Chapter 10
Managing Degraded Lands for Realizing Sustainable Agriculture Through Environmental Friendly Technologies

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Abstract Ever increasing population and shrinking fertile and productive agricultural land resources are viewed as the biggest threats to sustainability of world's resources. To feed more mouths, and reverse land degradation, many biological, engineering, and chemical strategies have been tried; unfortunately these have met partial success. Land and environmental degradation is on the increase, declining the productive capacities of the fertile soils. The land issues like soil erosion (water and wind), salinity and waterlogging; and desertification are hammering crop yields and have severely disturbed the ecosystems in Pakistan. In this chapter attempts have been made to enlist factors and causes responsible for land degradation and resultant lower crop-yields. The prime causes of land degradation and low crops yields in Pakistan are: poor irrigation and drainage practices, deforestation, over-grazing, loss of biodiversity, water scarcity, frequent droughts, migration and unending new residential areas, mass-scale agriculture, flash floods, rising populations, prevailing poverty, and weak link between research-extension-farmers. Degraded lands can be rehabilitated by employing an integrated approach comprising physical, chemical, hydrological, and biological methods. However, it would require scientific diagnostics of the degradation level and to be able to make informed decisions to combat the issues in a holistic way. It is imperative that technical programs must be intervened/interwoven with the extension education components aiming at creating awareness, capacity building, and the active participation of farming community including civil society, NGOs, women groups and youth folks.

Keywords Salinity • Waterlogging • Erosion • Saline agriculture • Community involvement • Women groups

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10.1 Introduction

Pakistan is spreading over an area of 79.61 million hectare (mha). The arable lands in Pakistan are 23 million ha (PCST 2005a). Roughly quarter of the total area available for cultivation is suitable for intensive agriculture. Desertification and degradation processes have affected about 68 million ha of fragile lands across the country (Sheikh and Soomro 2006; Khan et al. 2012). Currently Pakistan sustains about 180.7 million inhabitants (Economic Survey 2011–2012), and the population is increasing at the rate of 2.1 % per annum (Anjum et al 2010), and hence the country has no option other than over-exploitation of its fragile natural resources including soil to produce more food to meet the ever increasing demands of growing population. As a result of these urgencies, the sustainability of natural resources and environmental protection and conservation issues have arisen in the country. On the other hand, land-holdings are getting further sub-divided and fragmenting due to prevailing law of family inheritance, swallowing good agricultural-lands, primarily meant for crop production (Zia et al. 2004; Baig and Straquadine 2011). Resultantly, today per capita cultivated land is decreased to only 0.16 ha (FAO 2000; Sheikh and Soomro 2006). In addition, significant areas of current agricultural lands are being taken over by urbanization and industries. The climate change will add further constraints to achieve and ensure food security in Pakistan. Thus, the future requirements of food and fiber are to be met through agricultural enhancements on finite land resources.

Keeping in view the current land degrading status and the future threats plus emerging food and fiber requirements for the ever-increasing population, concerted efforts have to be made to enhance agricultural productivity from the available resources. Such an agricultural enhancement is possible through, adopting innovative technologies, such as conservation agriculture (no or low-tillage, rainwater harvesting, use of alternate water sources (treated wastewater) for agriculture, using salt and drought tolerant crop varieties, climate smart irrigation practices, and enhanced fertilizer use efficiency. Despite, agriculture in Pakistan has realized an impressive growth during the past many decades, yet the average yields of all crops realized by the farmers still happen to be lower than their potential and yields realized by the progressive farmers and research organizations (PCST 2005a). Wide yield-gaps exist between the average and potential crops yield (Table 10.1). Unfortunately, crop yields of wheat, rice, and maize crops are stagnant regardless of efforts being made by research and extension services in the country, the yield stagnation is thought to be due to deteriorating soil-resources (Zia and Rashid 1995; Zia et al. 2004; PCST 2005b) and impact of climate change that yet has to be quantified.

At this juncture and critical scenario, several environmental threats have put the sustainable economic future of the country at stake. Among all these, land degradation perhaps appears to be the most prominent threat impacting the environment and the production systems (Shah and Arshad 2006). Among the other issues faced by the national agriculture, quality improvement and complete rehabilitation of degraded land resources should be kept on high national agenda to realize

Table 10.1 Potential yield and yield gaps of various crops (tonnes per ha). (Source: Pakistan Statistical Pocket Book (PSPB 2005). Government of Pakistan. Statistics Division, Federal Bureau of Statistics. Islamabad, Pakistan)

Crops	Potential yield	National average	Yield gaps
Wheat	6.4	2.2	4.2
Rice	9.5	2.0	7.5
Maize	6.9	1.5	5.4
Sugarcane	160.0	46.0	114.0

sustainable agriculture. Therefore, the situation requires identifying the causes and factors degrading our soil-resources and devise socially acceptable, economically viable and practicable and feasible technologies. The objective of this chapter is to realize sustained crop yields; outline improvement strategies to recover soil health and productivity. In this chapter, efforts have been made to discuss land issues, improvement measures to devise suitable farming systems focusing on producing more food, conservation of natural resources while ensuring clean and pollution-free environment.

10.2 Threats and Root Causes of Land Degradation in Pakistan

Land has been recognized as a very precious natural resource, sustaining human and plant life (Bhatti and Khan 2012). The soils of Pakistan used to be very fertile and were producing enough to feed every single individual of the country. Today the country's healthy lands have low fertility status plus show symptoms of various ailments. Many researchers (Zia and Rashid 1995; Zia et al. 2004; Ahmed and Qamar 2004; Shah and Arshad 2006; Sheikh and Soomro 2006; Anjum et al. 2010; Khan et al. 2012) have enlisted different types of land degradation in Pakistan and have tried to identify the possible reasons and causes, however, important ones are: poor irrigation systems, insufficient drainage, deforestation, water erosion, over-grazing, water shortage, frequent droughts, farmer's migration to urban areas, intensification of agriculture, flash floods, population pressures, high poverty levels and soil salinization and sodication. Poverty and lack of farmers' education remain the prime reasons causing land degradation. Land degradation acts as a strong barrier to sustainable land management and prevents the intensification of agriculture.

Agriculture sector will remain the leading driving force for national growth and the major contributor to the economy of Pakistan. Having the direct or indirect involvement of about 62 % of the country's population, agriculture sector contributes 21 % to the GDP and employs 45 % of the total workforce. The sector furnishes the raw materials to the industries and provides about 60 % of foreign exchange earnings. Today an increase in agricultural growth has become unavoidable and in the near future Pakistan will have to double its cereal production, especially wheat, to meet food requirements of its ever-growing population. Ahmad and Zia (2003) reported that the introduction of high yielding crop varieties, application of high rates of farm inputs and over-exploitation of natural resources have caused a number of environmental problems. On the other hand, due to the economic pressures, monoculture oriented commercial agriculture (cash crops) and short fallows accelerated the land degradation. To achieve agricultural enhancements, farmers are using high rates of fertilizers and apply heavy and frequent irrigations. These practices could build-up of high chemicals that may reflect in the agricultural commodities. In addition, non sustainable agricultural practices lead to waterlogging and salinization of prime agricultural lands. After working 8 years in Pakistan, the SLMP (2011) discovered that unsustainable land management practices is another cause of land degradation that comes in the form of soil erosion, loss of soil fertility and associated crop productivity, flash floods, sedimentation of water courses, and deforestation and the associated loss of carbon and biodiversity assets. The report further ascertains that this land degradation will continue at an accelerated pace, causing severe damages to the structural and functional reliability of the already stressed ecosystems of the country. In addition, some workers believe that introduction of generous subsidies offered by the government to realize intensification in agriculture is likely to enhance the problem such as degradation of the agro-ecosystems, pollution of streams and rivers (pesticides, fertilizers remains), nutrient mining, and reduction or elimination of beneficial micro-organisms. Commercial investments in monoculture oriented agriculture may ultimately lead to the loss of traditional local agriculture production systems and valuable crop varieties.

10.2.1 Declining Water Resources

Best local agriculture production can be achieved only if best soils and sufficient water resources are made available. Looking at the world map of physical and economical water scarcity produced by IWMI, it reflects that most of Pakistani lands fall in the highly water scarce areas. In country, either development of water resources is approaching or has exceeded sustainable limits, more than 75 % river water flows have been diverted to agriculture, industry or domestic purposes.

Few decades ago Pakistan used to be a water surplus country. However, presently water availability has been extremely declined and hence water scarcity has emerged as an extremely sensitive issue. Farmers are competing for water with other sectors in the sowing seasons. If the water continues to be used at the current rate, it is projected, that within the next five decades, some 90 % of all available sources of water will be completely consumed. According to Khaliq (2007), current surface water resources are meeting only 40 % of total water requirements of the country. Similarly estimates made by the International Water Management Institute (IWMI) reveal that Pakistan would be among the top 17 water scarce countries that may face severe water shortage by 2025. According to PCST (2005a), the countries having less that 1,000 m^3 per capita per year will start facing persistent but an acute shortage of water. At present, in Pakistan about 1,250 m^3 per capita water is available annually, indicating the threatening water stress situation, the country is going to face. While discussing the reasons negatively impacting the water resources, Ahmed (2007) reports that over-using of water and application of heavy irrigations to the crops more than their requirements would certainly and seriously harms the water resources. Being an agricultural based economy, the availability of water for irrigating the crops in the growing seasons is critically important. Qureshi et al. (2010) ascertains groundwater has an essential role in agriculture. However, when efficient irrigation application methods are employed significant water losses can be minimized and checked. However the prime factors responsible for low water use efficiencies include: water losses in the poor water conveyance systems (from source to fields) in the open and poorly maintained and structured water-courses and channels, unleveled agricultural fields; over-watering (including over-pumping of groundwater) in the absence of modern irrigation systems (drip, sprinkler, subsurface etc.). In order to address the demand of growing population, and an effort for climate change adaptation, the needs to focus on enhancing agricultural productivity through better protection and management of the limited water resources. Use of alternate water sources such as treated wastewater (rich in nutrients-NPK), will reduce farmers dependency on costly fertilizers, and can also help improving water and nutrient use-efficiencies. To realize the inherent and potential benefits of such technologies, it is imperative to make them available to the farmer, (the ultimate stakeholder) by developing a strong link between research-extension-farmer.

10.2.2 Issues Related to Irrigation and Drainage Practices

The scientists have agreed on the consensus that efficient irrigation systems are must to intensify agricultural production and to optimize water uses. Commonly used flood irrigation leads to significant wastage due to seepage and evaporation. Despite the world's largest contiguous canal irrigation network in Pakistan, its working efficiency is 40–45 % (Economic Survey 2010–2011) and 30 % as national average (Bhutta and Smedema 2007). About 80 % of cultivated area receives irrigation water from these canals and appreciable agricultural productions (90 % of agricultural output) are realized in the country (PCST 2005a). At the same times, the overall poor water management at the system and farm levels is causing waterlogging and salinization in the cultivated areas.

Despite the presence of magnificent canal irrigation system, realization of stagnant and lower crop yields than their potential has always been a concern after the era of green revolution. The situation prompted Shah et al. (2011) to identify the reasons for lower and poor crop yields and factors responsible include: inadequate and poor drainage, excessive water losses, outdated land and water management practices, split, patchy and fragmented land-holdings, and waterlogging and salinity. In the country the waterlogging issues arise due to the human activities like: the hindrances caused in natural drainage due to construction of roads; improper alignment and poor maintenance of irrigation channels; and insufficient drainage of excessive rainwater. Once the agricultural areas are affected by waterlogging and salinization, it also threatens the ecosystem in the nearby vicinity.

10.2.3 Droughts and Flash Floods

Pakistan suffered from severe drought during 1997–2003, consequently water shortages for humans, livestock, and agriculture were experienced, and in addition the agricultural fields and infrastructures were badly affected. Continuing water shortages and droughts have negatively affected the Pakistan's economy, and increased vulnerability and hardships particularly for the rural communities. Frequent droughts in Pakistan and elsewhere cause widespread damages even to the biological potential of the fertile lands. Some 3 million inhabitants and 7.2 million livestock heads have been adversely affected by the droughts experienced in many parts of the provinces of Balochistan, Sindh, and southern Punjab. A sizeable portion of human population lost their lives and thousands of livestock and wild ungulates also got perished due to the drought conditions. The droughts also rigorously influenced livelihoods of locals and in cases forced them to migrate toward the places where they could find jobs, feed themselves, and provide feed, fodder and forage to their livestock. Consequently, such mass-scale migrations disrupted traditional land use patterns, resulting in the disappearance of permanent loss of traditional management practices and enhanced the land degradation and desertification processes.

Similarly, flooding has been a regular feature occurring due to the heavy downpour received during the monsoon season in arid and semiarid regions of the country, causing losses of millions of dollars and thousands of human lives. The country experienced the worst flood of the history of mankind in 2010 that washed away the thousands of human beings, livestock, and tonnes of standing and stored agricultural produce causing damages of millions of dollars. Excessive flooding washes away the top soil, buries it under the infertile sediments and obstructs cultivation; such phenomenon results in the land degradation and loss of biodiversity.

10.2.4 Deteriorating Range Resources Due to Overgrazing

Spreading over an area of 28.5 million ha (32.4 %), the rangelands are in the highly deteriorated conditions. Today, rangelands are highly vulnerable to degradation due to climate change and anthropogenic activities. Despite, rangelands are still sustaining some 163 million of livestock heads (PCST 2005b; Economic Survey 2010–2011) making Pakistan the fifth largest producer of milk in the world (PCST 2005b; Economic Survey 2010–2011; Baig and Straquadine 2011). Livestock rearing is an important component of Pakistan's agriculture sector and an income generating activity for small farmers contributing to livelihood improvement. As such 35–40 million rural masses depend upon livestock and 30–40 % of their incomes are generated from this sector (Economic Survey 2010–2011). Approximately, the sector accounts for 55.1 % to the agriculture value added and 11.5 % to GDP. High demand of livestock products (milk, butter, meat) of ever increasing population and the present situation of the farmers, perhaps this pressure doubled livestock number since 1967, leading to overgrazing and exceeding the carrying capacity of rangelands and the result is rangelands degradation. Overgrazing degrade the rangelands in many ways, such as but not limited to, soil compaction, loss of vegetation, and subsequent denudation leading to soil erosion, loss of productive surface soil (rich in organic matter), and ecosystem fragmentation. Recent estimates (Ahmad and Zia 2003) reveal 48.3 % rangelands are completely degraded, declining 15–40 % of their capacity to support livestock needs. Providing another estimate Farooq et al. (2007) report that rangelands of Pakistan, covering an area of 50.9 mha (63.9 %) are a very precious resource base for livestock, however it is diminishing, leading to low livestock production and loss of productivity.

On the other hand Anjum et al. (2010) report the degradation of more than 60 % rangelands producing even less than one-third of their potential due to overstocking beyond their carrying capacity. They further noted that over-grazing of rangelands had brought their productivity levels as low as 15–40 % of their potential. In addition, aridity and prolonged droughts have further adverse impacts on their vegetation (Farooq et al. 2007). Such deteriorated rangelands are difficult to rehabilitate. In this situation, it would be wise to devise and launch an integrated rangeland management approach to keep its rangelands protected and productive (sustainable) while maintaining a healthy balance between vegetation and livestock (Intercooperation Pakistan 2006). There is a need to develop grazing systems in the rainfed areas like: closing and re-opening at the appropriate times. To enhance vegetation on rangelands and ensure the year-around availability of feed for the livestock, re-seeding with the palatable grasses, and leguminous species remains imperative.

10.2.5 Diminishing Forest Resources

Forests play pivotal role in the national economies through sustaining the supply of wood and wood products. In addition forests also improve environmental quality through carbon sequestration. Worldwide, land use change (forests to agriculture) has contributed to 33 % anthropogenic CO_2 emission (IPCC 2007), and within the last 50 years, some 30–50 % mangroves forests are reduced through deforestation, and urbanization of coastal lands. Mangroves store more than five times carbon than other forests on per unit area basis; this could be attributed to their special rooting structure, capable of retaining high amount of organic matter (Shahid 2012).

Though Pakistan presents the wide diversity of landscapes and vegetation, yet ranks among the countries with the highly low forest cover. Forests spread over a small area of 4.0 million ha, which is 5.0 % of the total area in the country (PCST 2005b; Siddiqui 2007). The area under forests includes state-owned forests, communal forests, and privately owned forests as well. By using another criterion to estimate the extent of forests Shah and Arshad (2006) report that forests spread over an area of about 12 million ha. Of this total forest area, different forests types cover different hectarage like: scrub and planted trees (4.2 million ha), natural and modified coniferous scrub, riverain and mangrove forests (3.5 million ha), tall tree forests (2.4 million ha), scrub forest (1.1 million ha), and plantations (0.7 million ha).

Pakistan suffers from the highest deforestation rate in the world (Economic Survey 2009–2010), where forests are disappearing at an alarming rate, that is three times higher than other South Asian countries. Irshad et al. (2007) reported an indiscriminate removal of vegetation/forest due to ruthless removal of timber, woodfuel, and other non-timber forest products, at the rate higher than the natural forest regeneration. Pakistan loses about 3.1 % of forest cover annually. Since most of the households still continue to use woody biomass as firewood for cooking and heating, therefore, making the forests disappear (higher rate) at an annual rate of 5 % (Anjum et al. 2010). FAO (1996) noted the national forests disappear on some 77,000 ha annually because of illegal felling and ruthless cutting. FAO is of the view that the continuation of an absolute annual loss such an alarming rate, the forests in Pakistan would completely disappear by 2015.

Although, a desirable range of a country's land under forest is 20–25 % whereas only 5.0 % of Pakistan's total area is under forests (Siddiqui 2007). According to Khan et al. (2012) all the major forest types and vegetation cover have been affected severely in the recent years due to the factors like: ruthless and indiscriminate removal of forests; their poor, unplanned and unscientific management; overgrazing; and ecological changes, resulting the anthropogenic activities. Whereas according to Ahmed and Zia (2003) key factors responsible for the degradation of forest resources in Pakistan include: shallow soils on steep slopes, unsuitable soil structure, degradation in soil productivity, inadequate irrigation, poor quality planting stock, low survival rate of new seedlings, poor regeneration and low stocking in coniferous forests, low intensity of cultural practices and defective and inappropriate logging practices.

Deforestation in the country results severe environmental issues like: soil erosion, floods, droughts and increasing desertification, and non-protection of coastal lands. The indiscriminate removal of forests leaves the soil exposed and absorbs less rainwater falling on the bare-ground. The situation can cause water runoff and soil erosion, and ultimately may lead to desertification. The removal of productive surface soils exposes low quality subsurface soil leading ultimately to low agricultural production and, in turn results an enhanced poverty.

10.2.6 Increasing Population Pressures

Pakistan with an estimated population of 180.7 million in 2011 remains the 6th most populous nation in the world (Economic Survey 2010–2011); its population is growing at 2.03 % per annum (Anjum et al. 2010). Rising of the population continues at the current rate, the projected population of the country may touch the figure of 217 million by 2020, 234 million by 2025 and could be doubled by 2050. This situation will put more pressure on the available resources which are also shrinking due to natural and anthropogenic factors, leading to fragmentation of agriculture and ecosystem degradation (Sheikh and Soomro 2006).

10.2.7 Migration and Permanent Settlements

Pakistan is predominantly an arid country with 80 % falling in the arid and semi-arid regions (Shah et al. 2011). Today Pakistan stands among the most arid countries with an annual rainfall of below 240 mm (Farooq et al. 2007). Due to prolonged droughts especially the dry areas, Sindh, and Balochistan provinces are unable to produce enough food production to feed its populations, making them suffer from malnutrition and migration. Resultantly, the more productive and irrigated neighboring areas experience a high influx of migrants. Forced migrated population often competes with the sitting populations for land resources especially they want their share for water and grazing resources for their livestock, placing greater pressures on the natural resources.

This sort of migration often puts greater social and economic pressures on the locals forcing them to bring basic changes in their lifestyles. For example, with the electrification of the villages and increased road network in previously remote areas of Balochistan, transhumance practices are weakening. Many graziers and pastoral communities have now started permanently residing in the areas located near the roads. In order to develop new agriculture lands, they are digging deep wells for meeting irrigation requirements of their lands. Such developments can make the traditional use of rangelands degraded and in cases may lead the vegetation cover to completely disappear.

10.2.8 Rising Poverty Levels

In the recent economic crises, poverty levels have increased in rural areas and declined in the urban areas. About one-third of the total households in the country were below the poverty line, whereas, poverty levels in rural areas reached about 39 %. In absolute numbers, about 36.45 million poor persons were living in the country in 2004–2005. The population living below the poverty line in rural areas was about 28.10 % and 14.9 % in urban areas in 2004–2005 (Economic Survey 2006–2007). In the year 2006, about 27.0 % in rural areas, and about 13.1 % people in the urban areas were operating below the poverty line in the year 2005–2006. In this situation, poor and small farmers were forced to make use of their limited land resources more intensively to meet their urgent and pressing needs by over-exploiting and compromising the long term sustainability of their lands and other natural resources. Also, the prevailing weak safety nets can further make the rural poor vulnerable. In the event, when their livelihoods are at stake, they feel threatened due to little or absence of safety nets, they are forced to increase pressures on natural resources. In Pakistan, currently available social safety nets for the poor, marginalized and vulnerable are not strong enough, neither meeting their needs and nor within reach.

For the livelihood of the rural poor, opportunities and support through the safety are quite meager, predominantly for those depending upon the natural resources (Baig and Straquadine 2011).

10.3 Soil Issues and the Processes of Land Degradation

Marginal soil and land-resources have the potential to result the low agricultural yields. Anthropogenic activities, in addition to the natural processes and rising population-pressures cause the problems like: wind and water-erosion; water-logging; salinity/sodicity; loss of organic matter and decreasing biodiversity. Persistent salinization and sodicity issues are constantly declining the productive capacities of the healthy and fertile soils (Ahmed and Qamar 2004; Shah and Arshad 2006). It is estimated that almost 38 % of Pakistan's irrigated land is waterlogged, and about 14 % is saline. Use of agricultural chemicals has also gone up by a factor of about 10 since 1980. Soil erosion and water-logging are known to be the most significant and major constraints causing serious damages to our land resources and the environment.

10.4 Waterlogging in Pakistan

Pakistan has the largest canal network in the world supporting its agriculture primarily in the Indus Basin covering an area about 16.6 million ha. Water remains the most critical input to realize crop-production but canals systems are viewed as a blessing and a problem. On the one hand, irrigation projects require huge financial allocations and on the other hand, just after a few decades, the irrigated areas require heavy expenditure for lowering the water-table (resulting from seepage from the canal-system and mismanaged irrigation). It is believed (Shah et al. 2011) that excessive water percolation from the canal system causes the issue of waterlogging. The other reasons leading to waterlogged conditions possibly could include: growing of high delta crops like sugarcane on permeable lands, construction of roads and buildings can obstruct the natural drainage channels. Among the other factors responsible for waterlogging, improper alignment and poor maintenance of open drainage systems, inefficient disposal of rain water are worth to mention.

Khaliq (2007) reported an area of 1.55 million ha to be affected by waterlogging in the country. On the other hand, the Soil Survey of Pakistan reported the total waterlogged area reaches 4.11 million ha during the summer rains in the country and the waterlogged area is thought to be doubled during the post-monsoon season. Depth of water during post-monsoon is three times higher than observed in pre-monsoon season. High water-table could considerably lower the agriculture and crop yields. Factors like restricted aeration in the root zone under waterlogged and salinized soil conditions, reduced bearing-capacity of soil, weak foothold of the crop plants and an increased attack of crop-diseases seriously reduce the crop yields (Zia and Rashid 1995; Zia et al. 2004).

10.4.1 Suggested Innovative Remedies to Control Waterlogging

The following technologies, if properly adopted, can help lower the water-table, combat and manage the water-logging issue to a great extent:

- Immediate initiatives are needed to shift its irrigation resources perennial to non-perennial.
- Measures for the construction of surface-drains and tile-drains must be undertaken.
- Installation of tube-wells for the purpose of irrigation and vertical drainage should be done.
- Lining of canals, water-channels, and lowering of water-levels of canals deserving sufficient measures are required to be undertaken.
- Seepage through canals results the issue of waterlogging. Canals system can be improved by employing scientific planning and designing and research based management principles of irrigation.
- Waterlogging issue can also be addressed if canals are managed on proper scientific lines.
- In order to optimize the water-use, cultivation of high-delta crops on moderately to rapidly permeable soils must be avoided, high values crops requiring less water need to be encouraging.
- In the waterlogged areas, water-tables can be lowered down by planting trees (bio-drainage).

10.5 Soil Salinity Problem in Pakistan

An estimate given by Ghafoor et al. (2004) indicates that salt-affected soils both in the irrigated and nonirrigated areas spread over 6 million ha. Similarly scientists (Zia et al. 2004; Ahmed and Qamar 2004) have reported roughly 5.7–5.8 million ha of irrigated areas affected by varying degrees of salinization. Of this, 44.1 % is saline, 55.4 % is saline-sodic and 0.5 % sodic soils. Most of salt-affected soils are located in the province of Punjab (2.6 million ha), followed by Sindh (2.3 million ha).

Shah and Arshad (2006) reported slightly a higher figure, with an area of 6.28 million ha affected with salinity and sodicity at the national level. The majority of salt-affected soils are saline-sodic in nature. On the contrary, WAPDA (2007) reported a decline in salt-affected lands from 6.0 to 4.5 million ha in 1980s. The soil sodicity has significantly reduced the drainage capacity of the soils that in turn results lower crops yields, declined fertility and loss of biodiversity (Shah et al. 2011). An account of extent of salt-affected soils of Pakistan is presented in Table 10.2.

Table 10.2 Soils affected by various types of salinity and sodicity (000 ha). (Source: S & R Directorate, SCARP Monitoring Organization, WAPDA, Lahore, 2001–2003)

Type of soil	Punjab	Sindh	KPK/FATA	Balochistan	Pakistan
Soils with surface/patchy salinity and sodicity					
Irrigated	472.4	118.1	5.2	3.0	598.7
Unirrigated	–	–	–	–	–
Gypsiferous saline/saline-sodic soils					
Irrigated	152.1	743.4	–	76.6	972.1
Unirrigated	124.5	536.3	–	160.1	820.9
Porous saline-sodic soils					
Irrigated	790.8	257.0	25.7	29.4	1102.9
Unirrigated	501.0	150.1	7.8	364.0	1022.9
Dense saline sodic soils					
Irrigated	96.7	32.5	0.9	–	130.1
Unirrigated	530.0	379.7	8.9	714.8	1633.4
Total	2667.5	2217.1	48.5	1347.9	6281.0

10.5.1 Suggested Innovative Remedies to Control Salinity

Reclamation of saline soils can be easily achieved if sufficient good quality water is available. In dense soils, salts are leached down into the deep horizons by employing intermittent deep-plowing and heavy irrigation. Further, removal of salts can be achieved by adopting rice-berseem rotation, leading to improved soil-productivity. Under such rotation, if the last harvest of berseem (*Trifolium alexandrium*) is incorporated into the soil, this practice helps building the organic matter and improves the soil physical health. Afterwards, rice-wheat cropping, with Sesbania as green manuring crop should be planted and chopped into the soil. If green manuring is not practiced, then farmyard manure (FYM) should be applied instead. By employing such initiatives, the saline-sodic soils can be made productive for realizing improved yield (Zia and Rashid 1995; Zia et al. 2004; Baig et al. 2005).

10.6 Integrated Approach of Soil Management and Reclamation

In order to increase yield per unit area on the marginal soils (saline, saline-sodic, sodic) through improving soil and water use efficiencies, effective, efficient and long-term soil quality improvement requires the use of an integrated approach including physical, chemical, hydrological, and biological methods specific to the site's conditions (Shahid 2002; Shahid et al. 2013). However the combination of innovative strategies needs to be adopted on the basis of the site characteristics to make such lands productive and realize sustainable production systems, presented as under:

10.6.1 Chemical Amelioration Approach

Small scale interventions aiming at improving the soils conditions are founding blocks of any reclamation approach (Shah et al. 2011). Chemical methods are used to rectify soil sodicity. The objective is to reduce the exchangeable sodium percentage (ESP) below threshold value (ESP 15). The prime purpose is to enhance the concentration of calcium in soil. This process involves the application of chemical amendments like gypsum ($CaSO_4.2H_2O$), sulfur (S) and acids (HCl, H_2SO_4). However, the acids are only used in case soils are sodic and calcareous. The acids decompose $CaCO_3$ and its equivalents and Ca is induced to replace exchangeable sodium from soil exchange complex. To be effective, gypsum amendment required for reclamation has to be based on gypsum requirement determined in the laboratory. Calcium replaces excessive Na^{+1} from the clay particles/complex while forming sodium-sulfate. Since sodium-sulfate happens to be a soluble salt, therefore, it can be leached out of the root-zone with the heavy irrigations. Sulfur through biological oxidation by *Thiobacillus thiooxidans* transformed to sulfuric-acid, which helps in reclamation of sodic soils.

10.6.2 Biological Approach

In this approach, soil is made productive and reclaimed by growing *Sesbania bispinosa, Leptochola fusca,* and other green-manures crops like Berseem (*Trifolium alexandrium*). Growing of salt-tolerant plants, crops, grasses, shrubs, and trees has been a very successful mode of utilizing and improving the salt-affected soils effectively. The tree species like *Atriplex and Eucalyptus, Chenopodium, Suaeda, Salicornia, Kochia, Sesbania, Salsola Juncus,* and many other species have been successfully tried in reclaiming the salt-affected soils. Deep rooted plants and trees with high evapo-transpiration demand are capable of presenting biological drainage, in turn providing favorable environment for the succeeding crop species (Irshad et al. 2007). Deep roots of the tree are known to improve the physico–chemical conditions of the soils by improving soil structure, increasing pore space, enhancing water and nutrient holding capacity (Baig et al. 2005). However, there is a need to explore for suitable leguminous and crops like alfalfa, berseem, sesbania, and other promising species that could improve the organic contents of soils and create enabling environment for the biological life (Khan et al. 2012).

10.6.3 Physical Approach

Numerous physical methods have also been employed to reclaim the salted lands. Among these, the appropriate methods are: land leveling, salts scraping, deep plowing and tillage, subsoiling and sanding. Laser leveling seems essential for uniform water distribution. These practices do help in reclaiming salt-affected soils through improving physical conditions of soil (Zia et al. 1986; Zia et al. 2004; Shah et al. 2011). By employing the appropriate tillage practices that change the soil surface conditions resulting into low salinity in the root-zone (bed shaping and irrigation management). Experiments on managing salted soils indicate that salts tend to accumulate on the ridges away from the wet zone particularly upon the application of water in furrows (Shahid et al. 2011). They further reported that harmful effects of salinity can be minimized by placing the seeds on the off-center slopes of a single row. Such practices would expose the seed to the minimum salinity zone and provide the best possible moisture conditions. In addition by disrupting the dense layers, reclamation process can be enhanced by improving permeability through the operation of subsoiling.

10.6.4 Hydrological Approach

Hydrological approach is concerned with water use and drainage. By adopting an engineering approach, it is assumed that salinity issue in the irrigated areas can be reversed by adopting drainage schemes, aiming at lowering the water tables (Qureshi and Barret-Lennard 1998). For realizing successful reclamation of saline-sodic soils, leaching and drainage are two known and established basic requirements. In case, soils are permeable, artificial drainage is not required, but such a condition seldom happens in saline-sodic soils. Various types of drainage-systems (vertical drainage by installing tube-wells; horizontal drainage; tile drainage; surface drainage) are employed in order to achieve soil-reclamation.

Conventionally, saline soils have been reclaimed by employing techniques like flooding or by ponding water. In order to move the salts down into the deeper soil horizons, the leaching requirement (LR) is very important parameter to calculate. Rhoades (1995) has described procedures to calculate LR and to predict the yields losses causing by salinity. Putting the modern irrigation systems (sprinkler, drips, sprayers, and subsurface system) into the practices can certainly improve water use efficiency; however, each irrigation system has the potential to develop salinity at the specific soil zone and this issue needs to be examined and monitored carefully.

10.6.5 Saline-Agriculture Approach

Saline agriculture or biosaline approach refers to economic utilization of salt-affected soils for realizing economic agricultural yields by fitting plant life without having their reclamation. This particular approach involves the cultivation of salt-tolerant species of agricultural importance and significance and adaptation of special agronomic practices to improve the yields of these crops (Irshad et al. 2007). In Pakistan, the most prominent salt-tolerant plant-species tried and tested in the reclamation programs include: Kallar grass (*Leptochola fusca*), *Artiplex spp., Acacia spp. and Eucalyptus spp.* (Zia et al. 1986; Zia and Rashid 1995; Qureshi and Barret-Lennard 1998; Zia et al. 2004; PCST 2005a).

Table 10.3 Salt-tolerant plants potentially suitable for planting under saline conditions. (Source: Kahlown and Majeed 2002)

Type of crops	Salt tolerant crops shrubs and trees
Forage crops	Sorghum (*Sorghum bicolor*); millet (*Pennisetum americanum*); barley (*Hordeum vulgare*); alfalfa (*Medicago sativa*); clover (*Trifolium alexandrinum*); cluster bean, rape (*Brassica napus*); oats (*Gvena sativa*)
Grasses	Sindicus; Panicum; Gayana kallar grass (*Leptochloa fusca*); Bermuda grass (*Cynodon dactylon*)
Bushes	Atriplex; Blue bush; Asparagus
Fruit trees	Zizyphus; date (*Phoenix dactylifera*); falsa (*Grewia asiatica*); ber (*Ziziphus mauritiana*); pomegranate (*Punica granatum*); guava (*Psidium guajava*)
Forest tree	Jand (*Prosopis cineraria*); tamarix; swanjna (*Moringa Olifera*); neam (*Azadirachta indica*); desi acacia ampliceps jungle kikar (*Prosopis juliflora*); Safayda (*Eucylptus*); vilaiti kikar (*Parkinsonia*); Iple-Iple (*Leucana leucocephala*)
Shrubs	Kikar (*Prosopis juliflora*); jojoba (*Ziziphus mauritiana*)

Recently Shah et al. (2011) have reported very encouraging results of biosaline agriculture approach. The researchers have successfully demonstrated restoring the productivity of thousands of hectares of salt-affected soils by growing trees like *E. Camaldulensis* and salt-bushes like *Atriplex amnicola and Atriplex lentiformis*. An account of suitable grasses, crops plants, trees, shrubs is presented in Table 10.3.

In another project, focusing on reclamation and rehabilitation of salt-affected soils, Shah et al. (2011), tried to develop and promote sustainable biological farming systems for the degraded lands. They were quite successful in demonstrating technical and social interventions for the rehabilitation of degraded lands. As the outcome of their research, they also developed a package of saline agriculture technologies, consisting of salinity/waterlogging tolerant trees, crops, grasses and fodders; fish farming and installation of tube-wells. By employing these technologies, farming communities were able to elevate their incomes, poverty levels went down, livelihoods and environments were improved and above all women of the area felt empowered. In addition to making the degraded lands productive, researchers also focused on capacity building and the participation of local communities. The benefits realized as the result of these efforts were three times more than the cost of the projects and the researchers believe that the tangible benefits realized by the farmers clearly indicate the rate of acceptance and adoption of the reclamation technology package, evolved by them.

10.7 Soil-Erosion in Pakistan

Almost 76% of the country's total area has been severely affected by the wind (40%) and water (36%) erosion. Approximately, 1 billion tonnes of soils are being washed away annually, depositing in the dams and ultimately falling into the Arabian Sea (Irshad et al. 2007). Soil loss caused by water erosion is quite high in

Khyber Pakhtoonkhawa (KPK) province and is followed by Northern Areas (NA), Baluchistan and Punjab provinces (Irshad et al. 2007). About 50–60 % of the annual rainwater is lost through runoff, causing moisture shortage and erosion on the rainfed areas receiving medium to high rainfall. The susceptibility to erosion or the extent of erosion hazard depends upon the soil types. Soil orders primarily affected by soil erosion include: Alfisols, Entisols, Inceptisols, and Mollisols. However, water-erosion mostly occurs either in active flood-plains or on sloping hills (affected severely by water-erosion). In the country, low rainfall areas like: Thar, Thal sand desert of Cholistan, and vast areas of Province of Balochistan have been affected by the wind-erosion (NAP 2002; SLMP 2011)

10.7.1 Water-Erosion

Water erosion has affected an area of about 11 million ha (Khan et al. 2012).Water erosion is mostly prevalent in high rainfall steep slopes, particularly in the Potohar region (Shah and Arshad 2006). In these rainfed areas, almost 50 % rain water is being lost as runoff (Anjum et al. 2010). Water erosion is a major hazard on areas, receiving poorly managed for logging operations; indiscriminate land clearance; overgrazing, and removal of vegetation for feed, forage and fuel and inadequate management of runoff. All these factors make the soil bare and lead to erosion. In addition widespread use of annual crops on the farms further aggravate erosion problem.

The soils in the Indus basin are considered to be relatively young, recent and undeveloped. The surrounding mountains have some of the world's steepest and largest slopes. Strong and forceful summer rainfalls, along with melting of snow in high mountains, contribute to the hazards of soil-erosion. In addition, the other key factors responsible for soil erosion include: land-use practices, vegetation cover, type and structure of the soil. For example, an active water-erosion, a continuing process could be witnessed on the loose soils of Pothowar Plateau, also experiencing great potential for gully-formation and taking away the highly productive topsoil. In the northern mountainous region of the country, the water-erosion on the steep slopes is low in the areas covered with the permanently closed canopy-forests whereas the erosion hazard is greater on the steep slopes when cultivated with arable crops.

At the upstream, due to deteriorated riverside infrastructure, fertile top-soil is washed away, considerably decreasing the productivity of the erosion subjected lands. On the other hand, at the downstream, the deposition of the tonnes of sediments significantly lowers the efficiency of hydropower-generation and irrigation-systems (Khaliq 2007; Khan et al. 2012).

10.7.1.1 Innovative Remedies for Water Erosion

Water erosion is a very common phenomenon noticed on the rainfed lands, subjected to heavy loss, primarily occurring due to water flows due to rains, the improper land use under inappropriate cropping systems, grazing by the free roaming livestock and illegal ruthless removal of vegetation cover (Irshad et al. 2007). Water-erosion primarily could be attributed to the hammering action of raindrops and uncontrolled water flow. To control soil erosion and to conserve soil moisture, various types of structures can be constructed at appropriate locations to dispose off the excess runoff including retaining walls, water disposal outlets, spillways etc (Rashid et al. 2008). Many researchers (Zia et al. 2004; Sheikh and Soomro 2006; Irshad et al. 2007; Anjum et al. 2010) have presented remedial measures to combat the issue which are enlisted as under:

- Adoption of the practices like cover and strip cropping are important in controlling water erosion.
- Measures are needed making the water flow to the areas where it is desired to be taken at a controlled velocity.
- Construction of drop-structure and use of flood-retarding structure are useful measures
- Establishing the surface-cover (mulches) would reduce the force of the hammering action of rain. Such surface-covers are capable of intercepting the rain before hitting the soil.
- Maintaining a good cover of grass on the areas having the potential of erosion hazard. Strong cover provided by the grasses and grassy waterways proved a good option to check water erosion.
- Maintenance of borders ("Watbandi" land-leveling and terracing) in the field would reduce the amount of runoff by promoting infiltration and check erosion.
- Minimize clean cultivation and keep the lands always covered with vegetation
- Adequate, strong administrative and policy measures deserve strict implementation to halt, reverse the deforestation, and stop the illegal cutting of forest vegetation.
- Rangelands of the country are severely deteriorated for having been exposed to unplanned and un-scientific grazing of free roaming livestock. Rangelands must be managed by employing appropriate grazing plans like: rotational grazing.
- Initiatives like adoption of practices like low or zero tillage and the concepts of conservation agriculture are to be introduced to the areas facing the issue.

The lands with *Gully erosion* are not easy and economical to reclaim. However, control of runoff and erosion is extremely important on such lands to halt further deterioration. In addition, the affected areas can be improved by bringing vegetation covers back by employing the controlled grazing systems. Small and medium sized gullies, with suitable outlet, could be managed effectively by diverting of run-off water at the gully heads. Large gullies can be converted into the leveled lands by constructing the drop-structure. Such measures would help slowing down the water flow; reduce sediments loads by checking runoff. Impounding of runoff water at gully-heads would check gully formation, besides making drinking water available (Zia and Rashid 1995).

Pakistan Agricultural Research Council (PARC) has developed a model by employing an integrated land and water-conservation approach and has successfully been practiced in the Pothowar Plateau. The crops, pastures, orchards, fruit and forest trees, are raised on the land keeping in view to its suitability and capability. Approximately, 4 % of total area was used for making grassed water-ways and ponds. The lands of the area were developed requiring minimum operations, without disturbing or removing the soil. Today, gullies have been completely reclaimed and erosion problem has been fully eliminated from the area. Forest-trees have yielded appreciable wood, fruit trees are bearing fruits and crops are resulting reasonable yields, converting the problem area and wastelands into continuous sources of income. However, by adopting this model, farmers of the similar areas can make their degraded lands productive to realize sustainable productions (Zia and Rashid 1995; Zia et al. 2004).

The *Steep sloping lands* occur mostly in the northern and western mountains of the country. Steep sloping lands can be used for agricultural production; however, they should be dealt with great care. Some of the innovative but remedial strategies presented by (Baig et al. 1999; Zia et al. 2004) to check erosion and realize sustainable agriculture include:

- Making of stone bench-terraces would protect steep slopes and prevent erosion and run-off; promote water infiltration and support the growing vegetation.
- Lands with more than 15 % slope should not be put under plow for further expansion of the area to practice agriculture.
- Development of terraces would check runoff; utilize water efficiently to realize better hill farming.
- Scientific but research-based range-management site-specific strategies suitable to local environmental features must be adopted to improve rangelands.
- Soils should be used for forage-production by introducing a mixture of legume and grasses instead of growing monoculture oriented crops, such as only maize crop in hilly areas.
- Measures for the improvement of existing bench-terraces are needed as they also act as water-disposal systems, including grassy waterways and drop-structures.

10.7.2 Wind Erosion

Sandy areas along Makran Coast are also severely affected by the wind erosion. Land degradation by wind-erosion causes about 28 % of total loss of soil experienced in country (Khaliq 2007). The arid environment and the aridity phenomenon prevailing in the areas remain the prime and immediate physical cause of erosion. However, erosion is common to witness in the areas around habitations and watering-points trampled by livestock. The most damaging and degrading factor responsible for the wind erosion hazard could be the over exploitation of rangelands for fuel-wood and nomadic livestock grazing, without taking into account their carrying capacity. Winds are responsible for the movement of sand dunes, depositing thick layers of sand on roads, railway tracks and croplands, and threatening rural dwellers. Fine soil-particles, organic matter constituents and other soil-nutrients are lost during strong winds blowing (Muhammad 1994; Zia et al. 2004; SLMP 2011).

The province of Punjab experiences the highest magnitude of soil loss due to the strong winds than Sindh, Baluchistan and Khyber Pakhtoon Khawa (KPK) provinces of Pakistan (NAP 2002; SLMP 2011).

10.7.2.1 Innovative Remedies for Wind Erosion

Wind-erosion can be checked by employing less aggressive cultivation techniques. The measures that could maximize the residue-conservation and reduce soil-pulverization are to be put into practice. Many researchers (Alim and Javed 1993; Baig et al. 1999; Zia et al. 2004) presented various remedial measures to combat the wind erosion, salient points of their suggestions and the suitable options includes the following:

Cultivation Techniques

- It would be beneficial to use tined implements, rather than cultivating the soil with the disc implements, as the latter buries the surface-residues.
- Blade and chisel plow, with steep points should be used. Such implements will result the formation of clods and check erosion.
- Bare and naked soils should not be cultivated frequently. Therefore, the number of cultivations should be reduced to avoid breaking of clods and minimize the soil disturbance.
- Implements, such as chisel plow, which go deep into the soil produce the bigger size of clods and this practice would prevents and checks erosion. Soil-clods greater than 2 cm in size should comprise and cover at least 50 % of the soil-surfaces. Such initiative could be a productive and preventive measure toward erosion control.

Vegetation Cover

At least half of the ground should be covered with the vegetation to protect the productive lands; otherwise, erosion hazard may deteriorate these lands capable of sustaining plant and human life. The use of vegetation will help controlling erosion by:

- Holding, arresting and trapping the eroded soil-particles and vegetation can decrease and diminish the erosive power.
- Providing resistance against the wind force and reducing the wind-speed at ground level.
- Acting as a cover against the wind-forces, thus preventing wind from removing soil.
- Adopting controlled grazing plan and by placing check on the uprooting, cutting and burning of natural vegetation.
- Growing of hedges around cultivated fields located near the active sandy ridges and areas exposed to the winds has been proved very efficient and effective practice to control erosion and keep the lands intact.

- Planting the wind-breaks around the erosion-vulnerable areas. Such plantations help slowing down the wind velocity and in turn check erosion.
- Practicing strip-cropping on vulnerable areas has been recognized as an economical way of combating erosion.

10.8 Implications for Agricultural Extension Education and Awareness Programs

The scientists and the researchers of the country have been able to devise suitable technologies for the rehabilitation of degraded lands to realize sustainable economic yields. However, any technology, no matter how efficient, useful and productive it is, would be of no use unless it is adopted and put into the practice by the end-users i.e., farmers.

While working with the rural communities on the lands degraded with salinity, researchers like Shah et al. (2011) established the importance of such community participation in the salted land rehabilitation programs. They organized training programs for the community including Women's Interest Groups (WIGs) on the community management skills for participatory planning and implementation of development programs. The successful demonstration plots and reclamation technologies became popular among the farmers. Resultantly, farming community participated in such programs while sharing the costs.

Therefore, at this juncture, agricultural extension has a pivotal and prime role in reversing the land degradation processes and making them productive. To realize this objective, it is imperative to create awareness among the rural masses on the prevailing issues, potential technologies available to mitigate these issues for improving the situation.

There is a need to educate the rurals, policy-makers, planners, government officials, members of the civil society and NGOs etc. Initiatives on capacity building, organizing of workshops, training courses for the communities including farmers, youth women groups; support from electronic and print media are important. Bright chances and rich opportunities do exist to make the problem soils productive, realize sustainable crop yields if all the stakeholders equip themselves with necessary technical skills on the subject and play their roles in the rehabilitation programs with dedication and devotion.

10.9 Conclusions and Recommendations

Pakistan is known for its agrarian based economy. Some 90% of its land has been classified as arid or semiarid, facing the issues like drought and soil degradation leading to desertification. Almost 68 million ha of land area falls in the fragile regions. Only one fourth of the country's land mass is irrigated, supporting high input and intensive agriculture. However, the land degradation threats faced by both the low and potential areas include: wind and water erosion, salinity, sodicity, waterlogging, flooding, and loss of organic matter result lower agricultural yields. Among the major limitations determining agricultural potential are: flooding and ponding; presence of surface/subsurface clays making tillage operations difficult, excessive sands, subsoil compaction or plow pan formation; surface crusting; nutrient depletion and structure deterioration.

To feed the rapidly multiplying population and to keep the land resources healthy and productive for the future generation, and to mitigate the environmental issues damaging natural resources, it is imperative to closely look into reasons of land degradation and adopt innovative measures to reverse these processes. Putting innovative technologies into the practice depending upon the nature of the issue could be highly helpful. For example, by adopting engineering and biological approaches and strategies described in the chapter can surely tackle the problem of water-logging in Pakistan. Similarly, white-alkali (saline soils) containing sufficient soluble salts can be managed and reclaimed through intermittent deep plowing and heavy irrigations.

The rapidly vanishing vegetation resources are accelerating land degradation processes. Therefore, it is very important to maintain the existing natural vegetation and protect it from excessive browsing, ruthless and illegal cutting and uprooting, and burning. Also, there is need to focus on bringing vegetation back and re-greening of bare slopes; reseeding with suitable grasses and plant species; proper care of growing plants until they are fully established, and protecting vegetation from grazing livestock. The introduction of rotational grazing on such areas can facilitate the rehabilitation process.

However, steep slopes should not be cultivated and in case land has already been cleared for cultivation such slopes should either be replanted or reseeded with suitable tree/bush species, or proper bench terraces should be constructed and maintained. Alternate sources of fuel, food, fodder and other requirements should be provided to the locals living in the hilly areas to retain the vegetation cover in place.

Saline agriculture is a promising solution to utilize saline soils and saline water where other solutions of reclamation do not work or seem impractical, however lands are made productive by growing salt-tolerant crop plants, grasses, bushes, shrubs, and tress. Many plants grown on salt-affected soils have economic value, high nutritional value for use as forage or fodder crops and many have high contents of proteins and oils in their seeds.

By employing sea/brackish water for irrigation, it is quite possible to realize sustained high yields of biomass and seed by growing halophytes/salt tolerant plants. Besides the role of halophytes in drainage and reclamation processes, they also make agriculture more sustainable. That is why saline agriculture has emerged as a first rate alternative measure to improve environment and combat pollution.

Black alkali (saline-sodic/sodic-black soils) can be made productive by adopting an integrated land reclamation approach. The particular strategy consists of the use of chemical amendments (like gypsum, calcium chloride, sulfuric acid, hydrochloric acid, sulfur and ferrous sulfate), by-product of sugar industry (press mud);

biological means, such as use of FYM, green manures; composts; and physical methods, namely deep plowing, chiseling and sanding.

The judicious and wise use of brackish and unfit underground water for crop-production on salt-affected soils is an economical and suitable remedy to adopt. The strategies reported in the chapter if adopted with spirit would certainly combat issues like water and wind-erosion and halt the loss of soil fertility. Integrated approaches to maintain and enhance soil-fertility and health and the judicious fertilizer-management for improving crop yields should be put into practice.

However, rejuvenating the health of salt-affected soils and their chemical reclamation is a time consuming and costly business, in most cases out of reach of ordinary farmers, therefore, bio-saline approach is another option for growing salt-tolerant crops, shrubs, fruit, and forest trees.

The country experiences the issues like waterlogging and salinity do arise due to the seepage from the canals however; they can be addressed by the lining of water conveyance system including canals and water courses. Such initiative not only improves the conveyance efficiency but also checks the over efficiency of the irrigation system. The pressurized irrigation systems (like drip and sprinkler) involve the highly efficient technology capable of saving water without its wastage and damaging land resources.

Finally, beyond any doubt, human induced pressures are deteriorating the precious land and other natural resources while causing serious and irreparable damages to our environment. It is, therefore, essential to cope with land degradation problem on the basis of war-footing. In the situation to manage the land resources on sustainable basis, it is imperative to devise and introduce frameworks and instruments, capable of matching, accommodating and addressing the local needs in the best possible manners.

In addition to the remedial measures suggested in this chapter, awareness and capacity building programs through extension and education are of paramount importance. Enabling policies, creation of suitable conducive environment and more importantly their implementation with real spirit to complement the existing efforts are the essential ingredients of any rehabilitation program.

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