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Afforestation and development of wasteland through agroforestry

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Abstract
Tree growth is reported to exert an ameliorative effect on wastelands by improving their physical, chemical and biological properties. Several tree species and tree planting techniques for Agroforestry have been described, which can go a long way in greening barren undulating areas. The paper examines the possibilities of afforestation as an alternative for development of wasteland. The paper describes the use of agroforestry as a holistic approach to waste land management, and the steps in the application of agroforestry principles to waste lands. Appropriate techniques are identified as energy farms (fuel plantations and shelterbelts), silvopastoral systems, agrosilvopastoral systems with plantation crops, fish culture in dammed sites, and the use of multipurpose trees. Agroforestry has potential to contribute to restoration and conservation alongside productivity of land has been expressed in many ways, emphasizing soil conservation, land degradation, food security, land use for integrated natural resources management, or biodiversity conservation and also has played a significant role in the rehabilitation of wastelands, desert and lands degraded by salinisation, water and wind erosion. Wise management of Agroforestry puts forward a suitable substitute to control deteriorated asserts to increase yield and to protect environment. Providing vegetative cover to such lands with woody and herbaceous species can put these lands to optimal use and also increase the forest cover of the country. Yield potential of these degraded lands is quite low and these lands are best suited for silvopastoral and other tree-based system.

Keywords: Afforestation, agroforestry, forest, wasteland, salinisation

Introduction

India shares 16 per cent of the world population, while its land is only 2 per cent of the total geographical area of the world. Because of the obvious reason of high population, the burden on the land is commonly beyond its carrying capacity. In India, productive lands especially the farmlands are under continuous degradation and are rapidly converting into wastelands. At present, approximately 68.35-million-hectare area of the land is lying as wastelands in India. Out of these lands, approximately 50 per cent lands are such non-forest lands, which can be made fertile again if treated properly. The vulnerable non-forestlands, had to undergo the greatest loss mainly due to the enormous biotic pressure on it. India’s luxuriant green village forest and woodlands are under rapid deterioration for the last 5 decades. National Wastelands Development Board (NWDB) defined wasteland as ‘‘that land that is degraded and is presently lying unutilized (except as current fallow) due to different constraints.’’ NWDB conjointly steered that any land that isn't producing green biomass in line with the status of soil and water should be treated as wasteland. Although no accord have been acquired definition of barren however it's for the most part accepted that wastelands are the areas that are underutilized and which produces less than 20 per cent of its biological productivity (Mishra *et al.*, 2013). It has been assured that agroforestry systems are treasures of ecosystem services that may act as an emblem of nine planetary boundaries of world. The multi-functional role of agroforestry (Sahoo and Wani, 2019) [10] has been stressed by each of the Millennium Ecosystem Assessment and also the International Assessment of Agricultural Science and Technology for Development.

Nearly, 6.75 Mhaof India’s land area are either sodic or saline type. However, 6.41 Mha lands are degenerated due to water logging. These lands constrain plant growth due to the diffusion effects of salt, poor physical conditions resulting in poor aeration, nutrition imbalances, and toxicities. To meet the necessities of food and alternative agricultural commodities for the burgeoning population is a big challenge for agricultural community. With the increasing demand for good quality land and water for urbanization and development projects, in future, agriculture will be pushed progressively to the marginal lands and use of poor-quality water for irrigation is inevitable. With use of acceptable planting techniques and salt-tolerant species, the salt-affected lands are brought under viable vegetation cover. Further, in most of the arid and semi-arid regions the groundwater aquifers area saline. Generally, growing of regular arable crops with saline irrigation does not give sustainable production. Concerted analysis efforts have shown that by applying acceptable planting and alternative management techniques (e.g., sub-surface planting and furrow irrigation), the degraded salty lands (including calcareous) are place to various uses (agroforestry) and salt-tolerant forest and fruit trees, forage grasses, medicinal and aromatic, and alternative high price crops is equally remunerative. Such uses have extra environmental advantages together with carbon sequestration and biological reclamation. The International Panel on global climate change (IPCC) Third Assessment Report on global climate change (McCarthy *et al*., 2001) [5] has recognised the potential of agroforestry for addressing multiple issues and delivering a spread of economic, environmental and socioeconomic edges. Food producing trees grown in agroforestry systems will increase the nutritional and economic security of poor people living in tropical countries (World Bank, 2006) [4]. As an example, the fruit of the many wild edible species have carbohydrate contents on a dry weight basis ranging from 32 to 88% (Sundriyal and Sundriyal, 2001) [14]. Agroforestry ought to thus be seen as a system that addresses the declining quality of the environment, as well as the soil, whereas additionally increasing the variability of produce by the farmer. This will not only increase the farmers' financial gain however additionally facilitate ensuring food security and balance. The retention of trees in farming systems has been recognized to increase crop output within the semi-arid region of Adamawa state (Amadi *et al*., 2003) [3]. Ajake (2012) [2] also acknowledged the outcomes of forest trees in relation to income creation, medical management, job creation, raw materials, and food among others. Soil health means the potential to fulfill ecosystem services (ESs) as a living system consisting of different flora and fauna. Soil health can be determined by Soil organic matter (SOM) content, as it is an energy source and habitat for biota. By its effect on soil physical, chemical and biological properties, SOM content and its actions also governs various ecosystem services crucial for human benefits and nature conservancy. Because of the extended use of extractive farming practices, least use of biofertilizers, and soil degeneration by erosion, salinization and other processes, the SOM content in agricultural soils of India is generally under the critical limit of 2% in the root zone. Thus, agronomic yield, water quality and sustainability, soil biodiversity and other ESs are under great risk (*i.e*., eutrophication of water, pollution of air, continuous loss due to erosion, release of greenhouse gases). Therefore, there is a compelling need to rehabilitate SOM content, also improve and sustain soil health by incorporation of recommended management practices (RMPs). The transformation of degraded soils to a restorative land use through afforestation and incorporation of site-specific RMPs are critical to enhancing soil health. Some RMPs consists conservation agriculture (CA), optimum use of fertilizers based on strategies of carbon-centric integrated nutrient management, nutrition sensitive agriculture, and use of cover cropping and complex systems. Change of the fertilizer sector in accordance to efficiency rather than rate of input, emphasizes on rehabilitation of soil health with rise in soil organic carbon content in the root zone by adoption of RMPs such as CA, agroforestry, and CNPK rather than NPK.

A vegetation cover prevents soil erosion, conserves water, removes excessive salts, restores soil microbiological activity, increase percolation, lowers soil temperature and increases the agricultural productivity of adjoining lands. Degraded lands are potentially the most promising areas amongst the wastelands. The paper examines the possibilities of afforestation as an alternative for development of wastelands. The degraded or wasteland may be used to bridge the gap between the demand and supply of food, fodder, timber, fuel and also for resource conservation by afforestation.

Ameliorative role of forests

Tree growth is known to loosen the soil through the root system and to improve the water permeability of the solonetzic soils substantially as against virgin lands and land under agricultural crops (Vadiunina, 1964) [16]. The shade of the trees retards moisture evaporation and thus minimizes salts accumulation on the surface (Yadav, 1980) [20]. When growing salt-tolerant plants in a saline environment, the bare soil is covered by plants. Soil evaporation is replaced by plant transpiration, thereby reducing or hindering the salt accumulation, thus reducing salt accumulation in the tillage layer. The plants also assimilate salt from the soil and accumulate salts in aerial plant parts. The salt is then removed through harvest. After growing salt-tolerant plant species in a saline environment, the amount of organic matter micro-organisms in the soil is increased because of the humic action of rotted roots and fallen leaves. The soil’s nutrient conditions are improved, resulting in enhanced soil fertility. After the five years’ successive growing period the porosity increased by up to 20% at the tillage layer (0–100 cm) and a reduction in the soil bulk density was also observed.

The soil salinity decreased although brackish water was used as irrigation water. The salinity of the irrigation water was less than that of the soil solution so salts could be removed by the leaching process. However, young plants are more sensitive to salt than mature plants. To ensure plant germination, fresh water is recommended to be applied during the beginning of growing periods. (Yuan, L. 2011) [23]. Tiwari & Singh (1996) [15] observed a decrease in the content of soluble salts and pH under *Acacia auriculiformis*. The canopy cover of forest trees has a great influence on soil fertility and microclimate (Misra and Kandya, 1970) [8]. Verma *et al*., (1982) [18] reported that different tree species differed widely in modifying the properties of sodic soil. The mixed canopy of *Acacia nilotica* and *Syzygium sp*. reduced the pH to normal and increased the organic matter of soil followed by other mixed canopies and single species.

Selection of alkali tolerant forest species

In the case of highly alkaline soils, it may not be possible to grow tree species without reclaiming the planting site to some extent (so that the cost of reclamation is not prohibitive) so that the quick establishment of the planted seeding is insured (Tiwari, 1996) [15]. Even if planting is to be done without spending much on the amendments, it is essential to choose those species which are inherently capable of producing a prolific deep-root system, resist high salt content and can thrive under semi-arid and condition with a low/moisture supply. The high salt concentration in the soil cause physiological drought and therefore, the chosen species should also be resistant towards high salt concentration (Yadav, 1978) [19].

Table 1: Effect of *Acacia auriculiformis* canopy on properties of an alkali soil.

Depth (cm)	Organic matter (%)	Nitrogen (%)	pH	Soluble salts
Original soils				
00-05	0.54	0.057	10.6	1.24
05-25	0.21	0.032	10.6	1.24
25-57	0.18	0.017	10.5	0.90
59-95	0.08	0.010	10.4	0.67
Soil under *Acacia auriculiformis*				
00-09	2.87	1.140	8.2	0.26
03-15	0.31	0.043	9.8	0.38
15-71	0.23	0.036	10.5	1.31
71-100	0.15	0.015	10.8	1.05

Source: Tiwari & Singh, 1996 [15]

Alkali tolerance of forest species

Although several forest species have been found to show greater tolerance to alkali condition as compared to field crops, yet they differ among themselves in their alkali tolerance. The alkali tolerance limits of useful tree species have been worked out under different alkali situations approximate limits based upon the work done by different workers are presented in table 2.

Table 2: Relative tolerance of tree species to alkali conditions.

Alkali severeness	pH range 1:2	Tree species
Low	0.5-9.0	*Azadirchta exotic, Terminalia arjuna, Azadirachta indica, Albizzia lebbek,*
Medium	9.0-9.5	*Eucalyptus tereticornis, Ziziphus pp., Acacia auriculiformis*
High	9.5-10.0	*Acacia arabica Butea monosperma Dalbergia sissoo Pongamia pinnata*

Planting techniques

Techniques of planting trees successfully should aim at providing better conditions near the roots in alkali soil, survival of the newly planted trees is the main problems as they cannot tolerate high pH and ESP values. The adoption of suitable soil- working method is an important item of planting techniques on alkali lands. The main requirements of soil-working involves: (i) production of a loose soil amenable to rapid proliferation of the root system, (ii) the soil mass should be able to retain the maximum amount of moisture, particularly during the period of stress, (iii) the high ESP soil should be lowered at least around the root region by using amendments, (iv) the fertility status of the soil mass should be improved by the additions of organic manures and fertilizers, and (v) the hardpan or *kankar* layer if any should be broken.

The two common methods of soil manipulation for tree planting are Pit technique and Auger whole technique. In Pit technique, the pits are either filled with good imported soil or the soil of pit is treated with amendment to provide a favourable medium for initial growth during the establishment period. The depth of the pit is about 1 m so that the hard layer, if any, is broken. Although the technique of plant in a pit filled with good imported soil helps in the establishment of the planted species, it entertains the possible danger of subsequent alkali development due to salt diffusion from the surroundings soil (Yadav, 1978) [19]. The treatment of original alkali soil with FYM at the rate of 25 per pit and gypsum at the rate of 50 percent GR resulted in the survival and study growth of *Acacia arabica, Albizzialebbeck, Eucalyptus hybrid, Acacia auriculiformis* and *Terminalia arjuna* (Tiwari & Singh, 1996) [15].

Auger hole technique involves the reclamation of a very small fraction of the total area and aims at training the roots to go deeper into the soil, which mitigates the adverse effect of high alkali in the surface layer. As the roots go deeper they find a relatively better environment including moisture availability. All this results in a proliferation of roots and a much better growth of the tree in a short time (Abrol and Sandhu, 1980) [1]. The auger hole method is practical and economical as it involves the digging of auger holes of a small diameter. Auger holes also ensure the breaking up of the kanker layer which otherwise hinder root penetration of the roots to deeper layer where the trees can get water easily and thus ensure in their healthy growth (Mehta, 1983) [6].

Utilizing wasteland through agroforestry

Rehabilitation of wasteland can bedone by community participation like social forestry,joint forest management through afforestation of worthy species like Jatropha, Neem, Acaiaspecies, etc. These degraded and wasteland are reclaimed and restored through scientific plantation technique, either sole tree plantation under afforestation schemes or practice of different agroforestry models based on specific location. Agroforestry models for fodder production *viz*. silvopasture, hortipasture and agrisilviculture systems are generally established in degraded cultivable lands. Besides fodder production, livestock production can also be done by modifying wasteland through agroforestry system which is also an environmentally safe system of land use. Agrisilviculture system of fodder production (Napier-Bajrahybrid grass +*Sesbania grandiflora* as agrisilviculture system of fodder production is more successful for irrigated lands. Among the agroforestry models, Napier-Bajrahybrid grass + *Albizia lebbeck* as tree component and *Cenchrus ciliaris*+ *Stylosanthes scarab* as pasture component was recommended for greening of wasteland in rainfed condition.

Gullied/Ravenous land

The ravine areas are most fragile ecosystem and subjected to various kinds of natural resource losses and threat to biodiversity. Threat to biodiversity is mainly due to uncontrolled and reckless use of the forest area under ravines.

However, crop cultivation in these lands is not desirable as it leads to accelerated erosion, thus adding to their fast degradation. The best scientific land use of these lands is to place them under permanent vegetation through agroforestry interventions involving forest and fruit trees along with the grasses. The sustained ravine ecosystem and livelihood of the people can be achieved by the plantation and management of native tree species like *Anogeissus pendula*, *Acacia leucophloea*, *A. nilotica*, *Ziziphus spp*., *Carissa carandas* and *Capparis decidua*. After successful checking of the ravine extension, the most important measure for reducing the risk of degradation of catchments of gullies and marginal lands along the ravines is introduction of trees and grasses in the ravine lands. Depending on the problems and needs of the area, trees may be introduced as alley, boundary plantation, or scattered tree plantation in the field. The highly eroded soils coupled with extremes of temperature and limitations of moisture hamper the survival and growth of trees. The tree and grass species (Table 3) selected should have ability to withstand stress, fast growing, easy to establish, multipurpose uses, fibrous roots and potential to ameliorate the soil. For the reclamations of ravines, agroforestry interventions and various agroforestry practices have been applied successfully. Under agrihorticulture systems, fruit trees such as lemon (*Citrus limon*), mango (*Mangifera indica*), ber (*Ziziphus mauritiana*) and amla (*Emblica officinalis*) can be grown with agricultural crops in humps and gully beds (Verma, B., & Bhushan, L. S., 1986) [17]. In Yamuna ravines at Agra, Prajapati *et al*., (1993) [9] observed that *Dendrocalamus strictus* produced30–33 harvestable culms every 3 years after proper establishment at a spacing of 3m × 3m to 8m × 8m bamboo and gave average bamboo yield of 4000 poles ha^{-1}. Cultivation of grasses with the multipurpose trees is also a viable option for economic utilization of ravines. Medium and shallow gullies can be used under forest and fruit tree-based pastoral systems. Suitable grass species for protection and improving the fodder availability in ravine regions are *Dichanthium annulatum*, *Cenchrus ciliaris*, *Cenchrus setigerus*, *Panicum antidotale*, *Panicum maximum*, *Pennisetum purpureum*, and *Brachiaria mutica*. *Acacia* + *D. annulatum* and *D. annulatum*one generated 5.8 and 2.6 % of runoff and 1.26 and 0.62 t ha^{-1} of soil loss, respectively in ravenous catchments of Chambal at Kota compared to 14.7 % of runoff and 3 t ha^{-1} of soil loss from agricultural catchments. The effectiveness of the grasses and trees as a substitute land use for high yielding and productive utilization of degraded ravine lands were proved by production of 4.5 t ha^{-1} of airdry grass + firewood from such degraded lands (Sharda and Venkateswarlu, 2007) [12,]. Sethy *et al*., (2011) [11] planted *Emblica officinalis* (amla) on gully humps, bamboo on gully bed and interspace was planted with Cenchrus ciliaris and different trenching densities as treatment. The production of amla fruit ranged from 1.31 t ha^{-1} in control (no trenches) to 6.61 tha^{-1} in treatment involving trenching for trapping75 % runoff, the production of grass ranged from 7.71 to 9.91 t ha^{-1}. Besides, providing improved ecosystem services and filling the gap between demand and supply, ravine area development also contribute to regain livelihood security in communities with scarce resource availability. (Sikka *et al*., 2016) [13].

Choice of species for ravine rehabilitation

Species	Planting location	Uses
Acacia catechu	Gully slopes and humps	Fuelwood, fodder and MFP
Leucaena leucocephala	Gullyslopes	Fodder and fuelwood
Acacia nilotica	Humptop, slope and ravine beds	Fodder, fuelwood, smalltimber
Acacia tortilis	Humptop, slope and ravine beds	Fuelwood and fodder
Ailanthus excelsa	Gully slopes and humps	Fodder, fuelwood and timber
Albizia lebbeck	Humptop	Fodder and fuelwood
Azadirachta indica	Humptop and beds	Fodder, fuelwood, pesticides and timber
Balanites aegyptiaca	Hump top and slope	Fuelwood and MFP
Brachiaria mutica	Humptop, slope and ravine beds	Fodder, soil binder and silage
Cenchrus ciliaris	Humptop, slope and ravine beds	Fodder, hay, silage and soil conservation
Dalbergia sissoo	Hump top and slope	Fuelwood and small timber

Source: Modified from Sikka *et al*., 2016 [13]

Steepy/ Sloping areas

The main profit that agroforestry brings to steepy areas depends in its potential to combine soil protection along with productive functions. For the sloping lands having problems of soil erosion, loss of soil fertility, scarcity of fuelwood or fodder, agroforestry may often be the chosen form of land. For the application of research and development in agroforestry priority must be given to slopy areas.

As the slopes are very steep, reaching to over 40° (84%), it need hardly be said that the erosion hazard is severe; there is also a serious hazard of accelerated landsliding if the slopes are cleared. The rest of the forests were owned by the State. Along with the tree garden in the hill side, farmers grow swamp rice where it is possible. The gardens are largely multi-storey tree arrangements, with herbaceous crops being only subsidiary. Among the commonest species is the beloved durian, cinnamon, coffee, nutmeg, and many timber species. These are farmed in various combinations, at least partly planned, e.g., durian + cinnamon + timber species. It is an agrisilvicultural system, established mainly in gaps, although gardens are sometimes prohibited or new ones established, providing a period of long-term fallowing. As in all home gardens, the spatial arrangement is mixed and dense. The trees fulfil functions of food and cash crop production, fuelwood and timber production, and erosion and landslide control. (Michon *et al*., 1984) [7].

Conclusion

Land degradation is a major challenge for farming communities and natural ecosystem in India. The root cause of land degradation is increasing biotic pressure on productive land beyond its carrying capacity and unscientific land use practices which leads to formation of wasteland.Afforestation of degraded lands, conversion to a restorative land use, and adoption of site-specific recommended management practices are critical to development and rehabilitation of wasteland. These wastelands are reclaimed and restored through scientific plantation technique, either through afforestation or practice of different agroforestry models based on specific location. To fill the cleft between the demand and supply of food, fodder, timber, fuel and also for resource conservation afforestation or practice of different agroforestry is very effective.Agroforestry is being viewed as widely accepted agent for restoration and reclamation of the wasteland due to its multifunctional role and wide adaptability. With use of acceptable planting techniques and judicious selection of suitable species, the wasteland can be brought under viable vegetation cover. Agroforestry could be a better alternative for managing the wasteland for higher productivity with environmental safeguard due to its potential to augment the declining quality of soil and environmentas well as increasing the variability of farm produce and thereby additionally ensuring the nutritional security. Agroforestry interventions through fodder production under permanent vegetation cover viz., silvopasture andhortipasture systems could be the best choice for reclamation and restoration of degraded lands.

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