Multipurpose Tree Species for Bio-remediation of ProblematicSoils

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Multipurpose trees are deliberately grown and managed for more than one output. They may supply food in the form of fruit, nuts, leaves etc; while at the same time supplying firewood, add nitrogen to the soil, or supply some other combination of multiple outputs. "Multipurpose tree" is a term common to agro-forestry, particularly when speaking of tropical agro-forestry where the tree owner is a subsistence farmer.

Tree species can be multipurpose in two ways:

- **A single tree can yield more than one product**: For example, farmers in South India grow *Gliricidia sepium* as live fence that provide fuel, fodder, and green manure for agricultural crops - all at the same time.
- **Trees of the same species, when managed differently, can yield different product:** for example, *Leucaena leucocephala* is managed so that some trees will principally yield wood while others principally produce leaf meal

While all trees can be said to serve several purposes, such as providing habitat, shade, or soil improvement; multipurpose trees have a greater impact on a farmer's well being because they fulfill more than one basic human need. In most cases multipurpose trees have a primary role; such as being part of a living fence, or a windbreak, or used in an ally cropping system. In addition to this they will have one or more secondary roles, most often supplying a family with food or firewood, or both.

When a multipurpose tree is planted, a number of needs and functions can be fulfilled at once. They may be used as a windbreak, while also supplying a staple food for the owner. They may be used as fencepost in a living fence, while also being the main source of firewood for the owner. They may be intercropped into existing fields, to supply nitrogen to the soil, and at the same time serve as a source of both food and firewood.

Common multipurpose trees of the tropics include:

- *Gliricidia sepium* – the most common tree used for living fences in Central America, firewood, fodder, fixing nitrogen into the soil.
- Moringa *(Moringa oleifera)* – edible leaves, pods and beans, commonly used for animal forage and shade (it does not fix nitrogen as is commonly believed)
- Coconut palm – used for food, purified water (juice from inside the coconut), roof thatching, firewood, shade.

- Neem (*Azadirachta indica*) – limited use as insect repellent, antibiotic, adding nitrogen to the soil, windbreaks, biomass production for use as mulch, firewood.

Ideally most trees found on tropical farms should be multipurpose, and provide more to the farmer than simply shade and firewood. In most cases they should be nitrogen fixing legumes, or trees that greatly increase the farmer's food security.

Features of good MPT species:-

- Have good organic content and nutrients in foliage.
- Roots are deep with good soil binding properties.
- Can be grown in problem soils.
- Nitrogenous stabilizing.

The capacity of trees to maintain or improve soils is shown by the high fertility status closed nutrient cycling under natural forest, the restoration of fertility under forest fallow in shifting cultivation and the experience of reclamation forestry and agroforestry. Trees improve soil fertility by processes which:

- Increase addition to the soil
- Reduce losses from the soil
- Improve soil physical, chemical and biological conditions

The most important sets of processes are those by which tress:

- Check runoff and soil erosion
- Increase nutrient inputs, through nitrogen fixation and uptake from deep soil horizons
- Promote more closed nutrient cycling

Some MPTs adopted by farmers:-

- **Arid Zone:** *Prosopis cineraria* (Khejri), *P. juliflora* (Mesquite tree), *Tecomella indulala* (Rohida), *Zizyphus* spp. (Ber), *Azadirachta indica* (Neem), *Eucalyptus camaeldulensis* (River red gum), *Acacia tortilis* (Israeli babul).
- **Semi-arid Zone:** *Acacia nilotica* (Gum Arabic tree / Babul), *Acacia tortilis* (Israeli babul), *Albizia lebbek* (Sirish / Women's tongue), *Albizia amara* (Krishna Siris), *Prosopis juliflora* (Mesquite tree), *Azadirachta indica* (Neem), *Eucalyptus hybrids* (Hybrid Eucalyptus), *Leucaena leucocephala* (Subabul).
- **Humid Zone:** *Albizia lebbek* (Sirish/ Women's tongue), *Albizia procera* (Safed Sirish), *Paraserianthes falcataria* (Moluccan albizia), *Leucaena leucocephala* (Subabul), *Acacia mangium* (Australian Sag).
- **Central Indian Plateau:** *Albizia amara, Albizia lebbek, Acacia nilotica, Butea monosperma* (Palash), *Prosopis juliflora.*

- **Eastern and Western Coastal Region:** *Casuarina equisetifolia* (Saru), *Leucaena leucocephala, Prosopis juliflora.*
- **Temperate Himalayan Region:** *Ficus* spp., *Alnus* spp., *Salis* spp.
- **Sub-temperate Lower Hills and Gangetic Plain:** *Acacia nilotica, Albizia lebbek, Azadirachta indica, Melia azedarach* (Pride of India), *Leucaena leucocephala.*
- **Eastern Himalayan Zone:** *Acacia mangium, Acacia auriculiformis* (Akashmani), *Paraserianthes falcataria, Albizia lebbek, Albizia procera.*

Bio-remediation of problem soils :

Remediate means to solve a problem and bio-remediation means to use biological organisms/ agent to solve an environmental problem such as contaminated / problem soils or contaminated ground water. Bioremediation is the use of microbes to clean up contaminated soil and groundwater. Microbes are very small organisms, such as bacteria, that live naturally in the environment. Bioremediation stimulates the growth of certain microbes that use contaminants as a source of food and energy. Contaminants treated using bioremediation include oil and other petroleum products, solvents, and pesticides.

Problematic soils are these soils which are not suitable for arable forming because of specific limitations. In general, problem soils are two types i.e. physical problem and chemical problems. Agro-forestry systems have the potential tool to make use of marginal and degraded lands through the soil improving effect of trees. It proves to be one of the cheapest and best modes for the reclamation of all problematic soils. Agro-forestry systems like silviculture, silvi-pasture *etc.* can improve the physical and chemical properties of the soil along with additional return on long-term basis.

1. **Bioremediation of physical problems of soils :** For the bioremediation of physical problems of soil like sandy soils, subsoil hardening or hardpan, surface crusting, water logged soils, peat and marshy soils etc. Tree species i.e. *Eucalyptus robusta* (Swamp mahogany), *Syzygium cumunii* (Jamun), *Terminalia arjuna* (arjuna), *Salix tetrasperma* (Indian willow), *Dalbergia latifolia* (Shisham), *Eucalyptus camaeldulensis* (River red gum), *Eucalyptus grandis* (Rose gum) and some grasses like *Bracharia mutica* (Para grass) and *Cynodon dactylon* (Bermuda grass), *Dichanthium caricosum, Brachiaria decumbens* etc. are commonly used.
2. **Bioremediation of chemical problems of soils:** The different chemical problems of soils i.e. salt affected soils (saline, sodic and saline – sodic) etc also reclaimed or managed by the following tree and grass species.
   - **Saline Soils :-**Promising woody species -
     - *Salvadora persica* (mustard tree)

- *Prosopis juliflora* (mesquite tree)
- *Acacia nilotica* (Babul)
- *Butea monosperma* (Palash)
- *Terminalia arjuna* (Arjuna)
- *Salix* sp. (Indian willow)
- *Dalbergia sissoo* (Sissoo)
- *Casurina equisetifolia* (Saru)

Highly salt tolerant and high biomass producing grasses species include

- *Aeluropus lagopoides* (mangrove grass or rabbit-foot aeluropus)
- *Suaeda fruticose* (shrubby seablight)
- *Cynodon dactylon* (Bermuda grass, Dhoob grass)
- *Brachiaria ramose* (Brown top Millet)

❖ **Sodic Soils :-**

- *Prosopis juliflora* (mesquite tree) and *Dichanthium annulatum* (Karnal grass) improves the soil conditions to such an extent that after some time or year.
- Some fodder species can be grown under trees such as - Berseem (*Trifolium alexandricum*), Senji (*Melilotus parviflora*) and Shaftal (*Trifolium resupinatum*)
- Relative tolerance of fruit trees to sodicity :

Exchangeable Sodium Percentage (ESP) for Sodicity tolerance	**Trees**
Sensitive : < 20	*Mangifera indica* (Mango) *Artocarpus heterophyllus* (Jack fruit) *Musa paradisiaca* (Banana)
Low : 20 – 30	*Psidium guajava* (Guava) *Citrus limon* (Lemon) *Vitis vinifera* (Grape)
Medium : 30 – 40	*Punica granatum* (Pomegranate)
High : 40 – 50	*Ziziphus jujube* (Ber) *Tamarindus indica* (Tamarind) *Manilkara zapota* (Sapota) *Limonia acidissima* (Wood apple) *Phoenix dactylifera* (Date palm)

❖ **Saline-Sodic Soils**

- *Acacia auriculiformis* (Akashmoni)
- *Azadirachta indica* (Neem)
- *Casurina equisetifoia* (Saru)

- *Dalbergia sissoo* (Sissoo)
- *Ailanthus excels* (tree of heaven)
- *Prosopis cineraria* (Khejri)
- *Acacia tortilis* (Israeli babul)
- *Acacia nilotica* (Babul)

Types of Bioremediation:

Based on place where wastes are removed, there are principally two ways ofbioremediation:

1. ***In-Situ* Bioremediation:** Most often, in situ bioremediation is applied to eliminate the pollutants in contaminated soils and groundwater. It is a superior method for the cleaning of contaminated environments because it saves transportation costs and uses harmless microorganisms to eliminate the chemical contaminations. Two types of in situ bioremediation are distinguished based on the origin of the microorganisms applied as bioremediants.
   a) **Intrinsic bioremediation:** This type of in situ bioremediation is carried outwithout direct microbial amendment and through intermediation in ecologicalconditions of the contaminated region and the fortification of the naturalpopulations and the metabolic activities of indigenous or naturally existingmicrofauna by improving nutritional and ventilation conditions.
   b) **Engineered in situ bioremediation:** This type of bioremediation is performed through the introduction of certain microorganisms to a contamination site. As the conditions of contamination sites are most often unfavourable for the establishment and bioactivity of the exogenously amended microorganisms, therefore here like intrinsic bioremediation, the environment is modified in away so that improved physico-chemical conditions are provided. Oxygen, electron acceptors, and nutrients (for example nitrogen and phosphorus) are required to enhance microbial growth.
2. ***Ex-Situ*Bioremediation:**The process of bioremediation here takes place somewhere out from contaminationsite, and therefore requires transportation of contaminated soil or pumping ofgroundwater to the site of bioremediation. This technique has more disadvantagesthan advantages.Depending on the state of the contaminant in the step of bioremediation, ex-situ bioremediation is classified as:
   a) **Solid phase system (including land treatment and soil piles):** The system issued in order to bioremediate organic wastes and problematic domestic and industrial wastes, sewage sludge, and municipal solid wastes. Solid-phase soil bioremediation includes three processes including land-farming, soil biopiling, and composting.

b) **Slurry phase systems (including solid–liquid suspensions in bioreactors):** Slurry phase bioremediation is a relatively more rapid process compared to the other treatment processes.

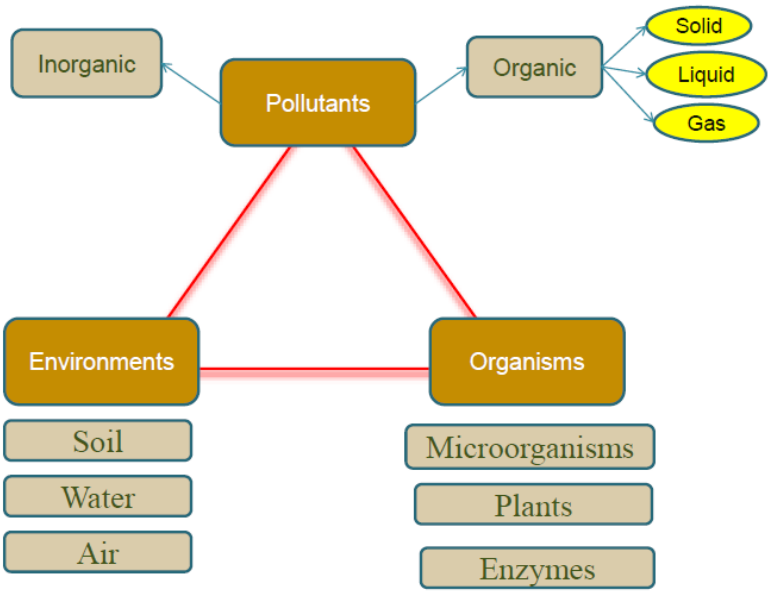

Fig. 1:Bioremediation is a triple-corners process

Bioremediation Techniques:-

There are several bioremediation techniques, some of them have been listed asfollows:

1. **Bio-augmentation:** The addition of bacterial cultures to a contaminated medium used frequently in In-situ processes. Two factors limit the use of added microbial cultures in a land treatment unit: (a) non indigenous cultures rarely compete well enough with an indigenous population to develop and sustain useful population levels and (b) most soils with long-term exposure to biodegradable waste have indigenous microorganisms that are effective degraders if the land treatment unit is well managed.
2. **Bio-filters:** The use of microbial stripping columns used to treat air emissions.
3. **Bioreactors:** The use of biological processes in a contained area or reactor for biological treatment of relatively small amounts of waste. This method is used to treat slurries or liquids. Slurry reactors or aqueous reactors are used for ex situ treatment of contaminated soil and water pumped up from a contaminated plume. Bioremediation in reactors involves the processing of contaminated solid material (soil, sediment, sludge) or water through an engineered containment system. A slurry bioreactor may be defined as a containment vessel and apparatus used to create a three-phase (solid, liquid, and gas) mixing condition to increase the bioremediation rate of soil-bound and water-soluble pollutants as a water slurry of the contaminated soil and biomass (usually indigenous microorganisms) capable of degrading target contaminants.

4. **Bio-stimulation:** The stimulation of the indigenous microbial populations in soils and/or groundwater. This process may be done either in situ or ex situ.
5. **Bio-venting:** The process of drawing oxygen through the contaminated medium to stimulate microbial growth and activity. Bio-venting is the most common in situ treatment and involves supplying air and nutrients through wells to contaminated soil to stimulate the indigenous bacteria. Bio-venting employs low airflow rates and provides only the amount of oxygen necessary for the biodegradation while minimizing volatilization and release of contaminants to the atmosphere.
6. **Composting:** An aerobic and thermo-phillic process that is mixes contaminated soil with a bulking agent. Composting may be performed using static piles, aerated piles, or continuously fed reactors. Composting is a technique that involves combining contaminated soil with nonhazardous organic amendments such as manure or agricultural wastes. The presence of these organic materials supports the development of a rich microbial population and elevated temperature characteristic of composting.
7. **Land farming/Land Treatment/Prepared Bed Bioreactors:** Solid phase treatment system for contaminated soil that may be applied as an in situ process or ex situ in a soil treatment cell. Land farming is a simple bioremediation technique in which contaminated soil is excavated and spread over a prepared bed and periodically tilled until pollutants are degraded. The goal is to stimulate indigenous bio-degradative microorganisms and facilitate their aerobic degradation of contaminants. In general, the practice is limited to the treatment of superficial10–35 cm of soil.
8. **Bio-piling:** Bio-piles are a hybrid of land farming and composting. Essentially, engineered cells are constructed as aerated composted piles. Adding compost to contaminated soil enhances bioremediation because of the structure of the organic compost matrix.
9. **Phytoremediation:**Phytoremediation deals with the cleanup of organic pollutants and heavy metal contaminants using plants and rhizospheric microorganisms. It is inexpensive, eco-friendly and an efficient means of restoration of polluted environments especially those that of heavy metals. Nonetheless, the level of soil contamination, the quantity of metal contaminant in the soil, as well as the ability of plants to aggressively take up metals from the soil, determine the success of phytoremediation at any polluted site. Plants utilized in phytoremediation are the hyper-accumulators with very high heavy metal accumulation potential and little biomass efficiency, and non-hyper-accumulators, which possess lesser extraction capacity than hyper-accumulators, but whose total biomass yield is substantially higher and are fast-growing species (Fig. 2).

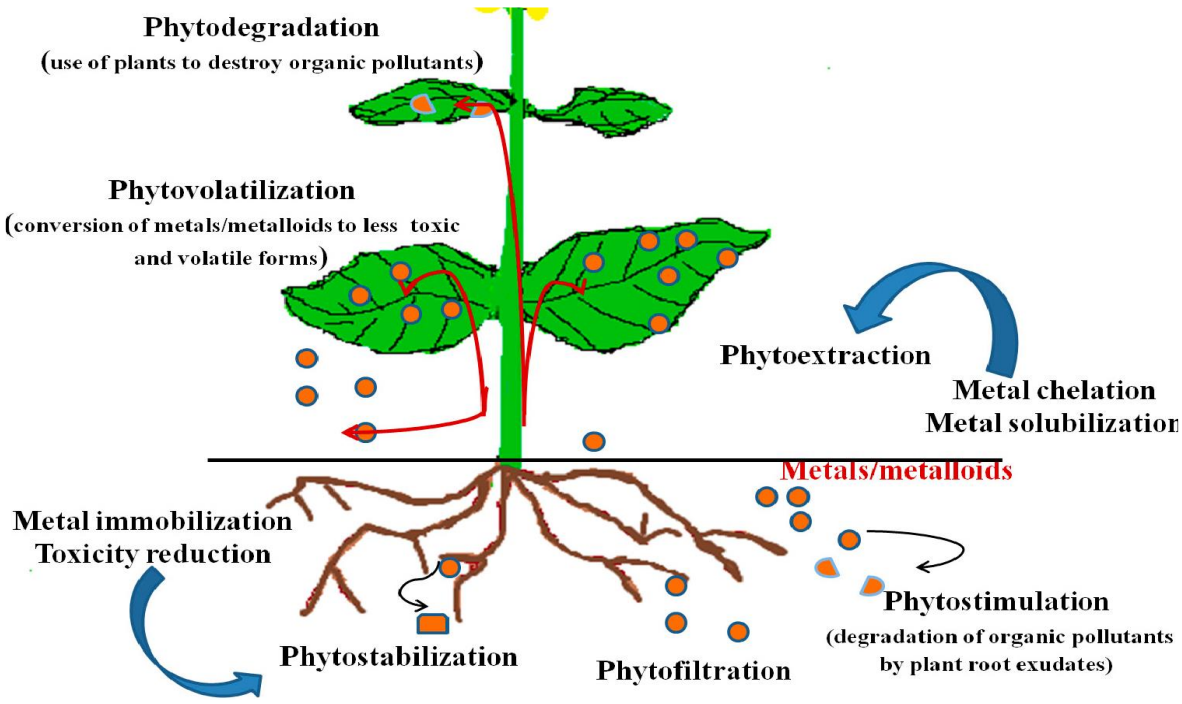

Fig. 2: Processes involved in phytoremediation

Advantages of bioremediation:

- Bioremediation is a natural process and is therefore perceived by the public.
- Bioremediation is useful for the complete destruction of a wide variety of contaminants.
- Instead of transferring contaminants from one environmental medium to another, for example, from land to water or air, the complete destruction of target pollutants is possible.
- Bioremediation can often be carried out on site, often without causing a major disruption of normal activities.
- Bioremediation can prove less expensive than other technologies that are used for clean-up of hazardous waste.

Disadvantages of bioremediation:

- Bioremediation is limited to those compounds that are biodegradable. Not all compounds are susceptible to rapid and complete degradation.
- There are some concerns that the products of biodegradation may be more persistent or toxic than the parent compound.
- Biological processes are often highly specific to the microbial populations, suitable environmental growth conditions, and appropriate levels of nutrients and contaminants.
- It is difficult to extrapolate (deduce) from bench and pilot-scale studies to full-scale field operations.
- Bioremediation often takes longer than other treatment options.

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