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Role of Agroforestry in Phytoremediation of Contaminated Soils: Review

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Abstract

Some plant roots can ingest and immobilize unclean things, while others can process or group natural and supplement contaminants. The contribution of trees in decontamination of soil is taken into account; this review was formulated with the objectives of emphasizing of the role of agroforestry in phytoremediation of contaminated soils. Agroforestry is environmentally sounding natural resources management system. It promotes multiple benefits to the land users. Its role of naturalizing polluted soils is not trifling. There are potential agroforestry species undertaking decontamination of polluted soils. As an example, poplars and willows arc a number of the foremost preferred tree species. Varieties of agroforestry suitable plant species are found to be promising for phytoremediation of organic toxins. In tropical agroforestry Legume species have ability to decontaminate polluted soils. This bioremediation has opportunities since agroforestry species have multiple purposes. There must be a risk management to stop take-up of contaminants as a challenge. Generally, due to multipurpose nature, phytoremediation by agroforestry species is effective and environmentally sound. So it needs repeated field experiment of various agroforestry species and contaminates.

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Keywords

Agroforestry, Rehabilitating Polluted Soils, Bioremediation, Multipurpose Species

Introduction

Background

Agroforestry is defined as a dynamic, ecologically based, natural resources management system that, through the integration of woody perennials on farms, ranches, and in other landscapes, diversifies and increases production and promotes social, economic, and environmental benefits for land users (Nair, 1993; ICRAF, 2002; Orlando, 2004).

In this system there is ecological and economic interaction between the trees/shrubs and other components including the soil (Nair, 1993; ICRAF, 2002; Alao and Shuaibu, 2013; Atangana *et al.*, 2014).

Soil is a vital part of the natural environment. Soil is always responding to changes in environmental factors, along with the influences of man and land use. Its physical and chemical properties are affected by past land use, current activities on the site, and nearness to pollution sources.

Soil toxins adversely affect the physical, chemical and natural properties of the soil and diminish its profitability (Mishra *et al.*, 2015). Anthropogenic activities have deliberately added substances, for example, pesticides, manures and different changes to soils are wellsprings of tainting (Shayler *et al.*, 2009).

There are various kinds of soil contaminations, specifically agrarian soil contamination, industrial waste causing soil contamination, urbanization causing soil contamination and others (Hong-Bo *et al.*, 2010; Dağhan *et al.*, 2015).

A number of ways have been suggested to restrain the pollution rate. For instance, the cheapest pollution control method is using trees to decontaminate polluted soils for agricultural soils. It is an environmentally friendly approach because it is achieved via natural processes (Chibuike and Obiora, 2014).

The role of perennial based farming, so called agroforestry in rehabilitating polluted soils has been investigated, through exploiting the ability of trees to capture nutrients and pollutants (Smith, 2010).

The role of agroforestry in protecting the environment and providing a number of ecosystem services is promoted as a key benefit of integrating trees into farming systems. As traditionally employed, these benefits were intuitive to the farmers and landowners that managed agroforestry systems, although the scientific evidence to support such benefits is only now coming to light (Jose, 2009).

Literatures has shown that trees can take up contaminants from soil into their biomass, help breakdown pollutants to non-toxic compounds and control water dynamics including contaminated groundwater flow and contaminated water penetration into soils via evapotranspiration (Volk *et al.*, 2006; Udawatta, 2011; Zhu *et al.*, 2019).

Role of trees to decontaminate pollution, which is scientifically called Phytoremediation (Schnoo, 1995; Salt *et al.*, 1998) involves extraction of soil pollutants by roots and accumulation or transformation by plants, (Atangana *et al.*, 2014). It is one of those environmental services provided by agroforestry, is the use of plants to decontaminate polluted soils (Burken and Ma 2006; Liste and White, 2008).

Phytoremediation can be defined the use of green plants (trees, shrubs, grasses and aquatic plants) and their associated microorganisms to remove toxic substances from the soil (Presad, 2004; Dickinson *et al.*, 2009; Laghlimi *et al.*, 2015).

Hyperaccumulators are plants that can tolerate metals and organic pollutants and extract them from contaminated soils and accumulate them at concentrations far exceeding what normally would be found in plant tissues (Van der Ent *et al.*, 2013; Reeves *et al.*, 2017).

Agroforestry systems restore contaminated soils through the decontaminating effects of legumes, hyperaccumulators, and hydraulic lift (a major mechanism behind soil water redistribution between soil layers in agroforestry systems) Atangana *et al.*, 2014).

Legume species that are used in tropical agroforestry for nitrogen fixation in soils most often have the ability to decontaminate polluted soils, as symbiotic associations between legumes and symbioses (*Mycorrhiza* and *Rhizobium* spp.) and actinomycorrhizal plants (*Mycorrhiza* and *Frankia* spp.) enhance phytobial remediation.

Hyperaccumulators are used for soil decontamination in several agroforestry systems, including riparian buffer systems, tree-crop combinations, and short woody rotation crops (Atangana *et al.*, 2014).

As reported by Atangana *et al.*, (2014) and Favas *et al.*, (2014) Phytoremediation may occur as phytostabilization, phytoextraction, phytovolatilization, phytofiltration and rhyzodegradation.

By taking into consideration the contribution of trees in decontamination of soil, present review has been formulated with the following objective.

Objectives

General objective

To emphasis the role of agroforestry in phytoremediation of polluted soils.

Specific objectives

To review potential of Agroforestry tree species for phytoremediation

To review opportunities and challenges of agroforestry based phytoremediation of polluted soil

Concept of phytoremediation

Contaminants within the environment pose a worldwide problem for wildlife and human health. Phytoremediation may be a recently developed technology that gives a cheap solution by using plants, and associated soil microbes, to scale back the content or toxic effects, of contaminants within the environment. As mentioned in Suresh and Shankar, (2004) it is a pro-missing, ecologically-friendly approach to remediate contaminated soil using plants and remove toxic elements from the environment.

Woody plants or trees with developed root systems and large biomasses are especially attractive for vegetation and phytoremediation in metal-polluted sites (Lee *et al.*, 2009; Capuana, 2013).

Additionally, exploring native plants with phytoremediation potential is a particularly important strategy, as indigenous plants are often more dependent in terms of survival, growth and reproduction under environmental stress than exotic plants (Yoon *et al.*, 2006).

According to Greipsson (2011) Phytoremediation technologies are categorized in to four: (a) phytostabilization, where contaminants are retained in the soil and prevent further dispersal. Contaminants can be stabilized in the roots or within the rhizosphere. (b) Phytodegradation, Involves the degradation of organic contaminants directly, through the release of enzymes from roots, or through metabolic activities within plant tissues .In phytodegradation organic contaminants are taken up by roots and metabolized in plant tissues to less toxic substances. Phytodegradation of hydrophobic organic contaminants have been particularly successful. Poplar trees (*Populus* spp.) have been used successfully in phytodegradation of toxic and recalcitrant organic pollutants. It involves the degradation of organic contaminants directly, through the release of enzymes from roots, or through metabolic activities within plant tissues. In phytodegradation organic contaminants are taken up by roots and metabolized in plant tissues to less toxic substances. Phytodegradation of hydrophobic organic contaminants have been particularly successful. As reported by Capuana (2013) Poplar trees (*Populus* spp.) have been used successfully in phytodegradation of toxic and recalcitrant organic compounds(c) phytovolatilization, where contaminants are converted inside plants to a gaseous state and released into the atmosphere via the evapotranspiration process, For example, hybrid poplar trees have been used to volatilize trichloroethylene (TCE) by converting it to chlorinated acetates and CO_2 and, (d) phytoextraction, where plants are used to accumulate contaminants in the aboveground, harvestable biomass.

Phytoremediation potential of agroforestry species

There are potential of agroforestry species with having decontamination of polluted soils by different sources. For instance, as reported by Shankar *et al.*, (2005) there are Four promising agroforestry tree species viz., *Albizia amara, Casuarina equisetifolia, Tectona grandis*, and *Leucaena leucocephala* as a pot culture experiment was conducted in green house to study the potential of chromium (Cr) in a plants. The roots of such plant accumulated more chromium by addition of acid within the tissues of roots. In their study as an example, *Albizia amara* is a potential chromium accumulator.

The suitability of *Leucaena leucocephala* for phytoremediation of heavy metal-polluted and heavy metal-degraded sites has demonstrated. *L. leucocephala* has numerous inherent characteristics that can be exploited to boost phytoremediation and lower the cost of regenerations (Senku *et al.*, 2017). The species can survive in harsh environmental conditions with the exception of heavily frosted conditions and occurs in a wide range of ecological settings.

The species is fast growing, capable of to produce a vast amount of seeds that can germinate into numerous seedlings to carry on further remediation of the polluted site. It can produce large quantities of phytomass that can accumulate heavy metals and can repeatedly be harvested to regenerate a polluted area through phytoextraction.

Many metal hyperaccumulators have been reported in but few are from agroforestry land uses. However, a legume, *Pearsonia metallifera; Annona senegalensis* and *Albizia adianthifolia; Idenspilosa* and *Crotalaria micans; Sesbania rostrata* were reported in the review by Atangana *et al.*, (2014).

According to Oh *et al.*, (2015) Agronomic characteristics of sorghum (Sorghum bicolor L.) in an agroforestry system with suitable trees, may be a plant with high tolerance to diverse growing conditions, high biomass production, various processes for bioenergy production and low nitrogen fertilizer requirements. Therefore, agroforestry determined the potential of sorghum for phytoremediation of multiple heavy metal contaminated soil and thus the promotion effects on phytoremediation potential by a lead-tolerance fungous isolated from lead contaminated soil.

A study in Chinaby Nie *et al.,* (2010) showed that intercropping maize with suitable plants was effective for phytoremediation nitrogen pollutions.

Indigenous European hardwood species management (eg Traditional coppicing) of agroforestry system was more favorable to offsetting almost certain tone per year within the traditional system (Simpson *et al.*, 1998).

Trees which have deep roots take up large quantities of water, nutrients and other contaminants (Isebrands *et al.*, 2014). For instance, Poplars and willows arc foremost preferred tree species for phytoremediation because they grow rapidly.

Phytoremediation of Heavy Metal Contaminated Soils by agroforestry

Major soil toxins (e.g. Heavy metals) are the main environmental contaminants and pose a severe threat within the soil environment (Laghlimi *et al.,* 2015).

The remediation of soils contaminated by heavy metals could be a cost intensive and technically complex procedure and traditional remediation technologies are supported biological, physical, and chemical methods, which can be utilized in conjunction with each other to scale back the contamination to a secure and acceptable level (Jadia and Fulker, 2009).

The most common heavy metal contaminants are Cd, Cr, Cu, Hg, Pb, and Zn. They mainly sources as naturally within the soil environment from the pedogenetic processes of weathering of parent materials and Human activities (Laghlimi *et al.,* 2015).

As reported Rea *et al.,* (2004) cited in Peuke and Rennenberg (2005) Phytoremediation Mechanisms evolved to tolerate naturally occurring heavy metals in the soil, which either disrupt or inhibit enzymatic activity by displacing other metal cofactors, or generate reactive oxygen species and free radicals that bind to the sulphur and/or nitrogen atoms of proteins.

Due to different characteristics, For instance, Plants have several cellular structures and physiological processes to maintain homeostasis and detoxify supra-optimal metal concentrations. These include metal binding to mycorrhizal fungi, metal binding to cell walls, exudation of metal chelating compounds and a network of processes that take up metals, chelate them and transport these complexes to above-ground tissues where they are sequestered into vacuoles (Clemens *et al.,* 2002).

Because of different reasons deforestation and forest degrading has been aggravated and people are facing to natural forests clearing. But it is obvious that pollution sources and effects are near residences. So, Agroforestry as an emerging technology is considered for remediation of contaminated soils because of its multiple roles (Vaziri *et al.,* 2013).

Phytoremediation of Organic Polluted Soil by agroforestry

According to Harmens *et al.,* (2013) organic chemicals, like phthalic esters, Polycyclic Aromatic Hydrocarbons, Polybrominated Diphenyl Ethers, Polychlorobiphenyls, Petroleum Hydrocarbons, prologueas pesticides causes pollution to the soil. These organic chemicals can be removed by woody based farming called agroforestry.

A number of agroforestry suitable plant species are found to be promising for the phytoremediation of organic pollutions (Chen *et al.,* 2013). According to Gerhardt *et al.,* (2009) there are two approaches for the phytoremediation of organic-polluted soils. First, organic pollutants are often haunted directly by plants which is named phytoextraction. Second, organic pollutants can be degraded by plant-secreted enzymes or microbial community rhizoremediation.

Rhizosphere increases the abundance genes for remediation and plant exudates increase solubility of organic pollutants (Nwoko, 2010). Agroforestry systems with diverse plant species are potential for phytoremediation by modified legume Rhizosphere (Chen *et al.,* 2013). The removal of organic pollutants by multispecies may result from the accelerated degradation rate, elevated soil microbial biomass, microbial functional diversity, and degrading enzymes activities (Wei and Pan, 2010) and improved tillage activities.

According to Burken and Schnoor (1997) there are four mechanisms involved in phytoremediation by agroforestry tree species for organic pollutants. The first is direct uptake and accumulation of contaminants and metabolism in plant tissues. For example the uptake of agrochemicals (e.g. pesticides/insect side) by plants.

Second is Transpiration of volatile organic compounds through stomata. Third is Release of exudates help for microbial activity and biochemical transformations in the soil. Plants exude a spread of materials into the rhizosphere. root exudates include compounds like organic acids, simple sugars, and amino acids, also as larger and more complex polysaccharides proteins, and lysates from dead cells. Additionally, several key plant enzymes, including dehalogenases, nitroreductases, peroxidases, laccases, and nitrilases, are commonly found in plant root exudates (Schnoor, 2002).

As the result the Exuded enzymes are implicated within the degradation of a variety of contaminants in in the soils and sediments (Schnoor *et al.*, 1995). Fourth is Boost of mineralization into relatively nontoxic compounds (eg. carbon dioxide, nitrate, chlorine and ammonia).

Phytoremidiation through short rotation woody species

As one category of agroforestry practices Short rotation woody crop (SRWC) is the intensive culture of fast growing hardwoods at close spacing for rotations. In addition to its primarily objective as fuelwood, it has potential for phytoremediation of soil toxins (Alker *et al.,* 2002 and Donald *et al.,* 2004).

According to Donald *et al.*, (2004) More than one third of the world's population in the energy of the developing country mainly depends on wood. From aforementioned amount 86% is used for fuel. African countries such as Angola, Chad, Ethiopia, and Tanzania depend more than more than 90% on fuelwood.

Due to forest cover change there are Research and development farmers efforts in India, Kenya, Ethiopia and Rwanda practicing agroforestry for fuelwood and improving the environment.

There are five agroforestry systems identified by Garrett and Buck (1997) Represent opportunities for incorporating SRWC. 1. Alley cropping 2. Riparian vegetative buffer strip 3. Tree-animal systems (silvopasture) 4.Forest crop systems (forest farming)5. windbreak systems (shelterbelts), riparian systems and windbreaks have the greatest potential.

Poplar trees in SRWCs in the riparian component of agroforestry systems effective in lower subsurface NO3-N concentrations and stabilizes degraded agricultural stream banks while growing rapidly (O'Neill and Gordon 1994). Nutrients, pesticides, and sediments from stream banks can be removed effectively by Riparian buffer strip (Schultz *et al.,* 1995).

Agroforestry system is used relatively for a particular phytoremediation than SRWC. SRWC is applied when the system is properly established and maintained.

Opportunities and challenges of agroforestry based of contaminated soil remediation

Opportunities facing phytoremediation of contaminated soil

Various physical, chemical and biological processes are already being used in remediation of contaminated soil (Cunningham, 1995; Helena and Gomes, 2012). For instance Soil washing, solidification/stabilization, vitrification, electrokinetic treatment, chemical oxidation or reductions have been used.

In contrast to these adoption of less invasive, effective method called 'green Remediation' is employed. The biomass of the plants can be used for renewable energy sources.

In addition to its economic benefit as energy sources, it reduces pressure on natural and healthy virgin forest resources. It has ecological benefits like erosion control, improving soil quality and functionality and wildlife habitat (Gomes, 2012).

In the case of heavy metals and radionuclides plants extract and translocate a toxic cation or oxyanion to above-ground tissues for later harvest and removal (Angronsveld *et al.,* 2009). It also reduces the cost of removal of contaminant by excavation.

Generation of valuable products like timber, bioenergy, feedstock for pyrolysis, bio fortified products are the major cones of phytoremediation (Van *et al.,* 2001).

Phytoremediation is the ideal technology for mitigating landfill environmental problems including soil and ground water contamination, leachate generation and gas emissions (Kim and Owens, 2010). Crops constitutes high contaminants are potentially used as material for metal enrichment (Aken, 2008). Bioremediation of contaminated soil by agroforestry trees (woody based farming) have a number of opportunities as reported by Paz *et al.,* (2013).

It's more cost-effective
More environmentally friendly and sounding
More aesthetically pleasing than conventional methods.
Cheap and environmentally sounding
It is also advantages for plant biodiversity management and conservation

Challenges facing phytoremediation

Some plants need water to absorb contaminates from the soil and their uptakes proportional to water uptake will consume. Quinn *et al.,* (2001) have observed efficiency of water uptake by developing model for hybrid poplars tree on contaminant plume. Quinn and Johnson (2005) speculated that large trees with no water poured showed delayed responses for remediation of toxins. Moisture stress can hinder the effectiveness of remediation process.

Another drawback of phytoremediation is it is more effective on layers only on the first meter. However, Quinn *et al.,* (2001) and USEPA (2003) show that both the modeling and the results of the application of deep-rooting technologies allow trees to impact soil and groundwater to depths of <30 m.

Contaminants may cause problems in later use stages of production, biofuel and n food chains. They may affect the human organic phenomenon and health if not well managed (Andersson *et al*., 2009). Therefore, there must be a risk management of the crops or crop choices (Bardos *et al.,* 2013).

A major disadvantage of phytoremediation is its relatively slow and requires several years or even decades to halve metal contamination in soil (Mcgrath and Zhao, 2003). The other problems are if the plants are not adapting to climatic and environmental conditions at contaminated sites (Favas *et al.,* 2014). However agroforestry species are suitable for such case.

Plant species selection for phytoremediation

There are characteristics of plants that qualify species for phytoremediation. The root depth of the plant has direct impacts the depth of soil which will be remediated (USEPA, 2001).
Since agroforestry trees and shrubs are manageable for desired objectives they are more preferable for phytoremediation of contaminated soils.

For instance vegetation programs agroforestry species in mining soils has achieved stable persistent cover because they represent two functional sorts of plants with different roles within the improvement of mine soils. For a extended duration, as considered for many phytoremediation processes, it can't be expected to wash up the soil only by one plant species used exclusively in monoculture (Cechmankova *et al.,* 2011).

In agroforestry system combined with Grasses, their highly developed root, can stabilize the soils and reduce erosion, while legumes can add nitrogen to the soil, preparing the establishment of other plant species typical of later stages of succession (Carvalho *et al.,* 2013). The major criteria selection for agroforestry species for phytoremediation is its legume nature. Legume species that are used in tropical agroforestry for nitrogen fixation are highly desirable (Atangana *et al.,* 2014). All manageable characteristics of trees/shrubs in agroforestry are suitable for phytoremediation of contaminated soil. This is great opportunities to solve agricultural pollution s from and near farm.

From current review it's concluded that Agroforestry plays a crucial role in decontaminating the polluted soil. There are some potential agroforestry suitable plant species, which are found to be promising candidates for the phytoremediation of pollution. As an example, species like *Albiziaamara, Casuarina equisetifolia,* teak, and *Leucaena luecocephala* were potentially wont to control the soil pollutants like chromium (Cr) accumulation. Agroforestry based phytoremediation shows cost effectiveness, aesthetic advantages, future applicability. However, if Contaminants in a plant not properly utilized in safe manner may cause problem in later stages of use in products and is its relatively slow phase, because it requires several years. For phytoremediation, species selection varies significantly. It depends on local conditions like soil structure, depth of a hard pan, soil fertility, cropping pressure, contaminant concentration, or other conditions. Mostly it's preferable if selected based on their root depth, the character of the contaminants and therefore the soil, and regional climate.

Agroforestry trees are more preferable with characteristics of rapid growth, large amount of biomass, strong resistance, and effective, Stabilization soils and ability to remediate differing types of soils, can stabilize the soils and reduce erosion, while legumes can add nitrogen to the soil, preparing the establishment of other plant species typical of later stages of succession. Generally there should be strong field experiments on different agroforestry species and contaminants' by researchers, environmentalists and other concerned bodies.

References

Aken, B. V. 2008. Transgenic plants for phytoremediation: Helping nature to clean up environmental pollution. *Trends Biotechnol.*, 26: 225–227.

AnderssonSköld, Y., Enell, A., Blom, S., Rihm, T., Angelbratt, A., Haglund, K., Wik, O., Bardos, P., Track, T. and Keuning, S. 2009. *Biofuel and other biomass based products from contaminated sites – potentials and barriers from Swedish perspective*

Angronsveld, J., Herzig, R., Weyens, N., Boulet, J., Adriaensen, K., Ruttens, A., Thewys, T., ssilev, A., Meers, E., Nehnevajova, E., vander Lelie, D. and Mench, M. 2009. Phytoremediation of contaminated soils and groundwater.

Atangana, A., Khasa, D., Chang, S. and Degrande, A., 2014.Phytoremediation in Tropical Agroforestry. In *Tropical Agroforestry* (pp.343-351). Springer Netherlands.

Bardos, P. Y. Andersson-Sköld, S. Keuning, M. Polland, P. Suer, and T. Track, REJUVENATE. (2013) *Crop-based systems for sustainable risk based land management for economically marginal degraded land*, SNOWMAN Project No. SN-01/20 Final.

Briggs, G. G., Bromilow, R. H., and Evans, A. A. (1982), Relationships between lipophilicity and root uptake and translocation of non-ionized chemicals by barley. Pest. Sci., 13: (495-504)

Britt, C., Bullard, M., Hickman, G., Johnson, P., King, J., Nicholson, F., Nixon, P. and Smith, N. 2002. *Bioenergy crops and bioremediation – a review*, London: Department for Food, Environment and Rural Affairs.

Burken J.G. and Schnoor J.L., (1997) Uptake and metabolism of atrazine by poplar trees, Environ. *Sci. Technol.* 31: 1399-1406

Burken, J.G. and Ma, X., 2006. Phytoremediation of volatile organic compounds. In *Phytoremediation Rhizoremediation* (pp. 199-216). Springer, Dordrecht.

Capuana M (2013). Heavy metals and woody plants - biotechnologies for phytoremediation. iForest 4: 7-15.

Carvalho, A., Nabais, C., Roiloa, S.R. and Rodriguez-Echeverria, S. (2013) Revegetation of Abandoned Copper Mines: The Role of Seed Banks and Soil Amendments. *Web Ecology*, 13, 69-77.

Cechmankova, J., Vacha, R., Skala, J. and Havelkova, M. (2011) Heavy Metals Phytoextraction from Heavily and Moderately Contaminated Soil by Field Crops Grown in Monoculture and Crop Rotation. Soil and Water Research, 6, 120-130.

Chen J, Xu QX, Su Y, Shi ZQ, Han FX (2013) Phytoremediation of Organic Polluted Soil. *J. Bioremed. Biodeg.*, 4: e132. doi:10.4172/2155-6199.1000e132.

Chibuike, G.U. and Obiora, S.C., 2014. Heavy metal polluted soils: effect on plants and bioremediation methods. *Applied and environmental soil science*, 2014.

CIAT, T., 2002, March, ICRAF, 2002. In *Soil fertility degradation in sub-Saharan Africa: leveraging lasting solutions to a long-term problem. Conclusions from a workshop held at the Rockefeller Foundation Bellagio Study and Conference Centre. March* (pp. 4-8).

Clemens S (2001) Molecular mechanisms of plant metal tolerance and homeostasis. *Planta* 212: 475–486.

Dağhan, H. and Öztürk, M., 2015. Soil pollution in Turkey and remediation methods. *Soil Remediation and Plants: Prospects and Challenges*, pp. 287-312.

Dickinson, N.M., Baker, A.J., Doronila, A., Laidlaw, S. and Reeves, R.D., 2009. Phytoremediation of inorganics: realism and synergies. International Journal of Phytoremediation, 11(2), pp. 97-114.

Favas, P.J., Pratas, J., Varun, M., D'Souza, R. and Paul, M.S., 2014. Phytoremediation of soils contaminated with metals and metalloids at mining areas: potential of native flora. *Environmental risk assessment of soil contamination*, 3, pp. 485-516.

Fiorese, G. and Guariso, G. 2010. A GIS-based approach to evaluate biomass potential from energy crops at regional scale. *Environ. Model. Softw.*, 25: 702–711.

Garrett H.E. and Buck L. 1997 Agroforestry practice and policy in the United States of America. *For Ecol Manag* 91: 5–15

Gerhardt KE, Huang X-D, Glick BR, Greenberg BM (2009) Phytoremediation and rhizoremediation of organic soil contaminants: Potential and challenges. *Plant Sci.*, 176: 20-30.

Gomes, H.I., 2012. Phytoremediation for bioenergy: challenges and opportunities. *Environmental Technology Reviews*, 1(1): 59-56.

Greipsson, S., 2011. Phytoremediation. *Nature Education Knowledge*, *3*(10), p.7.

Harmens H, Foan L, Simon V, Mills G (2013) Terrestrial mosses as biomonitors of atmospheric POPs pollution: a review. *Environ Pollut*: 173:245-254

Helena I. Gomes (2012) Phytoremediation for bioenergy: challenges and opportunities, Environmental Technology Reviews, 1:1, 59-66, DOI:10.1080/09593330.2012.696715

Hong-Bo, S., Li-Ye, C., Cheng-Jiang, R., Hua, L., Dong-Gang, G. and Wei-Xiang, L., 2010.Understanding molecular mechanisms for improving phytoremediation of heavy metal-contaminated soils. *Critical reviews in biotechnology*, *30*(1), pp.23-30.

Isebrands, J.G., Aronsson, P., Carlson, M., Ceulemans, R., Coleman, M., Dickinson, N., Dimitriou, J., Doty, S., Gardiner, E., Heinsoo, K. and Johnson, J.D., 2014.Environmental applications of poplars and willows. *Poplars and Willows. Rome: The Food and Agriculture Organization of the United Nations*, pp.258-336.

Jose, S., 2009. Agroforestry for ecosystem services and environmental benefits: an overview. *Agroforestry systems*, *76*(1), pp.1-10.

Kim, K.-R. and Owens, G. 2010. Potential for enhanced phytoremediation of landfills using biosolids: A review. *J. Environ. Manage.*, 91: 791–797. (doi:10.1016/j.jenvman.2009.10.017

Laghlimi, M., Baghdad, B., El Hadi, H. and Bouabdli, A. (2015) Phytoremediation Mechanisms of Heavy Metal Contaminated Soils: A Review. Open Journal of Ecology, 5, 375-388. http://dx.doi.org/10.4236/oje.2015.58031

Lee DB, Nam W, Kwak YS, Cho NH, Lee SS (2009).Phytoremediation of heavy-metal-contaminated soil in a reclaimed dredging area using *Alnus* species. Journal of Ecology and Field Biology 32: 267-275.

Liste, H.H. and White, J.C., 2008. Plant hydraulic lift of soil water–implications for crop production and land restoration. *Plant and Soil*, *313*(1-2), pp.1-17.

McGrath SP, Zhao FJ (2003) Phytoextraction of metals and metalloids from contaminated soils. CurrOpinBiotechnol 14: 277–282

Mishra, R.K., Mohammad, N. and Roychoudhury, N., 2015. Soil pollution: Causes, effects and control. *Tropical Forest Research Institute*, *3*(1), pp.20-30.

Nair, P.R., 1993. *An introduction to agroforestry*. Springer Science & Business Media.

Nie, S.-W., Gao, W.-S., Chen, Y.-Q., Sui, P. and Eneji, A. E. 2010. Use of life cycle assessment methodology for determining phytoremediation potentials of maize-based cropping systems in fields with nitrogen fertilizer over-dose. *J. Cleaner*

Nwoko CO (2010) Trends in phytoremediation of toxic elemental and organic pollutants. Afr J Biotechnol 9: 6010-6016.

O'Neill G.J. and Gordon A.M. 1994.The nitrogen filtering capacityof Carolina poplar in an artificial riparian zone. J Environ Qual 23: 1218–1823

Oh, K., Cao, T., Cheng, H., Liang, X., Hu, X., Yan, L., Yonemochi, S. and Takahi, S., 2015.Phytoremediation potential of Sorghum as a biofuel crop and the enhancement effects with microbe inoculation in heavy metal contaminated soil. *Journal of Biosciences and Medicines*, *3*(06), p.9.

Paz-Alberto, A.M. and Sigua, G.C., 2013. Phytoremediation: a green technology to remove environmental pollutants.

Peuke, A. D., and Rennenberg, H. (2005). Phytoremediation. *EMBO Reports*, *6*(6), 497–501. http://doi.org/10.1038/sj.embor.7400445

Pivetz, P. (2001) Phytoremediation of Contaminated Soil and Ground Water at Hazardous Waste Sites. EPA/540/S-01/500, United States Environmental Protection Agency (EPA), Washington DC, 36 p.

Prasad, M.N.V., 2004. Phytoremediation of metals and radionuclides in the environment: the case for natural hyperaccumulators, metal transporters, soil-amending chelators and transgenic plants. In Heavy metal stress in plants (pp. 345-391).Springer, Berlin, Heidelberg.

Reeves, R. D., Baker, A. J. M., Jaffré, T., Erskine, P. D., Echevarria, G. and van der Ent, A. (2017) A global database for plants that hyperaccumulate metal and metalloid trace elements. *New Phytologist*.doi: 10.1111/nph.14907

Rowe, R. L., Street, N. R. and Taylor, G. 2009. Identifying potential environmental impacts of large-scale deployment of dedicated bioenergy crops in the UK. *Renewable Sustainable Energy Rev.*, 13: 271–290.

Salt, D.E., Smith, R.D. and Raskin, I., 1998.Phytoremediation. *Annual review of plant biology*, *49*(1), pp.643-668.

Saraswat S, Rai JPN (2011) Prospective application of *Leucaena leucocephala* for phytoextraction of Cd and Zn and nitrogen fixation in metal polluted soils. Int J Phytoremediation 13(3):271–288

Schnoor, J. L. (2002), Phytoremediation of Soil and Groundwater, Technical Evaluation Report 02-01, Ground Water Remediation Technologies Analysis Center, Pittsburgh, PA.

Schnoor, J.L., Light, L.A., McCutcheon, S.C., Wolfe, N.L. and Carreia, L.H., 1995.Phytoremediation of organic and nutrient contaminants. *Environmental science & technology*, *29*(7), pp. 318A-323A.

Shanker, A.K., Ravichandran, V. and Pathmanabhan, G., 2005.Phytoaccumulation of chromium by some multipurpose-tree seedlings. *Agroforestry systems*, 64(1):83-87

Shayler, H., McBride, M. and Harrison, E., 2009. Cornell Waste Management Institute. .

Simpson, J. A., Picchi, G., Gordon, A. M., Thevathasan, N. V., Stanturf, J. and Nicholas, I. *Task 30 Short rotation crops for bioenergy systems. Environmental benefits associated with short-rotation woody crops,* 64(1):83-87

Smith, J., 2010. Agroforestry: reconciling production with protection of the environment a synopsis of research literature.

Ssenku, J.E., Ntale, M., Backeus, I. and Oryem-Origa, H., 2017.Phytoremediation potential of Leucaena leucocephala (Lam.) de Wit.for heavy metal-polluted and heavy metal-degraded environments. In *Phytoremediation Potential of Bioenergy Plants* (pp. 189-209).Springer, Singapore.

Subhashini, V. and Swamy, A.V.V.S. (2013) Phytoremediation of Pb and Ni Contaminated Soils Using Catharanthusroseus (L.). Universal Journal of Environmental Research and Technology, 3: 456-472.

Suresh B, Ravishankar GA (2004). Phytoremediation - a novel and promising approach for environmental clean-up. Critical Review in Biotechnology 24: 97-124.

Udawatta, R.P., Garrett, H.E. and Kallenbach, R., 2011. Agroforestry buffers for nonpoint source pollution reductions from agricultural watersheds. *Journal of environmental quality*, *40*(3), pp.800-806.

United States Environmental Protection Agency (2001) Brownfields Technology Primer: Selecting and Using Phytoremediation for Site Cleanup. USEPA, Washington DC, 46 p.

Van der Ent, A., Baker, A.J., Reeves, R.D., Pollard, A.J. and Schat, H., 2013. Hyperaccumulators of metal and metalloid trace elements: facts and fiction. *Plant and Soil*, 362(1-2), pp.319-334.

Vaziri, A., Panahpour, E. and MirzaeeBeni, M.H. (2013) Phytoremediation: A Method for Treatment of Petroleum Hydrocarbon Contaminated Soils. International Journal of Farming and Allied Sciences, 2, 909-913.

Volk, T.A., *et al.*, The development of short-rotation willow in the northeastern United States for bioenergy and bioproducts, agroforestry and phytoremediation. Biomass and Bioenergy, 2006. 30: p. 715-727.S

Wei S, Pan S (2010) Phytoremediation for soils contaminated by phenanthrene and pyrene with multiple plant species. J Soils Sediments 10: 886-894

Yoon J, Cao XD, Zhou QX, Ma LQ (2006). Accumulation of Pb, Cu, and Zn in native plants growing on a contaminated Florida site. Science of the Total Environment 368: 456-464.

Zabaniotou, A. A., Kantarelis, E. K. and Theodoropoulos, D. C. 2008. Sunflower shells utilization for energetic purposes in an integrated approach of energy crops: Laboratory study pyrolysis and kinetics. J Phytoremadation, 13(3): 271–288

Zhu, X., Liu, W., Chen, J., Bruijnzeel, L.A., Mao, Z., Yang, X., Cardinael, R., Meng, F.R., Sidle, R.C., Seitz, S. and Nair, V.D., 2019. Reductions in water, soil and nutrient losses and pesticide pollution in agroforestry practices: a review of evidence and processes. *Plant and Soil*, pp.1-42.

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