REDUCING POVERTY VIS-À-VIS COMBATING SALINITY THROUGH REFORESTATION IN SOUTH ASIA: A CASE STUDY[1]

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Abstract

Several countries in Africa, Asia and Latin America are facing acute problem of poverty as majority of population is living below poverty line. In view of scarce resources, there is a need that some practical and economically sound strategies be developed to efficiently utilize the natural resources specially soil and water for the welfare of rural poor. Undoubtedly, few solutions e.g., reduction in human population, enhancement of agricultural productivity, development of industrial sector and creation of employment opportunities etc. are the common parameters in many countries to free the masses out of clutches of poverty but nevertheless large tracts of land are still lying barren and unutilized which could be made productive to raise the living standard of the people in the such areas. Lack of awareness among masses and mismanagement seem to be the key reasons in several developing countries leading to little or no progress in this direction.

Involving local communities in reforestation and selection of suitable species in combating salinity seem to be one of the economically viable approaches to reduce poverty as several million ha. area has been severely hit by this menace in many countries of South Asia. The paper describes the screening/selection of species following use of some soil amendments to successfully establish trees on these marginal and extremely low nutrient lands. It is anticipated that the rural communities could be greatly benefited if they are provided some minor incentives like provision of quality germplasm of suitable species along with short term training in nursery and planting techniques. A bare minimum annual net income of US$ 80 to 90 per acre could be obtained if a 5 – 6 year old plantation of *Eucalyptus camaldulensis* (source no.15441) is sold to a nearby pulp mill. Simultaneously, growing nitrogen fixing tree species on these problematic sites in the region would not only improve fertility level but could also reduce the problem of fodder and fuel wood to certain extent.

Key words: poverty reduction, salinity, choice of species,

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Introduction

Large areas of agricultural land have been lost to cultivation due to the twin menace of soil salinization and waterlogging in several countries of southern Asia. Recent estimates show that in Pakistan, 5.33 mha of land out of 20.8 m ha cultivable land has been affected by salinity and 1.55 mha by waterlogging. Continuous seepage from the network of unlined irrigation system over years and lack of natural drainage has resulted in rise in ground water table. The phenomenon led to waterlogging of large tracts of soils along rivers, canals and distributaries and evaporation of excess water from surface of adjoining soils has resulted in their salinization.

A lot of efforts have been put to eliminate the problem of soil salinity and waterlogging through sinking tube wells and development of surface and sub-surface drains under several drainage projects throughout the country. However, the efforts have not been successful to the desired level due to several reasons. The drainage/reclamation approach, besides being costly and energy extensive, also suffers practical implications such as environmental degradation and disposal of brackish drainage water. Therefore, other options, which are relatively less expensive and environmentally sustainable, need proper consideration.

Plants, particularly trees, are commonly referred to as 'biological pumps' and play an important role in the overall hydrological cycle in an area. No doubt, the rate of evapo-transpiration in an area will depend primarily on the vapor pressure deficit in the atmosphere; however, the importance of vegetation cover cannot be ignored as plants have significant influence on water table underneath the plantation and also in the surrounding area. Therefore, few researchers have made efforts to find out suitable species for waterlogging and salinity in Pakistan.

Hussain and Gul (1991) e.g. recommended local tree species like *Tamarix aphylla, Acacia nilotica, A. modesta* and few exotics such as *Acacia ampliceps, Acacia stenophylla,* and *Casuarina obesa* for planting under saline and sodic conditions provided the soil is properly worked and weed competition is decreased. It was concluded that planting tree species could reduce salinity level by improving soil conditions and leaching of salts to deeper layers of soil and thus assist in lowering water table. Later on Arif and Hussain (1993) studied the effect of sodium chloride on growth of some leguminous forest tree species at nursery stage. The results indicated that although the growth of *Acacia ampliceps* was reduced but did show a fair degree of tolerance to the highest concentration of sodium chloride (0.878 %-1.580%) compared with *Albizzia lebbek, Acacia nilotica* and *Leucaena leucocephala*. Sheikh and Malik (1983) working on a planting site with pH varying from 8.2-9.5 and electrical conductivity ranging form 2.7-28.0 mmhos/cm; recommended species like *Tamarix articulata, E.camaldulensis, Prosopis juliflora* with survival of 53, 44 and 43% respectively after one growing season. Yadav (1980) observed that the success of plantations and improvement in soil depend to a great extent on the kind of planting technique and soil working methods. Species like *Prosopis juliflora*, Hybrid *Eucalyptus* and *Acacia nilotica* could be grown successfully by treating the soil of the planting pit with gypsum and farmyard manure along with application of a small dose of nitrogenous and phosphatic fertilizers. Sahibzada (1993) and Marcar (1996) recommended few salt tolerant species in Pakistan. Iqbal (1990) concluded that *E. camaldulensis* had been found to be the most salt tolerant and salt-resistant compared with *Acacia nilotica, Prosopis juliflora* and *Albizzia lebbek*.

Some workers have also studied the effect of these species on water use efficiency and water table control. Kapoor (1997) reviewed and compared the results of three studies conducted in India, Australia and USA regarding the use of tree plantations to control ground water table and reduce the volume of drainable water. In India a draw down upto 8 m at a distance of 50 m from the edge of plantation was observed during a period of 6 year. In Australia the water table underneath the plantations was 2-4 m lower than the adjacent pasture. The draw down impact was restricted to about 20 m from the edge of plantation in 1984 and to 40 m in 1991. On the other hand in USA there was no appreciable draw down of water table despite high evapo-transpiration (115 cm) by Eucalyptus plantation during the 220 days of study in 1990. This was because that a cumulative irrigation of 121 cm was applied during the same period. However, the potential of tree plantation to suck large quantities (115 cm) of shallow ground water was clearly evident. Benyon *et al.* (1999) compared water use between seven year old *E.camaldulensis* and six year old *E. occidentalis* and found that *E. camaldulensis* on saline soil used more water per tree than either the species on moderately saline soil. On moderately saline site, *E. occidentalis* used twice as much water per tree as *E. camaldulensis* tree a year older.

Sweeney and Frahan (1992) reviewed the work on water use of eucalypts by many researchers at number of locations in Australia. Juvenile *Eucalyptus* transpired up to 3 mm per day in summer while evapo-transpiration from 9 year old *Eucalyptus* species at North Bannister (WA) ranged from 1200 to 2300 mm per year. Other water use figures include 558 mm over 5 months of summer for 12-year-old *E. occidentalis* plantation and up to 739 over 16 months for a mature eucalypt forest. Clifton *et al.* (1993) studied water uptake by *Eucalyptus* species at three sites in northern Victoria (Australia). Transpiration rates varied greatly with tree, age and across the sites. Daily totals ranged between a minimum of l/tree and maxima of 467 and 253 l/tree respectively at site 1 and 2. Transpiration rates in excess of 200 l/tree/day were frequently recorded for several trees at both sites generally during late spring and early summer. At site 3, average rate of 54.6 l/tree/day was observed with a range between 2 and 113 l/tree/day. In other studies (Morris & Collopy, 1999), annual water use of *E. camaldulensis* and *Casuarina cunninghamiana* over a two-year monitoring period was similar (about 350 mm). These researchers concluded that continuous use of groundwater by these trees suggests that plantations may contribute to control shallow water table and salinity. Therefore, enhanced water use could be achieved by plantations irrigated with pumped groundwater or drainage water that would lead to more productive plantations as well as more efficient disposal of excess water. Masrur (1998) summarized that water consumption of pure stands of different species which ranged as: *Prosopis* (1000 mm), *Poplar* (1800 mm) and *Tamarix* (2200 mm).

The results on range of sites and species in Pakistan, Thailand and Australia suggest that the differences between species at a given site are mainly attributable to differences in their growth rate (i.e. the sapwood area per hectare.) Annual water use by the plantations studied ranged from 300 to 2100 mm (Morris 1997).

Studies conducted by the Nuclear Institute for Agriculture and Biology, Pakistan showed that, on a sodic site, annual water use by *Eucalyptus microtheca* (1050 mm) was relatively lower than *E. camaldulensis* (1400 mm). *E.camaldulensis,* dependent on saline ground water at highly saline site, also transpired about 1100 mm of water per year. *Acacia ampliceps* used appreciably low water (625 mm) despite a basal area similar to *E. camaldulensis*. Lowest water use was recorded in an under-stocked natural stand of *Prosopis juliflora*. The higher water use by *E. camaldulensis* than *E. microtheca* was due to more rapid growth and larger sapwood area in the former species. The question of what species to grow for biological drainage at a particular site is the key point for desired success. The choice of species is important for optimal water use but only in terms of maximizing growth and hence the sapwood area. Studies at NIAB (Anonymous, 1997) have shown that *Eucalyptus camaldulensis* had similar sap flux density (SFD) and annual water use under low and high salinity conditions. However, higher annual water use (2225 mm) by *Acacia nilotica* at low salinity site compared to 1248 mm at high salinity site was attributed to greater sapwood area at the former site, despite no evidence of reduction in SFD by high salinity (Khanzada *et al.*, 1998). Although this paper describes the installation of piezometres to monitor water table but the results are not presented, as these are very preliminary. However, few salt tolerant species tested at 2 sites in Pakistan are being monitored for growth and the results of rearly growth of some species at two sites are recommended for large scale planting on problematic areas in Pakistan to reduce poverty in the region.

Material and Methods

A three dimensional approach was followed to work out best species for small-scale farmers to combat salinity and to improve the living standard of the rural poor. Two extremely saline sites (Fig.1) were selected for rehabilitation and to undertake following operations.

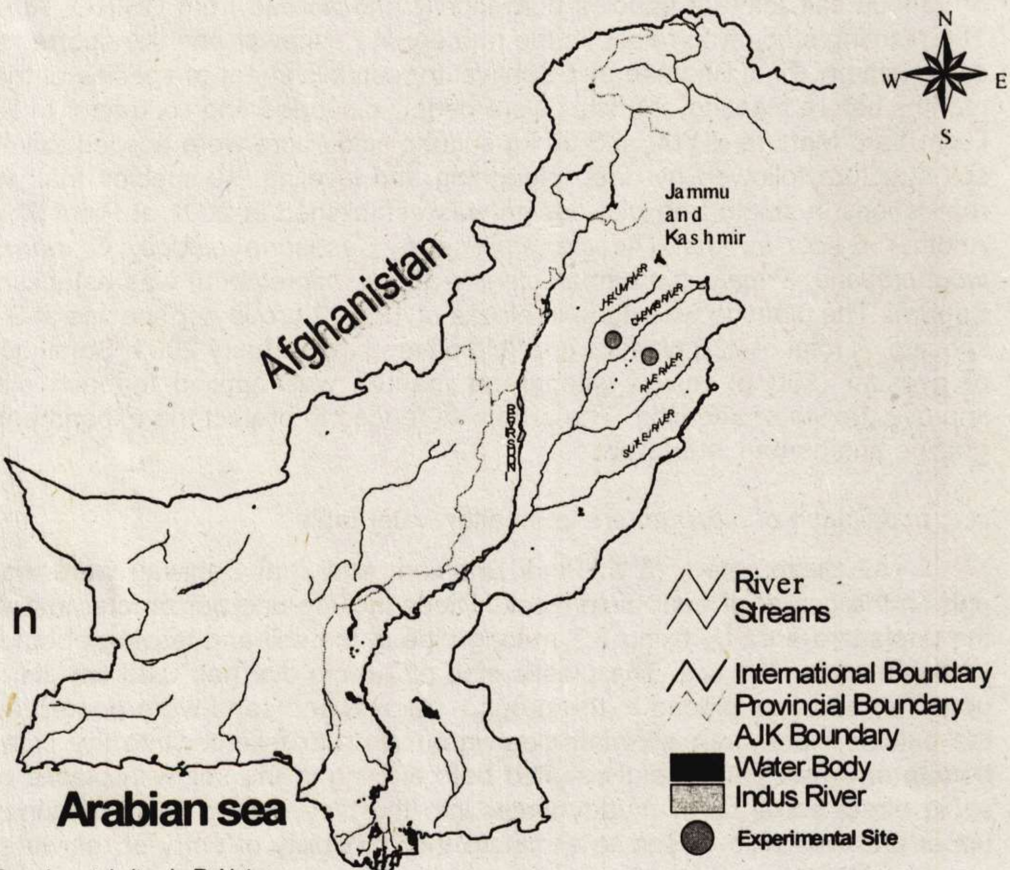

Fig.1. Experimental sites in Pakistan

i. Soil and water analysis

Soil samples were collected from 0-30 cm depth following a grid design system for two planting sites viz. Pindi Bhattian and Sahiwal, Punjab province, Pakistan. Samples of tube-well water used for irrigation by farmers were also collected for analysis. These soil samples were analyzed for particle size, pH and electrical conductivity (EC), organic matter, phosphorus, carbonate bicarbonates, chlorides and soluble cations. Altogether 52 soil samples were collected from both sites. Due to high salinity, there had been no trees or crops and the land was virtually abandoned by the users.

ii. Establishment of field trials

Efforts were made to procure seed of proven provenances/seed sources of various salt tolerant species both locally and abroad from CSIRO, Australia. The planting stock was raised in the nursery at Peshawar and transported to two sites namely, Pindi Bhattian and Sahiwal for establishment of species of trial. Six months before planting, the sites were deeply ploughed and six tractor trolleys of Farm Yard Manure (FYM) and 50 kg sulfuric acid / acre were applied to improve soil structure followed by deep ploughing and leveling. 10-species trial with 30 replications in single tree plot design was established in 2001 at Pindi Bhattian. Another 6-species trial (*Acacia ampliceps, Casuarina glauca, C. obesa, C. junghuhniana, Eucalyptus camaldulensis* and *E. microtheca*) was established at Sahiwal. The planting was done in blocks of 10 x 12 group per species at 2 x 2 m spacing. A total of 720 plants were field planted in February 2002. Small quantity of gypsum (500 g) mixed with green manure was applied to each plant to improve growth of seedling. The area was fenced to protect the experiment from grazing and human interference.

iii. Installation of piezometers to monitor water table

12 piezometers (5 at Pindi Bhattian; and 7 at Sahiwal) were installed right in the center of each field/block. These include one peizometer installed in the unplanted area by fixing 2.7 m long pipe in the soil and leaving about 0.3 m in length above the soil. The plastic pipe of 7.5 cm dia. had 0.25 cm dia. holes upto 1 m and was placed in the ground. Gravel and sand were poured around the outside blank area allowing clean ground water to enter into the pipe. The bottom end was permanently sealed before fixing in the soil with plastic cap to avoid direct entrance of muddy water into the pipe and to avoid choking. The upper end was also closed to eliminate the possibility of entry of rainwater into the pipe. Monthly water table is being monitored.

Results and Discussion

The soil samples including tube well water were analyzed for pH, EC, Na, K, Ca, Mg, CO_3, HCO_3, Cl and SAR for two sites. The results are given in table 1.

Table 1. Pre-planting chemical characteristics of soil and tube well water at 2-saline sites in Pakistan.

	Pindi Bhattian Site		Sahiwal Site	
Parameters Studied	Tube Well Water	Soil (range)	Tube Well Water	Soil (range)
PH	7.95	8.2-9.78	7.95	9.83-10.2
EC (dsm^{-1})	1.5	3.5-23.0	1.8	9 9.9-17.0
P (mg kg^{-1})	-	2.84-15.46	-	2.37-6.03
SOM (%)	-	0.17-0.66	-	0.21-0.71
$CaCO_3$ (%)	-	9.13-22.50	-	10.77-20.6
Soil Saturation Extract				
Na " $mmol^{-1}$	87.36	24.35-115.0	8.37	76.1-137.8
K " $mmol^{-1}$	0.49	0.55-4.49	0.20	0.6-1.42
Ca (mmol L^{-1})	0.11	0.50-4.44	0.41	1.57-6.65
Mg " $mmol^{-1}$	0.38	0.58-1.91	0.32	0.84-1.48
CO_3 " $mmol^{-1}$	1.0	0.6-1.3	1.0	2.0-4.0
HCO_3 " $mmol^{-1}$	3.0	2.0-5.6	3.0	4.9-9.6
SAR " $mmol^{-1}$	11.89	20.76-127.3	13.9	65.1-97.7
Cl " $mmol^{-1}$	49	44-570	53	123-188
pH	-	8.48-9.45	-	9.4-9.56
EC (dsm^{-1})	-	4.4-21.0	-	9.0-16.2

The data on soil analysis revealed that both the sites are strongly saline – sodic affecting the physical conditions of soil, which is highly degraded to the extent that salt was accumulating and blackish colour was visible on the surface. In view of severe problem of salinity-sodicity, addition of organic manure followed by deep ploughings to break the underneath hard crust has been recommended. Acidification of the soil with H_2So_4 at the rate of100-120 kg ha^{-1} was also done. The quality of tube well water is marginal having the problem of salinity and sodicity. The soil features and analysis further confirmed that agricultural crops could not be grown without intensive management and reclamation methods. An integrated approach e.g. chemical amendments preferably acidification and application of gypsum followed by deep ploughings, addition of organic matter and biological measures such as growing of salt tolerant species was adopted. Results on the survival and growth of few species grown at 2 sites are discussed below.

1. Pindi Bhattian

Survival of species after 6 months planting is as under:

S.No.	Species	Survival (%)
1.	Tamarix aphylla	99
2.	*Casuarina glauca*	94
3.	*Acacia nilotica*	89
4.	*Acacia stenophylla*	87
5.	*Acacia ampliceps*	87
6.	*Eucalyptus camaldulensis (15441)*	86
7.	*Casuarina obesa*	82
8.	*C. junghuhniana*	80
9.	*Eucalyptus microtheca*	79
10	*Terminalia arjuna*	48

The above data indicate that *Tamarix aphylla* and *Casuarina glauca* exhibited the highest survival (94% and above) at the initial establishment stages under saline and water logged conditions. Moreover, height- growth data after 2 years planting at the same site yielded encouraging results following the analysis of variance (Table 2).

Table 2. Results of analysis of variance of 10 species trial at Pindi Bhattian

Source of variation	Df	Sum of squares	Mean square	F value
Species	9	970142.09	107793.6	21.99**
Seedlings within Species	290	1421310.61	4901.1	

There were significant differences in height growth at age of 2 years among 10 species tested under severe saline conditions at Pindi Bhattian . Duncan Multiple Range Test was applied to find out significant differences among means of these species. Ranking for height represented the following picture:

Species Ranking	Mean (cm)
E. camaldulensis (15441)	263.9
T. aphylla	239.0
C. glauca	226.3
A. ampliceps	212.3
C. junghuhniana	190.3
C. obesa	163.6
A. stenophylla	156.9
E. microtheca	139.4
A. nilotica	138.4
T. arjuna	60.1

The test showed that *E. camaldulensis* (source 15441) and *Tamarix aphylla* could be used for planting as these showed height growth among all other species tested at the same site. However, use of a proven seed source to combat salinity in Pakistan cannot be over emphasized.

Mass afforestation of *E. camaldulensis* under Forestry Planning and Development Project (1985-1995) has created some doubts in the minds of foresters as well as among farmers in Pakistan as it pumps ground water at higher rate than any other species and 2ndly it affects the crop yield. This is a myth with no scientific data available in the country. The water requirements of the species do vary with the site but the results of *Eucalyptus camaldulensis* are comparable with others as shown in table below:

Table 3. A Summary of reported values of annual water use by different tree species.

Species/ Monitoring Period	Location / site	Annual Water Use (mm)	Source
Eucalyptus sp. (Juvenile)	Hotham Valley Western Australia	1095* (= 3mm/day)	Sweeney & Frahan (1992)
Eucalyptus sp. (9 year old	North Banniwster, Western Australia	1200-2300	
E. occidentalis (12 years old 5 months Summer	Australia	1340* (=558 mm in months)	
E. camaldulensis (18-20 year old) 2 years	Kyaram, Victoria, Australia	303	Morris *et al.* (1998)
E. grandis (2 years)		325	
E. camaldulensis (2 years)	Girgarre, Victoria, Australia	340	Morris and Collopy (1999)
Casuarina Cunninghamiana 2 years)	Girgarre, Victoria, Australia	360	
Prosopis sp.	USA	1000	Masrur (1998)
Baccharis sp.	USA	1430	
Poplars	USA	1800	
Tamarix sp.		2200	
E. camadulensis	Dong Bung, Thailand		Morris (1997)
	(high salinity)	270	
	(low salinity)	1230	
Acacia nilotica	Sindh, Pakistan		Khanzada *et al.* (1998)
	(high salinity)	1248	
	(low salinity)	2225	
Prosopis pallida		524	
Acacia ampliceps		300	
E. camaldulensis	Lahore	1400	NIAB, Faisalabad.
E. microtheca	"	1050	
E.camaldulensis	Pacca Anna,		
	Faisalabad	1170	
	(low salinity)	1090	
Acacia ampliceps	(high salinity)	625	
Prosopis juliflora	Pacca Anna	235	

Note: References listed above have been taken from a report submitted to the Government of Pakistan prepared by Dr. Zahid Hussain, Sr. Director, PARC, Islamabad. Dated 18th July, 2000.

It can be concluded that the water requirements of *Eucalyptus* do not differ much from other species. It has been observed that the crop yield especially wheat is little affected compared with cotton. There is however, a need that more data may be collected to arrive at some conclusions. One thing is quite clear that saline spots, which are lying unutilized by the communities, could be rehabilitated following proper soil amendments, preparation and choice of suitable species. Once the trees are well established, data on water use efficiency would bring about useful information on these trials.

2. Sahiwal

Mean survival (%) and height (cm) of one year old seedlings of 6 species at this site is as under:

S.No.	Species	Survival (%)	Height (cm)
i.	*Acacia ampliceps*	95.8	99.7
Ii.	*Casuarina glauca*	95.0	141.2
iii.	*Eucalyptus microtheca*	93.3	130.1
iv.	*Casuarina obesa*	80.0	121.5
v.	*Eucalyptus camaldulensis (15441)*	79.2	75.8
vi.	*C. junghuhniana*	67.5	132.5

Acacia ampliceps had been rated the best at above saline site as it exhibited 96 % survival with good growth habit and form. This should be grown in combination with *E. camaldulensis* to meet the demand of pole / firewood and fodder. In areas where fodder is scarce, *Acacia ampliceps* is recommended which can coppice easily with excellent leaf biomass and early fruiting/ seed production characteristics at age of two years.

Almost all rural communities in these areas are still using animal dung cake as firewood because of non-availability of any other source of energy. It has been estimated that an average family of 5-6 persons consumes minimum 8 tons of firewood per annum for cooking only, which is equivalent to 18 tonnes of animal dung cake. One tonne of animal dung is estimated to supply 3.5 kg N_2, 1.5 kg P and 2 kg K. Therefore, 18 tonnes of animal dong cake would yield 63 kg N_2; 27 kg P and 36kg K. As per current market rate, the price of these three fertilizers comes to Rs. 1200/- or US$ 20. Reclaiming saline soils and reforestation is an income generation activity as it costs less and pays more. The farmers therefore can easily improve their land by adding animal dung to the fields and could also meet fuel wood requirements by growing *E. camaldulensis* on marginal and unutilized lands. The fertility level of soil could also be improved by planting *Casuarina* as it fixes atmospheric nitrogen into the soil. All such efforts would not only make unproductive area more productive but would also reduce poverty in Pakistan. Before such areas are reclaimed, important thing is the use of proper provenance/ and source. It is therefore highly recommended that seed orchards of true to type seed source be established over larger areas to overcome the seed demand of local people. An orchard already exists but a lot more needs to be done to combat salinity at national level.

A spacing of 3 x 3 m between rows and plants of *E. camaldulensis* with *Acacia ampliceps* in between would be an ideal form of planting to meet the problems of timber/ poles and fodder in the area. There would be approximately 4000 seedlings per ha. of both the species if 10 % mortality is taken into consideration because of harsh soil and climatic conditions. A minimum net annual income of US$ 230 per ha. is expected from at least 1000 trees at of *E.camaldulensis* age 6 or 7 when these would attain acceptable dia for a paper mill.

Conclusions and recommendations

Bio-saline technology advocates an enhanced role of suitable trees to combat salinity and waterlogging vis-à-vis helping rural communities to meet their needs of wood and fodder. Reforestation of salt affected soils is possible with proper site-preparation, choice of species and development of nursery and planting techniques. On account of specific location, nature of ownership, paucity of good quality water, refractory nature of soil etc; several areas can not be put to production of profitable agricultural crops ad hence offer a good opportunity to reclaim marginal lands vis-à-vis improve the fertility level by growing nitrogen fixing trees. In view of these facts and in the light of success story to combat salinity, following important recommendations are made:

- Depending upon salinity level, addition of sulphuric acid @ 250-300 kg per hectare uniformly mixed with irrigation water and applied 4 to 6 months before the planting is recommended. Later on the application of 6 tractor trolleys of farmyard manure with at least 3 deep ploughings and leveling would improve the soil structure. For trees, a sandy clayey soil is preferred. Gypsum @ 7.5 tonnes /hectare may be used if the land is highly saline.
- Seedlings in the nursery should be grown in a salt free medium and planted in the field when they attain minimum size of 25-30 cms.
- Monsoon planting season i.e. August/September is preferred over the spring season.
- A pit of 60 cm depth and 25 cm dia with seedlings placed at the top of the

ridge of a furrow is recommended. Silt may be added upto 30 cm before planting any seedlings into the pit. The seedlings may be flood irrigated soon after planting taking care that water should be completely drained off the field after irrigation.

- A spacing of 3 x 3 m of *E. camaldulensis* with seedlings of *Acacia ampliceps* in between would bring about higher income to the rural poor and would also help to meet his fuel wood and fodder requirements.
- Weeds may be removed manually upto 2 years after field planting.
- Best timber species like *Casuarina obesa* and best fodder species e.g. *Acacia ampliceps* be grown on saline soils to improve fertility level. An agro-sylvo-pastoral system is encouraged.
- Additional income can be obtained though thinning and pruning at age of 3 or 4 years.
- A minimum net income of US$ 225 per hectare/year from unutilized piece of land could improve the living standard of a small-scale farmer by providing the stock to a pulp mill, when the trees would attain a dia. of 12 –15 cm.
- Once the land is improved, suitable agricultural crops in conjunction with desirable trees may be grown to fetch better income from problematic sites.
- Farmers be trained in nursery techniques and advised to add animal dung into their fields to improve fertility level and to increase productivity.

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