, ability to be cultivated in various forms, multiple uses of leaf foliage, and positive impact in environmental safety approaches such as ecorestoration of degraded lands, bioremediation of polluted sites, water conservation, soil erosion prevention, and improvement of air quality through carbon sequestration [9]. It also has a larger foliage production, a shorter gestation period, and better environmental adaptation, amongst other attributes. Various roles of mulberry in protecting the environment are categorised and described below under the categories such as carbon sequestration, ecorestoration, soil and water conservation, bioremediation of heavy metals and afforestation (Fig. 1).

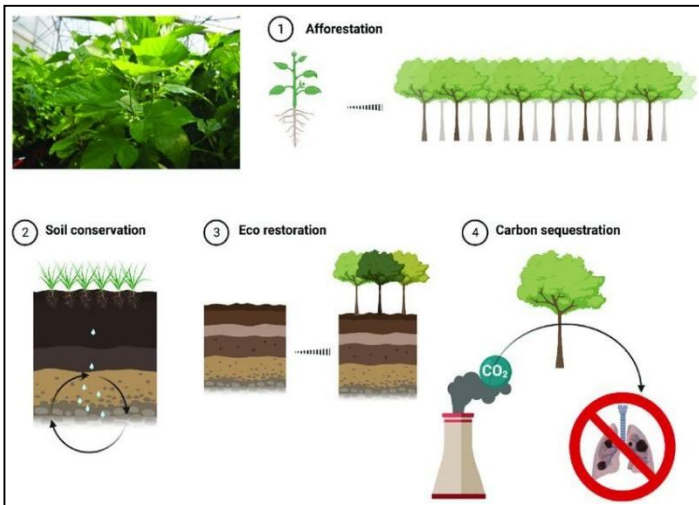


Fig.1 Importance of mulberry in environmental safety [10]

ROLE OF MULBERRY IN CARBON SEQUESTRATION

Sericulture provides environmental benefits such as air purification, carbon sequestration, and soil and water conservation, which is primarily linked to mulberry production [11]. Mulberry, with its great photosynthesis, rapid growth, and high biomass, has the potential to enhance air quality. Mulberry leaves have the ability to absorb air pollutants such as carbon dioxide, carbon monoxide, hydrogen fluoride, sulphur dioxide, and chlorine from the atmosphere [12], and its roots have the ability to uptake carbon pollutants and heavy metal pollutants from the soil. [13].

One hectare of mulberry could absorb one tonne of CO₂ in one day and release 0.73 tonnes of oxygen, which could be used to breathe by 1000 people [14]. According to the data, 1 ha of mulberry trees can absorb around 6.24104 kg of CO₂ and emit 4.60104 kg of O₂ per year [15].

Mulberry roots are larger in diameter near the stem portion and then rapidly decrease in size; a long rope-like structure with secondary and tertiary roots, as well as root hairs, forms a fibrous mat-like structure, allowing them to uptake high concentrations of carbon pollutants from the soil [16; 17]. Mulberry plants are recognised as good carbon sink and heavy metal resistance plants because their aerial portions can absorb air pollutants and their roots can absorb soil contaminants. Mulberry trees are believed to have innate resistance to chlorine since their leaves remain unharmed even at greater levels of chlorine pollution [18]. Mulberry can absorb industrial waste gas and nitrogen compounds effectively. Furthermore, mulberry, which has a high resistance to sulphur dioxide, a high absorption capacity for fluoride, and an ability to resist fluoride, a clean air species [19].

Mulberry can absorb 5.7 g of sulphur dioxide per kg of dried leaves, thus mulberry forestry may absorb massive amounts of sulphur dioxide gas every day [20]. These properties have led to the mulberry plant's efficient application in bioremediation of air pollutants in metropolitan areas and phytoremediation of carbon pollutants in contaminated soil near industries and chemical factories.

ROLE OF MULBERRY IN ECORESTORATION

Mulberry trees have a high level of genetic flexibility, allowing them to adapt to a variety of agro-climatic conditions. Mulberry is a woody perennial tree with large root systems, rapid growth, high biomass production, ease of establishment and management, wide dispersion, and the capacity to grow in a variety of soil conditions [21; 22]. Mulberry plants grow best in fertile land with deep, sandy, or clayey soil that is porous, but they can also grow in barren areas with coarse soil that is low in nutrients [23].

Mulberry trees are extremely resilient and important. Mulberry, for example, may thrive in arid and semi-arid desert environments with annual rainfall of less than 300-600 mm. Mulberry's robust and deep root system develops a highly tangled and dense network with secondary and tertiary roots in any type of soil, allowing it to resist dry and unfavorable environmental spells. These properties also enabled the mulberry bushes to endure sand storms and wind currents. Mulberry plants might thus be grown even on desolate lands with heavily contaminated pollutants, or in lands at higher altitudes or heights prone to heavy wind currents.

Mulberry also grows well in disturbed lands with waterlogging conditions, under drought stress, and in salinity conditions [24, 25; 26], owing to its deeper and wider rooting system and wider adaptability in arid, semi-arid areas with varying soil pH conditions [27]. Mulberry trees are extremely resistant to water logging when dormant. When the anti-season water-logging resistance features of mulberry were investigated it was discovered that mulberry grows better when submerged in water level over 10m for more than 6 months [28].

Mulberry may grow in severe climatic conditions ranging from -30 °C chilling temperature to temperatures above 40 °C [29]. Mulberry's hardy trait is proven by its distribution pattern over the world, extending from temperate to tropical climates. Desert mulberry is an ecotype of mulberry that has been successfully cultivated in desert areas of China's Xinjiang region. As this ecotype allows mulberry trees to be grown in deserts

locations with minimal irrigation, it is recommended for natural restoration of deserted areas and desertified grasslands [30].

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Mulberry plants have also been effectively used and established for the ecorestoration of salinated fields and stony desolate places.

ROLE OF MULBERRY IN BIOREMEDIATION OF HEAVY METALS

A variety of anthropogenic activities such as mining, excessive fertiliser application, and wastewater irrigation in agriculture, large amounts of heavy metals are discharged into soil each year, resulting in severe soil contamination worldwide [31;

32]. Excessive heavy metals in soils can harm neighbouring ecological systems, groundwater, plant, animal, and human health [33].

Heavy metal pollution has the characteristics of concealment, irreversibility, long-term repercussions, and severe consequences [34]. Heavy metal poisoning of soil has proved to be a severe global environmental hazard.

Carbon-based pollutants such as insecticides, fungicides, fumigants, rodenticides, and weedicides degrade slowly in the soil over 10-

50 years, i.e. soil microbes use these pollutants as a carbon source and mediate their degradation through metabolic activities [35], but the rate of remediation is slow and time-consuming.

Heavy metal pollution, on the other hand, is considered very hazardous and non-biodegradable in nature.

Because neither bacteria nor plants use heavy metals as either metabolites, nor do they use them as nutrients and minerals. Heavy metals entering the human body through the water system or other sources can trigger organ malfunction with serious consequences for the human health system [36]. As a result, it is critical to prevent heavy metal contamination in soil and water, and there is also an urgent need to remediate these very hazardous and toxic contaminants.

Phytoremediation is considered the most successful method for heavy metal cleanup since it is eco-friendly, cost effective, and exploits possibilities on a vast scale [37; 38]. Plants have a greater ability to absorb water-soluble heavy metal contaminants from the soil and store them in specialised structures such as vacuoles [39]. Plant selection and analysis of contaminated soil sites play an important role in heavy metal phytoremediation [40], as climatic conditions should favour the growth of the plant species being used, and the level of heavy metal contamination should also be predetermined for an effective remediation process.

There are currently 360 different types of hyperaccumulators, with the majority of them belonging to the Cruciferae [41]. Although the role of hyperaccumulators in the remediation of heavy metal polluted soil has shown great promise, their practical applicability is limited due to their shallow roots,

slow development, dwarf plant, low biomass, and low dry matter accumulation. As a result, the total amount of heavy metal intake and accumulation by hyperaccumulator is little, and repair efficiency is low [42]. Many studies have suggested that using some woody plants to remove or stabilise heavy metals in polluted soils could be an efficient approach [43; 44; 45]. Among the various tree species, mulberry has a larger capacity to remediate heavy metals from contaminated soils due to its wider, deeper, and superior rooted system [46].

Although mulberry has a lower heavy metal concentration than hyperaccumulators, the total amount of heavy metal migration is still significant due to the vast volume of mulberry biomass. The intake of heavy metal by mulberry is influenced by mulberry species, growth stages and duration, soil physicochemical parameters, and heavy metal type.

Heavy metals such as chromium, lead, copper, nickel, cadmium, zinc, manganese, and mercury are being remediated utilising various mulberry species [47; 48; 49; 50] investigated the accumulation of heavy metal mercury in *Morus nigra* leaf, stem, and root parts. Initially, different quantities of mercury nitrate (30, 50, and 70 mg/L) were added to the soil. Two-year-old *Morus nigra* saplings were planted in the treated soil and grown for eight months. After eight months, the plant parts were separated and dried in an oven at 70 °C to make a fine powder, which was then used to determine mercury levels in samples of each plant part using the atomic absorption spectroscopy method. At 70 mg/L and 30 mg/L densities, the highest and lowest concentrations (mg/kg) were 55.67 and 22.2 in the leaf, 58.00 and 28.6 in the stem, and 65.00 and 35.3 in the root portions, respectively. The results clearly show that the absorption of mercury metal was higher in root parts than in leaf and stem parts. Even though mercury is not used as a nutrient, it is easily absorbed by the roots of the mulberry (*Morus nigra*). Mulberry is thus recommended for phytoremediation of mercury-contaminated soils.

A pot experiment and an indoor test were done to investigate the effects of varying Pb levels on the growth of mulberry and folia quality [52]. The results showed that plant height increased with decreasing Pb concentrations (200 mg/kg dry soil). When Pb concentrations in the soil exceeded 200 mg/kg dry soil, mulberry growth and leaf quality began to be hindered.

A pot experiment was conducted to investigate the transportation characteristics of Pb in the soil-mulberry-silkworm food chain and concluded that the concentrations of Pb in different organs of mulberry were in the order of roots > stems > leaves and that mulberry planting and silkworm feeding could be a potential way in remediation of Pb-polluted soils [53]. Cd migrated better than Pb in mulberry [54], and Cd was primarily collected in the roots, followed by the stem. The Cd content of leaves, on the other hand, was minimal. When Cd concentrations in soils were in the 8.4975.8

mg/kg range, almost 40% of Cd absorbed by mulberry was concentrated in roots, and approximately 16% in leaves [55]. Despite the fact that the Cd content in soils reached 145 mg/kg, the deadly concentration of mulberry, the Cd concentration in mulberry leaves was only 3.32 mg/kg [56]. Mulberry leaf yield was more than or equal to that of the control when Cd levels in the soil were less than 22.3 mg/kg. When the Cd content exceeded 22.3 mg/kg, the yield of mulberry leaves was reduced, and the leaves displayed toxic symptoms [57]. On the other hand, a micro-

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plot experiment was conducted and it was concluded that when the concentration of Cd in soils was less than 10 mg/kg, mulberry growth and leaf production were unaffected [58]. The output of mulberry leaves was reduced by 10% to 30% when Cd concentrations were in the range of 20~40 mg/kg. The mulberry tree was impending death when the Cd concentration was reached 145 mg/kg. Mulberries absorbed 50% of the Cd in their roots and only 10% in their leaves. Mulberry revealed a strong resistance to the toxicity of Pb, Zn, and As in soil and could grow normally in polluted soil with 734 mg/kg Pb, 1194 mg/kg Zn, and 53 mg/kg As [59]. The enrichment ability of mulberry to four heavy metals was investigated (Cu, Pb, Cd, and Zn) by planting mulberry trees in the Liuyang Qibaoshan mining area of Hunan Province [60]. They concluded that the quantity of each metal differed in different parts of the mulberry (root, stem, leaf, and bark), and the amount of Cu, Pb, Cd, and Zn moved by mulberry in each square metre plough layer soil was 12116.1 mg, 7409.83 mg, 2056.4 mg, and 254532.8 mg, respectively. Many papers have demonstrated that there were a few alterations in the growth and development of silkworms, as well as the production and quality of cocoon when the silkworm was fed on mulberry leaves grown in contaminated field areas. Developing sericulture may be a safe, cost-effective, and environmentally friendly way to use heavy metal-contaminated lands [61; 62; 63].

ROLE OF MULBERRY IN WATER AND SOIL CONSERVATION

The availability of groundwater, as well as the water holding and retention capacity of various soils, has grown over the last two decades for optimum agricultural output and the maintenance of ecological balance under the soil subsurface. The preservation of ecological balance beneath the soil subsurface is critical for the survival of soil microbes, decomposers, and other beneficial organisms that play an important role in biogeochemical cycles where nutrients and minerals are recycled. Humus and other sources that maintain soil fertility. Soil conservation is also given high priority, as soil erosion caused by rain and floods results in infertile soil and ecosystem disruption.

Mulberry afforestation restores soil carbon, improves soil water holding capacity, controls soil erosion, recycles nutrients, and maintains soil microflora [64]. Mulberry plants grown as trees are reported to be better suited for water and soil conservation. Mulberry plantations on lands/soils can reduce runoff during flooding by up to 10%-20% [65]. As compared to slope lands, annual runoff in plain lands mulberry plantation sites can be reduced by 38% under 5 years old and 91% under 10 years old bush plantings [66]. It is estimated that

the runoff coefficient in mulberry can be lowered by 10-20% when compared to the traditional planting pattern approach. It has also been reported that mulberry tree hedgerows have a considerable effect on total runoff and nutrient enrichment ratio. It has been shown experimentally that mulberry trees had a considerable effect on soil erosion prevention. Annual runoff volume was reduced by 38% and 91% beneath 5 and 10 year old mulberry bush belts, respectively, compared to agricultural sloped land.

Water retention capacity of mulberry-planted soils is reported to be greater than that of open land [67; 68]. Mulberry has a complex root system with a vertical distribution of up to 4 metres. Mulberry tree roots are horizontally distributed 4-5 times the crown area, sometimes as much as seven or eight times [69]. The buried depth of a three year-old taproot would approach 1.5 m, and the lateral root and rootlet may stretch more than 4 m. The underground root system is a massive network structure that has a significant impact on soil and water conservation. Mulberry's deep and wide-spreading root system allows soils to retain and store water at higher rates than other plant species. The deep and densely tangled network of mulberry root system has been found to improve soil shear strength and hence the anti-erosion capacity of mulberry-planted areas.

Mulberry tree canopy interception could account for 15%-40% of rainfall [70]. The penetration rate and coefficient of permeability of soil in a mulberry garden were 1.91 and 3.07 times higher, respectively, than in open ground [71]. As a result, 50% to 70% of rainfall could percolate into the ground and become groundwater. Because of canopy interception and garden storage for rainfall, the actual rainfall generated slight water flow, accounting for only 4% of the total rainfall. The weed beneath the mulberry could also form a barrier, reducing flow speed while preventing runoff and soil erosion. Mulberry is useful for forestation, windbreak, and sand fixation due to its drought resistance, cold resistance, barren resistance, and wide adaptation and spread. Mulberry plantations are extremely effective at suppressing sand storms. Mulberry has become a popular plant for windbreak and sand-fixation in northern China, including Xinjiang, Shaanxi, and Beijing. A hectare of mulberry can strand 27.2 tonnes of dust per year.

Mulberry has also been observed to produce root exudates, which nourish and enhance soil microflora and fauna. Flavones found in the fine roots of mulberry trees have been shown to boost the growth of a PCB degrader, the bacteria *Burkholderia* sp. LB400 [72; 73]. 17 perennial plants were tested for the presence of phenols that could aid in the growth of PCB-degrading bacteria and concluded that mulberry has numerous advantages that would contribute to its usage in phytoremediation. Mulberry is able to adapt to dry climates

as some drought-resistant mulberry types have a wilting coefficient of 9, which is lower than that of wild apricot (13), white elm (13), and poplar (13). Mulberry trees are a good

(table 1). Mulberry likewise has a low transpiration coefficient (table 2). It may thrive with a pH range of 4.5 to 9.0 and a soil salinity of 0.2% [75]. Mulberry is a

Tree			
Commonname	Scientificname	Water useefficiency	Ref.
Mulberry	<i>MorusalbaL.</i>	48.99	[76]
Coneflower	<i>Echinacea angustifolia deCandolle</i>	13.00	[77]
Seabuckthorn	<i>HippophaerhamnoidesLinnaeus</i>	7.57	[78; 79]
Poplar	<i>PopulusdeltoidsMarshal</i>	40.00	[80]

choice for enhancing saline, alkaline soil. Mulberry's water usage efficiency (WUE) is significant in climate change mitigation. Water use efficiency of mulberry is higher than other plants which are important in climate change mitigation

bettercandidate than other tree species in terms of ecological function and sand, soil, and water conservation.

Table 1 Comparison of water use efficiency of mulberry and other plants important in climate change mitigation

Table 2 Comparative transpiration coefficient of mulberry and other drought tolerant species

Tree		Novel characteristics			
Common name	Scientific name	Transpiration coefficient	Root system	Uses	Ref.
Mulberry	<i>Morus alba L.</i>	350-450	Tap rooted	Sericulture, fodder, food, medicinal, timber, landscaping	[81; 82; 83; 84]
Conebush	<i>PetrophilediversifoliaR.Br.</i>	300	Fibrous root system	Ornamental	[85]
Coneflower	<i>Echinacea angustifolia de Candolle</i>	383	Fibrous root system	Ornamental	[85]
Seabuck thorn	<i>Hippophaerhamnoides Linnaeus</i>	483	Cluster roots	Medicinal	[86]
Poplar	<i>Populus deltoids</i>	513	Tap root	Paper	[87]

Marshal

manufacture,
timber

(Source: [88])

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ROLE OF MULBERRY IN AFFORESTRATION

Mulberry is a perennial plant that grows quickly and is highly heterozygous, making it better suited to thrive in a variety of soil, temperature, and pH conditions. Due to its shape, leaf colour, growing vigour, tenacity, and resistance, mulberry is regarded as the most suited tree species for landscaping in urban settings. Due to less flexibility in foliar gas exchange features and better quantitative growth traits in low water regimes, several mulberry genotypes exhibit higher leaf yield. The genotypes' stronger osmoprotective capabilities, a biochemical response to water-limited growth regimes, enable them to withstand drought stress. The plant can withstand drought and other natural disasters quite well [89]. This is due to the mulberry ecotypes having undergone both natural and artificial selection. It can be grown in either rain-fed or irrigated environments with an annual rainfall range of 600 to 2500 mm. It may be grown successfully in a variety of terrain types, including flat, hilly, valleys, and sloppy places. It can be used as an agroforestry plant in the farming system. The use of agroforestry is well established to be an effective strategy for reducing climate change; the mulberry-incorporating agroforestry system would be an appropriate alternative farming method [90]. These are shade-resistant and can thrive and flourish in a variety of environments from 0 to 3300 metres above sea level and on a wide variety of soils. It can be grown in cities along highway medians, riverbanks, flood plains, public gardens, field crop boundaries, as street trees and in recreational club areas. Mulberry plantations are a good choice for afforestation because they can restore soil carbon, maintain soil water retention, prevent soil erosion during floods and water logging conditions, improve soil nutrients, support soil microflora, improve air quality, and withstand wind currents and sand storms.

CONCLUSION

Mulberry's extensive ecological flexibility to light, temperature, water, soil, and other natural circumstances enables it to serve a variety of ecologically protective roles. The authorities should advocate the establishment of this plant species in order to increase the amount of green cover and reduce pollution throughout cities and urban areas, along road edges, and in social forestry. Since ecological safety is now one of the most crucial aspects of global safety mulberry trees should potentially be used to address ecological problems. Ecological mulberry growth not only aids in the overall management of the environment's ecology but also achieves better levels of sustainable development in ecologically vulnerable places.

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