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AMELIORATIVE EFFECT OF MULTIPURPOSE TREE SPECIES (MPT'S) ON COASTAL DEGRADED SOILS

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Abstract

The introduction of fast growing multipurpose tree species (MPT's) are the only sustainable solution and suitable option for rehabilitating the vast degraded lands and to stop the further degradation of the agro ecosystem. Field experiments were conducted in coastal degraded agricultural lands with 8 MPT's. Based on the ameliorative effects, the choice of MPT's for rehabilitation of degraded lands in the coastal agroecosystem of Northern Tamil Nadu are *Pongamia pinnata* for moderately saline waterlogged clay soil, strongly saline waterlogged clay soil, strongly saline non-waterlogged sandy loam soil and strongly saline non-waterlogged sandy soil, *Ceiba pentandra* for moderately saline non-waterlogged sandy clay loam soil, *Tamarindus indica* for strongly saline non-waterlogged sandy clay loam soil and *Casuarina equisetifolia* for moderately saline non-waterlogged sandy soil.

Key words : Afforestation, land reclamation, saline soils, waterlogged soils, wastelands.

Introduction

Agenda 21 for the sustainable management of land resources envisages an integrated approach to the planning and management of land resources. It seeks to promote an appropriate environmentally sound physical planning and land use practices that contribute to conservation and sustainable use of natural resources (Anonymous, 2004). Tamil Nadu has a coastline of 1000 km (15 per cent of total coastal length of India) under 13 districts comes under 18th agroecological region of India namely Eastern Coastal Plain, Hot Sub Humid to Semi arid Eco region with coastal alluvium derived soils (S7CD 2-5) (Anonnymous, 1992 and Venkateswarlu *et al.*, 1996). This region is the ideal and common working unit of all agricultural activities; however the presence of substantial extent of degraded soils hampered the agricultural productivity. Today barely five per cent of the land under this region is under natural vegetation (Meher, 2002; Rex Immanuel and Ganapathy, 2019a). The major constrains in the reclamation of potentially available arable lands in the coastal districts of Tamil Nadu are saline / alkaline soils 1.81 m. ha, degraded sandy coastal lands 0.48 m. ha and water logged soils 0.38 m. ha (Anonnymous, 2000).

Chemical reclamation of such degraded lands is expensive; growing trees to reclaim them offers a cost-effective and promising option (phyto-remediation). Many tree species possess attributes which characteristics successful multipurpose trees (MPT's) adapted to a wide range of tropical environments including infertile and saline soils can be readily established and managed (Rex Immanuel *et al.*, 2018a). Field based research and demonstrations are to be proved to the farmers and the suitability of a proven need based technology desires greater attention in the complex coastal region. Introduction of multipurpose tree species (MPT's) for the degraded coastal agroecosystem could offer ecological sustainability and economic security to the farming communities. Research has shown that the effects of MPT's can be very site specific, especially on degraded sites (Rex Immanuel *et al.*, 2018b and Rex Immanuel, 2019). It has been suggested that appropriate tree species for afforesting the degraded lands in the coastal agroecosystem exhibits high survival rates, quick initial growth, a rapid establishment, adaptations of the root systems and the ability to cope with poor nutrient, saline, water logging and drought stressed conditions (Rex Immanuel and Ganapathy, 2019b; Rex Immanuel and Ganapathy, 2019c). The degree of amelioration varies with different tree species, extent and habit of their growth, nitrogen fixing ability, plant density, age of plantation and management practices (Gill *et al.*, 1998). Hence, the present experiment was designed to test the relative importance of MPT's on the subsequent ameliorative effects in the degraded coastal agroecosystem soils.

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Materials and Methods

Studies were conducted in the coastal agro ecosystem of Northern Tamil Nadu, to study the ameliorative effects of selected MPT's on degraded lands. Based on the soil, bioclimatic type and physiographic situations, India is grouped in to 20 agro-ecological regions and 60 agro-ecological sub regions (Velayutham *et al.*, 1999). From among them, North Tamil Nadu Coastal Plains (S7Dm 4) were selected purposively because of the presence of considerable extent of degraded soils which hampered the agricultural productivity and also offer a scope for scientists to reclaim and re-instate to its original form. The study sites are located from Northern Coleroon river basin to North Chennai and covering the coastal areas of Cuddalore, Villupuram, Kanchipuram and Thiruvalluar districts.

The coastal agro-ecosystem of the region extends from semi arid to sub-humid climate with mean annual rainfall of 1350 mm of which 80 per cent is received during North-East monsoon (Oct. – Dec.) and the remaining is through South West monsoon and summer showers. The potential evapotranspiration varies from 1700 to 1900 mm resulting in an annual water deficit of 350–550 mm. The length of the crop growing period varies from 80 to 120 days. The mean annual maximum and minimum temperatures are 33.5°C and 23.5°C, respectively.

Based on the outcome of the pot culture experiments two MPT's per location were used for different degraded soils (table 1).

Rhizosphere (0.50 m distance from the plant) soil samples from the upper 15 cm layer of each treatment were collected to estimate the ameliorative effect of MPT's before the start of the experiment and at the end of every year.

Results

The physical properties of degraded soils did not much change during the initial two years however it was greatly changed after three years of MPT's planting. The observations recorded on the soil analysis for the 1st, 2nd and 3rd years after planting are presented for different degraded soils.

Physical properties

The rhizosphere soil bulk density decreased considerably in all the experimental sites expect in SZ_6 and SZ_7 sub zones. The reduction in rhizosphere bulk density over the initial soil sample was 5.56 per cent in *Acacia nilotica* (SZ_1), 5.85 per cent in *Tamarindus indica* (SZ_2), 2.46 per cent in *Ceiba pentandra* (SZ_3), 4.29 per cent in *Pongamia pinnata* (SZ_4) and 4.13 per cent in *Tamarindus indica* (SZ_5). However, SZ_6 and SZ_7 regions the bulk density of the sandy soil improved due to the agronomic strategies followed with a progressive increment was 6.31 per cent in *Casuarina equisetifolia* for SZ_6 and 3.70 per cent in *Acacia ferruginea* for SZ_7 (tables 2 and 3).

Appreciable difference in soil pore space was observed as a result of planting of MPT's in the degraded sites. On the third year after planting, the improvement over initial was 8.21 per cent (SZ_1) in *Acacia nilotica*, 8.79 (SZ_2) and 4.41 per cent (SZ_3) in *Tamarindus indica*, 4.56 per cent (SZ_4) in *Ceiba pentandra* and 6.97 per cent (SZ_5) in *Pongamia pinnata*. However, in SZ_6 and SZ_7 sub zones the pore space of the sandy soil decreased due to MPT's planting and the reduction was 2.66 per cent in *Casuarina equisetifolia* and 1.61 per cent in *Pongamia pinnata*, respectively (tables 4 and 5).

The WHC of the rhizosphere soil varied considerably due to the planting of MPT's in all the selected sites expect in SZ_1 and SZ_2 degraded soils. The increment over initial was 5.8 per cent (SZ_3) in *Ceiba pentandra*, 4.68 (SZ_4) and 6.63 per cent (SZ_7) in *Pongamia pinnata*, 4.04 per cent (SZ_5) in *Tamarindus indica* and 10.11 per cent (SZ_6) in *Casuarina equisetifolia* (tables 6 and 7).

Chemical properties

The results of the soil analysis revealed that the soil pH was favorably reduced after the planting of MPT's in the degraded soils. The reduction was 1.8 per cent (SZ_1), 2.62 per cent (SZ_2), 4.13 per cent (SZ_4) and 3.21 per cent (SZ_7) in *Pongamia pinnata*, 2.66 per cent (SZ_3) in *Ceiba pentandra*, 2.88 per cent (SZ_5) in *Tamarindus indica* and 3.87 per cent (SZ_6) in *Casuarina equisetifolia* (tables 8 and 9).

The EC_e of the rhizosphere soil decreased substantially with time under MPT's planting. The reduction over initial was 5.67 per cent (SZ_1), 6.94 per cent (SZ_2), 7.57 per cent (SZ_4) and 5.52 percent (SZ_7) in *Pongamia pinnata*, 5.81 per cent (SZ_3) in *Ceiba pentandra*, 4.89 per cent (SZ_4) in *Tamarindus indica*

Table 1 : Details of MPT's used in different degraded locations.

S. no.	Degraded locations	Geographical location	Multipurpose trees	Spacing	Plot size	No. of trees plot^{-1}
1	Moderately saline waterlogged clay (SZ_1)	11°24'N 79°45'E	T_1 - *Pongamia pinnata* T_2 - *Acacia nilotica*	4.0m x 4.0m 3.0m x 3.0m	150m^2 150m^2	09 17
2	Strongly saline waterlogged clay soil (SZ_2)	11°39'N 79°47'E	T_1 - *Pongamia pinnata* T_2 - *Tamarindus indica*	4.0m x 4.0m 5.0m x 5.0m	250m^2 250m^2	16 10
3	Moderately saline non-waterlogged sandy clay loam soil (SZ_3)	11°58'N 79°52'E	T_1 - *Anacardium occidentale* T_2 - *Ceiba pentandra*	5.0m x 5.0m 5.0m x 5.0m	250m^2 250m^2	10 10
4	Strongly saline non-waterlogged sandy loam soil (SZ_4)	12°17'N 80°00'E	T_1 - *Anacardium occidentale* T_2 - *Pongamia pinnata*	5.0m x 5.0m 4.0m x 4.0m	250m^2 250m^2	10 16
5	Strongly saline non-waterlogged sandy loam soil (SZ_5)	12°32'N 80°09'E	T_1 - *Anacardium occidentale* T_2 - *Tamarindus indica*	5.0m x 5.0m 5.0m x 5.0m	250m^2 250m^2	10 10
6	Moderately saline non-waterlogged sandy soil (SZ_6)	12°42'N 80°13'E	T_1 - *Anacardium occidentale* T_2 - *Casuarina equisetifolia*	5.0m x 5.0m 2.0m x 2.0m	250m^2 150m^2	10 37
7	Strongly saline non-waterlogged sandy soil (SZ_7)	13°22'N 80°16'E	T_1 - *Acacia ferruginea* T_2 - *Pongamia pinnata*	3.0m x 3.0m 4.0 m x 4.0 m	150m^2 200m^2	17 13

Table 2 : Ameliorative effect of MPT's on bulk density (g cc^{-1}) of different degraded coastal soils.

MPT's	Degraded locations						
	SZ_1	SZ_2	SZ_3	SZ_4	SZ_5	SZ_6	SZ_7
Initial							
	1.62	1.71	1.22	1.40	1.21	1.11	1.08
(12 months after planting)							
T_1	1.62	1.70	1.21	1.38	1.20	1.12	1.09
T_2	1.61	1.70	1.22	1.39	1.19	1.13	1.08
(24 months after planting)							
T_1	1.60	1.69	1.21	1.38	1.19	1.12	1.11
T_2	1.59	1.67	1.21	1.37	1.17	1.14	1.10
(36 months after planting)							
T_1	1.57	1.64	1.20	1.35	1.18	1.13	1.12
T_2	1.53	1.61	1.19	1.34	1.16	1.18	1.11

Data statistically not analyzed.

Table 3 : Ameliorative effect of MPT's on the changes of the bulk density (%) in different coastal degraded soils (36 months after planting).

MPT's	Degraded locations						
	SZ_1	SZ_2	SZ_3	SZ_4	SZ_5	SZ_6	SZ_7
T_1	-3.09^b	-4.09^b	-1.64^b	-3.57^b	-2.48^b	+1.82^b	+3.70^a
T_2	-5.56^a	-5.85^a	-2.46^a	-4.29^a	-4.13^a	+6.31^a	+2.78^b

{(SZ_1T_1 - *Pongamia pinnata*, SZ_1T_2 - *Acacia nilotica*); (SZ_2T_1 - *Pongamia pinnata*, SZ_2T_2 - *Tamarindus indica*); (SZ_3T_1 - *Anacardium occidentale*, SZ_3T_2 - *Ceiba pentandra*); (SZ_4T_1 - *Anacardium occidentale*, SZ_4T_2 - *Pongamia pinnata*); (SZ_5T_1 - *Anacardium occidentale*, SZ_5T_2 - *Pongamia pinnata*); (SZ_6T_1 - *Anacardium occidentale*, SZ_6T_2 - *Casuarina equisetifolia*); (SZ_7T_1 - *Acacia ferruginea*, SZ_7T_2 - *Pongamia pinnata*)}.

and 6.99 per cent (SZ_6) in *Casuarina equisetifolia*, respectively on the third year after planting (tables 10 and 11).

The results of rhizosphere soil analysis revealed that OC content improved after the planting of MPT's. The increment was 13.04 per cent (SZ_1), 8.33 per cent (SZ_2), 14.81 per cent (SZ_4) and 12.15 per cent (SZ_7) in *Pongamia pinnata*, 10.00 per cent (SZ_3) in *Ceiba pentandra*, 11.11 per cent (SZ_5) in *Tamarindus indica* and 25.00 per cent (SZ_6) in *Casuarina equisetifolia*, on the third year after planting (tables 12 and 13).

The analytical report showed that N status of rhizosphere soil increased due to the planting of MPT's. The increase was 6.89 per cent (SZ_1), 5.63 per cent (SZ_2), 8.66 per cent (SZ_4) and 7.55 per cent (SZ_7) in *Pongamia pinnata*, 7.17 per cent (SZ_3) in *Ceiba pentandra*, 5.2 per cent (SZ_5) in *Tamarindus indica* and 9.67 per cent (SZ_6) in *Casuarina equisetifolia* (tables 14 and 15).

On the third year after planting the MPT's, the results of rhizosphere soil analysis revealed that the P_2O_5 was considerably increased (tables 16 and 17). The increment was 7.70 per cent (SZ_1), 4.11 per cent (SZ_2), 8.17 per cent (SZ_4) and 5.44 per cent (SZ_7) in *Pongamia pinnata*, 5.41 per cent (SZ_4) in *Ceiba pentandra*, 4.30 per cent (SZ_5) in *Tamarindus indica* and 5.99 per cent (SZ_6) in *Casuarina equisetifolia*.

The results of rhizosphere soil analysis revealed that K_2O favorably increased after the planting of MPT's. The increment was 5.13 per cent (SZ_1) in *Acacia nilotica*, 3.39 per cent (SZ_2), 5.65 per cent (SZ_4) and 5.82 per cent (SZ_7) in *Pongamia pinnata*, 5.41 per cent (SZ_3) in *Ceiba pentandra*, 2.91 per cent (SZ_5) in *Tamarindus indica* and 6.80 per cent (SZ_6) in *Casuarina equisetifolia* (tables 18 and 19).

Table 4 : Ameliorative effect of MPT's on the pore space (%) of different degraded coastal regions.

MPT's	Degraded locations						
	SZ_1	SZ_2	SZ_3	SZ_4	SZ_5	SZ_6	SZ_7
Initial							
	36.5	38.7	48.2	45.9	47.6	52.6	55.8
(12 months after planting)							
T_1	37.1	39.1	48.5	46.2	47.6	52.7	55.8
T_2	36.9	39.3	48.3	46.0	47.8	52.6	55.7
(24 months after planting)							
T_1	37.9	40.4	49.2	46.9	47.9	53.3	55.7
T_2	38.3	40.7	49.6	47.4	48.6	52.2	55.4
(36 months after planting)							
T_1	38.8	41.6	49.9	48.5	49.5	53.9	55.3
T_2	39.5	42.1	50.4	49.1	49.7	51.2	54.9

Data statistically not analyzed.

Table 5 : Ameliorative effect of MPT's on the changes of pore space (%) in different degraded coastal regions (36 months after planting).

MPT's	Degraded locations						
	SZ_1	SZ_2	SZ_3	SZ_4	SZ_5	SZ_6	SZ_7
T_1	6.30^b	7.49^b	3.52^b	5.66^b	3.99^b	-0.38^b	-0.90^b
T_2	8.21^a	8.79^a	4.56^a	6.97^a	4.41^a	-2.66^a	-1.61^a

{(SZ_1T_1 - *Pongamia pinnata*, SZ_1T_2 - *Acacia nilotica*); (SZ_2T_1 - *Pongamia pinnata*, SZ_2T_2 - *Tamarindus indica*); (SZ_3T_1 - *Anacardium occidentale*, SZ_3T_2 - *Ceiba pentandra*); (SZ_4T_1 - *Anacardium occidentale*, SZ_4T_2 - *Pongamia pinnata*); (SZ_5T_1 - *Anacardium occidentale*, SZ_5T_2 - *Pongamia pinnata*); (SZ_6T_1 - *Anacardium occidentale*, SZ_6T_2 - *Casuarina equisetifolia*); (SZ_7T_1 - *Acacia ferruginea*, SZ_7T_2 - *Pongamia pinnata*)}.

Discussion

Physical properties

Planting of MPT's *viz.*, *Acacia nilotica*, *Tamarindus indica*, *Ceiba pentandra*, *Pongamia pinnata*, *Casuarina equisetifolia* and *Acacia ferruginea* greatly improved the bulk density and pore space of the degraded soils. However, the maximum WHC was observed in *Pongamia pinnata*, *Ceiba pentandra*, *Tamarindus indica* and *Casuarina equisetifolia* planted experimental sites. The MPT's have an extensive characteristic root system for their proliferation and penetrating deeper layers is the major factor responsible for the improved soil properties. The physical interactions occurred in the

Table 6 : Ameliorative effect of MPT's on the water holding capacity (%) of different degraded coastal soils.

MPT's	Degraded locations						
	SZ_1	SZ_2	SZ_3	SZ_4	SZ_5	SZ_6	SZ_7
Initial							
	39.6	40.7	36.2	27.8	32.1	20.7	19.6
(12 months after planting)							
T_1	39.7	41.2	36.3	27.8	32.2	20.8	19.6
T_2	39.6	40.8	36.6	28.1	32.2	21.2	19.7
(24 months after planting)							
T_1	39.7	41.4	36.5	27.9	32.5	21.1	19.7
T_2	39.7	41.1	37.3	28.3	32.9	21.4	20.0
(36 months after planting)							
T_1	39.5	41.4	37.6	28.6	33.3	21.3	20.4
T_2	39.6	41.3	38.3	29.1	33.8	22.8	20.9

Data statistically not analyzed.

Table 7 : Ameliorative effect of MPT's on the changes of water holding capacity (%) in different coastal degraded soils (36 months after planting).

MPT's	Degraded locations						
	SZ_1	SZ_2	SZ_3	SZ_4	SZ_5	SZ_6	SZ_7
T_1	0.00	1.13	3.87[b]	2.78[b]	2.85[b]	02.90[b]	4.08[b]
T_2	0.00	0.01	5.80[a]	4.68[a]	4.04[a]	10.11[a]	6.63[a]

{(SZ_1T_1 - *Pongamia pinnata*, SZ_1T_2 - *Acacia nilotica*); (SZ_2T_1 - *Pongamia pinnata*, SZ_2T_2 - *Tamarindus indica*); (SZ_3T_1 - *Anacardium occidentale*, SZ_3T_2 - *Ceiba pentandra*); (SZ_4T_1 - *Anacardium occidentale*, SZ_4T_2 - *Pongamia pinnata*); (SZ_5T_1 - *Anacardium occidentale*, SZ_5T_2 - *Pongamia pinnata*); (SZ_6T_1 - *Anacardium occidentale*, SZ_6T_2 - *Casuarina equisetifolia*); (SZ_7T_1 - *Acacia ferruginea*, SZ_7T_2 - *Pongamia pinnata*)}.

rhizosphere, especially as a consequence of root growth, penetration and their proliferation, rhizodeposition, microbial activity and root-soil interface created a heterogeneous soil matrix with physical properties, which in turn helped in the improvement of soil properties. The alternative wetting the soil by rain and drying by the plant roots, higher root proliferation and fast root turnover rate in turn increased the formation of smaller aggregates in planted sites when compared to unplanted sites. The increased organic matter addition through litter fall in the succeeding years enhanced good root growth, which had a significant effect on improving soil property, water holding capacity and the productivity. The improvements of soil physical properties due to MPT's planting are in line with the earlier reports of Czarnes *et al*. (2000), Horn and Smucker (2005) and Whalley *et al*. (2005).

The mechanical site preparation techniques enhanced the porosity of the soil in the short term and facilitate root penetration in the early stages of the tree growth. Due to the unstable nature of the structure of degraded soils the benefits of site preparation techniques rapidly degenerates less than one year to their original compact state through slumping during the rainy season with the corresponding collapse of macro pores (Lesturgez *et al*., 2004). Pillai and Garry (1999) and Gregory

Table 8 : Ameliorative effect of MPT's on the pH of different degraded coastal soils.

MPT's	Degraded locations						
	SZ_1	SZ_2	SZ_3	SZ_4	SZ_5	SZ_6	SZ_7
Initial							
	8.32	8.41	7.90	8.24	8.33	8.26	8.41
12 months after planting							
T_1	8.27	8.36	7.90	8.24	8.32	8.25	8.38
T_2	8.29	8.35	7.88	8.22	8.32	8.21	8.40
24 months after planting							
T_1	8.20	8.29	7.86	8.19	8.26	8.18	8.32
T_2	8.26	8.32	7.78	8.10	8.24	8.10	8.26
36 months after planting							
T_1	8.17	8.19	7.80	8.07	8.15	8.12	8.19
T_2	8.23	8.27	7.69	7.90	8.09	7.94	8.14

Table 9 : Ameliorative effect of MPT's on the changes of pH (%) in different degraded coastal soils (36 months after planting).

MPT's	Degraded locations						
	SZ_1	SZ_2	SZ_3	SZ_4	SZ_5	SZ_6	SZ_7
T_1	1.80[a]	2.62[a]	1.28[b]	2.06[b]	2.16[b]	1.69[b]	2.62[b]
T_2	1.08[b]	1.66[b]	2.66[a]	4.13[a]	2.88[a]	3.87[a]	3.21[a]

{(SZ_1T_1 - *Pongamia pinnata*, SZ_1T_2 - *Acacia nilotica*); (SZ_2T_1 - *Pongamia pinnata*, SZ_2T_2 - *Tamarindus indica*); (SZ_3T_1 - *Anacardium occidentale*, SZ_3T_2 - *Ceiba pentandra*); (SZ_4T_1 - *Anacardium occidentale*, SZ_4T_2 - *Pongamia pinnata*); (SZ_5T_1 - *Anacardium occidentale*, SZ_5T_2 - *Pongamia pinnata*); (SZ_6T_1 - *Anacardium occidentale*, SZ_6T_2 - *Casuarina equisetifolia*); (SZ_7T_1 - *Acacia ferruginea*, SZ_7T_2 - *Pongamia pinnata*)}.

(2006) reported that the macro pores developed by the tree roots are stable and will persist. Moreover, actively growing plant root systems have the potential to ameliorate sub soils in poor physical condition by biological drilling and the decaying roots leave a continuous network of vertically oriented macropores that can be improved the structure of the compacted soil (Lesturgez *et al*., 2004 and Alvin *et al*., 2007).

Chemical properties

After three years of planting the soil chemical properties of rhizosphere soil differed appreciably between the MPT's planted sites. However, in the present study slow changes of available nutrients were observed during the initial years. This might be due to the increased demand for nutrients by the growing vegetation during the initial years. Further the organic matter additions through biomass of MPT's during the initial years were not adequate and easily blown away from the root zone by wind. Hence, during the initial stages of tree growth roots considered as an important source for nutrient cycling in the soils of degraded ecosystems.

As observed in the field experiments, the MPT's planting had favorable effect on decreasing the soil pH and EC_e. The reduction of soil pH and EC_e in the rhizosphere soil might be

Table 10 : Ameliorative effect of MPT's on the EC_e (dSm^{-1}) of different degraded coastal soils.

MPT's	Degraded locations						
	SZ_1	SZ_2	SZ_3	SZ_4	SZ_5	SZ_6	SZ_7
Initial							
	7.58	9.08	6.02	9.78	8.80	7.44	12.68
(12 months after planting)							
T_1	7.57	9.07	6.01	9.75	8.79	7.44	12.61
T_2	7.55	9.06	5.97	9.72	8.75	7.43	12.65
(24 months after planting)							
T_1	7.43	8.88	5.92	9.68	8.72	7.41	12.49
T_2	7.47	8.96	5.93	9.61	8.64	7.35	12.43
(36 months after planting)							
T_1	7.15	8.45	5.78	9.52	8.46	7.16	12.15
T_2	7.25	8.72	5.67	9.04	8.37	6.92	11.08

Table 11 : Ameliorative effect of MPT's on the changes of EC_e (%) in different degraded coastal soils (36 months after planting).

MPT's	Degraded locations						
	SZ_1	SZ_2	SZ_3	SZ_4	SZ_5	SZ_6	SZ_7
T_1	5.67^a	6.94^a	3.98^b	2.65^b	3.86^b	3.76^b	4.18^b
T_2	4.35^b	3.96^b	5.81^a	7.57^a	4.89^a	6.99^a	5.52^a

{(SZ_1T_1 - *Pongamia pinnata*, SZ_1T_2 - *Acacia nilotica*); (SZ_2T_1 - *Pongamia pinnata*, SZ_2T_2 - *Tamarindus indica*); (SZ_3T_1 - *Anacardium occidentale*, SZ_3T_2 - *Ceiba pentandra*); (SZ_4T_1 - *Anacardium occidentale*, SZ_4T_2 - *Pongamia pinnata*); (SZ_5T_1 - *Anacardium occidentale*, SZ_5T_2 - *Pongamia pinnata*); (SZ_6T_1 - *Anacardium occidentale*, SZ_6T_2 - *Casuarina equisetifolia*); (SZ_7T_1 - *Acacia ferruginea*, SZ_7T_2 - *Pongamia pinnata*)}.

Table 12 : Ameliorative effect of MPT's on the OC (%) status of different degraded coastal soils.

MPT's	Degraded locations						
	SZ_1	SZ_2	SZ_3	SZ_4	SZ_5	SZ_6	SZ_7
Initial							
	0.23	0.36	0.20	0.27	0.18	0.12	0.16
12 months after planting							
T_1	0.24	0.36	0.20	0.27	0.18	0.12	0.16
T_2	0.23	0.36	0.20	0.28	0.18	0.13	0.17
24 months after planting							
T_1	0.24	0.37	0.20	0.27	0.18	0.12	0.17
T_2	0.23	0.36	0.21	0.30	0.19	0.14	0.17
36 months after planting							
T_1	0.26	0.39	0.21	0.29	0.20	0.13	0.17
T_2	0.25	0.38	0.22	0.31	0.20	0.15	0.18

due to the action of organic acids produced by the tree roots. The significant reductions of soil pH and EC_e under the rhizosphere of trees are in concordance with the findings of Mehdi *et al*. (2002) and Mishra *et al*. (2004).

Table 13 : Ameliorative effect of MPT's on the changes of OC (%) in different degraded coastal soils (36 months after planting).

MPT's	Degraded locations						
	SZ_1	SZ_2	SZ_3	SZ_4	SZ_5	SZ_6	SZ_7
T_1	13.04^a	8.33^a	05.00^b	07.41^b	05.56^b	08.33^b	6.25^b
T_2	08.70^b	5.56^b	10.00^a	14.81^a	11.11^a	25.00^a	12.50^a

{(SZ_1T_1 - *Pongamia pinnata*, SZ_1T_2 - *Acacia nilotica*); (SZ_2T_1 - *Pongamia pinnata*, SZ_2T_2 - *Tamarindus indica*); (SZ_3T_1 - *Anacardium occidentale*, SZ_3T_2 - *Ceiba pentandra*); (SZ_4T_1 - *Anacardium occidentale*, SZ_4T_2 - *Pongamia pinnata*); (SZ_5T_1 - *Anacardium occidentale*, SZ_5T_2 - *Pongamia pinnata*); (SZ_6T_1 - *Anacardium occidentale*, SZ_6T_2 - *Casuarina equisetifolia*); (SZ_7T_1 - *Acacia ferruginea*, SZ_7T_2 - *Pongamia pinnata*)}.

Table 14 : Ameliorative effect of MPT's on the available N (kg ha^{-1}) status of different degraded coastal soils.

MPT's	Degraded locations						
	SZ_1	SZ_2	SZ_3	SZ_4	SZ_5	SZ_6	SZ_7
Initial							
	137.35	108.25	101.28	068.83	156.54	116.53	091.25
12 months after planting							
T_1	139.75	110.04	101.83	69.30	158.03	117.12	092.09
T_2	138.36	109.10	102.27	70.16	157.95	117.84	092.38
24 months after planting							
T_1	143.58	111.63	102.52	70.98	159.31	118.95	093.64
T_2	139.71	109.75	104.67	74.14	160.87	123.52	093.97
36 months after planting							
T_1	147.05	114.34	105.80	071.86	161.45	121.91	096.29
T_2	143.89	112.48	108.54	076.79	164.68	127.80	098.14

Data statistically not analyzed.

Table 15 : Ameliorative effect of MPT's on the changes of available N (%) in different degraded coastal agro ecological sub zones (36 months after planting).

MPT's	Degraded locations						
	SZ_1	SZ_2	SZ_3	SZ_4	SZ_5	SZ_6	SZ_7
T_1	6.89^a	5.63^a	4.46^b	3.53^b	3.13^b	4.62^b	5.52^b
T_2	4.76^b	3.91^b	7.17^a	8.66^a	5.20^a	9.67^a	7.55^a

{(SZ_1T_1 - *Pongamia pinnata*, SZ_1T_2 - *Acacia nilotica*); (SZ_2T_1 - *Pongamia pinnata*, SZ_2T_2 - *Tamarindus indica*); (SZ_3T_1 - *Anacardium occidentale*, SZ_3T_2 - *Ceiba pentandra*); (SZ_4T_1 - *Anacardium occidentale*, SZ_4T_2 - *Pongamia pinnata*); (SZ_5T_1 - *Anacardium occidentale*, SZ_5T_2 - *Pongamia pinnata*); (SZ_6T_1 - *Anacardium occidentale*, SZ_6T_2 - *Casuarina equisetifolia*); (SZ_7T_1 - *Acacia ferruginea*, SZ_7T_2 - *Pongamia pinnata*)}.

The tree planting significantly improved the OC content of the degraded soils. The improvement in OC content of the degraded soil by planting MPT's might be due to the exudation of photosynthetic carbon through its root system and the fast root turnover rate. Similar results have been reported by Hancock *et al*. (2007) they reported that the entry of 5 to 60 per

Table 16 : Ameliorative effect of MPT's on the available P_2O_5 (kg ha^{-1}) status of different degraded coastal agro ecological sub zones.

MPT's	Degraded locations						
	SZ_1	SZ_2	SZ_3	SZ_4	SZ_5	SZ_6	SZ_7
Initial							
	06.75	09.00	11.82	7.34	13.25	10.51	06.80
12 months after planting							
T_1	06.79	09.08	11.80	7.35	13.22	10.51	06.79
T_2	06.78	09.05	11.85	7.41	13.29	10.53	06.76
24 months after planting							
T_1	07.05	09.21	11.94	7.42	13.38	10.59	06.85
T_2	06.91	09.14	12.21	7.72	13.49	10.87	06.96
36 months after planting							
T_1	07.27	09.37	12.06	7.63	13.51	10.82	7.08
T_2	07.05	09.26	12.46	7.94	13.82	11.14	7.17

Data statistically not analyzed.

Table 17 : Ameliorative effect of MPT's on the changes of available P_2O_5 (%) in different degraded soils (36 months after planting).

MPT's	Degraded locations						
	SZ_1	SZ_2	SZ_3	SZ_4	SZ_5	SZ_6	SZ_7
T_1	7.70^a	4.11^a	2.31^b	3.95^b	1.96^b	2.95^b	4.12^b
T_2	4.45^b	2.89^b	5.41^a	8.17^a	4.30^a	5.99^a	5.44^a

{(SZ_1T_1 - *Pongamia pinnata*, SZ_1T_2 - *Acacia nilotica*); (SZ_2T_1 - *Pongamia pinnata*, SZ_2T_2 - *Tamarindus indica*); (SZ_3T_1 - *Anacardium occidentale*, SZ_3T_2 - *Ceiba pentandra*); (SZ_4T_1 - *Anacardium occidentale*, SZ_4T_2 - *Pongamia pinnata*); (SZ_5T_1- *Anacardium occidentale*, SZ_5T_2 - *Pongamia pinnata*); (SZ_6T_1 - *Anacardium occidentale*, SZ_6T_2 - *Casuarina equisetifolia*); (SZ_7T_1 - *Acacia ferruginea*, SZ_7T_2 - *Pongamia pinnata*)}.

Table 18 : Ameliorative effect of MPT's on the available K_2O (kg ha^{-1}) status of different degraded coastal soils.

MPT's	Degraded locations						
	SZ_1	SZ_2	SZ_3	SZ_4	SZ_5	SZ_6	SZ_7
Initial							
	153.76	206.45	107.37	164.13	149.65	087.78	070.25
12 months after planting							
T_1	152.14	207.12	105.62	164.29	151.37	087.16	070.67
T_2	152.69	206.00	108.23	165.74	150.58	087.93	070.58
24 months after planting							
T_1	155.32	209.43	107.81	167.32	152.04	088.75	071.86
T_2	157.17	207.65	109.64	169.07	151.98	089.14	072.12
36 months after planting							
T_1	160.34	213.45	110.60	170.50	153.62	090.61	073.17
T_2	161.65	211.04	113.18	173.41	154.01	093.75	074.34

Data statistically not analyzed.

Table 19 : Ameliorative effect of MPT's on the changes of available K_2O (%) in different degraded coastal soils (36 months after planting).

MPT's	Degraded locations						
	SZ_1	SZ_2	SZ_3	SZ_4	SZ_5	SZ_6	SZ_7
T_1	4.28^b	3.39^a	3.01^b	3.88^b	2.65^b	3.22^b	4.16^b
T_2	5.13^a	2.22^b	5.41^a	5.65^a	2.91^a	6.80^a	5.82^a

{(SZ_1T_1 - *Pongamia pinnata*, SZ_1T_2 - *Acacia nilotica*); (SZ_2T_1 - *Pongamia pinnata*, SZ_2T_2 - *Tamarindus indica*); (SZ_3T_1 - *Anacardium occidentale*, SZ_3T_2 - *Ceiba pentandra*); (SZ_4T_1 - *Anacardium occidentale*, SZ_4T_2 - *Pongamia pinnata*); (SZ_5T_1- *Anacardium occidentale*, SZ_5T_2 - *Pongamia pinnata*); (SZ_6T_1 - *Anacardium occidentale*, SZ_6T_2 - *Casuarina equisetifolia*); (SZ_7T_1 - *Acacia ferruginea*, SZ_7T_2 - *Pongamia pinnata*)}.

cent of photosynthetic carbon fixed by the plant transferred to the rhizosphere by exudation through its root system and the fast root turnover also added considerable amount of OC content of the rhizosphere soil.

The availability of soil nutrients *viz.*, N, P_2O_5 and K_2O increased due to planting of MPT's. The higher available N increment was observed in the rhizosphere soil of MPT's *viz.*, *Pongamia pinnata*, *Acacia nilotica*, *Tamarindus indica*, *Casuarina equisetifolia* and *Acacia ferruginea*. The improvement might be due to the N fixing ability of the trees and the activities of related microorganisms. The N fixing trees helps to increasing the available N status of the degraded soil are in accordance with the findings of Deans *et al.* (2003).

The entry of photosynthates through root excaudate, rhizodeposits and the release of organic anions by roots in the rhizosphere reduced the soil pH and EC_e of soil and created a favorable microclimate in the rhizosphere which enhanced the activity of soil microbial community. These microbial communities regulated the dynamics of organic matter decomposition which lowers the activity of polyvalent cations such as Ca, Fe and Al that form insoluable salts with phosphorus and thus liberating phosphorus from the soil and increased the availability of P_2O_5 in the degraded soil.

The tree planting helps to increase the K_2O content of the soil. This might be due to the organic acids produced by tree roots, which involved in distribution of potassium between non exchangeable to exchangeable forms. The intimate association of plant roots to the soil provides source of carbon supply in the form of root exudates to the soil and the microbes. The root exudates involved in nutrient cycling, mineralization and mobilization of nutrients in the soil which improved the soil health and enhanced the availability of nutrients to the growing plants. The results of the reports are in accordance with the findings of Hinsinger *et al.* (2005), Robinsen (2005), Gregory (2006), Hinsinger *et al.* (2006), Eaton *et al.* (2012) and Helman *et al.* (2014).

Conclusion

Growing of MPT's in the degraded agroecosystems could be considered as an innovative agricultural production system that will be both environment friendly and economically profitable for the farming community. It convert the unproductive land into productive through restoration, improved the sustainability of farming systems, enhanced soil fertility status, diversify farmer's incomes, provide new products to the wood industry and create novel landscapes of high value. The observations recorded on the soil analysis revealed that, the physical and chemical properties of rhizosphere soil were improved considerably due to planting of MPT's. The soil environment improved in the rhizosphere of *Pongamia pinnata* for moderately saline waterlogged clay soil, strongly saline waterlogged clay soil, strongly saline non-waterlogged sandy loam soil and strongly saline non-waterlogged sandy soil, *Ceiba pentandra* for moderately saline non-waterlogged sandy clay loam soil, *Tamarindus indica* for strongly saline non-waterlogged sandy clay loam soil and *Casuarina equisetifolia* for moderately saline non-waterlogged sandy soil.

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