Reclaiming Pakistani Cholistan Desert through Sustainable Strategies: Implications for Rural Extension

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KEYWORDS

Water scarcity; Droughts; Water harvesting technologies; Developmental initiatives; Desert-based Aquaculture; Rural extension

ABSTRACT

Cholistan Desert located in the Eastern Pakistan and Sothern part of Punjab province is an extension of Great Indian Desert. Spreading over an area of about 2.6 million hectares (26,000 km2), the sandy desert with an annual mean rainfall varying from 100-250 mm has hot, dry and arid climate. The population of the desert has touched the figure of 110,000. Although ecological and climatic conditions for all the living organisms are extremely poor and relatively hard and harsh yet livestock sector is supporting the livelihoods of its inhabitants. The area is subjected to the prime issues like: extreme scarcity of water, drought conditions, over-grazing, deforestation, wind erosion, salinity. In the past, Cholistan Desert was the home to the many wildlife species but unfortunately this natural resource is vanishing fast. The paper presents an overview of the available resources of the area; provides the critical analyses of the strategies/interventions tried so far and examines the available options to realize sustainable development. The paper aims at reclaiming the desert lands and converting them into productive ecosystems (at least to the possible extent) by conserving its precious natural resources like: lands, water, flora and fauna; and identifying the alternate measures to elevate the livelihood of desert dwellers. The secondary data were used to make inferences, draw conclusions and suggest remedial measures. Through sustainable strategies, the rich heritage of desert biodiversity can be conserved and promoted. A holistic approach comprising of the initiatives like: Rural Extension and Development Initiatives (REDI); Improved Water Harvesting Techniques (IWHT); Saline Agriculture Approach, Desert-based Aquaculture (DBA), and improved water storage facilities are imperative to launch in order to make the desert greener. Innovative technologies discussed in the article could possibly reclaim the desert; sustain more vegetation to feed a greater number of animal units. Such initiatives if taken have the potential to elevate the livelihood of inhabitants of Cholistan Desert.

إستراتيجيات إستدامة إستصلاح صحراء كوليستان البكستانيه: آثار الإمتداد الريفي

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المُستلخص

يقع صحراء كوليستان في الجزء الجنوبي من إقليم البنجاب، شرق باكستان ويعتبر امتدادا للصحراء الهندية الكبرى. تبلغ مساحته حوالي 2,6 مليون هكتار (26000 كلم^2) ، ومناخه حار وجاف وقاحل بمتوسط 100-250 ملم أمطار سنوية ويبلغ حجم السكان فيه حوالي 110000 نسمة. وبالرغم من هكذا الظروف المناخية القاسية والبيئية غير الملائمة يعتمد سكان الصحراء على تربية الحيوان سبيلاً لكسب العيش. كما تتعرض بيئة حزام صحراء كوليستان الى مُهددات طبيعية مثل الجفاف نتيجةً لندرة المياه، والتعرية الهوائية وملوحة التربة ، وأخرى بشرية مثل الرعي الجائر وإزالة الغابات، مما يتسبب في تلاشي الموارد الطبيعية وضعف التنوع البيولوجي. تهتم هذا الدراسة بعرض لمحة عامة عن الموارد الطبيعية المتاحة وتقدم عليها تحليلاً نقدياً للاستراتيجيات و التدخلات القائمة وتستخلص بعض الخيارات الممكنة لاستدامة التنمية والتي يذكر منها إجراءات استصلاح الأراضي لتحويلها إلى نُظمٍ إيكولوجيةٍ مُلائمة إلى حدٍ معقول من خلال المحافظة واستدامة الموارد الطبيعية الأساس مثل المياه والغطاء النباتي الحيواني، واقتراح تدابير بديلة لرفع المستوى المعيشي لسكان الصحراء. وعلى ضوء البيانات الثانوية توصلت الدراسة إلى استدلالات وتدابير عملية يمكن اعتمادها كإستراتيجيات مستدامة للتنوع البيولوجي منها برامج ومنهجيات الإرشاد والتنمية الريفية، وتقنيات حصاد وتخزين وتوزيع المياه مع التركيز على زراعة النباتات متحملة الملوحة، مما يؤدي إلى الاخضرار والثراء والتنمية البشرية والارتقاء بالصحراء .

الكلمات الدالة

ندرة المياه؛ الجفاف؛ تقنيات حصاد المياه؛المبادرات التنموية؛ الأحياء المائية الصحراوية؛ الإرشاد الريفي

Introduction

In Pakistan, Cholistan Desert spreads over an area of about 26000 km^2, roughly equal to 2.6 million hectares (Kahlown *et al.,* 2004; Ahmad, 2008; WWAP, 2009). The word "Cholistan" is taken from the Turkish language. In Turkish, the word "Chol" means - a desert. It is also believed that it originated from Iraqi word Chilistan: meaning waterless wasteland (Ahmad, 2011). Cholistan is a vast arid tract of a desolate sandy desert where the surface water is almost non-existent (Kahlown *et al.,* 2004). The ground water is highly saline and considered unfit for both humans and vegetation (WWAP, 2009). However the desert has the great potential for saline agriculture, bee-keeping and particularly saline fish-farming (PCST, 2005). Primary source of fresh water in Cholistan Desert is runoff caused by infrequent rainfall and the water collected in runoff is being utilized to meet the water requirements of human and livestock population. The water is collected in the muddy ponds i.e. Tobas (Ahmad, 2008). Many of them are located at inappropriate places which are formed without giving due consideration to the topographic features. Due to this negligence, the water collected in these ponds does not last for more than 3-4 months (Adeel and Safriel, 2008).

An ever-increasing population of the country at an alarming rate requires the presently available production systems to produce more to meet the growing needs for food and fiber. In the situation, national planning and development agencies are turning their attention to the vast wastelands like Cholistan Desert (WWAP, 2009). Many researchers like Khan *et al.,* 1996 Kahlown *et al.,* 2004; Ahmad, 2008; WWAP, 2009 have scientific evidences to believe that the desert can successfully sustain its livestock and human populations if managed on the sound scientific lines. They are of the opinion that by employing efficient water harvesting techniques, the shortage of water for human and livestock consumption can be overcome. Also, by launching developmental strategies like desert aquaculture and cottage industry, the livelihoods of desert residents can be elevated. The desert can also be reclaimed and turned into a green land by practicing saline agriculture (Adeel and Safriel, 2008). This paper examines the presently prevailing level and state of available resources, current problems faced by the rurals and review of the past efforts. In the article, an effort has been made to discuss some strategies for the over-all improvement of the desert. In addition, the possible role of extension education in undertaking the developmental initiatives has also been discussed. The objective of study is to realize the sustainable development and improve the livelihoods of desert dwellers having low income levels.

Material and Methods

(1) Study Area

(1.1) Location and Climate

Cholistan Desert is situated between 70^o 5' and 75^o 24' East longitude and 28^o 51' and 30^0 41' North latitude (FAO/ADB, 1993; Arshad *et al.,* 1995; Jowkar *et al.,* 1996; Ahmad, 1999a; Ahmad and Farooq, 2007) covering an area of 26330 km^2 (Ahmad, 2011). It is located in the Southern part of Punjab Province and Eastern Pakistan as shown in figure 1 (Kahlown *et al.,* 2004). Cholistan Desert is bounded by the Sutluj River and agricultural lands of Bahawalpur Division in the Northwest Sukur district in the South. An international boundary line runs between India and Pakistan in the Southeast. It is 480km long while its width varies from 32km to 192km (FAO/ADB, 1993; Arshad and Akbar, 2000). It is an arid hot and sandy desert receiving mean annual rainfall between 100 mm -250mm (PCRWR, 2009; Akram *et al.,* 2009) with an average annual rainfall of about 160 mm (Kahlown *et al.,* 2004) that varies from 100 mm in the North to 200mm in the South and may reach 250mm along the Pakistan-India boarder. In Summer, temperature may reach 50^{0}C or above (Akhter and arshad, 2006). May and June are the hottest months in the year. Mean winter temperature varies from 14^{0}C to 16^{0}C falling below zero in December and January. Also frost may occur occasionally for a few days once or twice in Winter usually in December. Relative humidity varies from 50-65 percent. With low rainfall and high temperature, evapo-transportation rate in the

desert is higher than the rate of rainfall, making the entire area extremely arid. Predominantly Aeolian sands and alluvial deposits developed the desert. Low rainfall, high rates and speedy downward movement of water into the sands and high evaporation are factors preventing the natural deposition of surface waters into the deeper horizons (Ahmed 2008; Akram, 2009). According to Sial and Arshad (2003), on the basis of soil, vegetation, topography and parent material, the desert is usually divided into 2 geomorphic parts namely, a, Lesser Cholistan and b, Greater Cholistan.

Figure 1: Map of Pakistan Indicating the Location of the Study Area, Cholistan Desert
(*Source: Ahmad, F. 2008*)

(a) Lesser Cholistan

The Northern part, comprising nearly 7770 km^2 is called "Lesser Cholistan" (Akhter and Arshad, 2006; Arshad *et al.,* 2008). It constitutes the desert margin, consisting of a series of saline alluvial flats alternating with low sandy ridges (Ahmad, 2008). With low sandy ridges, lands are saline, compact and hard, called Dahars in the local language. The area is covered with the stable and relatively less moving sand dunes which may reach up to the height of 30 meters (Akhter and Arshad, 2006).

(b) Greater Cholistan

The Southern part of the desert traversing deeper into the South and covering an area of 18130 Km^2, with an abundance of big sand dunes is called the "Greater Cholistan". It is a sandy desert developed by the winds, comprises old river terraces with big (Akram *et al.,* 2009) and various forms of sand dunes that may reach up to the height of 100 m (Akhter and Arshad, 2006). Only 20 percent of its area comprises flat plain of hard clay, locally called Dahrs (Ahmad *et al.,* 1992; Akhter and Arshad, 2006).

Discussion

(1) An Overview of the Natural Resources Available in the Cholistan Desert

(1.1) Soils/ Land Resources

Primarily the movement of Aeolian sands or alluvial depositions shapes the desert where granite is the major desert forming material and prime constituent. Soils are alkaline (pH values ranging from 8.2 to 8.4) with low organic matter and most of them are saline or saline-sodic. Due to the low organic contents of sodic soils, water-holding capacity of these soils is quite low and poor (Khan

et al., 1996; Akhter and Arshad, 2006; Akram *et al.,* 2009). Due to the deteriorated structure and the decreased activity of soil microorganism, erosion issue arises. When heavy thunder showers occur on the land with sparse vegetation, soil erosion takes place due to surface runoff (Khan *et al.,* 1996). Land Use system of Cholistan Desert has been presented in figure 2 However, issues like soil erosion can possibly be checked and reduced significantly by adopting appropriate measures, land use patterns and management techniques. In addition, present crop pattern can be replaced with a more desirable farming system as an alternate solution (Khan *et al.,* 1996; Akram *et al.,* 2009).

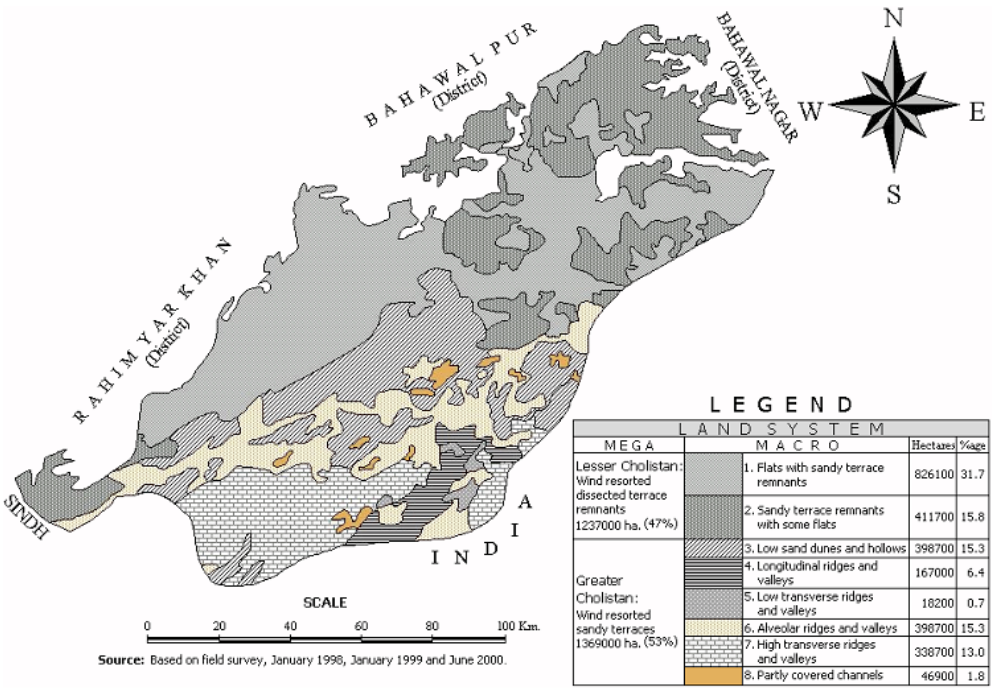

Figure 2: Land Use System of Cholistan Desert, (*Source: Ahmad, F. 2008*)

(1.2) Combating the Serious Issue of Soil Erosion

After water shortage, soil erosion emerges as the most prominent issue of the area; however it can be checked and addressed by adopting certain soil enhancement and rebuilding practices. These suitable, innovative and workable options and strategies include:

(a) Trampling and over-consuming by livestock can make the vegetative cover damage and disappear. In the situation, a reasonable grazing/range management plan for animals is needed.

(b) Grazing by livestock must not exceeds the carrying capacities of the lands; otherwise destruction of vegetation would continue.

(c) Rehabilitation of deteriorated ranges can be made by multiplication and propagation of native species.

(d) Planting of windbreaks and shelter-belts has proved an effective measure in reducing the wind speed at the soil surface. Also strip farming has been a successful practice to combat erosion.

(1.3) Land use Patterns

Agro-pastoralism and pastoralism are the two principal land use systems of the Cholistan Desert. Cotton - wheat crop rotation is followed on areas where sufficient irrigation water is available. Areas with insufficient irrigation water, crop rotations of sorghum (*Sorghum bicolor*); millet *(Pennisetum americanum*); chickpeas (*Cicer aertinum*) and pulses are followed. About 67% of the farmers of the Cholistan practice farming on irrigated areas of the desert whereas 33% farmers practice dryland agriculture. The livelihood heavily depends on the income generated through animal husbandry. The nomadic tribes throughout the year keep on

migrating their livestock from one place to another in search of water and feed, making the pastoral system of area unique (Akbar and Arshad, 2000; Baig *et al.,* 2007; Akram *et al.,* 2009).

(1.4) Range and Forest Resources

(1.4.1) Rangelands Productivity and their Relation to Sustain Livestock

The rangelands of Cholistan constitute about 2.61 million hectares. Akbar and Arshad (2000) reported that about 2 decades ago total livestock population in Cholistan was around 134798 Animal Units (AU). Whereas an AU represents an adult cow that weighs 350 kg (400 kg at international level), and roughly consuming about 7-10 kg dry matter forage per day under the ecological situation of Cholistan. The researchers (Akbar and Arshad, 2000) estimated the total annual dry matter forage demand was some 344409 tons whereas the accessible dry matter forage in the area was about 242951 tons. They reported the dry matter forage deficiency prevailing in the area of about 101457 tons/year. They also noticed that some 39709 AU/year are excess to the present carrying capacity. Whereas Akram *et al.,* (2009) believe that production capacity of the grazing lands of Cholistan can be enhanced by 10-35 percent by employing proper seeding techniques and using appropriate species. However, at the moment, keeping a higher number of livestock than the carrying capacity of the Cholistan Desert remains a great threat to the natural vegetation and possibly leads to an accelerated desertification.

(1.4.2) Development of Livestock Resources

Livestock rearing and production is the major economic activity in Cholistan to meet the subsistence needs of the people. However, livestock in this region suffers from frequent droughts, heat stress, under-nutrition and diseases resulting in high mortality and low productivity. Indiscriminate breeding and little effort towards any genetic improvement further compound the problem. The stock watering facilities are also very inadequate in greater part of the Cholistan Desert and wherever available water is generally brackish. The people with their livestock are on constant move along the rain-water catchments i.e. Tobas and Kunds. From July to February the grazing areas are in good shape but as Tobas and Kunds dry-up, the grazing areas are left with no more vegetation to sustain livestock. In this situation, rural dwellers of Cholistan move to the fringes of irrigated areas. The lack of grazing and stock watering resources force the livestock graziers and breeders to migrate to distant places in search of them. Some shepherds are continually on the move whereas others follow their traditional nomadic routes to the seasonal grazing areas and return to their permanent settlements during the monsoon season.

This sort of large-scale migration of livestock creates severe hardships for the livestock as well as the livestock grazers (Akbar and Arshad, 2000; Baig *et al.,* 2007). Consequently, water pipelines have been laid to ensure water supply round the year so that livestock herders may not migrate to the settled areas due to non-availability of water and fodder for their cattle. To improve the situation, model pastures of 32 blocks around each pond/reservoir have been introduced in the area. In addition to the installation of pipelines, plans are underway to install sprinkle irrigation systems through rain guns for the further development of the rangelands. The cattle graze one block of grass per day on rotation basis thereby giving rest period and the turn of the 1st block to be grazed comes after a period of 31 days (PCST, 2005).

(1.4.3) Vegetation of Forests and Rangelands

Cholistan Desert sustains the species that are well suited and adapted to the limited water supplies and can exist in dry and arid conditions. The vegetative cover not only sustains the livestock population owned by locals, but also reduces the wind velocity and combats erosion. However, factors like continued overgrazing of animals, removal of sparsely growing shrubs and trees for firewood, and temporary shelters made by inhabitants in the area have reduced the vegetative cover to the extent of only about 20% or less (PCRWR, 2009; WWAP, 2009). Important genera of grasses include *Cenchrus, Lasiurus* and *Panicum*. Shrubs preferred by livestock are species of *Calligonum and Holoxylon*. Indigenous trees like *Prosopis, Ziziphus* and Acacias are quite visible prime species (Rao and Arshad, 1991; Akbar and Arshad, 2000).

The rangelands with sparse vegetation can sustain about 2.4 million heads of livestock. Consequently, a livestock sector remains the principal source of livelihood of people of Cholistan (PCRWR 2009; WWAP 2009). The economy of Cholistan Desert is based on livestock. The nomads raise goats, sheep, cows, and camels in their herds. Camels are viewed as the predominant and popular species. The livestock thrives on well adapted shrubs and grasses which are typical of arid regions of Cholistan (Akbar and Arshad, 2000). A number of range management operations and initiatives have been undertaken to keep rangelands productive, capable of sustaining plentiful vegetation (Akbar and Arshad, 2000; Baig *et al.,* 2007).

(1.5) Water Resources

Unfortunately, the perennial or ephemeral streams do not exist in the Cholistan Desert. The occasional rainfalls happen to be the only source of fresh water for the consumption of both humans and animals (PCRWR, 2009; WWAP, 2009). Severe water deficit and shortage is the major factor limiting the development of Cholistan Desert. Due to the presence of high salt contents (medium to high range of dissolved solids) the ground water of the area has been classified as saline and unhealthy for human consumption (PCRWR, 2009). Many wells in the area have brackish water that is not suitable for both drinking and agricultural purposes (Akbar and Arshad, 2000; Baig *et al.,* 2007). Moderately to highly saline groundwater is available in major part of the area at 30-40m depth. With a few exceptions, the ground water contains 9000-24000 mg/l of dissolved salts (Baig *et al.,* 1980; Akhter and Arshad, 2006). Rains remain the only source of re-charge of the groundwater that contributes to various fresh water sources (Akram *et al.,* 2009). However, a significant portion of the rainwater is lost as runoff due to the predominantly sandy nature of the soils and topography of Cholistan (Akbar and Arshad, 2000; Baig *et al.,* 2007).

The dwellers of Cholistan primarily live and depend upon the water gathered during the rainy period and is collected and stored in man-made depressions or ponds. In Cholistan, there are 2 major types of these ponds namely Tobas and Kunds meeting water requirements:

(a) Tobas

Ponds that collect runoff and rainwater locally called tobas. "Toba" is a (Katcha - means earthen, made of mud) water pond not made of concrete which is dug in low lying area with the objective to collect rain water. The water from "Tobas" is consumed and shared by both the human and animals. According to WWAP (2009) such ponds abundantly exist in Cholistan Desert. However, only 600 out of 1600 existing ones seem functional and in operation. High rates of pollutants and sediments are transported to these ponds due to significant runoff, making their water contaminated and unfit for the human and livestock consumption.

(b) Kunds

These concrete structures are the ponds (large circular or rectangular tanks) that are mainly used to store rainwater for the household and human consumption. About 200 Kunds are available in the area normally with clean water unless they receive external contaminants. Most often they get polluted and contaminated when human and animal wastes are transported into them as runoff. However they are less contaminated than Tobas (WWAP, 2009; PCRWR 2009). The plane areas (surrounded by sand dunes) make the effective catchments for the collection of water or runoff. These catchments may vary from few to several hectares in size. These plane patches locally called Dahrs, are composed of very thick and compact clay.

(1.5.1) Drinking Water Facilities

Shortage of drinking water is the most acutely felt problem of Cholistan. The ground water existing in the Cholistan has been classified saline and unsafe for drinking purposes based on WHO standards (Akram and Chandio, 1998). It also contains impurities and water of suitable quality is most scarce commodity in the area. In most of the localities, it is extremely brackish and cannot be used for human/livestock consumption and even for construction activities (WWAP, 2009). Main source of drinking water in Cholistan is the rainwater and through rainwater harvesting techniques, it is stored in "Tobas and Kunds" (PCRWR, 2009; WWAP, 2009). The water stored in these ponds is

thought to be unhygienic, contaminated and unsafe for drinking purposes. Realizing the importance of water, the government has initiated some water supply schemes under various programs, providing safe drinking water through pipelines. So far more than 1/5th area of Cholistan has ensured supply of drinking water through pipelines. In order to make drinking water available inside Cholistan, pipelines will have to be laid in the desert to provide water to different communities (PCRWR, 2009).

Abundantly available, groundwater is brackish and has been classified as quite unfit for drinking purposes and livestock consumption for containing enormous quantities of dissolved salts and minerals (9000 to 24000) Mg/l in vast areas (Baig et al., 1980; Akbar and Arshad, 2000; Akhtar and Arshad, 2006). However, by employing the reverse osmosis membrane technology the brackish water can be made suitable for drinking by human beings household usage and livestock consumption by lowering its salt contents to acceptable limits. The desalination plant devised and used, can treat up to 50 m^3 (50000 liters) per day at a very nominal unit cost. As an outcome of the research, it appeared as an affordable price for humans use but seems reasonably high for livestock consumption and agricultural purposes. Under the given situation when the prices for fossil fuel are on the hike and on the other hand when large amounts of solar energy and heat in the desert are available free of cost, the use of solar and thermal energy with reverse osmosis membranes to obtain drinkable water from saline groundwater in the desert has a great potential and seems worth to put into practice on mass scale (PCRWR, 2009; WWAP, 2009).

(1.5.2) Water Harvesting Techniques

It is an established fact that low availability of water is the prime concern in desert area and rainfall is the only natural source of freshwater in these areas. However, more rainwater can be collected and stored by adopting appropriate strategies and by employing suitable "Rainwater-Harvesting Techniques". If rainwater collected and stored on scientific lines and consumed wisely, not only can meet domestic and livestock needs but can also help agriculture flourishing on small patches. An additional amount of water can be obtained by the collection of rainwater by altering the terraces and roofs of houses and building complexes into catchment areas (Qureshi, 2005). Location of water harvesting points in Cholistan Desert has been presented in figure 3.

Figure 3: Location of Water Harvesting Points in Cholistan Desert
(*Source: Ahmad, F. 2008*)

In addition, by using drain-pipes, rainwater from roofs can be collected into the water-collection pits as a rain-harvesting technique in the desert areas of Cholistan (PCST, 2005). Some other water-harvesting techniques have also been designed and developed after lengthy research trials and projects for ranges of Cholistan as well (Suleman *et al.,* 1995a,b). Among the successful techniques, pitcher irrigation proved the most promising and had been successfully adopted in Cholistan Desert.

Studies conducted by PCRWR, (2009) indicated that human water demand was about 0.80 million m^3 and for livestock it reaches to 18 million m^3 and the council believes that the desert has still the potential to collect addition 227 million m^3. PCRWR in (2009) also revealed that some 208 million m^3 of surplus water would become available for further uses if correct harvesting techniques water were employed at appropriate places and ponds are constructed on scientific lines considering topographic and hydro-morphological features.

(1.5.3) Saline Agriculture by using Salt/Drought Tolerant Plants

Many research dedicated efforts have been made to fit plant life on the saline soils and many plants grasses and crops have been screened that could be designated as tolerant to drought and osmotic stress. Species such as *(Acacia ampliceps); (Leptochola fusca); (Tamarix aphylla); (Parkinsonia aculeta);(Casuarina equisetifolia);* and *(Atriplex amnicola)* are capable of achieving rapid and economic growth in soils with ECe values as high as 20-30 dSm^{-1}. Saline agriculture has the great potential as a new farming system for the reclamation of the desert and should be implemented as an alternate strategy.

Moderate to highly saline groundwater remains the secondary source of water in the desert and is not useable for drinking. However, this kind of unfit saline and brackish waters have been utilized for the irrigation of many agricultural purposes in several countries under similar environmental conditions and physical settings.

According to Qureshi and Barret-Lennard (1998) salt-tolerant plants are capable of growing on salt-affected soils and can result economic yields of food, fodder and fuel. They adapt well on unsuitable lands and can grow on saline waters due to their certain built-in-mechanisms. Halophytic plants grow well on the soils or waters containing sufficient amounts of salts. Such plants, crops, and grasses have the great potential to reclaim the salted areas. Saline areas can be made productive by growing the salt-tolerant crops, using brackish water for irrigation and employing special cultural and farming practices and techniques (PCST, 2005). In Cholistan Desert, the scientists have been able to grow certain crops like wheat and barley successfully without compromising the crop yields by employing saline underground waters with EC ranging from 2 to 16 dS m^{-1}. About the volume of 8.6 billion cubic meters (BCM) which is roughly equal to 7.0 million acre feet (MAF) groundwater is still available for further multiple uses (PCST, 2005). Examples of salt tolerant crops, trees and shrubs, capable of flourishing under drought and saline environments of Cholistan are listed in the Table 1.

Table 1: Some Potential Drought Tolerant Plants that Can Grow Well in Cholistan Desert

Local Name	Botanical Name	Description
Kikar	*Acacia nilotica*	Tolerates high-level of groundwater salinity and can withstand extreme temperatures.
Kawar Gandal	*Aloe saponaris*	Tolerates a wide range of conditions. Usually grows in sub-desert scrub where the vegetation consists mainly of an open formation of grasses ephemeral herbs low thorny shrubs etc.
Ber	*Zizyphus mauritiana*	An intolerant tree that has no particular soil requirements and grow on a variety of soil conditions shallow to deep gravel sand to clay. It prefers a warm temperate to sub-tropical to tropical climate.
Kallar Jharian	*Atriplex Canescens*	It prefers sandy loam or loam soils to grow. It is recommended on marginal lands subject to prolonged drought or excess salinity.
Jojaba Hohoba	*Simmondsia chinensis*	It is most suitable to grow in Cholistan where annual rainfall is low and temperature is very high.
Karir Karil	*Capparis deciduas*	It is commonly found on the sandy plains of desert and sometimes occurs on sand dune also.
Lana	*Haloxylon salicornicum*	It is usually found in inter-dunal areas and windward sides of sand dunes throughout Cholistan Desert. It grows in soils with high Na content and high pH and helps reclaiming sodic soils.

Lani	*Suaeda fruticosa*	It is a small shrub that grows in saline areas of Cholistan Desert.
Masoor	*Lens culinaries*	It is a short slender many-branched annual legume with a bushy growth. Its water requirement is very low so it is drought-resistant.
Neem Nim	*Azadirachta indica*	It grows on soils that vary from rich loams to nutrient deficient soils and prefers an arid hot tropical and sub-tropical climate with a temperature range 1-45^{o}C.
Date	*Phoenix dactylifera*	Grows successfully in hot arid climates and saline environments; can survive in a temperature range of l0-58^{o}C.
Mesquite	*Prosopis juliflora*	It is an aggressive species that can grow in highly saline, alkaline and sodic conditions. It can tolerate a wide range of temperature between -10-50^{o}C.
Vilaiti kikar	*Parkinsonia aculeate*	It can tolerate drought. It is adapted to a variety of soil conditions and survives at the temperatures between -03-38^{o}C.
Jand	*Prosopis cineraria*	*P. cineraria*grows successfully in harsh climate of Cholistan Desert and in the deserts of Oman and other middle eastern countries; highly saline alkaline soils (pH values up to 9.8. It is adapted to a variety of soil conditions and survives at the temperatures between -06-50^{o}C.
Ipil ipil	*Leucana leucocephala*	It is an aggressive species that can grow in highly saline, alkaline and sodic conditions. It can tolerate harsh temperatures and is highly drought resistant.
Casurina	*Casuarinas equisetifolia*	It is an evergreen conifer like tree. It grows on slightly alkaline soils, withstands salinity but not waterlogging. It is an adapted is a heat-loving lowland tree and can tolerate drought for 6-8 months. It has a remarkable ability to stabilize sand dunes and control erosion.
Suphaida	*Eucylptus Camaldulensis*	Grows in slightly alkaline soils, where it can withstand some salinity and waterlogging. It prefers a semi-arid subtropical climate (-5- 40^{o}C) and it is drought tolerant and can stand a dry season up to 7 months.
Falsa	*Grewia asiatica*	It thrives well in tropical climates and other climates as well. It is highly drought resistant. It can grow in alkaline soil conditions. It can survive in saline-sodic soils.
Guava	*Psidium guajava*	Optimum temperatures for its growth range from 23-28^{o}C. It grows well in moderately saline-sodic soils; can grow on alkaline to acidic soil conditions.

(*Source: Qureshi and Barret-Lennard 1998; Kahlown and Majeed 2002; PCST 2005*)

(1.5.4) Desert Based Aquaculture

At present, the surface water in the Cholistan Desert is almost non-existent. The ground water is highly saline and is considered unfit for crop production. However, the desert has the great potential for saline agriculture, bee keeping and particularly saline fish-farming (PCST, 2005). Primary source of water in Cholistan Desert is runoff caused by infrequent rainfall and the water collected in runoff meets the water requirements of human and livestock population. The water is collected in Tobas and most of them are located at inappropriate places due to their construction without giving due consideration to topographic

features. Resultantly, the water collected in tobas runs only for 3-4 months (Adeel and Safriel, 2008). To overcome this issue, (knuds) ponds on scientific lines at suitable points have been constructed in order to minimize losses and have a sustainable and successful fish harvest.

(1.6) Wildlife Resources

Cholistan Desert, in the past, had been rich in sustaining sufficient wildlife and mammals like: Rhinoceros, Lions, and Leopards and a huge number of gorgeous game birds. Un-wise and un-regulated hunting of the species like Lion, Cheetah, Leopard, Deer, Wild-boars etc. has made them disappeared whereas Blackbuck, Chinkara, Nilgai, and Bustards have been listed among the most threatened species. Although Wild Ass could be seen near border of the Pakistan - India yet its number is also dwindling. Desert cat and Wild boar have almost vanished whereas hare and other rodents can be seen. Among the birds, some species of Partridge, Quails and Sand Grouse still can be seen. However, the prominent fauna presently found in the desert includes: Swan, Jackal, Fox, Rabbit, Tiloor, Falcon, Wolf, Deer and Blue Bull (Akbar and Arshad 2000; Baig *et al.,* 2007).

(1.7) Agricultural Resources

Generally, it is believed that there is less possibility of realizing good rainfed crop production in areas receiving annual rainfall less than 300 mm. Obviously, Cholistan is no exception where annual rainfall is scanty and uncertain. Crop-based agriculture does not seem practicable due to non-availability of irrigation water hyper-arid harsh climate and undulating topography (Adeel and Safriel, 2008). Although water is the only and major limiting factor for agricultural production yet with the adoption of dryland agriculture technologies, some salt-tolerant crops can be grown with brackish water irrigation. Traditionally farmers of Cholistan do grow crops like guar, millet and crops whenever they get sufficient showers, capable of meeting moisture requirements of crops to be grown (Akbar and Arshad, 2000; Baig *et al.,* 2007). On vast areas of the desert, crop production could be possible by practicing saline agriculture (PCRWR, 2009). An account of vegetation, suitable for the drought and saline conditions is presented in Table -1.

(2) An overview of the Issues and Challenges Faced in Cholistan

In addition to the water shortage, the area faces other issues and problems making the life difficult for the human beings, livestock and plants/crops/vegetation. It is a less developed and under-privileged region the peculiar ecological zone with an acute shortage of drinking water and fodder/pasture for livestock. Infrastructure and communication means and facilities are absent and the region lacks educational facilities. Basic health facilities for humans and livestock are not available. Keeping in view the potential and importance of livestock sector, there is a dire need to develop and initiate an appropriate and vibrant livestock marketing system in association with industry related milk, wool and other products of animal source. The region lacks the financial or moral support for the cottage industry and local handicrafts. Injudicious over-grazing, indiscriminate deforestation and vegetation removal by locals remain the prime challenges. Issues like: erosion (due to lack of vegetation) and salinity and expansion of cultivation to marginal lands pose serious sustainability threats to the vegetation and the ecosystem.

(3) Suggested Sustainable Technologies and Strategies

Many workers like Khan *et al.,* 1996; Akhter and Arshad, 2006; Ahmad 2008 have been stressing the need for the development and launching of an integrated and comprehensive strategy that could reduce the unfavorable consequences of drought seen on plants, animals and humans. In the situation, short and long term action-plans are urgently needed for the development of the area. In the long term strategy, the development of irrigation sources and the scientific planning for the effective and efficient use of land and water deserve due attention. However based on the secondary data available in the literature and personal experience of the authors, a comprehensive strategy needs to be developed and a holistic approach adopted.

(4) Implications for Rural Extension to Develop the Desert of Cholistan

Since the creation of Pakistan, numerous well-

planned, multipurpose developmental plans and programs have been launched only on the high potential areas of the Indus Valley blessed with the world's biggest canal irrigation system. Primarily, these developmental programs baked by national extension service were aimed at addressing agricultural issues, bridging the yield gaps and enhancing agricultural production. However, none of them focused on the developmental aspects in the under-privileged harsh area like Cholistan due to its little intrinsic potential for agriculture. The following frame-work if implanted with letter and spirit can certainly bring elevate the livelihoods of the neglected populations living on the areas where animals and human beings drink water from the same ponds.

(4.1) Framework for Extension Education

Rural Extension has great potential, productive and positive role to play in popularizing the desert reclamation and farming technologies. It is anticipated that national extension service needs to undertake activities that could focus on cottage industries, local handicrafts, livestock rearing and its products, innovative farming technologies. The rural Cholistan - an area that remained neglected, under-developed and un-privileged for long, needs a long term rural development strategy and the holistic approach in order to realize the real development. Rural Extension has many implications in the overall process of development and a brief account is as presented as under:

(4.1.1) Rural areas, particularly in the desert of Cholistan have low literacy rates; therefore, it seems appropriate to educate them by adopting pictorial extension modes for disseminating the desired information.

(4.1.2) Today electronic media has emerged as a very strong and powerful instrument in transferring new information and it should be combined with other initiatives to disseminate the appropriate technologies on the development and reclamation of the desert.

(4.1.3) Most of the desert occupants operate below the poverty line. They may not have the television sets to get new information but they can afford to have Radio sets, therefore, Extension Service can use Radio for their education.

(4.1.4) Participatory approach has been very successful for assisting Extension service and building confidence among the rural communities. Therefore, Extension Service should adopt this approach to realize capacity building; elevate the technical skills of the farmers, rural development professionals, members of the civil society, and NGOs working in the desert development.

(4.1.5) Extension needs to produce more skilled and educated human resources through its capacity initiatives and training programs on integrated desert development and management to make Cholistan productive and self-sustainable.

Conclusions and Recommendations

Arid hot and dry climate and severe water deficit are factors making agriculture to be adopted and practiced on narrow strips. Range management and livestock rearing business can be very successful on areas having limited scope for agriculture. The problems like extreme scarcity of water, wind erosion, over-grazing, deforestation, salinity and expansion of cultivation to marginal lands are quite common to notice in the desert.

(1) Adopt the saline agriculture practices and use the brackish and saline water to grow crops and grasses.

(2) Water harvesting techniques should be adopted on mass-scale for the collection of run-off water.

(3) Techniques for the conservation of water like Sprinkler and drip irrigation etc. should be practiced.

(4) Desert does receive maximum radiation, therefore the use of solar devices to save energy remains an option.

(5) Explore the options of using photovoltaic system for the electrification of small villages faced with aridity.

(6) Cottage industries and local handicrafts can fight against poverty elevate the livelihoods of locals.

(7) Locals are extremely deprived of basic facilities like education and basic health units;

(8) Replace the present crop pattern with the drought and salt-tolerant crops with less water requirements.

All of the above discussion leads to conclude that masses of Cholistan are lagging behind almost in all civic facilities and services of life and there is a dire need to adopt a holistic approach that comprises of developmental initiatives and conservation measures to protect precious natural resources especially water.

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