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Opportunities for Alternate Land Uses in Salty and Water Scarcity Areas

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ABSTRACT

Vast tracts of arid and semi-arid areas of the world are salt-affected (nearly 1 billion ha) and remain barren due to salinity or water scarcity. The salt-affected lands (sodic/alkaline and saline) constrain plant growth owing to the osmotic effects of salt, poor physical conditions leading to poor aeration, nutrition imbalances and toxicities. With use of appropriate planting techniques and salt-tolerant species these can be brought under viable vegetation cover. Auger-hole technique on sodic soils and furrow technique of tree plantation on saline soils have been found quite appropriate. Further, in most of the arid and semi-arid regions the ground water aquifers are saline. Usually cultivation of conventional arable crops with saline irrigation has not been sustainable. Concerted research efforts have shown that by applying appropriate planting and other management techniques (e.g. sub-surface planting and furrow irrigation), the degraded lands (including calcareous) can be put to alternative uses, where salt-tolerant forest and fruit trees, forage grasses, medicinal and aromatic and other high value crops can be equally remunerative. Such uses have additional environmental benefits including carbon sequestration and biological reclamation. Opportunities for alternate land uses through agroforestry systems on salty and water scarcity areas have been discussed in this paper.

Key Words: Alternate Land Uses, Auger-hole Planting Technique, Sub-surface Planting and Furrow Irrigation, Raised and Sunken Bed Technique, Saline Vertisols, Biological Reclamation, Carbon Sequestration

INTRODUCTION

Vast tracts of arid and semi-arid areas in the world including India are degraded and lie barren due to water deficits associated with scanty and uneven distribution of rainfall and long dry spells. These degraded lands usually lack water supplies for supplemental irrigation. The ground water aquifers are often very deep, saline and low yielding. The rehabilitation of these lands is limited to two possibilities: (i) the exploitation of plants native to arid environments, and (ii) devising efficient cropping systems and techniques for using limited saline groundwater resources judiciously. In the past, efforts towards utilization of saline waters were mainly aimed at enhancing the production of annual arable crops and notion of irrigated forestry or fruit trees, growing forages and other non-conventional high value crops has been considered to be less attractive leading to poor economic production. Recently, efforts of Central Soil Salinity Research Institute (CSSRI) proved that establishing salt-tolerant forest and fruit tree plantations, cultivating forages and other high value crops utilizing the saline ground waters might provide for an economic use of abandoned arid lands. There is large amount of information available about the tolerance of plant species to salinity, knowledge of soil salinity tolerated by forest and fruit trees and under-explored crops of high economic value are limited. Since irrigation with saline water results in addition of certain amount of salts to the soil and these salts may gradually accumulate in the root zone to detrimental level. Thus, optimal irrigation with saline waters should entail irrigation schedules to eliminate excessive building up of salinity in soil and at the same time ensure adequate plant growth. The traditional approach for sustaining the use of saline waters is to irrigate the arable crops more frequently and provide adequate leaching requirements. Nevertheless, such practices demand the application of additional quantities of saline water and thereby also result in enhancement of salt loads of soils. Frequent irrigation is usually advocated for shallow rooted crops in arid environments mainly because the added salts get pushed beyond the rooting zone. The optimizing of irrigation requirement of saline water for a particular crop is very important aspect of biosaline agriculture. But in deep rooted tree plantations, the additional salts going into the soil through enhanced frequency of irrigations during their establishment may rather aggravate the problem as these are likely to persist within their expanding rooting zones and subsequently hinder the growth of trees. Therefore, irrigation with saline waters should aim at creating favourable niches for the better establishment of saplings and also eliminate the buildup of excessive salinity. This could be achieved by using sub-surface planting and furrow irrigation technique irrigating only the limited area under furrows planted with tree saplings. The success of the system was attributed to both the reduced salt load and significant leaching of salts by the concentration of rainwater through runoff into these furrows. Along with suitable irrigation management of saline water, growing of viable and salt-tolerant crops of high economic value such as medi-cinal, oil yielding and petro-crops is of immense importance. These crops must not only be tolerant to salinity and drought stresses but also be well adapted to the local agro-climate. Thus, field trials involving some forest and fruit trees and under-explored crops of economic value were conducted for identifying the suitable species those could be satisfactorily grown with saline irrigation in arid regions sustaining the soil health. Besides this, many of these species were evaluated and identified for high pH (sodic) soils and also for waterlogged saline soils. Some of these results have been discussed here.

Salt-Affected Soils and Their Distribution

All soils contain a certain quantity of water-soluble salts, which are indeed essential for healthy growth of plants. If the quantity of soluble salts in a soil exceeds a certain threshold value (depends on the geochemical and environmental conditions, physico-chemical properties of soil, and chemical composition of salts causing salinity), the growth/yield of most crop-pants is adversely affected; such soils may be designated as *salt-affected*. These soils occur under different environmental conditions and have different morphological, physico-chemical, and biological properties, but one common feature, the dominating influence of electrolytes on the soil-forming processes, joins them into one family. Broad categorization of salt-lands into saline or alkali continued for many years. It was only after the publication of Handbook 60 by the US Department of Agriculture (Richards 1954) that scientists began categorizing salt-lands as saline, saline-sodic (alkali), or sodic (alkali), using the electrical conductivity of saturation extracts of the soil paste (ECe) expressed in dS m^{-1}, pH of the saturated soil paste of the same soil (pHs), and exchangeable sodium percentage (ESP) as the parameters (SSSA 1987). Salt-lands with ECe in excess of 4 dS m^{-1}at 25ºC, pH ordinarily less than 8.5, and ESP less than 15 were treated as *saline*. Saline-alkali soils were distinguished from saline soils by the ESP exceeding 15. Alkali soils were supposed to have low salt content to give an ECe less than 4 dS m^{-1} but ESP exceeded 15 and pHs ranged between 8.5 and 10. The Central Soil Salinity Research Institute (CSSRI) in Karnal had reservations about the terms “saline-alkali” and has been argued that, from management considerations (Abrol and Bhumbla 1978), soils of high pH with $Na/(Cl + SO_4)$ ratio greater than 1 indicate the presence of soluble Na_2CO_3 and $NaHCO_3$ (Gupta and Abrol 1990) and such soils should be termed ‘alkali’ irrespective of the soluble salts they contain. Regarding pH, it has been argued that at ESP 15, the pHs of soils of the Indo-Gangetic plains was about 8.2, which they defined as the lower limit for designating a soil as alkali. The ESP limit of 15 is also not sacrosanct, because in vertisols, a drastic reduction in soil permeability starts at ESP of 5 or 6. Salt-affected soils are found distributed in all the climatic situations. As per recent FAO/UNESCO Soil Map of the World (FAO/AGL 2000), the total area of saline soils is 397 million ha and of sodic soil 434 million ha (Table 1). In India, these cover about 6.8 million ha area.

Saline Ground Waters

The salty water is about 97.5% of the total global waters available (Shiklomanov 1993). Since human use of freshwater has increased more than 35 fold over the past three centuries, inland saline water has now great potential for the use in irrigation with the application of the adoptable water use technologies as a non-conventional water resource. Areas underlain by the saline groundwater aquifers or having salts in the soil profile constitute the sub-surface saline environment.

Table 1.Regional distribution (million ha) of salt-affected soils

Region	Total area	Saline soils	Sodic soils	Total
Africa	1899.1	38.7	33.5	72.2
Asia & Pacific and Australia	3107.2	195.1	278.6	443.7
Europe	2010.8	6.7	72.7	79.4
Latin America	2038.6	60.5	50.9	111.4
Near East	1801.9	91.5	14.1	105.6
North America	1923.7	4.6	14.5	19.1
Total	12781.3	397.1	434.3	831.4

The saline water environment exists in coastal areas, inland arid and semi-arid areas, and waterlogged and saline areas in the canal commands. The requirement of irrigation is more in the inland semi-arid to arid areas and the coastal belts, while the waterloggted areas need more drainage applications in conjunction with limited irrigation facilities.

Beneath many of the world's deserts are reserves of saline water. The major occurrences of saline waters are in the Thar Desert of Indian sub-continent, the Arab desert of the Middle East, the Sahara Desert in North Africa, the Kalahari Desert in Southern Africa, the Atacarma Desert in South America, the California Desert in North America, and in the West Australian Desert. With increasing demands of food, forage, fuel wood, timber and other necessities for ever increasing population and limited availability of good quality water the saline water irrigation is now considered as an imperative necessity for the sustainable agricultural development, which includes the use of saline ground water, saline drainage water and sewage wastewater for irrigation.

The adaptability of saline irrigation is decided by crop salt-tolerance limit, nature of soil, quality of saline water, intensity of rainfall, leaching characteristics, availability of fresh water, method of application of irrigation water, climate of the area, soil-water-crop-environment and human resource management practices, and the saline water irrigation economics. The information for saline water use on the global prospective is reported from at least 43 countries, which are using saline waters for irrigation in one or other form. These countries are virtually from the semiarid and arid regions, except some developed nations, which make use of the wastewater for irrigation. Different countries have proposed various water classification schemes and different saline water management strategies (cyclic or blending) in light of the local sources of saline waters and fresh waters, which constitute different levels of salinity, sodicity, specific ion toxicity, local climate, soil and crop practices. For assessing quality of irrigation water, main parameters determined are: salt content (EC, dS m^{-1}), sodium adsorption ratio (SAR = $Na^+/\sqrt{[(Ca^{2+} + Mg^{2+})]}$, mol/litre), residual alkalinity [RSC = $(CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$ meq/litre], divalent cation ratio (DCR = $\sum M^{2+}/\sum M^{n+}$), and presence of specific ions such as NO_3, F, B and Se. Based on the characteristics features of a majority of ground waters in use with the farmers in different agro-ecological regions and the above indices, irrigation waters have been broadly grouped (Minhas and Gupta 1992) into good water (ECiw <2 and SAR <10), saline water (ECiw >2 and SAR <10), high SAR saline water (ECiw >4 and SAR >10), and alkali waters (ECiw variable, SAR variable, and RSC >2.5).

Why Rehabilitate Salty Lands Through Agroforestry/Alternate Land Uses?

New obligations emerging out of the growing population demand that, to sustain production of food and fuel, each piece of land be best utilized consistent with ecology and land use capabilities. This means that even the degraded lands including salty soils may be either reclaimed for agricultural purposes or put these lands under alternate land uses. Despite the availability of technical know-how for reclamation and management of salt-affected and waterlogged soils, rehabilitation of these soils for crop production is very slow. The reasons are both social and economical. The salt-affected soils are either owned by poor-resource farmers or belong to community or government agencies.

Reclamation of slat-affected lands require additional inputs such as amendments (gypsum, press mud and pyrite in case of alkali lands) or installation of drainage (for saline or saline waterlogged soils), use of fertilizers (including green manure) and infrastructure of farm operations. This is a costly preposition. Requirement of extra resources on recurring basis and lack of interest in development of common lands for practicing intensive arable agriculture have been the major bottlenecks for the rehabilitation of salty lands on an extensive scale. Further, under most of the saline soils in arid and semi-arid regions, the groundwater is saline. In the scenario of scarcity of good quality water the use of poor quality waters for agriculture is inevitable. Therefore, the crops requiring more water for production are to be discouraged. Therefore, afforesta-tion or agroforesty involving trees, grasses and low-water requiring crops (when using saline water for irrigation) is considered an ideal land use for reclamation and management of salty lands and utilization of degraded lands using saline water. Even the common-property lands can be brought under farm-forestry. Besides providing fuel, fodder and timber, afforestation will also lead to bio-amelioration of salty lands. Afforestation of these lands will not only help in ecological and environmental considerations, but also be useful in relieving pressure on traditionally cultivated lands and forests. It has been proved by CSSRI that establishing salt-tolerant tree plantations utilizing the saline ground water (ECiw up to 10 dS m^{-1}) provides economic use of abandoned arid lands when irrigated in furrows for initial three years of tree establishment (Tomar et al. 2003). Further, grass species could be grown successfully with annual dry forage production of 3.4 to 4.2 Mg ha^{-1} with saline irrigation (Tomar et al. 2003). Besides soil amelioration, two of the definite advantages of irrigated forages were about three to four-fold increase in grass productivity as compared with natural pastures, and extension of production period to those of conventional shortages during summer months when the most nomad populations are forced to migrate to traditionally irrigated areas. Thus, the rehabilitation of arid and degraded lands with the plantation of slat-tolerant trees or silvi-pastoral systems with saline irrigation would not only render these otherwise non-productive lands to be more productive but also ensure conservation and improvement for long-range ecological security of these lands.

In recent years, it has been possible to raise non-conventional trees, shrubs and herbs of high economic value such as oil-yielding (*Salvadora persica, Ricinnus communis, Simmondsia chinensis, Eruca sativa, Salicornia begonia*, etc.) aromatic and medicinal crops (*Matricaria chamomilla, Cymbopogon martini, C. flexuosus, Vetiveria zizanioides, Plantago ovata, Adhatada vasica, Azadirachta indica, Catharanthus roseus, Aloe barbadensis,* and several others), and ornamental and seasonal flower (*Chrysanthemum indicum* and *Calendula officinalis*) and petro-crops (*Jatropha curcus, Ricinnus communis* and *Euphorbia artisyphilitica*) can be grown successfully using saline water (up to 10 dS m^{-1}) judiciously without any environmental degradation using scientific techniques. The herbaceous crops can be blended safely with woody trees. Even fruit trees such as *Carissa carudus, Aegle marmelos*, *Emblica officinalis, Feronia limonia* and *Ziziphus mauritiana* could be raised successfully having low-water requiring crops such as barley, cluster bean, pearl millet, sowa (*Anethum graveolens*) and tara-mira (*Eruca sativa*) as inter-crops.

Afforestation of Alkali/Sodic Lands

Alkali soils have a compact hard sub-surface layer or a caliche (calcite) bed (of nodulated or amorphous $CaCO_3$) in lower depths, which imposes physical impediment to root penetration/ development. Unlike soil reclamation for arable crops, where only plough layer is sought to be improved in the first instance, deep-rooted trees require reclamation of the soil to lower depths. The planting technique should further ensure efficient utilization of rainwater, and leaching of reaction products after interaction of amendments and to root development in the soil profile, soil structural improvement for increased water retention to encourage rapid root penetration in the vertical rather than horizontal direction, and minimize direct sodium toxicity hazards. Keeping this view, attempts were made to develop suitable techniques for planting trees on such lands.

Auger-hole Technique of Plantation and Suitable Species

In the past, planting methods like pits and trenches of various shapes and sizes were used for raising trees in alkali soils. Later on, it was suggested that such soils could be planted using soil replacement technique in which the soil from 90 cm x 90 cm x 90 cm pit was replaced by a normal soil brought from out side. These measures however, suffered from some intrinsic drawbacks like higher amendment needs, laborious and time consuming operation, leaving the $CaCO_3$ layer (which usually is located at about 0.5-0.7 m depth) untreated, and difficulties in preparing pits of this dimension in alkali soils. The difficulties were overcome through the development of tree planting technique termed as the *pit-auger-hole planting technique*. In this technique the auger is mounted on a tractor and used for making holes of dimensions 20-25 cm diameter and 1.2-1.8 deep. About 600-800 auger-holes are dug in a day of 8 hours.

This technique recognizes that in trees, owing to their deep root systems, management of the root zone by modifying the soil environment to greater soil depths using a limited quantity of amendments has a vital role. With this in mind a number of studies were conducted to establish positive benefits of this planting technique for tree plantations on alkali soils. CSSRI Scientists conducted experiments (Singh et al. 1993, Dagar et al. 2001, Singh and Dagar 2005, Singh et al. 2008) with different combinations and doses of amendments applied in auger-holes and concluded that original soil mixed up with 3-5 kg gypsum (50% of gypsum requirement in the auger-hole) and 8-10 kg farm yard manure (FYM) + 25 g zinc sulphate in each auger-hole is most suitable for alkali soils of high pH. Application of small dose of nitrogen in the auger-hole filling mixture and its regular application every year thereafter (25 g in monsoon and 25 g in winter) proved beneficial in non-leguminous tree species. Several long-term experiments have been conducted. In one experiment, 7 years old plantation of *P. juliflora*, *Acacia nilotica* and *Casuarina equisetifolia*, a biomass (firewood + small timber) of 28, 20 and 15 tones/ha/annum, respectively was obtained while in another experiment conducted on highly alkali soil (pH of profile 10.1 – 10.6), after seven years, out of 30 species only 11 had 70% or more survival. Only three species *Prosopis juliflora, Acacia nilotica* and *Tamarix articulata* were economically suitable (Figure 1) producing good bio-mass (51, 70 and 97 Mg ha^{-1}, respectively). Among other species *Eucaluptus tereticornis, Pithecellobium dulce, Terminalia arjuna, Dalbergia sissoo, Cordia rothii, Kigelia*

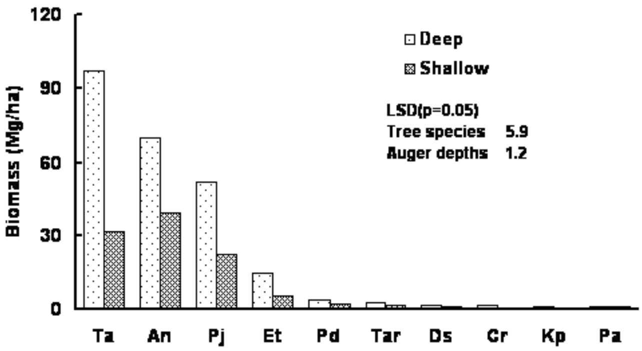

Figure 1. Biomass of different tree species after 7 years of growth on highly alkali soil when raised in deep and shallow auger holes. Tree species depict as: Ta=*Tamarx articulata*, An=*Acacia nilotica*, Pj=*Prosopis juliflora*, Et=*Eucalyptus tereticornis*, Pd=*Pithecelobium dulce*, Tar=*Terminalia arjuna*, Ds=*Dalbergia sissoo*, Cr= *Cordia rothii*, Kp=*Kigelia pinnata*, Pa=*Parkinsonia aculeata*.

pinnata and *Parkinsonia aculeata* showed 80-90% survival but not good biomass. Change in soil properties showed that *Tamarix articulata* ameliorated the soil by inducing the maximum reduction of exchangeable sodium percentage (ESP) and pH values followed by *P. juliflora* and *A. nilotica*. Increase in organic carbon in the surface 15 cm layer under respective species was 0.23, 0.26 and 0.10%, respectively. Twenty year old plantations of *P. juliflora, Acacia nilotica, Eucalyptus tereticornis*, *Albizia lebbeck* and *Terminalia arjuna* could ameliorate the alkali soil by adding organic matter through litter to the extent that arable crops could be grown successfully on this soil. Among the fruit trees, two methods of planting (i.e. auger hole and pit methods) were tested on highly alkali soil (pH > 10) using 5 kg and 10 kg of gypsum in each auger-hole and 10 and 20 kg of gypsum in each pit (90 x 90 x 90 cm) as soil amendments. After 7 years, *Ziziphus mauritiana, Syzygium cuminii, Psidium guajava, Emblica officinalis* and *Carissa carandus* were the most successful species for these soils showing good growth and also initiated fruit setting (Singh et al. 1997; Singh and Dagar 2005). The establishment cost for pits was almost double that of auger holes, justifying the auger hole technique as superior. There was no significant difference between each amendment dose; hence 5 kg gypsum in each auger hole is sufficient. Based on the evaluation of more than 5 dozen species planted with auger hole technique through series of experimentation on sodic soils), it could be concluded that *Prosopis juliflora* was the best performer for the sodic soils of high pH (> 10) followed by *Tamarix articulata* and *Acacia nilotica*. Species such as *Eucalyptus tereticornis, Terminalia arjuna, Salvadora oleoides, Cordia rothii* and fruit trees (with improved management) such as *Carissa carandus, Emblica officinalis* and *Psidium guajava* can be grown with great success on moderate alkali soil (ph < 10), preferably at pH around 9.5 or less (Table 2).

Silvipastoral System for Highly Alkali Soils

A large proportion of salt-affected lands (particularly in Indian subcontinent) does not belong to individual farmers, but is either government land or in the custody of village *Panchayats*. Reclamation of such lands for crop production is not feasible because of common property rights. Raising suitable trees and grasses would appear to be a promising use of these lands. As mentioned earlier, the most promising tree species for highly alkali soils are *Prosopis juliflora, Acacia nilotica* and *Tamarix articulata*. Highly salt-tolerant and

Table 2. Relative tolerance of tree species for soil sodicity.

Average pH_2 (0-1.2 m)	Fuelwood/fodder/timber species	Fruit tree species
> 10	*Prosopis juliflora, Acacia nilotica, Tamarix articulata*	Not recommended
9.6 – 10.0	*Eucalyptus tereticornis, Pithecellobium dulce, Prosopis alba, P. cineraria, Casuarina equisetifolia*[1], *Salvadora persica, S. oleoides, Capparis decidua, Terminalis arjuna*	*Carissa earandus, Psidium guajava, Zizyphus mauritiana, Emblica officinalis*
9.1-9.5	*Cordia rothii, Albizia lebbeck, Cassia siamea, Pongamia pinnata, Sesbania sesban, Parkinsonia aculeata, Dalbergia sissoo, Kigelia pinnata, Butea monosperma,*	*Punica granatum*[2], *Phoenix dactylifera, Achrus japota*[1],*Tamarindus indica*[1], *Syzygium cuminii, Feronia limonia*
8.2-9.0	*Grevillia robusta, Azadirachta indica, Melia azedarach, Leucaena lencocephata, Hardwickea binnata, Moringa loiefera, Populus deltoids, Tectona grandis*	*Grewia asidatica, Aegle marmelos*[2], *Prunus persica, Pyrus communis, Manigifera indica, Morus alba, Ficus* spp., *Sapindus laurifolium, Vitis vinifera*

[1] frost sensitive, [2] does not withstand water stagnation, may be raised on bunds.

high biomass producing grass species include *Leptochloa fusca, Brachiaria mutica, Chloris gayana,* species of *Sporobolus* and *Panicum.* Mesquite (*P. juliflora*) and *kallar* grass (*L. fusca*) based silvi-pastoral practice has been found most promising for firewood and forage production and also for soil amelioration (Singh et al. 1993, Singh and Dagar 1998). *L. fusca* grown with *P. juliflora* produced 46.5Mg ha^{-1} green forage in 15 cuttings over a 50 month period without any fertilizer or other amendment. *P. juliflora* produced 160 Mg ha^{-1} air-dried firewood in 6 years when planted at 2 m x 2 m spacing. This system improved the soil to such an extent that less tolerant but more palatable fodder species such as Persian clover (*Trifolium resupinatum*), berseem (*T. alexan-drinum*), Lucerene (*Medicago sativa*) and Sweet clover (*Melilolus denticulata*) could be grown under mesquite trees after 52 months producing 23.1, 21.3, 10.3 and 8.0 Mg ha^{-1} forage, respectively. The grazing lands of sodic soils are very poor in forage production under open grazing, but when brought under judicious management these can be explored successfully for sustainable production. Based on series of long-term experiments it was found that *L. fusca* can be rated the most tolerant grass to highly alkali soil and waterlogged conditions as compared to other grasses. In one experiment tree species such as *Acacia nilotica*, *Eucalyputs tereticornis* and *Parkinsonia aculeata* were planted on ridges and kallar grass (*L. fusca*) was established in the trenches between ridges. This system conserved rainwater during monsoon, which in turn increased the biomass of trees and intercrops of grasses. In addition to firewood and forage production, this system was found useful in checking runoff and soil loss.

Raised and Sunken Bed Technique

Many forests and fruit tree species can be raised on highly alkali soil (pH > 10) but some of these like pomegranate (*Punica granatum*) and bael (*Aegle marmelos*) and unable to tolerate water stagnation during rainy season. Raised and sunken bed technique of agroforestry was developed for such situations (Dagar et al. 2001). After re-filling the auger-holes with soil mixture in a leveled field as mentioned in above-mentioned technique, the auger-holes are marked with sticks. Parallel bunds, each of 1-2 m height and 1-2 m width were then constructed leaving 3-4 m space between them taking soil from interspaces. The seedlings were raised on middle of bund at marked places and small rings are made around seedlings for initial irrigation. The inter-spaces were cultivated growing water-loving crops such as kallar grass (*Leptochloa fusca*) or rice (salt-tolerant variety like CSR-10) during rainy season. For annual crops, the *kharif* season crops are *rabi* crops such as Egyptian clover (*Trifolium alexandum*) or wheat (var. KRL-4). However, the need to go in for auger-hole plantation of alkali vartisol soils could not be established but raised and sunken bed technique of agrofoestry was found most promising. Trees such as *Azadirachta indica* and fruiots like pomegranate and goose berry could be planted on raised bunds and rain-fed rice could be grown during rainy season in sunken beds. This technique could help in moisture conservation as in sunken beds the moisture could be retained for longer period due to accumulation of rainwater.

Growing Trees with Arable Crops

In this land-use system forest or fruit trees are raised in wider spaces (row to row 4-5 m, plant to plant 4 m) and the arable crops are cultivated in the interspaces. In one experiment, berseem (*Trifolium alexandrinum*), wheat, onion and garlic could be grown successfully for three years with fruit trees such as *Carissa carandus, Punica granatum, Emblica officinalis, Psidium guajava, Syzygium cuminii* and *Ziziphus mauritiana*. These crops could produce 10.6 to 16.7 Mg ha^{-1} forage from *L. fusca* 1.6 to 3.0 Mg ha^{-1} grains from wheat, 1.8 to 3.4 Mg ha^{-1} onion bulb and 2.3 to 4.1 Mg ha^{-1} garlic showing that during establishment of fruit trees, suitable arable cops can be harvested from inter-spaces of trees (Tomar et al. 2004; Singh et al. 2008).

The study concluded that growing trees along with crops should not be viewed only as a better and economically viable food, fodder, timber and firewood prosecution system, but also as a promising option to maintain long-term sustainability and also a practical solution for carbon sequestration in the soil. Many of the medicinal and aromatic under-explored crops are in great demand for both internal requirements and export. But since these crops are non-conventional in nature, it is not always feasible to produce these on fertile land, which can be used for arable crops. The marginal lands, specifically the salt lands where profitable returns are not possible from agricultural crops, can successfully be utilized for the cultivation of these high value crops with marginal inputs. Results of several experiments clearly indicated that aromatic grasses such as palmarosa (*Cymbopogon martini*) and lemon grass (*C. flexuosus*) could successfully be grown on moderate alkali soils up to pH 9.2 while vetiver (*Vetiveria zizanoides*) which withstands both high pH and stagnation of water, could successfully be grown without significant yield reduction on highly alkali soils (Dagar et al. 2004). Palmarosa could produce a fresh biomass of 56, 45, 36 and 18 Mg ha^{-1} (in 2 cuts) at mean pH of profile 8.4, 9.1, 9.5 and 9.9, respectively during first year of plantation, while 117, 93, 70 and 38 Mg ha^{-1}, respectively during second year (in 2 cuts). Lemon grass could produce 41, 33, 27 and 15Mg ha^{-1} during second year. Vetiver grass produced fresh foliage of 105-116 Mg ha^{-1} during first year and 103-141 Mg ha^{-1} during second year without any significant yield reduction at higher pH. The foliage can be used as hay or forage when green. Biomass of dry root (used for oil extraction) harvested after 2 years was 1.1 to 1.6 Mg ha^{-1}. In a separate experiment, medicinal Isabgol (*Plantago ovata*) produced 1.47 to 1.58 Mg ha^{-1} grain (including husk) at pH 9.2 and 1.03 to 1.12 Mg ha^{-1} at pH 9.6 showing its potential in moderate alkali soil (Dagar et al. 2006). *Matricaria chamomile, Catharanthus roseus* and *Chrysanthemum indicum* were other interesting crops, which could be grown on moderate alkali soil. All these crops can be blended in suitable agroforesty systems. Singh et al. (1997) reported that *Populus*-based system is quite profitable for semi-reclaimed (pH 9) alkali soils. When alkali soils are reclaimed through surface application of amendments and cultivated following rice-wheat rotation for 5-6 years, the soil profile is partially improved and becomes suitable for planting trees like eucalyptus, populus, teak (*Tectona grandis*) and sisoo (*Dalbergia sissoo*) on field boundaries, bunds and even in fields with wider spaces between the rows.

The identify crops and crop sequences that can be grown in association with established tree plantations on reclaimed or normal soils, a series of experiments were conducted (Dagar et al.,1995; Dagar and Singh 2004). The performance of various combinations of crops, viz. rice-berseem, rice-wheat, pearlmillet-lentil, pearlmillet-mustard, sorghum-gram, turmeric, ginger and potato was evaluated for 6 to 8 years old plantations of teak, maharukh (*Ailanthus excelsa*), tamarind (*Tammarindus indica*) and *Casuarina equisetifolia*. Though the yield of all the intercrops (except shade tolerant turmeric and potato) was lesser under trees compared with open area, the reduction was least under tamarind with lesser canopy spread. Berseem, lentil and rice were found ideal crops for tamarind but berseem and gram could also be grown in association with teak. When alternate rows of *Casuarina* (with 6 m x 6 m spacing) were removed and cultivated with potato, turmeric and taro (*Colocasia eseulenta*) the reduction in yield in partial shade was not much rather at times it was higher also.

Agroforestry for Salty Black Soils (Saline Vertisols)

The salty soils of black soil zone are generally either contemporary or of secondary origin. The contemporary salty soils exist in the topographic situation under poor drainage conditions. However, the soils that have become sodic due to injudicious use of irrigation water can be encountered in the irrigation command area. One long-term experiment after 14 years of plantation found that *P. juliflora* and *Azadirachta indica* were most successful species for these soils (Tomar and Patil 1998). The data of soil properties of soil surface (0-15 cm) showed that after 7 years of plantation under *P. juliflora* pH, ECe and ESP reduced from 8.8, 4 dS m^{-1} and 35 to 8.5, 1.29 dS m^{-1} and 10, respectively and under *A. indica* these values reduced to 8.5, 1.3 dS m^{-1} and 14, respectively. Among grasses, *Aeluropus lagopoides, Leptochloa fusca, Brachiaria mutica, Chloris gayana, Dichanthium annulatum, Bothriochloa pertusa* and species of *Eragrostis, Sporobolus* and *Panicum* are most successfully. Aromatic grasses such as *Vetiveria zizanioides* and *Cymbopagon martini* can be grown easily. *Matricaria chamomile* can withstand both high pH and ESP. In a separate fruit trial on soil of ESP 25, 40 and 60 it was found that gooseberry (*Emblica officinalis*) and *ber* (*Ziziyphus mauritiana*) are the most successful plantations for these soils. In one trial oil-yielding bush *Salvadora persica* was grown in combination with *Leptochloa fusca, Eragrostis* spp. and *Dichanthium annulatum* forage grasses on saline vertisol in Gujarat (AICRP 2000-04). The soil was clay loam (clay 40%, silt 31%, sand 29%) with pH ranging from 7.2 to 8.9 and ECe from 25-70 dS m^{-1}. The underground water was 0.5-2 m from surface with EC ranging from 55-60 dS m^{-1}. These grasses could produce on an average 3.72, 1.0 and 1.8 Mg ha^{-1} of green forage, respectively. During fourth year the seed yield of *Salvadora persica* ranged form 1.84 to 2.65 Mg ha^{-1} with oil contents ranging from 576-868 kg ha^{-1} at different salinity levels (Gururaja Rao et al. 2003). The experiments conducted in sodic vertisols with ESP 40 growing grasses like *Leptochloa fusca, Brachiaria mutica* and *Vetiveria zizanioides*, showed that all these grasses performed well and the forage biomass increased during second year. The uptake of sodium by *L. fusca* with highest followed by *B. mutica* at every stage of cutting. During three years these grasses could remove 144.8, 200.0 and 63.5 kg ha^{-1} sodium form soil, respectively. Thus, besides producing biomass silvi-pastoral system helped in amelioration of soil in terms of reducing soil pH, EC and ESP and increasing organic matter.

Afforestation of Waterlogged Saline Soils

The saline soils suffer from excessive concentration of salts, high water table often leading to water logging, and occurrence of poor quality underground waters in many areas. Poor root zone aeration caused by high water table (water logging) and excess presence of salts, which operate simultaneously, impair success of plantations on such soils. The planting techniques should be such that salt concentration in the root zone remains at a low level and the plants are able to escape adverse affects of high salinity. Though a series of experiments, techniques of plantations on waterlogged saline soils were developed.

Developing Sub-Surface and Furrow Planting Techniques

To provide better aeration and avoid excessive salinization planting on high ridges was often considered beneficial for establishing tree plantations on waterlogged saline soils. This method was compared with the sub-surface and furrow planting methods. Long-term field studies were conducted on about three dozen woody perennial species for afforestation of waterlogged saline soils in arid and semiarid regions of India. The initial electrolytic conductivity of soil (ECe) was 36-40 dS m^{-1} in the upper 30 cm and the watertable was shallow, fluctuating between 1.5 m depth to the surface in different seasons of the year, and the water was brackish (average EC 30 dS m^{-1}). During this study, it was observed that the greater the surface area of the ridges, the more salts accumulated in the surface 1 m root zone of ridge planted trees. In contrast, under the sub-surface planting method, roots were encountering a milder saline transmission zone and were meeting most of their water requirement from the phreatic zone. Difficulty of conserving rainwater on the ridge tops and the presence of salts causing higher susceptibility to soil erosion were the other disadvantages encountered with ridge planting. In the subsurface planting method the roots encountered a smaller saline transmission zone.

Further, the subsurface planting method was modified and furrow planting technique was developed. In this technique, a tractor-driven furrow maker was used to create about 60 cm wide and 20 cm deep furrows. The saplings of a tree species were planted at the base of the furrows. These furrows were subsequently used for irrigating the tree saplings. Establishment of saplings with furrow method was better than sub-surface method of planting. In addition to reducing the water application costs and increasing uniformity in water application, downward and lateral fluxes of water and salts from these furrows helped to create zones of favourable low salinity below their bases, especially when low-salinity irrigation water was used. Creation of such low 'salt-niches' favoured the establishment of young tree seedlings. With the furrow planting technique, salt concentrations were kept lower in the rooting zone of trees, such that the trees were able to escape the adverse effects of high salinity. Moreover, the furrow system seems more viable than the other techniques from a practical point of view for undertaking large-scale plantation of trees.

Suitable Species

Series of long-term experiments were conducted in semiarid regions (Tomar et al. 1998) on sandy loam soil containing high concentrations of chlorides and sulphates of sodium, calcium and magnesium. The soil pH of entire profile was 7.2 and ECe ranged from 25 to 80 dS m^{-1} (average 36.4 dS m^{-1}) in upper 30 cm layer and gradually decreased with depth. Groundwater was highly saline (EC 30 dS m^{-1}) and remained close to ground surface during rainy season creating water logging salinity of groundwater fluctuated, it was maximum (46 dS m^{-1}) during summer and minimum (2 dS m^{-1}) during rainy season.

The data on biomass production after 9 years of plantation showed that *P. juliflora* and *Casuarina glauca* was highest (98 and 96 Mg ha^{-1}), followed by *Acacia nilotica* (52-67 t ha^{-1} and *A. tortilis* (41 Mg ha^{-1}) when planted with subsurface or furrow technique showing their potential for saline waterlogged soils. Thus, on the basis of performance of trees for 6-9 years after planting in saline waterlogged soils it was found that species like *P. juliflora, Tamarix articulata, T. traupii, Acacia farnesiana*, *Parkinsonia aculeata* and *Salvadora persica* to be most tolerant to waterlogged saline soil and could be raised successfully up to salinity levels of ECe 30-40 dS m^{-1}. Species like *A. nilotica, A. tortilis, A. pennatula, Casuarina glauca, C. obesa, C. equisetifolia, Callistemon lanceolatus*, *Eucalyptus camaldulensis, Feronia limonia, Leucaena leucocephala* and *Ziziphus mauritiana* could be grown on sites with ECe 10-20 dS m^{-1}. Other species including *Casuarina cunninghamiana, Eucalyptus tereticornis, Terminalia arjuna, Albizzia carbaea, Dalbergia sissoo, Emblica officinalis, Guazuma ulmifolia, Punica granatum, Pongama pinnata, Samanea saman, Acacia catechu, Syzygium cuminii* and *Tamorindus indica* could be grown satisfactorily only at ECe < 10 dS m^{-1}. Based on the salinity level at which satisfactory growth of species occurred, salt-tolerant agroforstry species tried in India have been grouped into highly tolerant, tolerant and moderately tolerant categories (Table 3).

Table 3. Tolerant species for saline soils tried in India.

Very high salt-tolerant (ECe > 35 dS m^{-1})

Trees and shrubs
Prosopis juliflora, Salvadora persica, S. oleoides, Tamarix ericoides, T. troupii, Salsola baryosma etc.

High salt-tolerant (ECe > 25-35 dS m^{-1})

Trees and shrubs
Tamarix articulata, *Acacia farnesiana, Parkinsonia aculeata*

Tolerant (EC 15-25 dS m^{-1})

Trees and shrubs
Casuarina (glauca, obesa, equiselifolia), Acacia tortilis, A. nilotica, Callistemon lanceolata, Pongamia pinnata, Eucalyptus camaldulensis, Crescentia alata, Albizia lebbeck.

Grasses and forbs
Ziziphus nummularia, species of *Chenopodium, Dichanthium, Eragrostis, Panicum, Spartina, Paspalum, Sporobolus, Brachiaria, Chloris.*

Moderately tolerant (ECe 10-15 dS m^{-1})

Trees and shrubs
Casuarina cunninghamiana, Eucalyptus tereticornis, E. rudis, E. microtheca, Acacia catcechu, A. ampliceps, A. eburnea, A. leucocephala, Terminalia arjuna, Samanea saman, Albizia procera, Borassus flabellifer, Prosopis cineraria, Azadirachta indica, Dendrocalamus strictus, Butea monosperma, Cassia siamea, Feronia limonia, Leucaena leucocephala, Tamarindus indica, Guazuma ulmifolia, Ailanthus excelsa, Dichrostachys cinerea, Balanites roxburghii, Maytenus emarginatus, Dalbergia sissoo, Salix babylonica

Grasses & forbs
Andropogon annulatus, Anthistria prostrata, Paspalum notatum, Urochloa mossiambicensis, Glycine javanica, Phaseolus lunata, Cenchrus pennisetiformis, Lasiurus sindicus, Echinochloa colonum, etc.

Bund Plantation to Control Waterlogging in Canal Command Areas

In waterlogged areas near canals planting cloned *Eucalyptus* on bunds (of ~ one meter height) on farmers field (in two lines in a space of 1m x 1m) proved very useful, which not only controlled rise in water table but also helped in revenue generation as after 5 years of plantation farmers could sell the trees (at the rate of Rs 350 per tree) and these could coppice further. In saline areas lining of poly-sheets on bunds helped in controlling the development of salinity.

Channel Seepage Interception

Seepage from irrigation supply channels is a source of accessions to groundwater and subsequent salinity problems in many irrigation areas around the world. In India, seepage has resulted in significant environmental impacts. During studies conducted in IGNP (India) area, ground water under the tree plantation fell by 15.7 m over a period of six years. At 100 m from the edge of the plantation, the level of the groundwater was about 9 m higher than at the edge, with a draw down of 6.7 m. The higher ground water level further away from the plantation edge is apparently the result of recharge from irrigation of areas under cultivation. It is known fact that trees play very important role in controlling the waterlogging due to seepage. In one experiment conducted at Gangawati in Kanataka (India) on saline vertisol involving tree species (*Hardwickia binata, Sesbania grandiflora, Acacia nilotica, Dalbergia sissoo, Casuarina equisetifolia* and *Azadirachta indica*) in combination with grasses (Tomar and Patil 1998). Most of the trees were found effective in reducing seepage and soil salinity. The results revealed that *A. nilotica* intercepted highest (86.4%) incoming seepages from canal as compared to control (without trees) followed by *D. sissoo* with 84% interception. The interception was directly correlated with canopy spread. The trees with planted with napier grass in interspaces should more efficiency in controlling seepage. Among other species *Terminalia arjuna, Pongamia pinnata, Eucalyptus camaldulensis* and *Syzysium cuminii* among tree and *Leptochloa fusca, Phragmetes australis, Dichathium annulatum, D. caricosum, brachiaria mutica* and *paspalum* spp. among grasses have credibility for such situations.

Afforestation with Saline Irrigation

The traditional approach for sustaining the use of saline water is to irrigate more frequently and provide for leaching requirements. Nevertheless, such practices demand for application of additional quantities of saline water and thereby also result in enhancement of salt loads of soils. These approaches were advocated for shallow rooted crop plants in arid environments mainly because the added salts could be pushed beyond the rooting zone. But in deep rooted tree plantations, the additional salts going into the soil through enhanced frequency of irrigations during their establishment may rather aggravate the problem as these are likely to persist within their expanding rooting zones and may subsequently hinder the growth of trees. Therefore, irrigation with saline waters should aim to create favourable niches for the better establishment of saplings and also eliminate the over salinity buildup. This could be achieved by irrigating only the limited area under furrows planted with tree saplings. In this technique furrows (15-20 cm deep and 50-60 cm wide) are created at 3-5 m intervals with a tractor drawn furrow maker. Auger-holes (0.2 m diameter and 1.2 m deep) are dug at the sill of these furrows spaced at 2-3 m intervals. These are re-filled with the mixture of original soil plus 8 kg of farmyard manure, 30 g super-phosphate, 15 g zinc sulphate and 15 g of iron sulphate. Six months old tree saplings are transplanted during rainy season (July-August) at sites where auger-holes are dug. The irrigation with saline water is given in furrows only. The technique is known as subsurface planting and furrow irrigation system (SPFIM). The irrigation may be provided for initial three years (4-6 times in a year) and thereafter, plantations may be irrigated once during the winter only. Salt storage in soil profile may increase during irrigation period but the added salts get distributed in soil profile as a consequence of seasonal concentration of rainfall during monsoons and some episodic events of rainfall during the following years.

Establishing salt tolerant tree plantations utilizing the saline ground waters may provide for an economic use of abandoned arid lands. A long-term field trial with 31 tree species was conducted (Tomar et al. 2003) over 9 years on a calcareous soil in a semiarid part (annual rainfall about 350 mm) of northwest India using furrow method of irrigation as described earlier. The saplings were irrigated with saline water (EC 8-10 dS m^{-1}) for initial three years (4-6 times in a year) and thereafter plants were irrigated once in a year during winter. Most of the tree species (except *Syzygium cuminii, Bauhinia variegata* and *Crescentia alata*) showed quite high survival rate (71-100%) during first three years. Ranking in order of survival, growth and biomass yield showed that *Tamarix articulata, Acacia nilotica, Prosopis juliflora*, *Eucalyptus tereticornis, Acacia tortilis* and *Cassia siamea* were most successful species (Table 4). After 7 years of planting, the highest shoot biomass was harvested (Figure 2) from *Tamarix articulata* (71.9 Mg ha^{-1}) followed by *Acacia nilotica* (23.4 Mg ha^{-1}), *P. juliflora* (20.2 Mg ha^{-1}) and *Eucalyptus tereticornis* (14.8 Mg ha^{-1}).

Table 4. Ranking of top 10 tree species for their suitability on calcareous soils of arid land after 9 years of plantation.

Species	Ranking of tree species based on Survival (A)	Height x HDS (B)	Biomass (C)	Overall (A+B+C)
Acacia nilotica	1	4	2	1
Eucalyptus tereticornis	5	2	4	2
Tamarix articulata	9	1	1	2
Prosopis juliflora	2	7	3	3
Acacia tortilis	2	6	7	4
Cassia siamea	6	5	6	4
Acacia tortilis (hybrid)	5	7	5	5
Melia azadirach	8	3	8	6
Azadirachta indica	4	11	10	7
Acacia farnesiana	1	15	9	7
Pithecellobium dulce	7	13	11	8
Cassia fistula	10	10	12	9
Guazuma ulmifolia	11	9	15	10

Fruit trees like *Feronia limonia, Ziziphus mauritiana, Carissa carandus, Emblica officinalis* and *Aegle marmelos* have been established irrigating with saline water up to EC 10 dS m^{-1} and intercrops in wider spaces between rows (5 m) such as cluster bean and barley have been raised with success applying one or two irrigations (Table 5). This appears very viable agroforestry system for such soils.

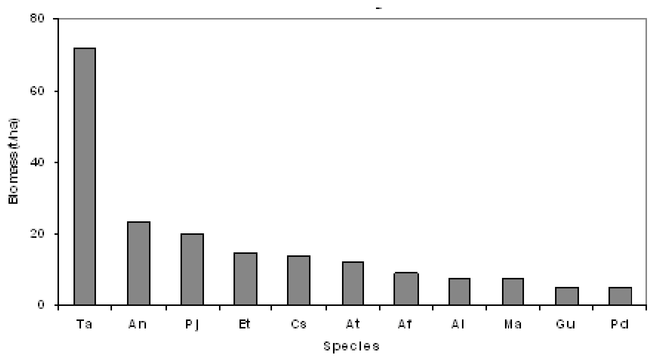

Figure 2. Biomass of trees after 8 years of planting {Af- *Acacia.farnesiana*, An- *A. nilotica*, At - *A. tortilis*, Ai- *Azadirachta indica*, , Cs – *Cassia siamea,* Et - *E. tereticornis, Gu- Guazuma ulmifolia,* Ma - *Melia azedarach*, Pd - *Pithecelubium dulce*, Pj - *Prosopis juliflora, Ta- Tamarix articulata*}

Table 5. Grain and straw yield (Mg ha^{-1}) of cluster bean and barley with different plantations

Fruit tree	Treatment	Cluster Bean Grain	Cluster Bean Straw	Barley Grain	Barley Straw
	T_1	0.88	1.46	3.58	3.88
Karonda	T_2	0.86	1.38	3.47	3.97
	T_3	0.81	1.27	3.45	3.71
	T_4	0.76	1.15	3.10	3.32
	T_1	0.79	1.29	4.19	3.40
Anwla	T_2	0.81	1.33	3.63	3.83
	T_3	0.76	1.24	3.24	3.34
	T_4	0.69	1.18	2.87	3.00
	T_1	0.75	1.23	3.27	3.45
Bael	T_2	0.71	1.21	3.22	3.35
	T_3	0.67	1.06	2.73	2.86
	T_4	0.63	1.02	2.52	2.64
LSD (p = 0.05)					
Factor A (species) =		0.13	NS	0.12	0.17
Factor B (treatment) =		0.02	0.11	0.14	0.15
Interaction (A x B)=		NS	NS	0.24	0.26

Treatments T_1- T_4 depict as planted in traditional rings and watered with water of low salinity (EC 4-5 dS/m); planted in furrows and irrigated with water of low salinity; furrow planting and irrigated alternately with water of low and high (EC 10-12 dS/m); and furrow planting and irrigating with water of high salinity, respectively.

At the same site, nine forage grasses were evaluated (Tomar et al. 2003) irrigating with saline water (EC 10 dS m^{-1}) and found that *Panicum laevifolium* and *P. maximum* were most suitable species producing annually 3.43-4.23 Mg ha^{-1} forage (Table 6). The forage was also available during lean period of summer when most of the people become nomadic along with their cattle.

Table 6.Gross dry matter yield (mean of 3 years; Mg ha^{-1}) and water use efficiency (kg ha^{-1} cm) of different grasses at three Diw/CPE

Species	Yield			Water use efficiency		
	0.2	0.4	0.8	0.2	0.4	0.8
Brachiaria mutica	9.54	12.15	11.72	26.7	12.15	11.72
Cenchrus setigerus	4.64	4.57	4.38	12.9	4.57	4.38
Cynodon dactylon	8.91	9.23	10.20	25.0	9.23	10.20
Panicum antidotale	9.34	11.41	11.77	26.2	11.41	11.70
P. coloratum	6.95	10.29	8.93	19.5	10.29	8.93
P. laevifolium	13.49	16.85	16.88	37.8	16.85	16.88
P. maximum (C)	10.87	13.04	12.72	30.5	13.04	12.72
P.maximum (wild)	14.00	14.72	13.72	39.3	14.72	13.72
P. virgatum	9.95	12.10	11.36	27.9	12.10	11.36
Mean	9.74	11.60	11.30	27.3	11.60	11.30

Diw/CPE = irrigation water/cumulative pan evaporation.

The salinity developed in soil profile during irrigation was leached down during rainy season. Thus, these grasses can successfully be grown with saline irrigation and may form part of silvi-pastoral system for such abandoned arid lands.

In series of experiments (Tomar and Minhas 2002, 2004a,b) the performance of winter annual flowers, aromatic grasses, and some medicinal plant species under saline irrigation was also evaluated on calcareous soils. It could be concluded that ornamental flowers such as *Chrysanthemum, Calendula* and *Matricaria* can successfully be cultivated irrigating with water of EC up to 5 dS m^{-1}. These species could yield 13.2, 4.7 and 3.5 Mg ha^{-1}, respectively fresh flowers in a season. If good quality water is available at site, a few irrigations with that particularly for establishment may increase the yield of flowers.

The aromatic grasses such as vetiver, lemon grass and palmarosa, when irrigated with saline water (EC 8.5 dS m^{-1}) could produce on an average 90.9, 10.4 and 24.3 Mg ha^{-1} dry biomass, respectively. Different cultivars of vetiver could produce 72.6 to 78.7 Mg ha^{-1} shoot biomass and 1.12 to 1.71 Mg ha^{-1} root biomass. The roots are used to extract aromatic oil. Amongst the species tested for medicinal value, the most promising was observed to be psyllium (*Plantago ovata*) with average yield of 1050 kg ha^{-1} and saline water (EC 8.5 dS m^{-1}) did not show any adverse impact when compared with canal water irrigation (Tomar et al. 2005). *Aloe barbadensis* was also equally tolerant and could produce 18 Mg ha^{-1} fresh leaves. *Ocimum sanctum* could produce 910 kg ha^{-1} dry shoot biomass. In a separate trial dill (*Anethum graveleus*), taramira (*Eruca sativa*) and castor (*Ricinus communis*) could produce 931, 965 and 3535 kg seeds per ha, respectively when provided with three irrigation of saline water (EC 10 dS m^{-1}. *Cassia siamea* and *Lepidium sativum* can also be cultivated successfully irrigating with saline water up to 8 dS m^{-1}. All these high value crops can successfully be grown as inter-crops with forest or fruit trees at least during initial years of establishment. Psyllium did not show any yield reduction with *Acacia* plantation even at later stages showing its suitability for partial shade tolerance.

EPILOGUE

With the ever-increasing human and cattle population, need for increased production the non-productive salt-affected lands have to be used for producing food, forages, timber, fuel wood, oil-seeds, medicine and other minor products. In the scenario of scarcity of good quality water for irrigation, the use of poor quality water particularly in the arid and semiarid regions is unavoidable. The judicious use of saline waters for conventional and non-conventional salt-tolerant crops through sustainable agroforestry systems is a viable option. Many halophytes combine high biomass and high protein or mineral levels with outstanding ability to a wide range of environmental stresses. Many of these find utilization as food, firewood, timber, forage, medicine and minor products. When grown on salty lands most of these act as bio-ameliorative and soil acts as sink for carbon sequestration. In agroforestry systems, these not only provide food security but also create employment and improve microclimate and general environment and help in biodiversity conservation.

Recently the attention is being paid towards commercial forestry, raising block plantation of commercial trees and also trees yielding bio-diesel such as Jatropha curcas. This approach will change the economical scenario by reducing the import of fossil fuels. As discussed in earlier sections, trees play a vital role both in lowering down watertable (in waterlogged areas) and also recharging the groundwater in dry regions where water table is fallowing drastically. By adopting agroforstry practices, we shall be able to diversify the cropping pattern when more production will be obtained per unit of water available. Adopting biosaline agroforestry, the nomadic behaviour of large population will be checked in dry regions. This will have a tremendous social impact.

We need a charge in our policies tilting towards agroforestry keeping following aspects in view:

- Value addition to agroforestry products
- Creation of market for new medicinal and commercial crops
- Judicious use of saline water in dry regions especially for raising silvi-pastoral systems. Rain harvest approach for raising fruit and forest trees
- Empowering women.
- Use of biotechnology and information technology in rural areas
- Training in the fields of transformation, processing, post-harvest techniques, proper marketing
- Creating multidimensional systems involving tree, cattle, goat/sheep, fishery and poultry components on the same piece of land
- Providing know row to raise non-conventional crops of high value
- Creating village knowledge centres with the help of Information Technology
- Training the Scientists and other stakeholders for creating and adopting low-cost technologies.

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