


Alternative farming systems suitable for Kachchh region of Gujarat




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FOREWORD

The arid zone of India covers about 12% of the country's geographical area and occupies over 31.7 m ha of hot desert and about 7 m ha of cold desert. The production and life support systems in the hot regions are constrained by low and erratic precipitation (100-420 mm/year), high evapotranspiration (1500-2000 mm/year), and poor soil physical and fertility conditions. The Gujarat state accounts for 19.6 % of the arid area in the country. Agriculture in the arid areas is constrained by climate, soil, water and socio-economic status. Due to the various constraints the agriculture in these areas as such, is non-sustainable, and the yields are highly variable. The overexploitation of resources has been deteriorating the resource base. The studies carried out in the Kachchh region of Gujarat indicate the significance of different alternative farming systems that shall be helpful for developing sustainable and eco-friendly farming in the arid region. It would also simultaneously prevent the deterioration of natural resource base while improving the economic conditions of growers/ stake holders. The farming systems that are tested and validated on the real farming situations of the region are discussed in this publication. Different intercropping systems, medicinal crops (henna and senna), horti-silvi based production systems and integrated farming systems are some of the highlights in this publication. It is hoped that, if adopted by the farmers as per the availability of their resources, will improve the profitability and sustainability of the system, besides sustaining natural resource base in the region.

I appreciate the efforts of the authors for compiling the relevant information and bringing out this publication. I am confident that this publication will be very useful to the farmers and the extension agencies engaged in agriculture for improving the productivity and sustainability of agriculture in the region.

(N. V. Patil)
Director
CAZRI, Jodhpur

Date: 20 November, 2009
Place: Jodhpur

PREFACE

Kachchh is the largest district (45,652 sq km) in the state of Gujarat and the second largest district after Leh in India. The rainfall is scanty, erratic and irregular with annual average of 315.3mm, distributed in 10 rainy days (average of last 15 years). Apart from the climatic constraints, the area faces other problems. Soil related constraints include low organic matter status, inherently low soil fertility in terms of macro and micro nutrients, crusting, presence of hard pan and shallow soil depths. The region experiences declining water table and poor water quality. The cultivated land constitutes only 16 % of the total district area. The major crops in the district are pearl millet, sorghum, pulses like green gram, moth bean and cash crops like clusterbean, groundnut and cotton. Monoculture of commercial crops is prevailing in the region, which aggravates the depletion of resource base in this fragile eco-system. Realising the problems, field studies have been carried out by various agencies in the region to suggest alternative farming systems that can provide enhanced production without compromising on the resource base and the sustainability. The different alternative farming systems that have been tested are discussed in this publication. Intercropping of two or more crops is one of the options to maximise returns per unit area. Arid horticulture and Agri-Horti systems provide a good promise to the growers in this region. In the more degraded lands, pasture and silvipasture systems can better conserve the natural resource base and arrest from deterioration, apart from contributing to enhanced production of the animal husbandry and live stock sector. Certain models of integrated farming systems that combine animal husbandry with the crop production are also discussed.

We would like to thank all the scientists and researchers, whose contributions are used in this publication. We hope that the information contained in this publication shall be useful to the growers, the developmental agencies and the researchers in Kachchh region of Gujarat.

We express our sincere gratitude to Dr. K.P.R. Vittal, former Director, CAZRI for his constant encouragement and to Dr.N.V. Patil, Director, CAZRI, for his valuable guidance and help in giving this bulletin to its final shape.

Date: 20 November, 2009
Place: Kukma,Bhuj

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Contents

1. Introduction

The arid zone of India covers about 12% of the country's geographical area and occupies over 31.7 m ha of hot desert and about 7 m ha under cold desert. The arid regions of Rajasthan, Gujarat, Punjab and Haryana together constitute the Great Indian Desert known as Thar Desert that accounts for 89.6 % of the hot arid regions of India. In Gujarat, 6.22 m ha area is under arid zone which constitute 19.6 % of the total arid area of the country.

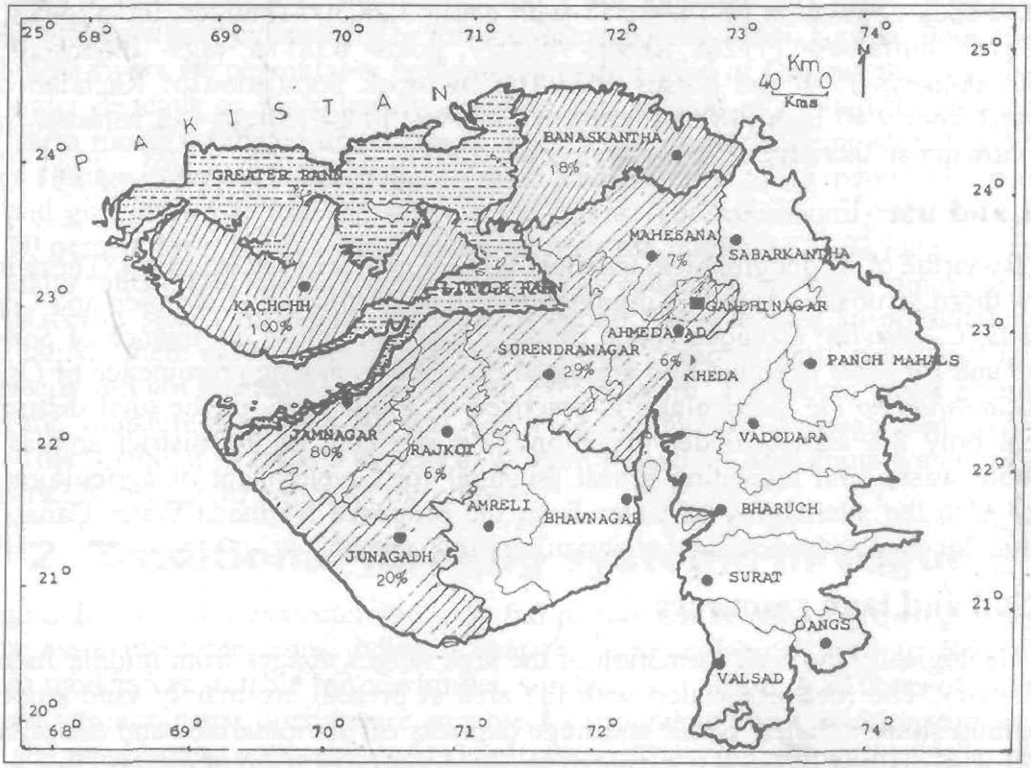

Fig. 1. Map showing the distribution of arid zones in Gujarat

The arid region in Gujarat is distributed in eight districts namely, Kachchh (100% of the district area), Jamnagar (80%), Surenderanagar (29%), Junagadh (20%), Banaskantha (18%), Mehsana (7%), Ahmadabad (6%) and Rajkot (6%) (Figure 1).

1.1. Climate

Kachchh district covers an area of 45,652 km^2 and the entire region is under arid zone. The average annual rainfall is 326 mm (based on 1972-94 data) which is highly variable and erratic leading to protracted droughts. Within a span of 23 years, six severe, three moderate and five mild meteorological droughts (IMD classification) were recorded. Apart from low and erratic rainfall, the region is characterized by high temperature (maximum 39-45 °C during May-June), high wind velocity (19-37 kmph during July) and high potential evapo-transpiration (251-266 mm during May-June). In the absence of favourable conditions for agriculture, livestock rearing is the alternative source of livelihood for the majority of the rural population in the arid region.

1.2. Animal resources

Animal husbandry is the major source of livelihood of the people in the district especially in northern part comprising areas like Banni. As on 2003, the district had a total livestock population of 14,98,351 with cattle 3,28,304 (indigenous -324488, cross bred-3816), buffaloes- 177268, sheep- 492077, goats- 458176, pigs- 26635, camels - 10477, donkeys-3596 and horses 1638.The livestock population of Kachchh district increased from 9.40 lakh (48 animals/ km^2) in 1962 to 14.13 lakh (73 animals/ km^2) in 1992 showing an increase of 50% (Arya *et al*., 2008).

1.3. Land use

By virtue of its geographical location, it has a number of ecosystems. These include the dry thorn scrub forests with a dominance of *Acacia nilotica, A. arabica* and *Capparis deciduas, C. aphylla*; a unique saline desert ecosystem with a dominance of *Salvadora oleides* and *Prosopis juliflora*, and grassland ecosystems having prominence of *Cenchrus sp, Dicanthium sp etc*. Agriculture is practised in about 16 % of the total district area, wherein only 2% area is under irrigation. Five per cent of the district area is under cultivable waste land indicating a vast potential for development of agriculture in the region. Also the availability of water from the proposed Narmada Water Canal would dramatically change the scenario of agriculture in Kachchh.

1.4. Soil and land resources

Geologically the rock formation of the area ranges in ages from middle Jurassic to late Tertiary. The rock associated with the area at present are mainly sand stone, lime stone, mud stone, schales, basalt and huge deposits of fluviomarine sand and mud. The CAZRI workers had grouped the soils of Kachchh into five textural groups (fine textured – 4.07 %, moderately fine textured- 3.98 %, medium textured- 3.02 %, coarse textured- 11.13 % and other miscellaneous- 63.1 %) and 32 soil series and 52 soil mapping units. The soil pH ranges from 8.0 to 9.0 and electrical conductivity from 0.22 to 29.15 $dScm^{-1}$. The soils are poor in organic carbon (0.28 to 0.62 %) and phosphorus (4-18 kg ha^{-1}) (Surendra Singh and Amal Kar, 1996). The available potassium is medium to high in these soils. The soils of Kachchh are deficient in micronutrients like Zn and Mn (Annual report, RRS, Bhuj, 2008). Coarse textured soils have the problem of excessive permeability leading to heavy loss of water and nutrients. The compact subsurface especially with shallow soils does not allow proper development of root systems in several crops and leads to decline in the yield. The soil salinity and alkalinity limits crop production, especially in Banni and its associated areas.

1.5. Water resources

There are very limited groundwater resources in Kachchh. The minimum depth to ground water is 10-20m. The discharge from open well is poor. The excessive ground water exploitation has led to increased salinity and deepening of ground water (Surendra Singh and Amal Kar, 1996).

Because of inadequate irrigation facilities from major and medium projects, minor irrigation continues to play a vital role in irrigation. Due to absence of mountainous region, the existence of Rann and the scanty rainfall, the region does not have many rivers. The few rivers rising from either the northern or the central ranges are Khari, Kayala, Poor and Paat. None of these rivers are perennial or navigable. In arid region of Gujarat, the availability of surface water depends on the intensity, duration and amount of rainfall. Out of the total 1482.71 mcm runoff estimated in the region, 847.38 mcm water is being stored in different irrigation storage reservoirs and village tanks. Thus, nearly 57.15 percent of runoff is surplus and goes as waste into the sea and the Ranns. The maximum probability of 340 mcm at 50 percent level is from Bhuj taluka whereas the minimum of 73 mcm is expected from Mundra taluka. Out of the twenty seven major ephemeral streams, runoff of twenty streams is being stored in twenty medium irrigation dams located in eight talukas. In Bhachau taluka, there is no medium irrigation scheme. Minor irrigation dams of below 1 mcm capacity are not normally provided with canal system. The stored water is useful to improve the moisture condition of soil and crop production (through bed cultivation system). This is similar to *Khadin* system in western Rajasthan. Maximum water utilization in the district is through irrigation of the crops.

2. Traditional farming systems in vogue

On the basis of soil characteristics, rainfall pattern and length of growing period, the suitability assessment for crops indicates that the agro-ecological zone in Banaskantha district are moderately suitable for pearlmillet, sorghum and maize. Arid areas of Jamnagar, Rajkot and Surendranagar districts are suitable for groundnut and moderate to marginally suitable for pearlmillet, sorghum, maize and castor. The crop suitability under rainfed conditions of arid Gujarat is in the order: pearlmillet> sorghum> maize> groundnut> tobacco> castor> cotton. The average productivity over the last 10 years is 857 kg ha^{-1} for pearl millet, 2669 kg ha^{-1} for wheat, 397 kg ha^{-1} for pulses, 248 kg ha^{-1} for clusterbean, 1420 kg ha^{-1} for castor, 1412 kg ha^{-1} for groundnut, and1194 kg ha^{-1} for mustard. Under irrigated condition, the crop suitability is in the order: groundnut> sorghum> castor> tobacco and cotton (Jain *et al*., 2003). The major crops of the Kachchh include cotton, groundnut, castor, pearl millet, clusterbean and sesame in *Kharif*. In rabi the major crops grown in the area include groundnut, cumin, wheat, mustard and coriander.

Horticultural crops are grown in about 18500 ha in Kachchh district. The major horticultural crops are date palm, mango, sapota, *ber*, banana, papaya, pomegranate and guava. The vegetable crops grown in the area are brinjal, potato, tomato, coriander, onion, chillies, ladies finger, cabbage, cauliflower, bottle gourd and bitter gourd. There are also medicinal plant growers who grow gugal, satavari, aloe vera, ashwagandha etc.

3. Constraints of the existing farming systems

The zone experiences multiple problems with respect to climate, soil, water, socio-ecological and technological fronts.

3.1. Climatic constraints

- Scanty, erratic and irregular rainfall: The rainfall in the taluk is scanty and is usually very uneven. The rains are mostly received as brief showers. Due to unevenly distributed rainfall, rainfed crops suffer from the moisture stress condition at their critical growth stages. Thus climate is the main factor for low yield potential of the region.

3.2. Soil and water related constraints

- Low fertility status of soils in terms of organic carbon, nitrogen, phosphorus, and potassium at some places and micronutrients like zinc, manganese and molybdenum.
- Crust formation in the soil, hindering germination and establishment of optimum plant stand.
- Shallow soil depth along with hard pan in subsoil restricting root growth of the plant.
- Declining water table of the ground water and degrading ground water quality.
- Intrusion of saline water in coastal belts.

3.3. Social constraints

- Migration of farming community.
- Indiscriminate use of fertilisers and overexploitation of ground water.
- Weakness of the cooperative rural credit structure.
- Inadequate rural infrastructure.
- Shortage of agricultural labour
- Poor economic condition of farmer.

3.4. Technological constraints

- Non availability of good quality seeds/planting material and insufficient amount of released crop/horticulture varieties.
- Inadequate availability in proper time, of inputs like fertilizer, pesticides and bio-fertilizers.
- Poor infrastructure of extension agencies.
- Low adaptability of modern and non-conventional practices like integrated soil management (crop rotation), integrated pest management and water saving measures.

4. Alternative farming systems and their economic viability

4.1. Intercropping

Intercropping is a form of multiple cropping that is prevalent in arid and semi arid regions of the country. The research evidences clearly established that intercropping system utilizes all the inputs more efficiently and is more sustainable and profitable than the sole cropping. The spacing, number of plants and their geometric arrangements play an important role in deciding the success and economic viability of any intercropping system. Considering the importance of intercropping in the arid zones, experiments were conducted to test the feasibility of different intercroppings in arid Kachchh region of Gujarat.

4.1.1 Castor + sesame intercropping

The studies on castor+ sesame intercropping (Figure 2) indicated that castor and sesame as sole crop produced 635 and 324 kg grain yield/ha, respectively. Though the adoption of intercropping in the row ratio of 1:3 decreased the yield by 27.4 and 17.3% over sole crops of castor and sesame, respectively, it was more than compensated by producing additional yield of intercrops (castor 461 kg ha^{-1} and sesame 268 kg ha^{-1}) in the system. Thus, the intercropping of castor+ sesame (1:3 ratio) gave the gross returns of Rs 16897 /ha with BCR of 1.40 as against Rs 12, 382 with BCR of 1.37 and Rs 9,558 with BCR of 1.39 by sole crops of castor and sesame, respectively. It is observed that intercropping sesame with other rainfed crops was more profitable than sole sesame under arid region of Gujarat (Devi Dayal *et al.*, 2009).

Fig. 2. Intercropping of castor with sesame

4.1.2. Castor + groundnut intercropping

The studies on intercropping castor with groundnut (Figure 3) revealed that sole crops of castor and groundnut produced an average yield of 570 and 150 kg ha^{-1}, respectively. The pod yield of groundnut reduced significantly due to deficient rainfall particularly during the reproductive stage (in September only 6.3 mm rainfall). The grain yield under intercropping was found to be reduced by 31.9% in castor and 16.6% in groundnut as compared to their sole crop treatments. However, considering the economics of the system, intercropping of castor + groundnut (1:3) gave gross return of Rs 11, 566/ha which was higher by Rs 1451/ha over the sole castor and by Rs 8,026/ha over the sole groundnut (Devi Dayal *et al.*, 2009).

Fig. 3. Intercropping of castor with groundnut

4.1.3. Sesame + clusterbean intercropping

The studies on intercropping of sesame + clusterbean (Figure 4) indicated that grain yield under intercropping system reduced by 28.8% in clusterbean and 40.4% in sesame as compared to their sole treatments. However, considering the net returns and BCR, intercropping of sesame with clusterbean (1:2) gave the maximum net returns of Rs 7,440/ha along with BCR of 1.80 compared with Rs 5,945/ha and BCR of 1.68 in sole clusterbean and Rs 2,851/ha and BCR of 1.37 in sole sesame. The Sustainable Yield Index (0.74) and Sustainable Value Index (0.76) were also higher in intercropping of sesame+ clusterbean (1:2) than that recorded by Sole sesame (0.73 and 0.73) and sole clusterbean (0.71 and 0.72). From the studies at RRS, Kukma it is concluded that intercropping involving clusterbean and sesame was more profitable and sustainable than their sole cropping (Meena *et al*, 2008).

Fig. 4. Intercropping of clusterbean with sesame

It was also demonstrated that intercropping of henna and clusterbean in 1:1 ratio may be followed to fetch higher net income.

4.2. Minor millets

Minor millets are crops of harsh environments. The crop has remarkable adaptability in arid environment owing to its drought tolerance and drought evading characters. The minor millets like finger millet, barnyard millet, foxtail millet etc are generally grown as rainfed crop in India. Alternative farming systems involving minor millets were evaluated for their performance at Bhuj. Two genotypes each of Proso millet (GPUP-19, K-1), Barnyard millet (K-1, VL-171), Foxtail millet (SIA-326, PS-4) and finger millet (VR-708, GPCL-26) were evaluated in 2003. Under the arid environments, the grain yield of these millets varied from 513 to 1785 kg ha^{-1}. Among these millets, fox tail millets gave maximum grain yield (1785.7 kg ha^{-1}) followed by proso millet (968.7 kg ha^{-1}) and finger millet (848.2 kg ha^{-1}). Variety PS-4 of foxtail millet, K-1 of proso millet, GPCL-26 of finger millet and VL-171 of barn-yard millet produced 29.0, 18.0, 2.0 and 17.0 % respectively, more grain yield compared to other varieties tested (Bhagirath Ram and Vyas, 2005).

4.3. Grain Amaranth

Grain Amaranth (*Amaranthus sp*) is a crop with multiple uses as food, fodder, medicine and industrial oil. Out of around 60 species of amaranth available world over, only four species namely, *A. hypochondriacus, A. caudatus, A. cruentus* and *A. edulis* are grown for grain. Amaranth grain possesses higher content of protein (16.0 %), lipids (8%) and minerals (3%) as compared to cereals.

The feasibility studies were conducted for amaranth cultivation in Kachchh, which was not a practice of the region due to want of irrigation. The varietal trial showed that variety GA-2 gave 19.3 % more seed yield than GA-1 (Figure 5). The studies revealed that application of nitrogen @ 90 kg ha^{-1} and irrigation of 200 mm water at four growth stages in equal quantity produced 8382 kg ha^{-1} dry biomass and 1206 kg ha^{-1} grain yield for the variety GA-2. A net economic return of Rs 20,000 were obtained and the study indicated that, cultivation of amaranths in Kachchh has a commercial viability and will be helpful for meeting the protein requirement in the diet (Vyas, 2007; Anonymous, 2009).

Fig. 5. Amaranth variety GA- 1 and GA-2

4.4. Henna

Mehandi "*Lawsonia inermis* L.", a bushy, glabrous, much branched shrub is often cultivated as hedge plant (Figure 6). The leaves of the plant contain dye "lawsone". The dye is used in colouring palms of hands, sole, nails and hair etc. It is utilized in printing of value – added textile product and dyeing of leather. Plant is also used as a prophylactic agent against skin diseases in the Indian system of medicine. Flower and seeds yield essential oils and fatty acids, respectively. The crop produce is in high demand in export market which fetches considerable foreign exchange in national exchequer. This is being extensively used as a cash crop for arid wastelands of Rajasthan. Looking to the importance of the crop, its suitability as a crop for arid Gujarat was studied and agro techniques were developed.

Figure. 6. A field view of Henna crop

Nursery preparation, planting and harvest: Henna can be propagated by cuttings as well as seedlings. The seeds require scarification by soaking in water, 60% HCl or H_2SO_4. The seed rate recommended is 10-12 kg ha^{-1}. Sowing is done in March on a nursery bed of size 30 m^2 that would be sufficient for planting one hectare. 10 t FYM, 40 kg nitrogen and 20 kg phosphorus per hectare are applied to the nursery before sowing. Watering is essential at every 2-3 days up to 1 month and weekly afterwards. Transplantation can be done during June-August when the seedlings attain 30-40 cm height. The main field is prepared by 2-3 deep ploughing. FYM @ 10-12 t/ha is applied along with field preparation. 50 kg nitrogen and 40 kg phosphorus per hectare is applied at planting. Seedlings are transplanted at a spacing of 30x30 cm after detopping both main stem and taproot. The crop starts yielding from 2nd year onwards and continues to yield up to next 25-30 years. Harvesting is done twice in April-May and October-November.

The studies indicated that decreasing light intensity increased shoot growth and lawsone content but decreased the dye concentration in leaf tissue (Vyas, 2004). Thus, the crop can be grown along with the multipurpose trees and in the orchard of fruit plants like mango, aonla etc. (Vyas and Swamy, 2003). The spacing trials were conducted with 40 X 40, 40 X 50 and 40 X 60 cm spacing so as to get a plant population of about 62,500, 50,000 and 41,700 plants per hectare, respectively. The study revealed that maximum dry leaf yield was obtained at the plant population of 50,000 plants per hectare at which the plant developed highest leaf: stem ratio. Net maximum returns were also obtained at the plant population of 50,000 plants per hectare (Rs.16, 346) followed by Rs.13, 216 and 10,443 under the plant populations of 41,600 and 62,500, respectively against the investment of Rs. 3000 per hectare (Vyas, 2005). Even during bad rainfall years (52.9 mm), henna could provide a net return of Rs.6331 per hectare at Bhuj. The full packages of practices have been developed at CAZRI, RRS, Kukma-Bhuj.

Fertiliser and manure

Application of bio fertiliser like *Azospirillum*, P-solubilising bacteria alone or in combination to 3 year old ratoon crop found to increase the leaf yield by 20.9, 15.9, and 11.6 %, respectively over the unfertilized control (Vyas and Purbey, 2005).

4.5. Senna

The spacing of 40 x 40 cm and the fertilizer application of 100 kg N/ha & 40 kg P/ha was found optimum for the region. Under normal rainfall situation, a total dry matter yield of 522.6 kg ha^{-1} was obtained which produces 290.3 kg material of medicinal value. This gave a net economic return of Rs. 3020 per hectare (Annual report, RRS, Bhuj, 2004).

4.6. Arid horticulture

Horticultural crops are grown in about 18500 ha in Kachchh district. The major horticultural crops are mango, date palm, sapota, papaya, citrus, guava, ber and pomegranate.

4.6.1. Cultivation of Mango

The mango cv. Kesar is cultivated in large area in the region and the produce is mostly exported.

4.6.2. Date palm cultivation

Date palm is an important traditional horticultural crop in the Kachchh region. Pareek and Sodagar (1986) divided the date palm growing region of Kachchh into three zones, namely, Zone-1), the areas very near the coast, having deep coastal soil and very high ground water level (1-3 m), Zone-2), the area away from the coast, with shallow to deep sandy soils and deep ground water level (10-20 m) and Zone-3), the area on the sides of rivulets, rivers and nalas and valleys between the hills, where rain water accumulates.

The overexploitation of the soil and water resources for intensive agriculture of crops like cotton, groundnut and castor has led to degradation of land by increased salinity. The date palm cultivation comes up well in these lands, where climatic features are conducive, due to the saline hardy nature of the crop. In Kachchh, date palm cultivation is concentrated in Mundra which supports 7300 hectares of plantation. The other date palm growing areas are Bhuj (790 ha), Anjar (1808 ha) and Mandvi (870 ha).

The local varieties are Yakubi, Ganshyam, Neelkanth and Harikrishna. The imported off shoots varieties which are use in the region are Barhee, Halawy, Khadrawy, Zahidi, Hayani, Bint Aisa, Medjool and Ameri. The varieties introduced to the region through tissue culture are Khunaizi, Medjool, Zaglool, Khasab, Ford and Khalas. The propagation is by seeds, offshoots or tissue culture. In the initial stages of establishing new plantations, intercrops like groundnut, cucurbits, etc can provide profitable income (Figure 7). Harvesting starts from 15^{th} July onwards and continues up to end of August. Date palm starts yielding at 4-5 years age (10-20 kg/plant) and economic production starts after 8-10 years (100-120 kg/plant) and the trees remain productive for a very long period. Trees of even 40 year age have been seen bearing heavily.

Fig. 7. Intercropping of groundnut with date palm in the initial stages of plantation establishment

4.6.3. Ber cultivation

The Indian ber known as jujube is one of the important cultivated fruit crops in the arid areas of India. Ber is a versatile crop. The fruits are rich in vitamin C, A and B complex and sugar and minerals like calcium, magnesium and zinc. Three ber fruits can meet the daily dietary requirement of ascorbic acid of adult man (Meghwal et al., 2007).

The various products like preserve, candy, jam and drink can be made out of the fruit. Gola, Seb, Kaithli, Banarasi Karaka, Maharwali, Umran, Meharun, Mundia are the important varieties. The harvest season in North India is from December to March and in South India from October to November. The harvesting is done by manual picking. Four to five pickings may be required since all the fruits do not mature together. The harvesting is to be done in the early morning. After harvest the fruits are to be precooled and graded.

In budded plants, the fruits are to be removed in the first two to three years and the major emphasis must be to train the tree to a proper shape. The fruiting should be allowed from third year onwards only. The peak fruit production is reached at 8-10 years of planting. The economic yield can be obtained up to 40 years depending upon care and management. The fruit yield per tree ranges from 80 to 200 kg.

Growing of *Gola* and *Seb* cultivars of ber under the spacing of 6 x 6m with other recommended practices for the region will be beneficial to the farmers. The doses of manures and fertilizers should be applied as per the age of the plant (Figure 8).

Fig. 8. Performance of Gola variety of Ber at Bhuj

4.6.4. Aonla cultivation

Saucer type planting pits by virtue of their more water harvesting capacity support better plant growth of aonla compared with trench type or normal pits. The other fruits i.e. pomegranate, custard apple, mango, bael and date palm under saucer type pits are also suitable for the region (Annual report RRS, Bhuj, 2006).

4.7. Agri- Horti systems

Agri-Horti system encompasses a combination of agriculture and horticulture enterprises combined together for the best utilization of land and other resources. This land management system aims at production of both agricultural crops and fruits. This practice can be adopted till 5-6 years or till canopy of trees becomes fully closed. If the fruit trees are widely spaced agriculture crops can be simultaneously grown. The practice is highly beneficial in fruit trees like ber which require pruning.

Trials were conducted at RRS, Kukma to develop viable agri-horti models suitable for the region. The horticultural components studied included ber, pomegranate and aonla and crops included clusterbean cv. *Maruguar*, cowpea cv. *GC-3* and moth bean, *CZM-2* (Figure 9 and 10). The results indicated that significantly higher plant height and number of pods per plant of clusterbean, cowpea and moth bean were observed under fruit plantations than their sole cropping (Table 1). Among the different land use systems, the maximum plant height and number of pods per plant of clusterbean, cowpea and moth bean under plantation of ber were observed and were higher than that under pomegranate and aonla.

Table 1. Effect of various alternate land use systems on growth parameters and yield of aonla, ber and pomegranate

Treatment	Plant height(m)	Plant spread (m) E-W	Plant spread (m) N-S	Fruit yield (kg/tree)
Aonla sole	2.16	1.11	1.29	-
Aonla + clusterbean	2.24	1.19	1.34	-
Aonla + cowpea	2.19	1.14	1.29	-
Aonla + moth bean	2.21	1.16	1.32	-
SEm±	0.042	0.032	0.029	
Ber sole	4.55	4.48	4.07	41.25
Ber + clusterbean	4.61	4.62	4.24	41.80
Ber + cowpea	4.56	4.51	4.11	42.45
Ber + moth bean	4.59	4.59	4.23	42.80
SEm±	0.034	0.056	0.068	0.72
Pomegranate sole	1.45	1.57	1.52	-
Pomegranate + clusterbean	1.51	1.63	1.57	-
Pomegranate + cowpea	1.47	1.59	1.55	-
Pomegranate + moth bean	1.50	1.61	1.57	-
SEm±	0.024	0.029	0.020	

Fig. 9. Alternate land use system involving combination of ber with arid legumes

Fig. 10. Alternate land use system involving combination of pomegranate with arid legumes

4.8. Pasture grasses

Grass is the main feed of most ruminant animals in many parts of the world. Grasses are herbaceous with annual or perennial habit and belong to family gramineae.

The trials conducted on *Lasirus sindicus* at RRS, Kukma-Bhuj indicated that the dry matter yield depending upon the rainfall (92.7 to 390.2 mm) varied from 22.6 to 16.45 t/ha (Vyas and Yadav, 1999). The studies on relative performance of prominent grasses under varying rainfall situation in Kachchh revealed increase in forage yield with increase in rainfall, with the forage production following the order, *Lasirus sindicus*> *C. ciliaris* > *C. setegerus* (Figure 11 and 12). The dry matter production of grasses increased by 86.1 % and 21.6 % when the rainfall was 115.0 % and 38.3 % above the average rainfall of the region (Vyas, 2003). The varieties of grass species *Cenchrus ciliaris* like Marwar Anjan, found to be consistently superior in terms of fodder production irrespective of considerable variation in the annual rainfall in the Kachchh region (Sudhakar *et al*, 1994).

4.8.1. Germplasm Evaluation

The evaluation of thirty-six germplasms of prominent grasses viz. *Cenchrus setigerus* (24), *Dichanthium annulatum* (6) and *Sporobolus marginatus* (6) collected from different parts of Kachchh region during *kharif* 2004, showed that genotype BH/CS-5 of *Cenchrus setigerus* and BH/DA-3 of *Dichanthium annulatum* performed better in respect of plant height, number of tillers per plant and tussock diameter. Maximum dry fodder yield was produced by *Lasiurus sindicus* (6,153 kg) followed by *Cenchrus ciliaris* (1,360 kg) and *Cenchrus setigerus* (1,188 kg) in a hectare of land (Annual report, RRS, Bhuj, 1998-99).

Fig. 11. A field view of *Cenchrus ciliaris*

Fig. 12. A field view of *Cenchrus setegerus*

4.8.2. Varieties

The improved varieties are Marwar Anjan (CAZRI-75), Bundel Anjan (*Cenchrus ciliaris)*, Marwar Dhaman (*Cenchrus setegerus)* and CAZRI-30-5 *(Lasirus sindicus)*

4.9. Silvipastoral system

In the dry areas, some grass species like *Cenchrus ciliaris, Cenchrus setigerus, and Lasirus sindicus* etc which are very well adapted to such harsh climate, perform well and make natural rangelands. The climax tree species like *Prosopis cineraria, Prosopis juliflora, Acacia nilotica, Zizyphus numularia* etc come up in these range lands and make a silvipastoral system. Animal husbandry flourishes in such locations and forms an integral part of the prevailing farming system. Silvipastoral studies were conducted at RRS, Kukma with combination of trees like neem, acacia and subabul and grasses namely *C. ciliaris* and *C. setegerus* (Figure 13). Neem + grasses combination was found to be most adapted silvi-pastoral system for the Kachchh region in term of both grass yield and tree growth (Figure 14). Among the grasses, *Cenchrus ciliaris* was found to be superior to *C. setegerus* in terms of fodder production (Annual report, RRS, Bhuj, 1996-97). Total number of tiller per grass plant and dry fodder yield of grass did not differ significantly due to association of trees with grasses in a silvipasture system (Devi Dayal *et al.*, 2008). The importance of pasture/ silvipastoral systems in improving the fertility status especially organic carbon and potassium of degraded soils has been demonstrated. With 20 years of cultivation under silvipastoral/ pasture systems, the soil organic carbon under grasses improved from 0.47 to 0.58 % in the surface layers and 0.23 to 0.28 % in the lower layers, potassium from 470 to 616 kg ha^{-1} in the surface and 197 to 284 kg ha^{-1} in the subsurface layers (Shamsudheen *et al.*, 2009).

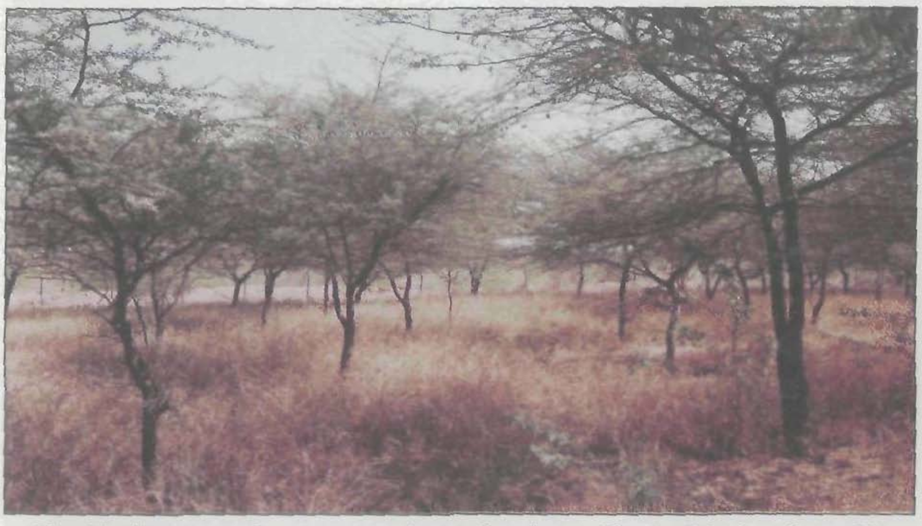

Fig. 13. Silvipasoral system involving *Cenchrus ciliaris* with *Acacia tortilis*

Fig. 14. Silvipasoral system involving *Cenchrus ciliaris* with *Neem*

4.10. Integrated Farming systems

The studies were conducted at SD Agricultural University, Sardar Krushinagar, Gujarat, to develop integrated farming systems for arid and semi arid regions of Gujarat. Three farming system models have been suggested for arid and semi arid conditions of North Gujarat (Patel *et al*., 2007a).

(A) Crops + dairy + horticulture + vegetable + floriculture + vermiculture

(B) Crops + dairy (buffalo) + cross bred

(C) Crops (existing + high tech agriculture) + dairy + cross bred

Crops: Pearlmillet (0.44 ha) - wheat (0.44 ha), mustard (0.22 ha) - pearlmillet (0.22 ha), hybrid cotton (1 ha) - fodder sorghum (1 ha)

Dairy: Buffalo (6 animals), Horticulture: Papaya (0.04 ha), Floriculture (0.06 ha)

Crops: Pearlmillet (0.50 ha) - mustard (0.25 ha)

Dairy: Cross bred buffalo (1)

Crops: Castor + pearl millet (0.50), hybrid cotton (1.00),

Dairy: Cross bred buffalo (1), (Patel *et al*., 2007b)

Resource allocation for different size of dairy units with crop production

Unit	Area (ha)	Farming system	Commercial crops (%)	Fodder crops	No. of buffaloes
A	2	Arable farming	100	00	0
B	2	Crops + livestock	75	25	3
C	2	Crops + livestock	50	50	6
D	2	Crops + livestock	25	75	9
E	2	Dairy farming	00	100	12
Total	10				30

Out of five alternatives of dairy unit and crop cultivation combinations, a dairy unit of 6 Mehsani buffaloes with 1 ha commercial crops and 1 ha fodder crops gives maximum input-out ratio (Patel *et al.*, 2007b).

5. Constraints in adoption of alternative farming systems

Although many technologies are developed at research institutions, its adoption by farmers is decided by many factors/ constraints as given below.

i) Technological constraints

There are technological constraints like timely dissemination of technologies developed by research institution to the farmers.

ii) Socio-economic constraints

The inclusion of modern technologies developed, in the existing farming system of the farmers are well decided by its economic feasibility. Any technologies worth giving more income than what is provided by the present technologies are soon adopted. In case of small and marginal farmers, the adoption is decided by the input requirements.

6. Logistic and policy support needed to overcome the constraints

The increased pressure of population and other uses of land and water in the region will change the present scenario of agriculture and the area under alternate land use system will increase in the near future. For sustained growth and economic returns, the farmers should get the inputs like seeds, planting materials, fertiliser and pesticides in time. Also the training on improved production techniques and post harvest products will be necessary. Marketing support for the produce from alternate farming systems like fruit production, henna etc will be essentially required. Policy change in terms of support price, availability of inputs and training in modern post harvest methods will go a long way in developing production, processing and marketing chain so that the economic and eco-friendly development of the region can be sustained.

7. Expected change in scenario of arid zone agriculture with the adoption of these systems

At present only 16 % of the total area of the Kachchh district is under agriculture. About 5 % of the district area is cultivable waste land which can be utilised for economic cultivation of orchards, grasses and other alternate land use systems. Since the ground water is of poor quality and soils are deficient in major and micro nutrients, the scope of alternate land use system is more in this fragile ecosystem. The research conducted in this region clearly indicate the superiority of orchards, agroforestry and other alternate uses to the traditional farming systems in terms of economic returns and environmental protection. Therefore, adoption of alternate land use systems will improve not only the sustainability of ecosystems and the economic condition of the farmers, but also the overall development of the region as it will promote a number of small cottage industries in the field of post harvest technology.

8. Conclusions

The arid region of Gujarat is spread in eight districts covering about 6.22 mha. The soils of the region are mostly sandy and are deficient in major and micro-nutrients. The rainfall is scanty, erratic and ground water is of poor quality. Under these circumstances, animal husbandry and horticulture based systems are more sustainable than the arable farming. The studies conducted for alternate land use systems in the region clearly indicate that as per land suitability, orchards namely, mango, sapota, date palm, ber, aonla etc can be grown successfully with sustained economic returns. The other options like growing of henna, senna, minor millets and medicinal plants are also sustainable and will improve the overall profitability of the system. In more degraded lands, agroforestry, pasture development etc can be maintained, so that quality fodder can be produced which will boost the animal husbandry and milk production in the region. The research studies also indicate the beneficial effects and economic sustainability of intercropping system over sole cropping.

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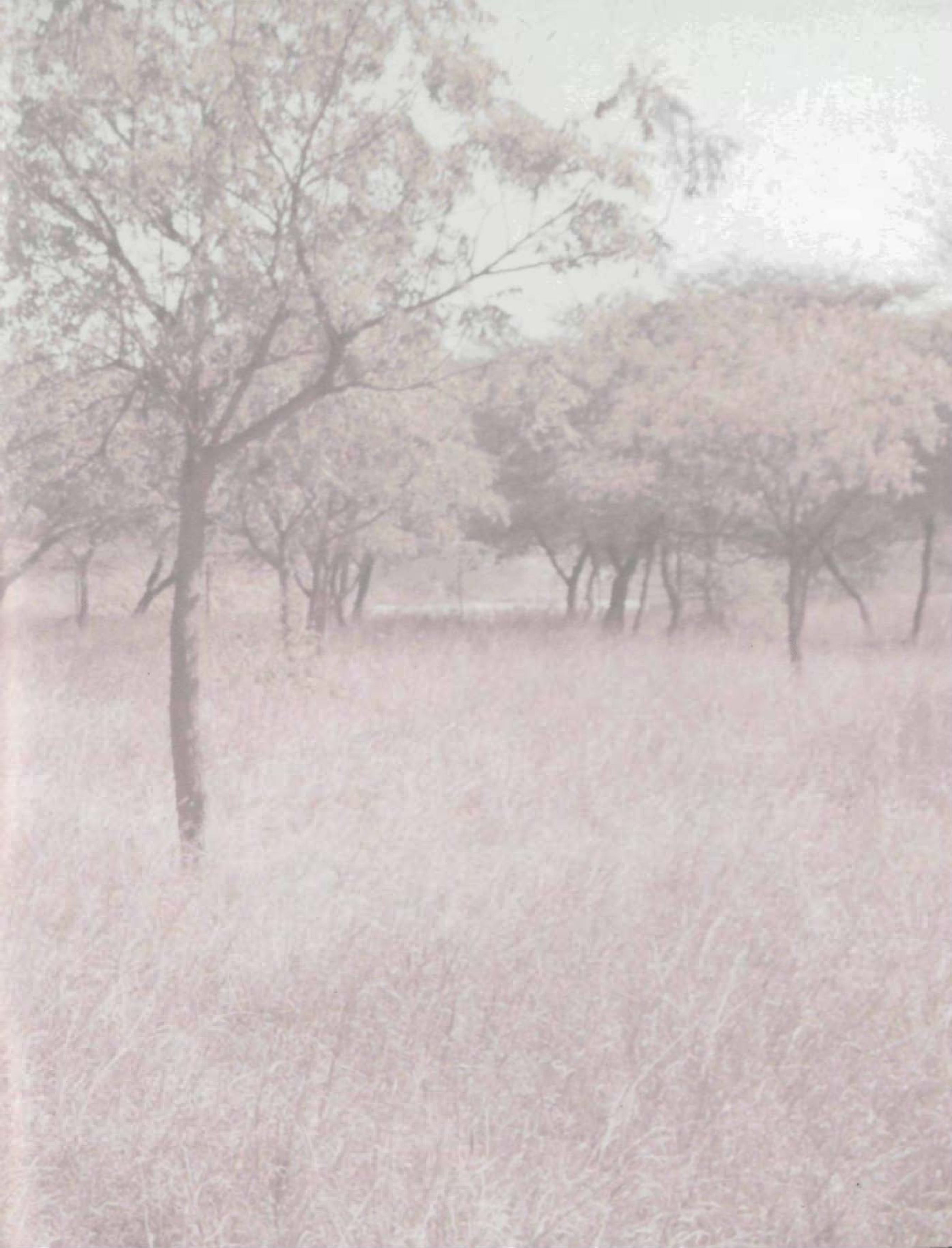


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