Review Article

EnvironmentalImportanceofMulberry:AReview

ABSTRACT

Mulberry is a woody, deciduous tree that is economically important. It is regarded as a distinctive plant on the planet due toits widespread geological distribution across continents, ability to be cultivated in various forms, multiple uses of leaf foliageand positive impact in environmental safety approaches such as ecorestoration of degraded lands, bioremediation of pollutedsites, water conservation, soil erosion prevention, and enhancement of air quality through carbon sequestration. Mulberry hasa robust root system. Mulberry root systems can significantly improve soil shear strength and anti-erosive capacity. Mulberryplantations are extremely effective in suppressing sand storms and conserving water and soil. The review investigates the role of mulberry trees in carbonsequestration,ecorestoration,soilandwater conservation, bioremediation of heavy metals andafforestation.

Keywords: Mulberry,environment;carbonsequestration;heavymetals;soilerosion

INTRODUCTION

Plantsplayavitalroleinmaintainingahealthyenvironment. Prior to the arrival of humans, the world wasprotected and had a high level of biodiversity with littledisturbances [1]. However, since thenineteenthcentury,duetoincreasingurbanisationandrisinghumanpopulation,enormousamountsofnon-biodegradable solid trash, liquid chemicals, and hazardousgases have been discharged into the environment from ourhouses,cars,andfactories[2].“Humanactivities over the last two centuries have resulted in theemergence of contemporary global issues such as climatechange, greenhouse effect, environmental protection andsafety,depletionofnaturalenergyresources,andasustainable environmentforfuturegenerations”[3]. Climate change is one of the mostimportantenvironmentalissuesconfrontinghumanitytoday.Recentclimatechangehasbeenascribedtoasignificantincreasein GHGemissions,mainlycarbondioxide (CO_2), caused by human activity. “According toavailable data, CO_2 concentrations have risen from 280parts per million by volume (ppmv) to 402.2 ±2.8 ppmvsince the 1750s, owing primarily to theuseoffossilfuelsandlarge-scaledeforestation”.[4]Thisscenario necessitates a paradigm shift in crop selection inordertocounteracttheeffectsofclimatechange[91-93].

Phytoremediationisanenvironmentallyfriendlyandpromising technology that uses plants to absorb, transport,degrade, or detoxify heavy metals and hazardous chemicalcompounds [5]. It is a relatively newtechnology that is seen as unique, efficient, cost-effective,andbeneficialtotheenvironmentwithwidespread acceptance.Oneofthegoalsofcurrentagriculturaldevelopmentislow-carbonagriculture.Farmersareincreasingly choosing for alternative farming methods thatare more profitable and resilient to an unexpected weather pattern as climate change continues to wreak havoc onagriculture.

Mulberry, which belongs to the genus Morus of the familyMoraceae and has about 36 varieties, is a hardy plant thatmay be found worldwide in practically all sorts of agroclimates from tropical to temperate. They are foundall across the world, from the tropics to the subarctic, andat altitudes ranging from sea level to 4000 m [6; 7]. Mulberry trees maygrow naturally at temperatures ranging from 40°C to-40°C,precipitationof300mmormore,andsoilpHvalues in the 4.5 to 9 range [8]. It is regardedas a unique planton thisplanetdue to itswidespreadgeologicaldistributionacrosscontinents,abilityto becultivated in various forms, multiple uses of leaf foliage,and positive impact in environmental safety approachesuch as ecorestoration of degraded lands, bioremediationofpollutedsites,waterconservation,soilerosion prevention,andimprovementofairqualitythroughcarbon sequestration [9]. It also has alarger foliage production, a shorter gestation period, andbetter environmental adaptation, amongst other attributes.Various roles of mulberry in protecting the environmentare categorized and described below (Fig.1).

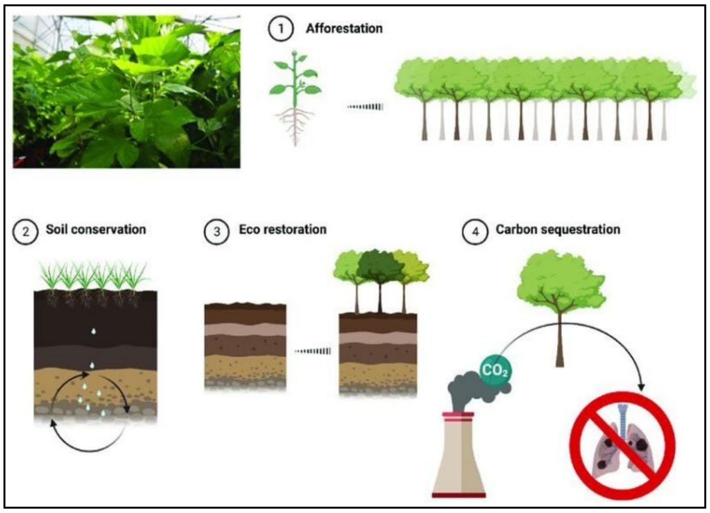

Fig.1Importanceofmulberryinenvironmentalsafety[10]

ROLEOF MULBERRY IN CARBON SEQUESTRATION

"Sericulture providesenvironmentalbenefitssuchas airpurification,carbonsequestration,andsoilandwaterconservation,whichisprimarilylinkedtomulberryproduction" [11]. "Mulberry, with itsgreat photosynthesis, rapid growth, and high biomass, hasthepotentialtoenhanceairquality.Mulberryleaveshaveabilitytoabsorbairpollutantssuchascarbondioxide,carbonmonoxide,hydrogenfluoride,sulphurdioxide, and chlorine from the atmosphere,anditsrootshaveabilitytouptakecarbonpollutants and heavy metal pollutants from the soil".[12-13]. "One hectare ofmulberry could absorbone tonne of CO_2in one day and release 0.73 tonnes of oxygen, which couldbe used tobreathe by 1000people"[14]."According to the data, 1 ha of mulberry trees can absorbaround 6.24104kg of CO_2 and emit 4.60104kg of O_2 peryear"[15]. "Mulberryrootsarelargerindiameternearthestemportion and then rapidly decrease in size; a long rope-likestructure with secondary and tertiary roots, as well as roothairs, forms a fibrous mat-like structure, allowing them touptake high concentrations of carbon pollutants from thesoil" [16; 17]. "Mulberryplants are recognised as good carbon sink and heavy metalresistance plants because their aerial portions can absorbair pollutants and their roots can absorb soil contaminants.Mulberry trees are believed to have innate resistance tochlorinesincetheirleavesremain unharmedevenatgreaterlevelsofchlorinepollution"[18]."Mulberry can absorbindustrialwastegasandnitrogencompoundseffectively.Furthermore,mulberry,whichhasahighresistancetosulphurdioxide, a high absorption capacity for fluoride, and an ability to resist floride, a clean air species [19].Mulberry "Mulberry can absorb 5.7 g of sulphur dioxide per kg ofdried leaves, thus mulberry forestry may absorb massiveamounts of sulphur dioxide gas every day" [20]. These properties have led to the mulberry plant'sefficient application in bioremediation of air pollutants inmetropolitanareasandphytoremediationofcarbonpollutantsincontaminatedsoilnearindustriesandchemicalfactories.

ROLE OF MULBERRY IN ECORESTORATION

trees have ahigh level of genetic flexibility,allowingthemtoadapttoavarietyofagro-climaticconditions. "Mulberry is a woody perennial tree with largeroot systems, rapid growth, high biomass production, easeof establishment and management, wide dispersion, andthe capacity to grow in a variety of soil conditions" [21; 22]. "Mulberryplantsgrowbestinfertileland with deep, sandy, or clayey soil that is porous, butthey can also grow in barren area with coarse soil that islowinnutrients"[23].
Mulberrytreesareextremelyresilientandimportant.Mulberry, for example, may thrive in arid and semiariddesert environments with annual rainfall of less than 300-600 mm. Mulberry's robust and deep root system developsa highly tangled and dense network with secondary andtertiary roots in any type of soil, allowing it to resist dryandunfavorableenvironmentalspells.These propertiesalso enabled the mulberry bushes to endure sand stormsand wind currents. Mulberry plants might thus be grownevenondesolatelandswithheavilycontaminatedpollutants, or in lands at higher altitudes or heights pronetoheavywindcurrents.
Mulberry also grows well in disturbed lands with waterlogging conditions, under drought stress, and in salinityconditions [24, 25; 26], owing to its deeper and wider rooting system andwideradaptability in arid,semi-arid areas with varyingsoilpHconditions[27].Mulberrytreesareextremely resistant to water logging when dormant. Whentheanti-seasonwater-loggingresistancefeaturesofmulberry were investigated it was discoveredthatmulberry grows better when submerged in water levelsover10mformorethan6months [28].
Mulberry may grow in severe climatic conditions rangingfrom -30 °Cchilling temperature to temperaturesabove40 °C [29]. Mulberry's hardy trait is proven by itsdistributionpatternovertheworld,extendingfromtemperate to tropical climates.Desertmulberryis an ecotype of mulberry that has been successfully cultivatedin desert areas of China's Xinjiang region.As this ecotypeallows mulberry trees to be grown in deserted locationswithminimalirrigation,itisrecommendedfor

naturalrestoration
ofdesertedareasanddesertifiedgrasslands"[30].

Mulberryplantshavealsobeeneffectively used and established for the ecorestoration ofsalinatedfieldsandstonydesolateplaces.

ROLE OF MULBERRY IN BIOREMEDIATION OF HEAVY METALS

"A varietyofanthropogenicactivitiessuchasmining,excessive fertiliser application, and wastewater irrigationinagriculture,largeamountsofheavymetalsaredischargedintosoileachyear,resultinginseveresoilcontamination worldwide" [31; 32]."Excessiveheavymetalsinsoilscanharmneighbouringecologicalsystems,groundwater,plant,animal, and human health" [33]. "Heavymetalpollutionhasthecharacteristicsofconcealment,irreversibility,long-termrepercussions,andsevereconsequences" [34]. Heavy metal poisoning ofsoilhasproventobeasevereglobalenvironmentalhazard. Carbon-based pollutants such as insecticides, fungicides,fumigants, rodenticides, and weedicides degrade slowly inthesoilover10-50years,i.e.soilmicrobesusethesepollutantsasacarbonsourceandmediatetheirdegradationthroughmetabolicactivities[35],buttherateofremediationisslowandtime-consuming. Heavy metal pollution, on the other hand, isconsideredveryhazardousandnon-biodegradableinnature. Because neither bacterium nor plants use heavymetalsasneithermetabolite,nordotheyuse themasnutrients and minerals. Heavy metals entering the humanbodythroughthewatersystemorothersourcescantrigger organ malfunction with serious consequences forthe human health system [36]. As aresult, it is critical to preventheavy metal contaminationin soil andwater,and thereisalso an urgentneedtoremediatetheseveryhazardous andtoxiccontaminants. Phytoremediationisconsideredthemostsuccessfulmethod 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 heavymetalcontaminantsfromthesoilandstoretheminspecialised structuressuch asvacuoles[39]. Plant selection and analysis of contaminated soilsitesplayanimportantroleinheavymetalphytoremediation[40],asclimaticconditions should favour the growth of the plant speciesbeing used, and the level of heavy metal contaminationshouldalsobepre-determinedforaneffectiveremediationprocess. Therearecurrently360differenttypesofhyperaccumulators,with the majority of them belongingtothe Cruciferae [41]."Althoughthe roleofhyperaccumulatorsintheremediationofheavymetalspollutedsoilhasshowngreatpromise,theirpracticalapplicability is limited due to their shallow roots, slowdevelopment,dwarfplant,lowbiomass,andlowdrymatteraccumulation.Asaresult,thetotalamountofheavymetalintakeandaccumulationbyhyperaccumulatorislittle,and repairefficiency islow"[42]. Many studies have suggested that usingsome woody plants to remove or stabilise heavy metals inpolluted soils could be an efficient approach [43; 44; 45]. Among the various tree species, mulberry has alargercapacitytoremediateheavymetalsfromcontaminated soils due to its wider, deeper, and superiorrooted system [46]. Although mulberryhasalowerheavymetalconcentrationthanhyperaccumulators,thetotalamountofheavymetalmigration isstill significantdue to the vastvolumeofmulberrybiomass.The intakeofheavymetalbymulberry is influenced by mulberry species, growth stagesand duration, soil physicochemical parameters, and heavymetaltype. Heavymetalssuchaschromium,lead,copper,nickel,cadmium,zinc,manganese,andmercuryarebeingremediated utilising various mulberry species [47; 48; 49; 50] investigated the accumulation of heavy metal mercury inMorus nigra leaf, stem, and root parts. Initially, differentquantities of mercury nitrate (30, 50, and 70 mg/L) wereadded to the soil. Two-year-old Morus nigra saplings wereplanted in the treated soil and grown for eight months.Aftereightmonths,the plantparts were separated anddried in an oven at 70 °C to make a fine powder, whichwas then used to determine mercury levels in samples ofeach plant part using the atomic absorption spectroscopymethod. At 70 mg/L and 30 mg/L densities, the highestand lowest concentrations (mg/kg) were 55.67 and 22.2 inthe leaf, 58.00 and 28.6 in the stem, and 65.00 and 35.3 inthe root portions, respectively. The results clearly showthat the absorption of mercury metal was higher in rootparts than in leaf and stem parts. Even though mercury is not used as anutrient, it is easily absorbed by the roots of the mulberry*(Morusnigra*).Mulberryisthusrecommendedforphytoremediation ofmercury-contaminatedsoils

"A pot experiment and an indoor test were done to investigatetheeffectsofvaryingPblevelsonthegrowth of mulberry and folia quality. The results showedthatplantheightincreasedwithdecreasingPbconcentrations(200mg/kgdrysoil).When Pb concentrations in the soil exceeded 200 mg/kg dry soil,mulberrygrowthandleaf qualitybegantobe hindered". [52]

"Apotexperiment was conducted toinvestigate the transportation characteristics of Pb in thesoil-mulberry-silkworm food chain and concluded that theconcentrations of Pb in different organs of mulberry wereintheorderofroots>stems>leavesandthatmulberryplanting and silkworm feeding could be a potential way inremediation of Pb-polluted soils"[53]. Cd migrated better thanPb in mulberry [54], and Cd was primarilycollectedintheroots,followedbythestem."TheCdcontent of leaves, on the other hand, was minimal. WhenCd concentrationsin soilswere in the 8.4975.8

mg/kgrange,almost40%ofCdabsorbedbymulberrywasconcen trated in roots, and approximately 16% in leaves”[55]. Despite the fact that the Cd content insoilsreached145mg/kg,thedeadlyconcentrationofmulberry, the Cd concentration in mulberry leaveswasonly 3.32 mg/kg [56].Mulberry leaf yield wasmore than or equal to that of the control when Cd levels inthe soil were less than 22.3 mg/kg. When the Cd contentexceeded 22.3 mg/kg, the yield of mulberry leaves wasreduced,and the leaves displayed toxic symptoms [57]. On the other hand, a micro plotexperiment was conducted and it was concludedthatwhentheconcentrationofCdinsoilswaslessthan10mg/kg,mulberry growth and leaf production were unaffected [58]. Theoutput of mulberry leaves was reduced by 10% to 30%when Cd concentrationswere in the rangeof20~ 40mg/kg. The mulberry tree was impending death when theCdconcentrationwasreached145mg/kg.Mulberriesabsorbed 50% of the Cd in their roots and only 10% intheirleaves. "Mulberry revealed a strong resistance to the toxicity of Pb,Zn,and As in soil and could grow normally in pollutedsoil with 734 mg/kg Pb, 1194 mg/kg Zn, and 53 mg/kg As"[59]."Theenrichment ability of mulberry to four heavy metals was investigated (Cu,Pb, Cd, and Zn) by planting mulberry trees in the LiuyangQibaoshanminingareaofHunanProvince" [60]."Theyconcludedthatthequantityofeachmetaldifferedindifferent parts of the mulberry (root, stem, leaf, and bark),and the amount of Cu, Pb, Cd, and Zn moved by mulberryin each square meter plough layer soil was 12116.1 mg,7409.83 mg, 2056.4 mg, and 254532.8 mg, respectively.Many papershave demonstrated thatthere were afewalterations in the growth and developmentof silkworms,as well as the production and quality of cocoon when thesilkwormwasfedonmulberryleavesgrownincontaminated field areas. Developing sericulture may be asafe, cost-effective, and environmentally friendly way touse heavy metal-contaminated lands"[61; 62; 63].

ROLE OF MULBERRY IN WATER AND SOIL CONSERVATION

The availabilityofgroundwater,aswell asthe waterholding and retention capacity of various soils, has grownover the last two decades for optimum agricultural outputand the maintenance of ecological balance under the soilsubsurface.Thepreservationofecologicalbalancebeneath the soil subsurface is critical for the survival ofsoilmicrobes,decomposers,andotherbeneficialorganisms that play an important role in biogeochemicalcycles where nutrients and minerals are recycled humusandothersourcesthatmaintainsoilfertility.Soilconservation is also given high priority, as soil erosioncausedbyrainandfloodsresultsininfertilesoilandecosystemdisruption.

Mulberry afforestation restores soil carbon, improves soilwaterholdingcapacity,controlssoilerosion,recyclesnutrients,andmaintainssoilmicroflora [64]. Mulberry plants grown as trees are reported to bebettersuited forwaterand soil conservation.Mulberryplantationsonlands/soilscanreducerunoffduringfloodingbyupto10%-20% [65].As compared to slope lands, annual run off in plain landsmulberry plantation sites can be reduced by 38% under 5years old and 91% under 10 years old bush plantings [66]. It is estimated that the runoff co-efficient inmulberry can be lowered by 10-20% when comparedtothe traditional planting pattern approach. It has also beenreported that mulberry tree hedgerows have a considerableeffect on total runoff and nutrient enrichment ratio.It has been shown experimentally thatmulberry trees had a considerable effect on soil erosionprevention. Annual runoff volume was reduced by 38 and91%beneath5and10yearoldmulberrybushbelts,respectively,comparedtoagriculturalslopeland [8].

Waterretentioncapacityofmulberry-plantedsoilsisreported to be greater than that of open land [67; 68]. Mulberry has a complex rootsystemwithaverticaldistributionofupto4meters.Mulberry tree roots are horizontally distributed 4-5 timesthe crownarea,sometimesasmuchassevenoreighttimes [69]. The buried depth of a three year-old taproot would approach 1.5 m, and the lateral root androotlet may stretch more than 4 m. The underground rootsystemisamassivenetworkstructurethathasasignificantimpactonsoilandwaterconservation.Mulberry'sdeepandwide-spreadingrootssystemallows soils to retain and store water at higher rates thanother plant species. The deep and densely tangled networkof mulberry root system has been found to improve soilshearstrengthandhencetheanti-erosioncapacityofmulberry-plantedareas.

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 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 (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 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

Tree			
Commonname	Scientificname	Water useefficiency	Ref.
Mulberry	*MorusalbaL.*	48.99	[76]
Coneflower	*Echinacea angustifolia* deCandolle	13.00	[77]
Seabuckthorn	*Hippophaerhamnoides*Linnaeus	7.57	[78; 79]
Poplar	*Populusdeltoids*Marshal	40.00	[80]

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

	Novel characteristics

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

(Source: [88])

ROLE OF MULBERRY IN AFFORESTATION

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[84]. 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, and 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 circumstancesenables it to serve a variety of ecologically protectiveroles. The authorities should advocate the establishment ofthis plant species in order to increase the amount of greencover and reduce pollution throughout cities and urbanareas, along road edges, and in social forestry. Sinceecological safety is now one of the most crucial aspects of global safety, mulberry trees should potentially be used to address ecological problems. Ecological mulberry growthnot only aids in the overall management of theenvironment's ecology but also achieves better levels ofsustainable development in ecologically vulnerable places.Mulberry has higher water use efficiency and lower transpirational coefficient than most plants which are used in climate change mitigation.Mulberries are used ecologically for medium- and long-term benefits since these purposes can only be served by waiting for the plants to achieve maturity.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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