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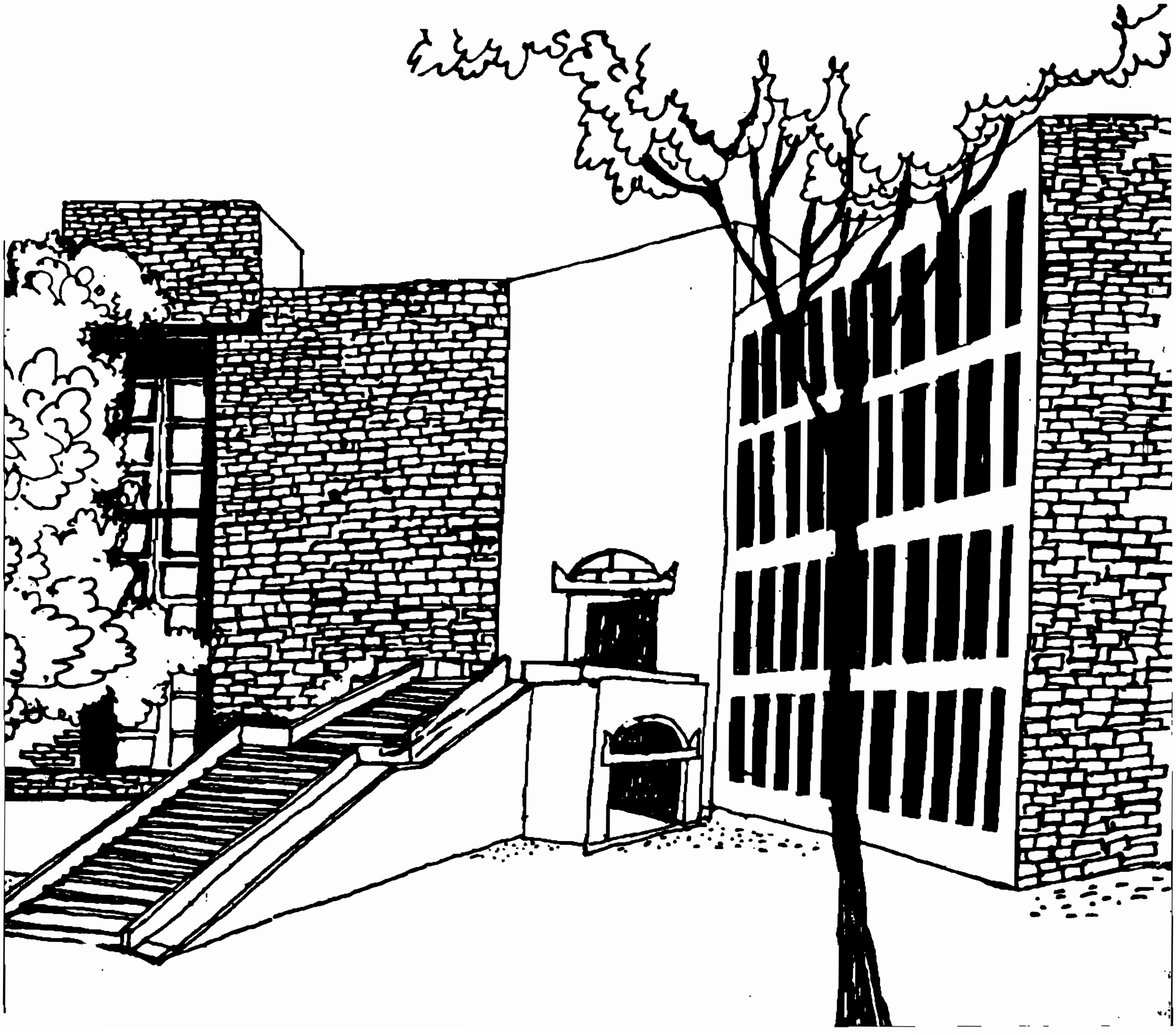

ENGINEERING THE AGRICULTURE IN KUTCH: FODDER FACTORY-I

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Agriculture

Kutch district lies in the north-west corner of Gujarat state. Agriculture and animal husbandry are the two main occupations there. Despite special efforts made by the government, the productivity of farm and grass lands in the district remains low.

Local production of fodder falls short of demand by a wide margin. Even in normal times, hay is imported from other parts, usually south Gujarat. In drought years which occur frequently, problem becomes especially acute. Cattle breeders take their stock out of district for long periods to pre-arranged locations for grazing. They return when rains set-in and grasses grow again in Kutch. Long journey to and from distant locations leads to increased loss of stock.

In this paper we discuss the main agro-climatic features of Kutch with a view to identifying technology needed to increase productivity of farm and grass lands.

Agro-climatic Features

Low productivity stems from harsh agro-climatic features of the district. Annual rainfall at Bhuj, the district headquarters, averages to only 400 mm. The rainfall is also very erratic as indicated by coefficient of variation which is 60%. Only crops with low water requirement such as millets, sorghum can be grown in rainy season. The yields of rainfed crops and grasses will be low and fluctuate significantly from year to year.

High ambient temperatures (figure 1) and windy conditions impose high evaporative demand. Annual pan evaporation in the year, 1990 at the same station was 1841 mm. **Figure 2** shows the mean monthly evaporation and rainfall. As can be seen, evaporation is considerably higher than the precipitation. There will be net moisture deficit practically all the time. Crops can not be raised beyond the rainy season without frequent irrigation. Not surprisingly, the land use data shows that only a very small proportion (5-10%) of the 'sown area' is double cropped. **Figure 3** shows the variation of relative humidity during the year.

Groundwater Quality

Presence of salts in soil or water causes a variety of problems. First, excessive salt content reduces availability of water to crops, adversely affecting the yield. Relatively, high sodium or low calcium reduces the water infiltration rate. Ions like sodium, chlorides and boron cause toxicity[1].

Water Quality for Agriculture [1] gives the guidelines to judge the suitability of water for irrigation. For instance, water with EC_e of <0.7 ds/m can be used for irrigation without restriction. Water with EC_e of 0.7-3.0 ds/m will have 'slight to moderate' and EC_e >3 ds/m 'severe' restriction on use. We obtained data on water quality from three different sources. These are discussed below.

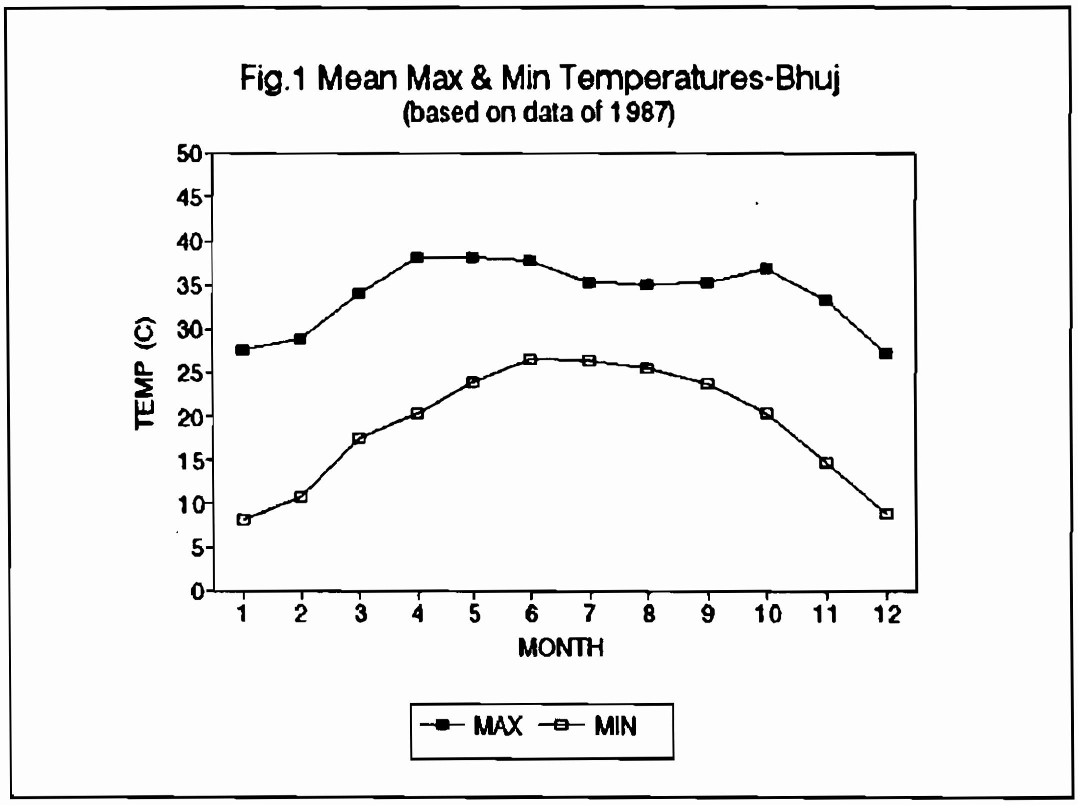


Fig.1 Mean Max & Min Temperatures-Bhuj
(based on data of 1987)
TEMP (C)
50
45
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
MONTH
MAX
MIN

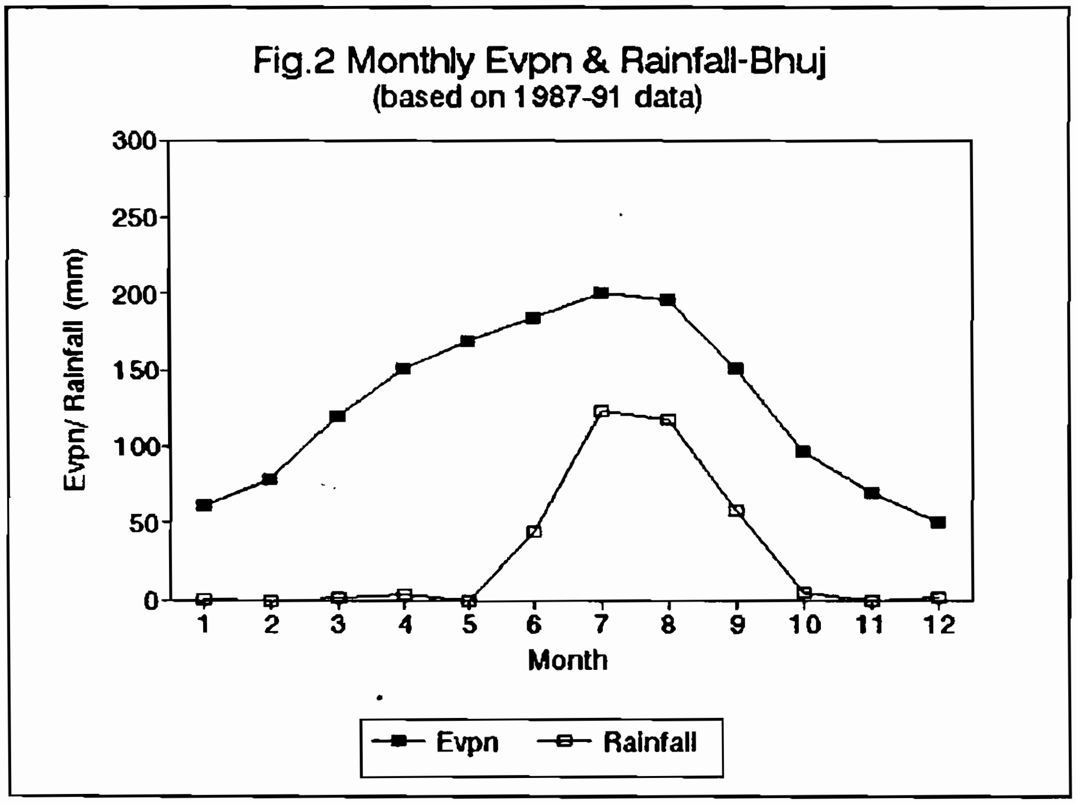
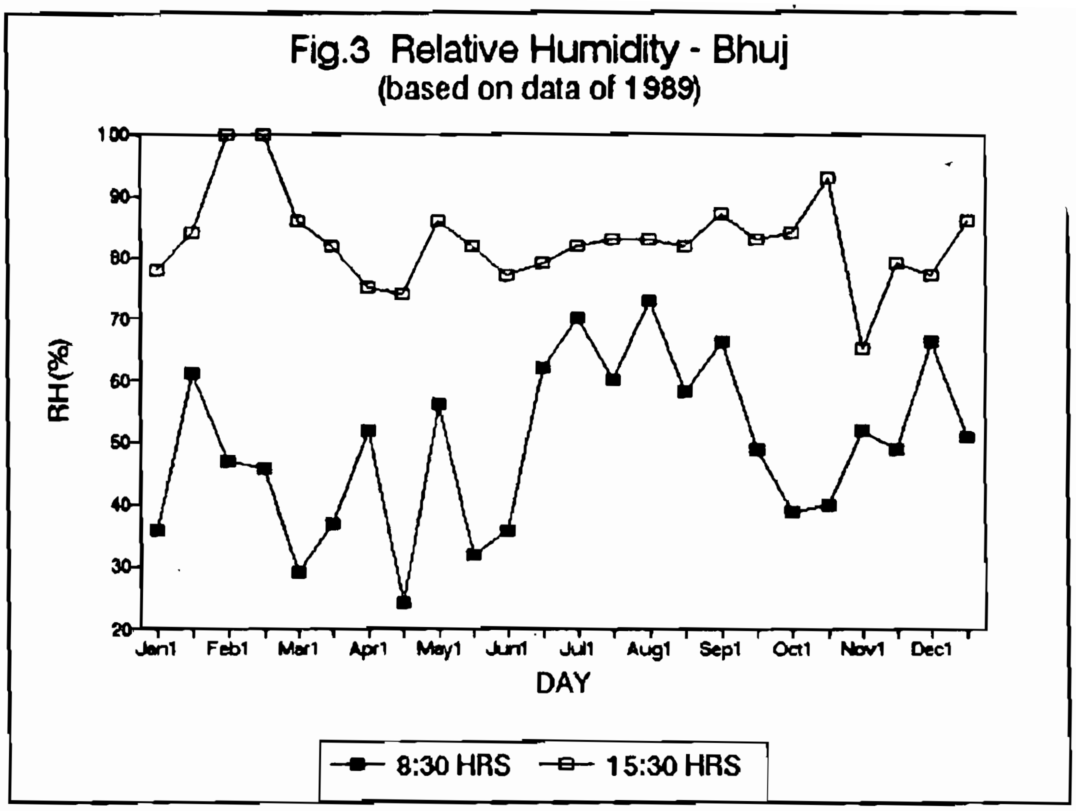


Fig.2 Monthly Evpn & Rainfall-Bhuj
(based on 1987-91 data)
Evpn/ Rainfall (mm)
300
250
200
150
100
50
0
1
2
3
4
5
6
7
8
9
10
11
12
Month
Evpn
Rainfall



Groundwater Resource Development Corporation (GWRDC) of Gujarat has collected extensive data on groundwater quality from a grid of observation wells. **Table 1** shows data of seven locations in Bhuj taluka. GWRDC officials indicated however that many of the observation wells are shallow bore-wells located near percolation tanks. As a result, the salinity levels indicated may be lower than what would really be the case in water from deeper aquifers. Nonetheless, the table shows that water at five locations will have severe and at remaining two moderate restriction on use.

Several agencies (including some non-government) are working on some or the other aspect of agriculture in Kutch. One such is the Gujarat Energy Development Agency (GEDA) which has undertaken five energy plantation projects. Depending on their need these agencies have done water and soil tests of their project sites. GEDA has done such tests at five sites, one of which is in village Latheri. Chemical analysis of water from four of the 22 wells of this village is given in **table 2**. Water of only one well (# 22) is suitable for irrigation.

We also obtained water quality data from several sites where gravity irrigation works have been built by the department of irrigation. These are shown in **table 3**. Out of six locations, one has water suitable for irrigation, four have 'moderate' and one 'severe' restriction on use.

On one hand, dry and hot weather imposes large evaporative demand on crops in Kutch. On the other, supplies of good quality groundwater is low. This will call for techniques of irrigation that can bring about dramatic increase in water use efficiency. Techniques that can enable one to use saline water directly for irrigation will be even more valuable. Microwatering systems are reported to be effective on both counts. These will need to be tried out and promoted at large scale.

Table 1
Water Quality of GWRDC Observation Wells (Bhuj Taluk)

Well location	Static water level (m)	EC_e (ds/m)	pH	HCO_3 (mg/l)	Cl (mg/l)
Lodai	19.10	3.264	7.8	366	760
Kurria	bore	3.432	7.8	427	880
Khavda	10.70	1.423	7.8	207	304
Jhara	19.60	10.040	7.6	793	2760
Desholpur	40.00	3.515	7.8	427	920
Bharapar	17.70	0.837	8.0	329	96
Chokar (W)	29.40	3.264	8.0	549	720

Note: EC_e was calculated from measured values of TDS.
Source: GWRDC records

Table 2
Water Quality of some Wells at Latheri (Kutch)

Parameter	Well # 22	Well # 1	Well # 2	Well # 18
Salinity				
EC (mmho/cm)	2.8	6.2	8.4	11
TDS (ppm)	1790	3970	5380	7040
Cations and Anions				
Ca^{++} (me/l)	2	2.2	2.2	2.4
Mg^{++} (me/l)	3	3.4	3.4	3.8
Na^{+} (me/l)	-	-	-	-
Cl^{-} (me/l)	16	19.6	24.8	28.2
CO_3^{--} (me/l)	2	2	2.2	2.4
HCO_3^{-} (me/l)	3.8	5.6	5.0	5.6
SO_4^{--} (me/l)	-	-	-	-
RSC	0.8	2.2	1.6	1.8
pH	7.8	8	8.1	8.1

Note

(a) Water of well # 22 is suitable for irrigation in all respects except CO_3^{--} which is high (usual range 0 - 0.1 me/l).

(b) Water of well # 1, # 2, # 18 will have severe restriction on use on account of salinity CO_3.

Source GEDA Field Office, Bhuj.

Table 3
Ground Water Quality at Selected Sites in Kutch

Site	Wells observed (no.)	Water level (m)	EC_e (ds/m)	pH
Bandi Irrigation Scheme, Rantadia (Bhuj)	9	3.30 - 9.40	0.50 - 3.40	7.70 - 8.30
Beraachia Irrigation Scheme, Bhavanipur (Abdasa)	5	3.75 - 9.60	0.69 - 1.63	7.40 - 8.00
Beraachia Irrigation Scheme, Beraachia (Abdasa)	3	5.50 - 5.80	1.25 - 3.60	7.60 - 7.90
Bitavaladia Irrigation Scheme, Kumbharia (Anjar)	5	4.10 - 10.00	3.44 - 12.81	7.40 - 7.80
Don Irrigation Scheme, Don (Mandvi)	8	75	1.20	8.20
Banni Area	12	1.50 - 11.00	1.10 - 8.90	7.10 - 8.90

Source: Three Decades of Soil Survey Organisation, Vol.II (1958-88), Superintending Engineer Soil, Drainage and Reclamation, Irrigation Department, Vadodara, Gujarat.

There are some locations where good quality water is found. The possibility of blending good with bad quality water to increase irrigation also exists. It may be necessary also to develop solar stills that require less space and yield high output. These can then be used as source of water for blending.

The problem of high water demand imposed by atmosphere can be ameliorated by growing plants--not in open field--but in enclosures or greenhouses. Moisture loss from vegetation inside greenhouses is reduced. Firstly, because hot wind blowing past the crops is eliminated. Secondly, the atmosphere inside the greenhouse becomes more humid than outside, reducing the ET of the vegetation. Mears[2] in a recent paper has outlined possible opportunities for greenhouses in India. He stated,

> "while a greenhouse is generally regarded as necessary to provide a warm environment in cold climates, it has also been shown that with properly designed cooling system it is possible to improve plant growing conditions under extensively hot conditions. Adaptation of modern cooling technologies to Indian conditions will undoubtedly lead to increased opportunities for production of high value plants and materials in areas where the environment is extremely harsh. Protected cultivation also has the potential benefit of substantially increasing plant productivity per unit water consumption which is important in many areas where good quality water are severely limited".

It was seen above that good quality water is severely limited in Kutch. Greenhouses could be a means to enhance water productivity. But in view of high ambient temperatures, it will be necessary to develop effective and cheap cooling mechanism.

Soils

Soils too in Kutch are salt-affected. Gujarat has 1.21 m.ha. of salt-affected soils. Major portion of these (40%) is in Kutch. **Table 4** shows the soil quality data in the command of the same irrigation works whose water quality was discussed earlier.

Table 4
Soil Quality at Selected Sites in Kutch

Site	Depth class	WHC (%)	Perme-ability (cm/hr	EC_e (ds/m)	pH	ESP	CEC (meq/100 gm)
Bandi Irrigation Scheme, Rantadia (Bhuj)	very deep	10.1-45.8	2.84-13.70	0.15-0.50	7.9-8.5	0.18-7.09	4.56-13.34
Beraachia Irrigation Scheme, Bhavanipur (Abdasa)	deep to very deep			<1	7.7-7.9		
Beraachia Irrigation Scheme, Beraachia (Abdasa)	very deep	23.2-51.0	0.28-1.70	0.10-0.69	7.4-8.5	0.50-1.60	10.10-28.00
Bitavaladia Irrigation Scheme, Kumbharia (Anjar)	moderate to very deep	29.5-68.8	0.19-3.88	0.34-1.57	7.4-8.4		
Chhari Irrigation Scheme, Chhari (Nakhtrana)	deep to very deep	24.45-61.94	0.09-34.23	0.40-3.70	7.4-8.5	<25	10.50-23.40
Don Irrigation Scheme, Don (Mandvi)	very deep			1.00-1.40	8.0-8.5		
Banni Area	deep to very deep			1.00-15.00	7.1-8.5	0.16-69.49	5.60-4.30

Source: Three Decades of Soil Survey Organisation, Vol.II (1958-88), Superintending Engineer Soil, Drainage and Reclamation, Irrigation Department, Vadodara, Gujarat.

Conditions that prevail in Kutch are also found in some other parts of the country as well as elsewhere in the world. Accordingly, efforts are being made at several places to find way to grow crops in arid areas, using saline water. We shall review some works that deal with growing plants and crops in arid regions similar to Kutch.

Some Experiences from Arid Areas

Hassan[3] raised potato and squash on two locations near Kuwait city. Soils were sandy in both locations. At the location where potato was grown pH of soil was 8, and ECe 1.8 ds/m. It may be noted that this is very similar to the soils at Latheri described earlier. Groundwater used for irrigation had salinity of 7.03 ds/m or 4500 ppm. This will have severe restriction on use. Aim of the work was to demonstrate the efficacy of microwatering system under such conditions.

Four different systems of irrigation were used--Furrow, spaghetti drip, lay flat drip and Seephose. Yield was 11 T/ha in plots irrigated by Spaghetti drip, 9 T/ha in those with furrow irrigation. Water productivity was also significantly higher with Spaghetti drip compared to others.

Baqi[4] reported the effort of developing plantation on the roadside of 150 km long highway between Abu Dhabi and another town Al Ain in UAE. The significance of the effort lies in the fact that the plantation had to be on sand, using water of salinity levels ranging from 1500 to 17000 ppm (2.34 to 26.56 ds/m). The higher value is nearly half that of sea water. Although the growth rates were affected by salinity levels of water, plantation did get established. The success was attributed to drip irrigation.

Uriel Or[5] reported on work done in Western terrace of Jordan Valley, a semi-arid region with desert, stony and marginal soils, and with annual rainfall of 100 to 200 mm. Temperatures ranged from 30 C to 40 C. Note, the temperatures are comparable to that at Bhuj, but rainfall is even lower. Tomato and cucumber were grown under drip, sprinkler and furrow irrigation, using two types of water regular (non-saline) and saline.

It was found that yields were highest under drip method. In the plots irrigated by drip the tomato yield was 68 T/ha compared to 53 T/ha of sprinkler and 51 T/ha of furrow irrigated plots. More importantly, when using saline water, yields were lower in case of sprinkler and furrow method. In case of drip, it was the opposite-yields were higher when using saline water.

Salih[6] reported the results of using microwatering system in a part of Iraq. The soils on the farm where experiments were done were salt affected with pH of 7.8 and EC_e 5.2 ds/m (0-15 cm). The area is arid, with rainfall of 200 mm per year. Temperatures range from - 2 C to 45 C. These conditions are harsher than those of Kutch. Potato and pea were grown with two irrigation treatments (drip and furrow). Yield of potatoes was superior in drip than that of furrow.

Salih listed other advantages of drip (a) high water efficiency in soils of high and low infiltration rates, (b) saline water can be used, and (c) minimizes re-salination of soils and crust formation.

Ayers *et al*[7] experimented with the use of saline water (5 - 11 ds/m) for irrigation in cotton crop in San Joaquin and Imperial Valleys in California. This was done to find ways to dispose off accumulated saline drainage water. They reported that yields when using saline water were comparable to the control (non-saline water). This was due to the fact that irrigation was done through drip method.

Wolff[8] who made extensive comparative study of drip irrigation in Germany and other countries listed 11 conditions under which drip will be a preferred alternative. Four of these are (a) limited availability or high price of water, (b) soil conditions and high evapo-transpiration values necessitating short irrigation intervals, (c) a high salt content in water. All these conditions prevail in Kutch.

Greenhouse

Greenhouse technology has been introduced in India only recently. Researches so far [9], [10], [11] relate to experiments done in colder, northern regions. These efforts aimed at demonstrating the use of greenhouses for growing vegetables and flowers in places and seasons where these could not be normally grown due to low temperatures. We have not come across any report of use of greenhouses in semi-arid regions of the country. One instance from Egypt is given below.

El-Aidy[12] grew tomato, cucumber and pepper in plastic tunnels in a semi-arid coastal region of northern Egypt. Some of the main advantages observed were: (a) this makes better use of limited water, (b) makes possible the use of saline water (2900 ppm or 4.5 ds/m), and (c) improves yields.

Let us recapitulate. Some of the above works show that saline water can be used for irrigation provided it is applied in small quantities at short intervals. Micro-watering devices, like the drip, make this feasible. Accordingly, micro-watering systems should form part of the new technology to make Kutch more productive.

Although, there are no examples yet of growing plants in enclosures in arid areas in the country, some works elsewhere show that yields as well as water use efficiency can be improved further in greenhouses and tunnels. Greenhouses and tunnels should also be part of the new technology to manage the problems of arid area.

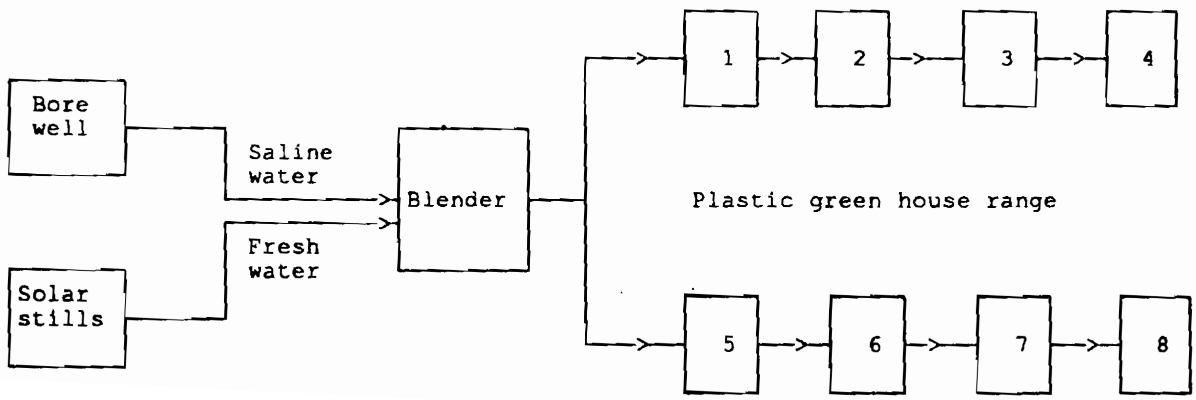
Above review has led us to conclude that protected agriculture using microwatering systems and greenhouses needs to be introduced in Kutch. Given below is an outline of fodder factory based on this approach.

Fodder Factory

The term, Fodder Factory (FF) refers to facilities where fodder will be grown continuously throughout the year under controlled environment. **Figure 4** shows a schematic outline of a proposed facility. It will consist of a bore well, a solar still, blending tank, micro-watering system and plastic green house range.

Figure 4

Schematic Outline of Fodder Factory



Water from bore well will be blended with that from the solar still or another source of better quality water located nearby. Blending will be to the degree necessary to bring the salinity of water down to a level that can be tolerated by the fodder crop. Fodder will be grown in plastic green houses or tunnels equipped with micro-watering system. Irrigation will be through microwatering systems. If necessary, greenhouses will have provision for passive or active cooling.

Fodder species that give high yields and are salt tolerant will be selected. Although, we are presently interested in increasing the supply of fodder, such facility as outlined here can be used to grow vegetables, etc. of high commercial value.

In the second part of this paper we will examine in detail the engineering and economic feasibility of fodder factories for Kutch.

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