ASSESSMENT METHODOLOGY

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Executive Summary

The Gareh Bygone Plain (GBP) is an 18000-ha expanse, of which over 6000-ha had been covered with the moving sand. Very little freshwater resources were available before the artificial recharge of groundwater (ARG) activities were started there in 1983. We intend to establish a cooperative that will provide livelihood for 40 young couples and an ideal condition for 30 research scientists and technicians. This is a unique opportunity to show that two of the seemingly worthless resources, floodwater and deserts, can be used for managing a fruitful life. Moreover, the researchers are in the same boat as the beneficiaries; either they reap the fruits or face the music. This is a good method for capacity building and dissemination of the results. This is also a site for the development of an assessment methodology, which the UN might find useful in evaluating the outputs of development projects implemented by that organization in similar environments.

The GBP, with a mean annual rainfall and Class A pan evaporation of 243 and 3200-mm, respectively, epitomizes anthropological degradation of natural resources, and also, how to implement an indigenous approach to rehabilitate such resources. No surfase freshwater resource is found in the GBP. The results of our assessment are as follows:

A.State of natural resources

- Class II soils, which are suitable for irrigated agriculture, cover 758.74-ha. Class III soils, which are suitable for spate irrigation and the ARG activities cover 1106.30-ha. Salt affected soils cover only 68.97-ha, 3.3% of the total studied area.
- Precipitation data for 202 raingauging stations in Fars province have been analyzed, the missing data for our research site have been synthesized, and the recurrence intervals have been determined. A CV of 0.46 for the GBP emphasizes merits of the ARG activities in such environments. The maximum runoff coefficient of 0.56 indicates the potential of the Agha Jari Formation for runoff farming in the GBP.
- A preliminary survey of the floral and faunal biodiversity has been made in the GBP. The microbial population of a soil is an indication of its quality, i.e., soils of good quality have significantly more microbes than soils of poor quality. This population for the spate-irrigated sites planted to *Eucalyptus camaldulensis* Dehnh. and covered with native range plants is 34 and 24- fold, respectively, relative to the original soils of the plain.
- The above ground carbon sequestration potential of an 18-year old, spate-irrigated *Eucalyptus camaldulensis* Dehnh. is 3.699-tons $ha^{-1}yr^{-1}$.This for *Acacia salicina* Lindl. is 3.392- tons ha^{-1} yr^{-1}.
- The major vegetation units and the species richness of the plain and the spate-irrigated areas, and their annual yields, have been determined.
- Invasion of a sowbug (*Hemilepistus shirazi* Schuttz) is remarkable. As this crustacean, which burrows deep into the hard crust and facilitates preferential flow, is not a known pest of our plants, we welcome such events.
- Comparison of aerial photographs and satellite imageries for different periods reveals a substantial increase in the area of irrigated fields due to the ARG activities, and some later decrease due to drought and/or over-exploitation of

groundwater. Water quality, as measured by its electrical conductivity, has improved from 20 to 329% due to the ARG activities.

- *En mass* cityward migration, which had occurred prior to 1983, when the ARG activities were started, was reversed in about 1984 after high yielding wells were dug. However, this would happen again if the present trend of illegal well digging and over-exploitation of groundwater is continued unchanged.

B. Characterization of stresses

- Low annual rainfall and an extremely hot weather during spring and summer make the GBP a hyperarid place, facing a large water shortage. Moreover, land degradation that is prevalent in the plain is another constraint to agricultural development.
- Nomad mentality is a major stress for the free souls who have been forced to change their life style. Sedentarization of pastoral nomads in a desert with fragile soils and inadequate water for irrigation has resulted in land and water degradation.
- Land tenure is another constraint that deprives many nomads of a decent living. The mean population growth rate, based on the most recent 5-year data is 1.7%. A very low HDI (0.552 as compared with 0.719 for the whole country, which is itself 106th amongst 175 countries) shows the low level of development for the people of the plain. mean annual per capita income for the occupants of the four villages that benefit from the ARG activities is $1190.00. The percentage of those living under the standard poverty line for Iran is 68. The mean annual cost of living per household, based on the purchasing power parity is $6742.2, of which 63.55% is spent on food; clothing, health, education, utilities, transportation and rent, in that order, comprise the rest. Mixed farming in a desert with recurrent droughts and low groundwater supplies, and having no alternative income sources, leads to poverty.

C. Description of indigenous, adaptive and innovative approaches

Floodwater spreading for spate irrigation and the ARG is an indigenous knowledge that has been practiced for millennia in different parts of Iran. However, the pastoral nomads, who were sedentarized by force, did not practice this technology. Implementation of an improved method of floodwater harnessing in the GBP has significantly increased groundwater resources and forage yield. Unfortunately, the present population of the GBP does not accept responsibility for maintenance and expansion of the ARG systems.

That is one of the reasons that we intend to establish a cooperative to work closely with young couples and their children to teach them how to steward the natural resources. On the positive side, as the price of farm products has skyrocketed in recent years, therefore, the nomad-farmers pay more attention to their fields and adapt agronomic practices proven in nearby farm fields. A very encouraging observation, which requires a detailed study for approval, is the high yield (up to 5-metric tons per ha) of wheat grain from a soil containing upwards of 72% sand, and irrigated at 3- week intervals.

A. State of Existing Natural Resources

Geomorphology

The experiment is going to be conducted on the debris cone formed by the Tchah Qootch *Well of Ram* in Farsi) River (28° 34' N, 53° 56'E), an ephemeral stream that flows out of a 171-km^2 intermountain watershed (Fig.1). This basin has been formed by the tectonic movements of the Zagros Mountain Ranges during the Mio – Pliocene time in the Agha Jari Formation. It covers only 0.35% of the Mond River Basin. Therefore, even the diversion of its total flow should not greatly affect hydrology of the entire basin.

The Agha Jari Formation, which covers 27680-km^2 in south – south –western Iran, ranges in age from late Miocene to Pliocene. This formation consists of rhythmically inter-bedded brown to gray, calcareous, feature – forming sandstones and low weathering, gypsum – veined, red marls and gray to green siltstones. The Agha Jari Formation lies conformably over the gray marls and limestones of the Mishan Formation, which is of early to middle Miocene in age. Although the Agha Jari Formation is usually capped unconformably by the Plio –Pleistocene Bakhtyari Formation, severe erosion during the Quaternary period has left only small, scattered patches of the Bakhtyari Formation on the Tchah Qootch Basin. The Bakhtyari Formation, which mainly consists of pebbles and cobbles of Cretaceous, Eocene, and Oligocene limestones and dark brown, ferruginous cherts, has provided the bulk of the alluvium in the debris cone; the Agha Jari Formation has contributed the rest.

The Agha Jari Formation forms the major bedrock on which the alluvium has been deposited. The known thickness of the alluvium ranges practically from none by the foothills to 43-m at the center of the Kowsar Station. Fine sand and gravel form the upper 12-m thickness of the alluvium; the rest consist of medium and coarse sand, gravel, and stones of different sizes, up to 40-cm in length.

The westward flowing Tchah Qootch River has deposited the debris cone in such a way that it slopes from east to southwest. The debris cone is terminated on its western extremity by the Shur (saline in Farsi) River of Jahrom, an effluent, perennial stream that flows southward in the thalweg of the Gareh Bygone Plain. The base flow of this river, which drains the Fasa watershed covering an area of 4530- km^2, is quite saline; the electrical conductivity ranges from 6 to 45 ds m^{-1} during the year. Since the general direction of the groundwater flow in the debris cone is westward, a substantial volume of water, which is not extracted from the aquifer, eventually turns saline and seeps into the Shur River of Jahrom. Although the salinity source has not been pinpointed as of now, it is postulated that the dissolution of a hidden salt dome by the karstic waters, which probably discharge through a thrust fault on the western margin of the Gareh Bygone Plain, pollutes the groundwater in the area.

Hydrology

Precipitation characteristics

Amount

The Gareh Bygone Plain (GBP) is an extremely dry place with a mean annual precipitation (MAP) of 243.3-mm, and Class A pan evaporation of 3200-mm. Moreover, temporal and spatial variations in this plain is high.

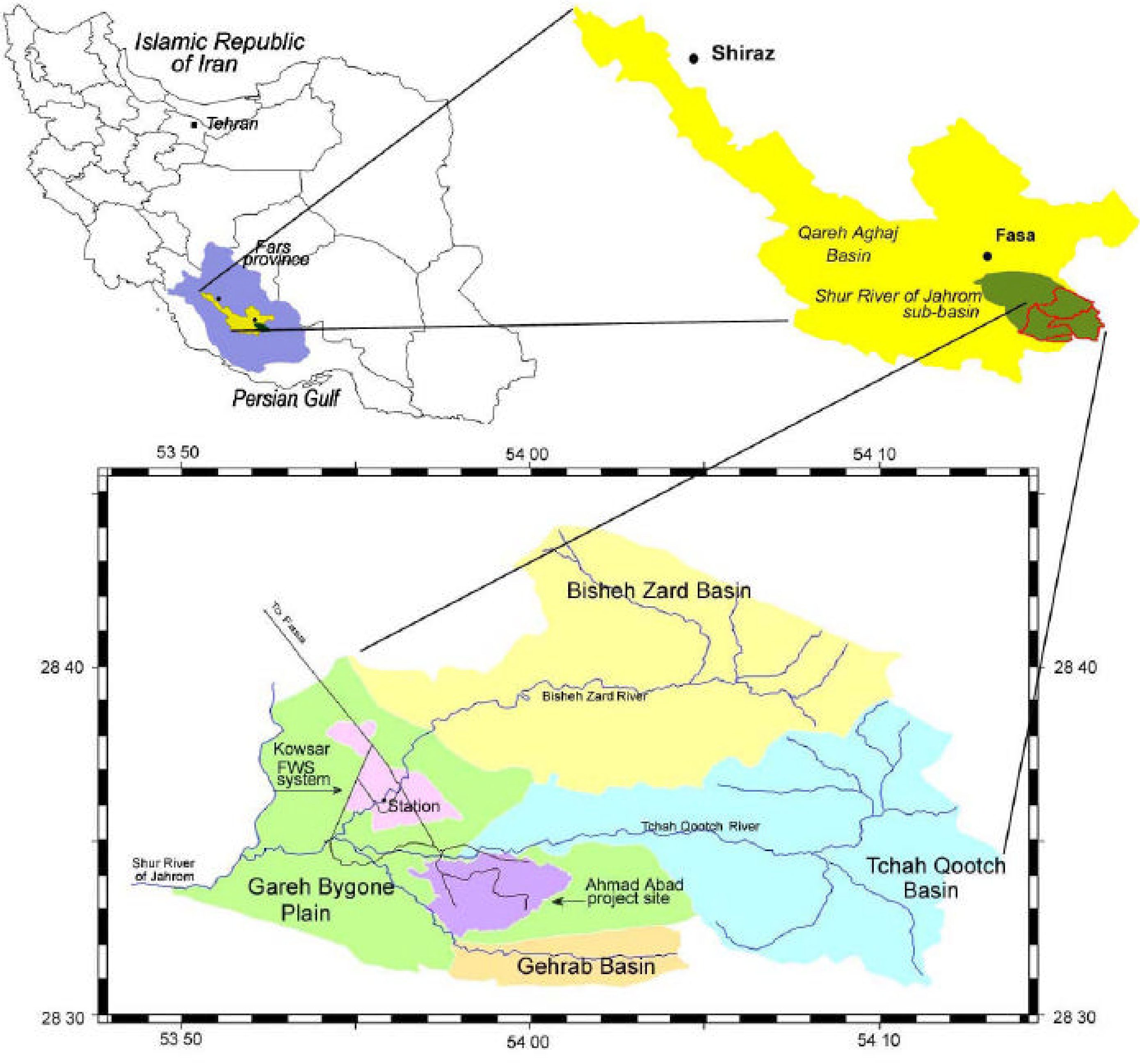

Fig. 1. Sketch map of study site in the Gareh Bygone Plain, Qareh Aghaj Basin, Fars province and Iran.

The closest meteorological station to the research site, which is operated by the Ministry of Power, is at Baba Arab, 15.7-km to the WSW of the Kowsar Floodwater Spreading and Aquifer Management Research, Training, and Extension Station (KS). Some particulars about the rain gauging stations in the vicinity of the GBP are presented in Table1. Location of these stations is depicted in Fig.2. Establishment of a meteorological station at the KS in 1996 has been instrumental in collecting 6 years of data.

Table1. Some particulars about the raingauging station in the vicinity of the Gareh Bygone Plain.

Station	Geographical characteristics					Establish.	Gap years	Position in relation to Kowsar Station	
	Longitude		Latitude		Elevation above mean sea level,m	year		Distance, km	Direction
	Degree	Minute	Degree	Minute					
Baba Arab	28	35	53	46	1080	1971	2	15.75	WSW
Barak	28	39	53	9	870	1971	2	75.78	W
Tangab	28	55	52	31	1400	1967	2	141.97	WNW
Tang Karzin	28	29	53	7	700	1972	3	80.58	SW
Hanifghan	29	6	52	33	1580	1972	3	145.48	NW
Dejgah	28	12	52	23	200	1982	2	157.38	SW
Dehram	28	27	52	20	420	1979	4	156.98	WSW
Dehrood	28	37	52	34	880	1982	7	132.57	WSW
Nobandegan	28	51	53	50	1270	1967	16	29.42	NNW
Fasa	28	57	53	39	1380	1971	3	47.44	NNW
Khosooyeh	28	35	54	22	1050	1967	4	43.15	E
Darb Ghaleh	28	55	54	23	1430	1966	4	56.19	NE
Gavozoon	28	49	54	27	1300	1968	2	56.24	ENE

The double mass curve method was employed to correlate this station's data with those of the Baba Arab Station (BAS). A significant correlation between the two stations (R^2=0.91) indicated that we may use the BAS's rainfall data to synthesize the 1970-1995 period's missing data for the GBP. The minimum amount of MAP, 54.5-mm belongs to the1977-1978 water year, and the maximum MAP occurred in the 1992-1993 water year. The MAP for a 30-year period ending in 30 September 2002, for the GBP and BAS is 243.4 and 244.6-mm, respectively.

Variations

Thirty years of annual rainfall data, and the maximum24-hour rainfall for each year are presented in Table 2. The mean and maximum monthly rainfalls are presented in figures 3 and 4, respectively. It is observed that the Dec.-Feb. period has the highest, and the July-Aug. period has the lowest amount of precipitation. However, as in any arid zone there is a probability of receiving convective storms in summer, as it occurred in the summer of 1994, in which 31-mm of rain was registered. The maximum 24-hour rainfall recorded at the KS occurred on 3 Dec.1986, which was 90-mm.

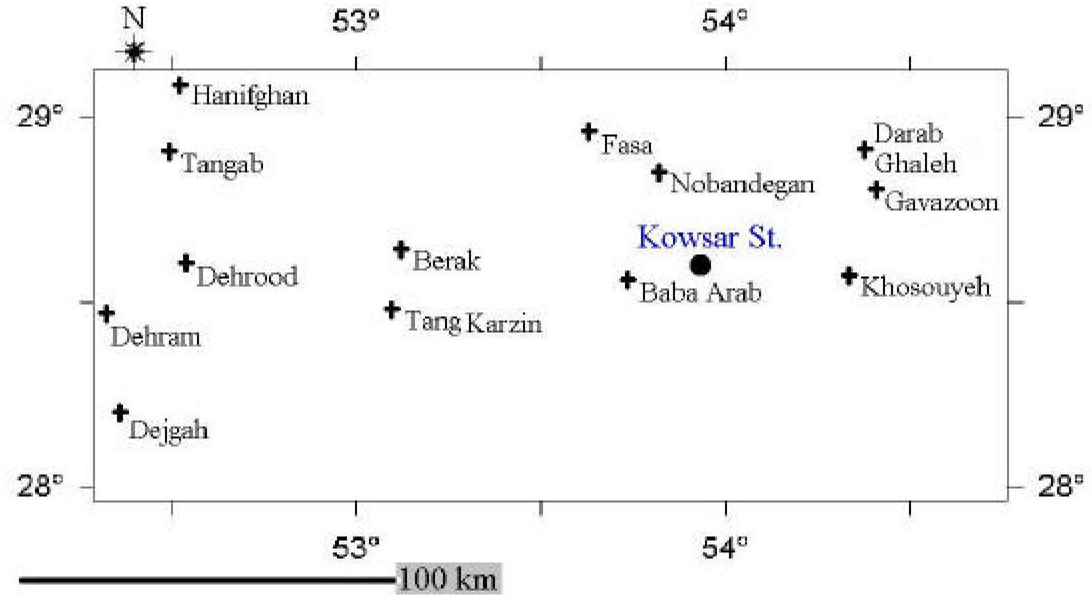

Fig.2. Location of the raingauging stations whose data were used in this study.

Table 2. Variations in the 30-year annual and maximum daily rainfall data for Baba Arab Station*.

Year	Precipitation, mm				Year	Precipitation, mm			
	Annual		Maximum daily			Annual		Maximum daily	
	Baba Arab	Kowsar	Baba Arab	Kowsar		Baba Arab	Kowsar	Baba Arab	Kowsar
1971-72	346.0	360.4	44.0	43.6	1987-88	210.5	216.7	35.0	34.8
1972-73	56.0	52.9	11.0	11.6	1988-89	159.0	162.1	28.0	28.0
1973-74	223.5	230.5	33.5	33.4	1989-90	211.0	217.2	23.0	23.2
1974-75	270.0	279.8	39.0	38.7	1990-91	267.0	276.6	45.0	44.5
1975-76	392.0	409.1	37.5	37.3	1991-92	273.5	283.5	34.0	33.9
1976-77	287.5	298.3	31.0	31.0	1992-93	556.5	583.6	66.0	64.9
1977-78	54.5	51.3	35.0	34.8	1993-94	165.0	168.4	27.5	27.6
1978-79	299.5	311.1	62.0	61.0	1994-95	285.0	295.7	53.0	52.3
1979-80	286.0	296.7	29.0	29.0	1995-96	514.0	538.5	66.5	65.4
1980-81	242.0	250.1	44.0	43.6	1996-97	208.5	249.8	39.0	38.7
1981-82	239.5	247.4	36.5	36.3	1997-98	273.5	260.5	38.5	38.2
1982-83	308.0	320.1	45.5	45.0	1998-99	188.0	209.7	46.5	46.0
1983-84	117.0	117.5	30.5	30.5	1999-00	83.0	68.0	36.5	36.3
1984-85	169.5	173.2	38.0	37.7	2000-01	141.5	143.0	31.5	31.4
1985-86	199.5	205.0	39.0	38.7	2001-02	201.0	191.5	29.0	29.0
1986-87	355.5	370.4	90	88.2	Mean	244.6	243.3	40.1	39.8

*- Kowsar station's data are derived from Baba Arab Station due to the close relationships that exist between the two stations. Rainfall measurement was started at the Kowsar Station in Mar. 1996.

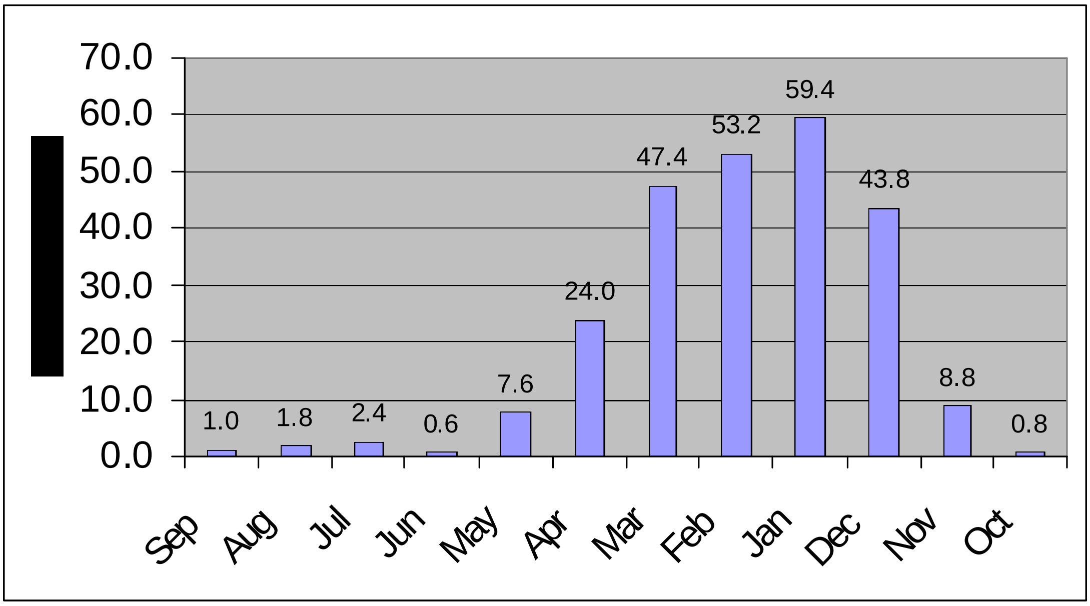

Fig. 3. Graphic presentation of the mean monthly rainfall at the Baba Arab Station.

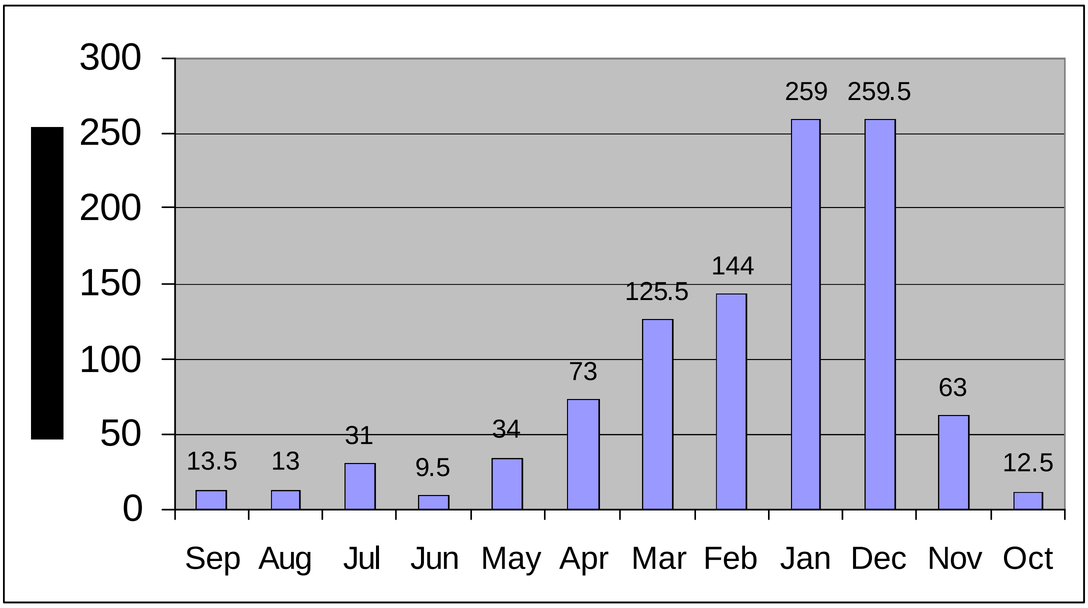

Fig. 4. Graphic presentation of the maximum recorded rainfall in each month at the Baba Arab Station.

Frequency

The recurrence interval (RI) for different periods were determined using the data of BAS benefiting from the Hydrological Frequency Analysis (HYFA) software. Preliminary analyses revealed that the Pearson type III and the gamma distribution best suit the maximum 24-hour and the MAP, respectively. The MAP and the maximum 24-hour rainfall for the RI of 2-100 are presented in Table 3. As it is revealed in this table, the maximum expected 24-hour rainfall in 200 years is 86.3-mm. As the maximum 24-hour rainfall recorded at the Kowsar Station has been 90.0-mm on 3 Dec. 1986, therefore, this rain belongs to a more than 200-year interval.

Table 3. The mean annual precipitation and maximum 24-hour rainfall for the recurrence interval of 2-100 years for The Baba Arab Station.

Parameter	Recurrence interval, year									Fitted distribu-tion	Method
	2	5	10	15	20	25	50	100	200		
	Precipitation, mm										
Max. daily	38.4	51.3	59.0	63.2	66.0	68.1	74.4	80.5	86.3	gamma	ML
Annual	228.7	333.5	394.7	426.9	448.7	465.0	513.4	558.8	602.1	Pearson III	

* - Gamma, two parameter gamma; PearsonIII, Pearson type III; ML, maximum likelihood

The rainfall data for all of the 202 rain gauging stations were collected. As 54 of these stations had less than 5 years of record, their data were eliminated from the analyses. Correction and filling in the missing data (synthesis) were made for 20 years for the remaining stations. The outlier data were then discarded. Means and coefficients of variation (CV) for such stations were calculated.

It is worth emphasizing that the rainfall intensity, which is a major factor in runoff inducement, is lacking for all of the stations whose data are used in this study. However, as the Agha Jari Formation (AJF), which covers the basins whose floodwaters are intended for diversion towards the research site, is relatively impermeable, a lack of rainfall intensity data is of no great concern. The minimum amount of rainfall that initiates a flow in the Bisheh Zard Basin is 5-mm, if it occurs in less than one hour. Therefore, these data are still very useful in predicting the flood occurrence. The maximum runoff coefficient for the AJF, which occurred on 3 Dec. 1986, was 0.56.

As a high CV is an indication of a great variation in the amount and the chance of rainfall occurrence, therefore, the CV of 0.46 for the BAS that is identical with that of the Gareh Bygone Plain, indicates a slim chance of receiving adequate rain every year. Therefore, the artificial recharge of groundwater systems have to be designed and constructed in such a way to harness the largest possible flow that is technically practicable, environmentally sound, financially viable, and socially acceptable.As the CV of above 0.35 is an indication of a highly variable precipitation regime, 101 stations in Fars province fall into this category.

Surface and Groundwater Hydrology

A few brackish seepage springs of no consequence provide the surface water used by the wild life and some livestock. Floodwater is the most important surface water available in the Gareh Bygone Plain. It is therefore apropos to deal with this subject in detail.

The financial viability of floodwater spreading projects dictates that hydraulic structures should be designed and built in such a way that the floods of specific magnitude will not damage them. The recurrence interval (RI) is defined as the average interval in years between the occurrence of such floods. Although there is no guaranty that a certain flow will occur at a desired time, the policy makers and planners wish to have solid grounds to base their plans and policies on. Moreover, as we are going to start an action-research project based on floodwater diversion for the development of a wasteland, it is essential to base our calculations on some semi-dependable numbers.

The paucity of reliable flow data for the Bisheh Zard Basin, and the total lack of data for the Tchah Qootch and Gehrab Basins, which all drain into the GBP, left us no choice but to collect the data from 11 neighboring gauged stations. These data were then analyzed using appropriate statistical software to arrive at close estimates for the maximum instantaneous flow (MIF) of each of the 3 sub-basins whose runoff will be diverted for spate irrigation of food and forage crops, and the artificial recharge of groundwater. Geographical characteristics of these sub-basins are presented in Table 4.

Table 4. Geographical characteristics of 3 sub-basins in the Gareh Bygone Plain.

Basin	Geographical coordinates		Area,	Elevation above mean sea level,m		Length of the longest	Time of concentration,
	Longitude	Latitude	km^2	Max.	Min.	stream, m	minutes
Bisheh Zard	53º55'- 54º11'	28º36' - 28º44'	193.828	1582	1170	28500	282
Tchah Qootch	54º00' -54º13'	28º32' -28º39'	171.218	1822	1183	26500	322
Gehrab	53º55' -54º04'	28º31' -2 8º35'	45.500	1823	1130	20000	205

Table 5 presents the estimated peak flow rates for the recorded events, and flood flow duration for the observed events for the Bisheh Zard Basin. The slope-area method was used to arrive at these numbers. Establishment of a hydrometry station on the Bisheh Zard River in 2001 has greatly enhanced accuracy of the flow data. Two typical hydrographs are presented in Appendix A.

Table 5. Maximum instantaneous flow rates and duration, occurrence, or just duration, of some flood flows in the Bisheh Zard River, 1983-2003.

Year	Date Day	Date Month	Est. peak flow, m^3/s	Duration, hours	Volume of diversion, million m^3	Year	Date Day	Date Month	Est. peak flow, m^3/s	Duration, hours	Volume of diversion, million m^3	Year	Date Day	Date Month	Est. peak flow, m^3/s	Duration, hours	Volume of diversion, million m^3
1982	10	Nov.	Sampling for quality determination			1989	18	Jul.				1995	25	Dec.			
1983	19-20	Jan.	48	24	0.07	1989	17	Dec.				1996	4	Jan.			
1983	6	Mar.	30	19	0.07	1990	9-10	Jan.				1997	25	Mar.		11	
1984	27	Feb.	70	20	1.1	1991	26	Jan.		14		1998	2	Jan.		4	
1984	21	Mar.	40	5	0.4	1991	20-21	Feb.		11		1998	5-6	Jan.			
1984	22-23	Mar.	50	34	1.8	1991	27-29	Feb.		40		1999	18	Jan.			
1984	24-26	Mar.	60	48	2.6	1991	5-7	Mar.		36		1999	6	Feb.		19	
1984	28-31	Mar.	60	40	2.1	1991	13-14	Mar.		29		1999	1	Mar.			
1985	4	Jan.	30	17	0.92	1991	29-30	Mar.		12		1999	8	Jul.			
1985	23-24	Jan.	40	20	1.2	1991	8	Aug.				1999	17	Aug.			
1985	12	May.	30	2	0.1	1991	8	Dec.				2000	17	Jan.			
1985	19-20	Dec.	70	26	3.1	1992	3-4	Jan.		16		2000	5	Oct.			
1986	8	Mar.	80	24	3.2	1992	21-22	Jan.		30		2000	10	Nov.			
1986	29	Jul.	100	13	1	1992	21-23	Dec.				2000	12	Dec.			
1986	6	Aug.	100	14	1.1	1993	8-9	Feb.				2001	10	Jan.			
1986	1	Dec.	200	24	3.9	1994	10	Mar.				2001	16	Dec.			
1986	2-3	Dec.	300	26	7.8	1994	27	Mar.				2001	12	Feb.			
1986	4-6	Dec.	130	34	2.4	1994	6	May.		5		2001	22	Feb.			
1986	6-7	Dec.	100	8	0.6	1994	6	Aug.				2001	17	Jul.			
1987	18	Aug.	20	2	0.7	1994	15-16	Aug.		14		2002	17	Mar.			
1988	18	Jan.	100	15	1.9	1994	2-3	Sept.				2002	22	Dec.		8	
1988	23-25	Feb.	30	50	2.7	1994	18	Nov.				2002	5-6	Feb.		20	
1988	5	May.				1994	25	Nov.		23		2002	25	Feb.		7	
1988	14	Sept.				1994	3-4	Dec.		23		2003	23	Mar.			
1989	15	Feb.				1994	7-10	Mar.				2003	26	Mar.			
1989	4	Feb.				1995	24-25	Jul.	30	15		2003	23	Jul.			
1989	14-15	Mar.				1995	6	Dec.				2003	5	Aug.			
1989	29	Mar.				1995	12	Dec.				2003	16	Aug.			

Table 6. presents the details of the gauged watersheds whose flow data were used to predict MIFs for the 3 sub-basins in this study.

Table 6. Characteristics of the 11 basins whose flow data were used in this study.

Basin	Station	Area, km^2	Longitude		Latitude		Establish.	Data collection period	Gap
							year		
Dejgah	Dejgah	18525	23	52	12	28	1985	15	1
Dejgah	Dehram	4300	20	52	27	28	1986	14	0
Dejgah	Dehrood	2400	34	52	37	28	1987	13	0
Dejgah	Tangab	1410	31	52	55	28	1967	33	2
Dejgah	Hanifghan	415	33	52	6	29	1975	25	4
Dejgah	Tang Karzin	13075	7	53	29	28	1972	28	0
Ghareh Aghaj	Baba Arab	3611	46	53	35	28	1988	12	0
Ghareh Aghaj	Berak	745	9	53	39	28	1977	23	0
Tang Charkhi	Khosouyeh	3410	22	54	35	28	1977	23	0
Tang Charkhi	Gavazon	900	27	54	49	28	1977	23	2
Tang Charkhi	Darb Ghaleh	1390	23	54	55	28	1367	12	0

Procedures

As the main objective of this study was the MIF estimation at certain RIs, three steps detailed below were taken:

1. **Collection, correction, and derivation of the missing data**. Available surface flow data for 11 gauging stations belonging to the Fars Water Organization, including the daily mean and MIFs, and the annual MIFs during the operating years of each station were entered into the Excel worksheet. The main data required for this study were MIFs during the longest period of stations' operation and the minimum of the missing data derivation. The MIFs for all 11 stations had some shortcomings, as the station personnel were not always on duty when the MIFs occurred, or were unable to measure the flow due to the hazards involved. However, the daily data are reliable as the water level recorders secured them.
2. **Discernment the outlier data**. For each station, both the maximum daily and MIFs data were plotted side by side, and the outliers were determined using the SPSS software. In this procedure, the points that were not inside the acceptable limits were discarded (5 in our case). Then a system of regression equations was derived, which showed the relationships between the maximum daily flow and the MIFs. Subsequently, the equation with the highest R^2 and F, and the lowest standard deviation were selected to estimate the missing data. As the complete and continuous maximum daily flow data for all the stations were not available, we used the MIFs of the stations whose data were highly correlated for this derivation. Thereafter, the MIFs were arrayed and their correlation matrices were set up. It was observed that the 25-year data (1975-76 to 2000-2001) span the longest duration that needs the minimum of derivation (synthesis). Thereafter, based on the regression equations showing the strongest correlation, the missing data for some stations were filled based on the stations having the complete and reliable data (Table 7).

3. **Frequency analysis**. Each series of the data was analyzed using the Hydrological Frequency Analysis (HYFA) software. Seven frequency distributions, based on 6 methods, were used to fit the plotting positions of the data. This software also tests the goodness of fit for frequency distribution using 3 methods: estimation of the standard error of estimate (SE), standard deviation, and chi-square. The distribution that has the lowest SE for different RIs better estimates the basic data. As these 3 methods do not always arrive at identical answers, the SE is used as the major criterion for closeness of estimates. The output of this step is estimation of the MIFs at certain RIs for each of the studied stations. These estimates, and the name of the best frequency distribution methods employed to arrive at those figures, are presented in Table 8.

4. **Local correlation**. Highly significant correlation exists between the area of each of the 11 studied basins and their estimates of MIF at different RIs (Table 9). Using these regression equations, the MIFs of ungauged basins for different RIs may be estimated. As an example, the desired data for the 2 sub-basins of the study area have been estimated (Table 10). As the minimum area of the gauged stations whose data were used in the derivation of the equations was 415-km^2, and the Gehrab Basin's area is only 45.5 km^2, therefore, using the equations did not give a correct estimation of the MIF for this basin. That was the reason for elimination of the row belonging to the Gehrab Basin in Table 10. The best line of fit between the MIFs for a 100-year RI and the area of basins is presented in Fig.5. This is an indication of the validity of our approach in the MIF estimation.

Table 7. Collected and derived data for the maximum instantaneous flows of 11 hydrometry stations used in this study*.

Year	Tang Karzin	Tangab	Dehram	Dehrood	Hanifghan	Dejgah	Gavazon	Khosouyeh	Darb Ghalae	Baba Arab	Berak
	Peak flow rate, m^3/s										
1975-76	1522.0	256.0	280.6	577.8	25.0	2118.2	188.8	117.7	215.9	757.9	235.0
1976-77	1185.0	103.5	218.1	445.2	5.8	1610.5	149.8	89.3	191.1	364.4	193.2
1977-78	1696.0	280.0	319.6	646.3	47.5	2380.3	94.8	11.3	156.2	1023.3	173.8
1978-79	856.0	130.0	170.5	315.7	1.9	1115.0	23.0	17.5	110.6	133.7	46.0
1979-80	1500.0	844.1	276.0	569.2	16.0	2085.0	138.0	18.3	183.6	727.4	82.5
1980-81	610.7	17.8	142.0	219.2	4.1	745.5	117.6	17.9	170.7	60.2	44.5
1981-82	610.0	110.0	141.9	218.9	35.2	744.4	65.1	23.0	137.3	60.1	81.0
1982-83	500.0	64.0	130.7	175.7	41.1	578.7	28.0	29.3	113.8	54.7	59.6
1983-84	152.8	64.0	100.8	39.0	4.7	55.7	8.4	5.4	101.3	148.5	45.4
1984-85	556.0	113.0	136.3	197.7	22.2	663.1	10.1	3.9	102.4	55.3	107.0
1985-86	1324.0	215.0	490.1	499.9	4.3	2850.0	34.8	21.7	118.1	507.5	150.0
1986-87	6409.0	1356.0	145.0	2500.8	319.0	9479.4	753.0	648.0	574.3	24334.8	1300.6
1987-88	603.0	828.0	406.0	129.0	77.2	480.0	23.6	14.5	111.0	59.3	128.7
1988-89	700.0	510.0	430.0	100.0	77.8	707.0	43.0	35.0	58.6	90.0	100.0
1989-90	485.0	410.0	181.0	125.0	44.4	537.0	23.7	4.5	224.0	36.0	145.0
1990-91	645.3	524.0	405.4	143.2	38.0	932.8	190.0	76.2	201.4	99.3	102.0
1991-92	530.0	315.0	530.0	180.0	64.5	1164.0	230.0	75.8	252.0	125.0	194.0
1992-93	1210.0	386.0	804.0	170.0	70.6	2342.0	152.7	752.5	337.0	475.0	245.0
1993-94	430.0	121.2	58.9	127.0	10.1	350.0	48.8	27.5	25.0	64.0	85.0
1994-95	1130.0	447.4	605.0	530.0	53.0	1180.0	160.0	105.0	242.1	283.0	280.0
1995-96	1430.0	370.0	505.0	560.0	17.9	1270.0	321.5	233.3	210.0	605.0	510.0
1996-97	258.0	206.5	177.0	146.0	2.5	361.0	36.0	40.0	104.0	180.0	58.5
1997-98	680.0	340.0	677.0	526.0	147.0	858.0	25.8	34.0	202.0	26.0	340.0
1998-99	1051.0	570.0	785.0	690.0	64.9	1042.0	540.5	260.0	488.0	259.0	255.0
1999-'00	875.0	145.0	400.0	245.0	32.4	583.0	27.9	6.1	95.0	25.8	102.0

*The figures in pale gray cells indicate derived data from internal correlation of each station. The gray cells indicate derivation based on correlation among stations.

Table 8. Maximum instantaneous flow at different recurrence intervals for 11 hydrometry stations used in this study.

Station	Fitted distribution*		Recurrence interval, year						
	function	method	2	5	10	20	25	50	100
			Peak flow rate, m^3/s						
Tang Karzin	Gamma	ML	899.0	1619.1	2114.6	2592.9	2744.7	3211.8	3674.7
Tangab	Gamma	ML	242.0	456.4	606.9	753.5	800.3	944.9	1088.9
Dehram	Gamma	M	296.1	497.0	631.1	758.5	798.6	921.2	1041.6
Dehrood	Gamma	ML	316.4	624.0	844.0	1060.4	1129.8	1345.1	1560.6
Hanifgan	Gamma	ML	32.2	79.4	116.3	154.3	166.8	206.1	246.3
Dejgah	Gamma	ML	1114.7	2261.3	3091.0	3912.3	4176.3	4997.3	5822.1
Gavazon	Gamma	ML	102.1	259.8	384.6	513.8	556.2	690.4	828.1
Khosooyeh	Pearson III	M	36.0	165.4	303.3	465.1	521.5	708.2	910.8
Darb Galeh	Gamma	ML	167.6	270.9	338.8	402.7	422.7	483.7	543.3
Baba Arab	2P-LogNor	ML	132.1	268.8	389.7	529.6	579.1	748.0	941.6
Berak	Log Pearson III	ML	138.3	269.0	381.3	509.1	553.8	705.3	876.9

* - Gamma, two parameter gamma; PearsonIII, Pearson type III; 2P-LogNor, 2 parameter lognormal; log Pearson type III; ML, maximum likelihood.

Table 9. Regression equations for estimation of maximum instantaneous flow at different recurrence intervals.

Regression coefficients	Recurrence interval, year						
	2	5	10	20	25	50	100
a	0.0588	0.1143	0.1535	0.1916	0.2037	0.2411	0.2781
b	47.92	93.945	136.36	185.36	202.56	260.51	325.55
R^2	0.919	0.938	0.944	0.947	0.648	0.948	0.94

The regression equation is in the form of Y=aX+b.

Table 10 . Estimates of maximum instantaneous flow for each of the 2 sub-basins in the Gareh Bygone Plain using the equations presented in the previous table.

Basin	Recurrence interval, year						
	2	5	10	20	25	50	100
Bisheh Zard	59.32	116.10	166.11	222.50	242.04	307.24	379.45
Tchah Qootch	57.99	113.52	162.64	218.17	237.44	301.79	373.17

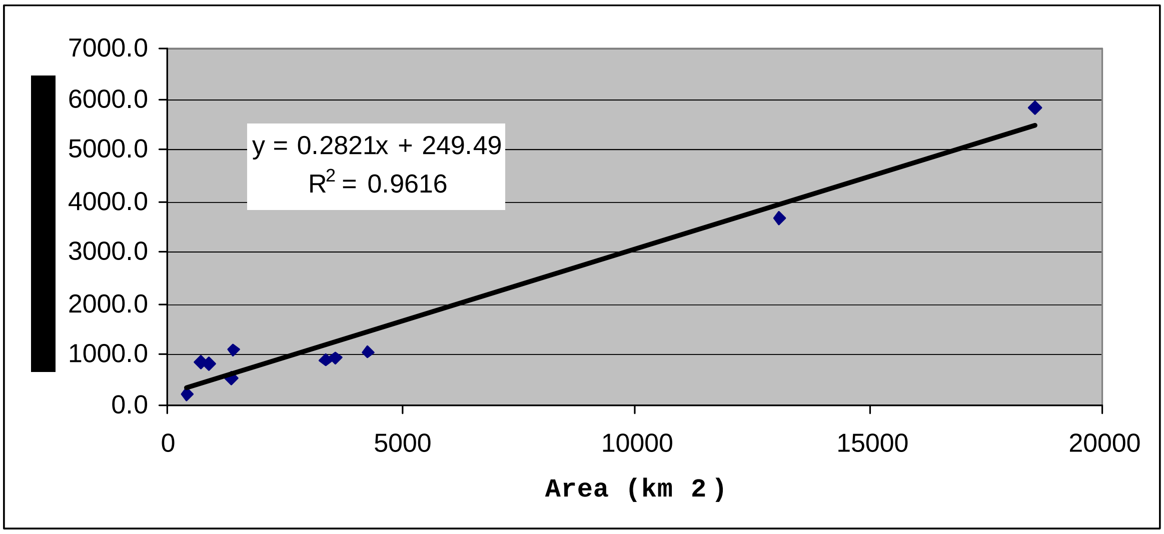

Fig.5. Maximum instantaneous flow rate as related to the basin area for the 100-year recurrence interval.

Groundwater

Transmissivity of the alluvium has been determined in two wells using the Jacob's method. The well in the northern part of the plain was 29-m deep, with the watertable at a depth of 22-m. The yield of this well was 15 liters per second (Ls^{-1}). The well in the middle of the plain was 21-m deep, with the watertable at a depth of 14-m. The yield of this well was 11 Ls^{-1}. A typical well log of the GBP is presented in Fig.6.

Mean transmissivity (T), using the data acquired from these two wells, was 790-m^2 per day, which is typical for a coarse-grained alluvium. Taking the width and depth of the Bisheh Zard aquifer at 5000 and 20-m, respectively, and the hydraulic gradient (i) at 0.0065, we have:

$Q = WTi = 5000\text{-m} \times 790\text{-m}^2 \times 0.0065 = 25675\text{-m}^3\text{day}^{-1}$ =297 liters per second

As there are close to 130 wells in the area of influence of the ARG systems, and assuming that 60 of them are operated simultaneously, at 20 Ls^{-1} for each well, 1200 liters per second are extracted from the aquifer, which is 4 times higher that it can supply. Therefore, over-exploitation results in salinization, and finally, in drying of the wells.

Contour map of the watertable in the plain based on the March 1994 data is presented in Fig.7. It is observed that the water level at the lowest point of the plain was 1115-m above the mean sea level (amsl) and, at the highest point was 1155-m amsl. The shape of contours reveal the presence of two directions of flow, one from the artificial recharge of groundwater systems (east-west), and one from the east, which indicates recharge from the Tchah Qootch ephemeral River.

According to the official data, annual groundwater extraction from the plain is 14 million-m^3. However, considering that 130 wells are operative, irrigating about 1193-ha at peak discharge, this figure seems underestimation of water exploitation by a large margin.

Outcropping of the impermeable Agha Jari Formation at the thalweg of the plain results in a permanent seepage of saline water into the Shur River of Jahrom. The Tamshir Hydrological Station estimates this flow to be about 2 million-m^3 per year. This points to the potential that this outflow might have. This water could be used to raise saltwater fish.

Natural and artificial recharge of groundwater

The Fasa District Water Organization has estimated the natural groundwater recharge of the plain at 10% of mean annual precipitation. This amounts to 5 million-m^3 per year. Using the HST-D model, Fatehi Marj (2001) has estimated the mean annual artificial recharge at 5 million- m^3. The most recent data for the hydrological year 2002-2003 for the Bisheh Zard River are presented in Table 11. Please make note that the mean flow rate is 1/2 of the peak flow rate.

The diverted water for the Tchah Qootch River in the same events was 6.4 million-m^3.Therefore, the total amount of diversion for the GBP 2002-2003 period was 13.227 million m^3. Our estimate is that about 70% of this volume (9.25 million-m^3) have reached the watertable.

Effect of the artificial recharge of groundwater (ARG) on changes in water level in 5 observation wells are depicted in Table 12. Wells No.1 and 2 are located inside of the influence of the ARG systems. Well No.3 is outside of the influence of the ARG systems. Well No.4 is located on the upstream of the ARG systems, but is still affected by the recharge activities. Well No.5 is located to the west of the Shur River of Jahrom, totally outside of the influence of the recharge systems. Taking the lower figure for the ARG system (2.08-m), and assuming the specific capacity of the alluvium at 10%, about 10 million- m^3 had been added to an aquifer, 50-km^2 in areal extent. Locations of the observation wells are depicted in Fig. 7.

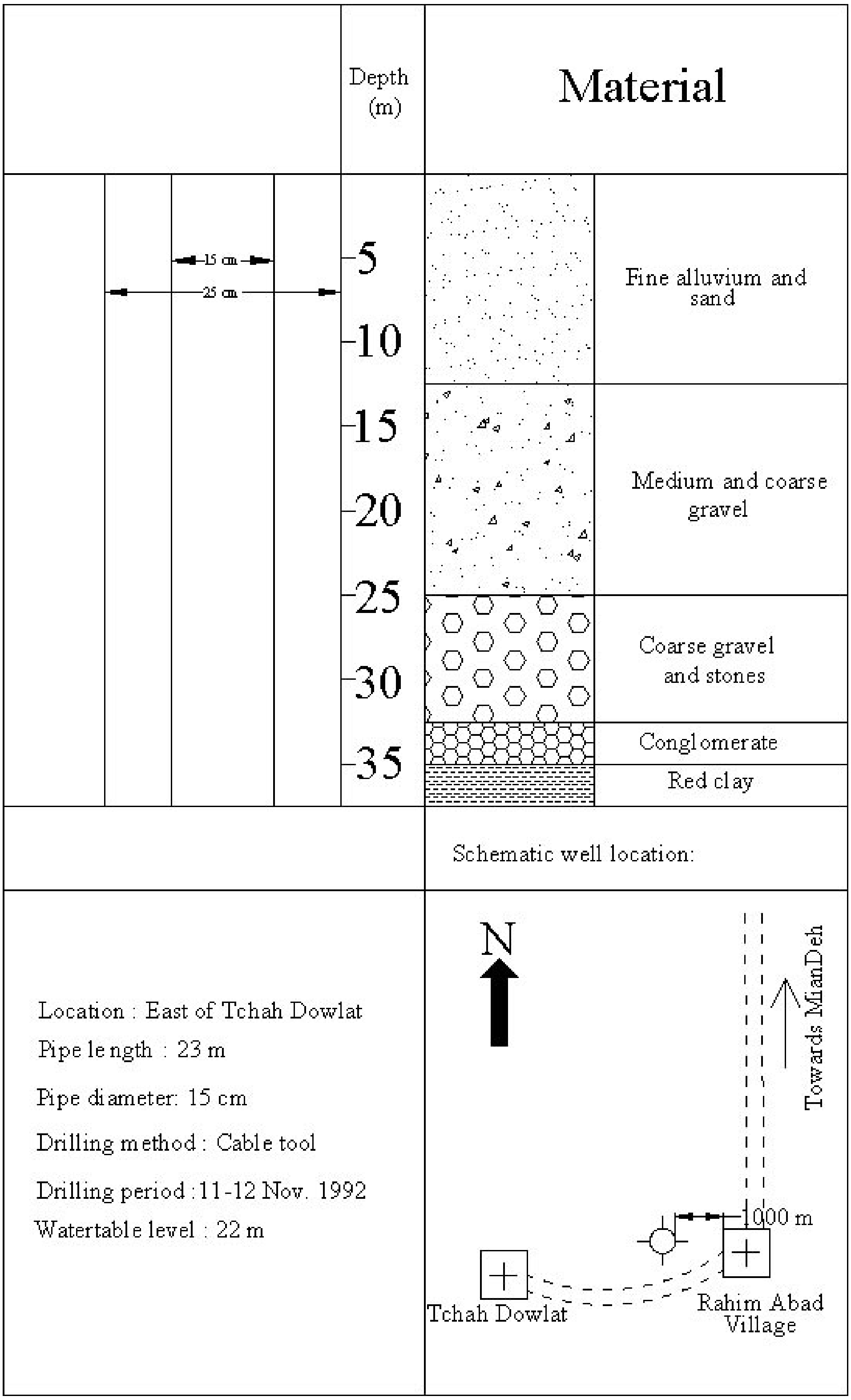

Fig. 6. Geological log of well no. 14, prepared from well cuttings.

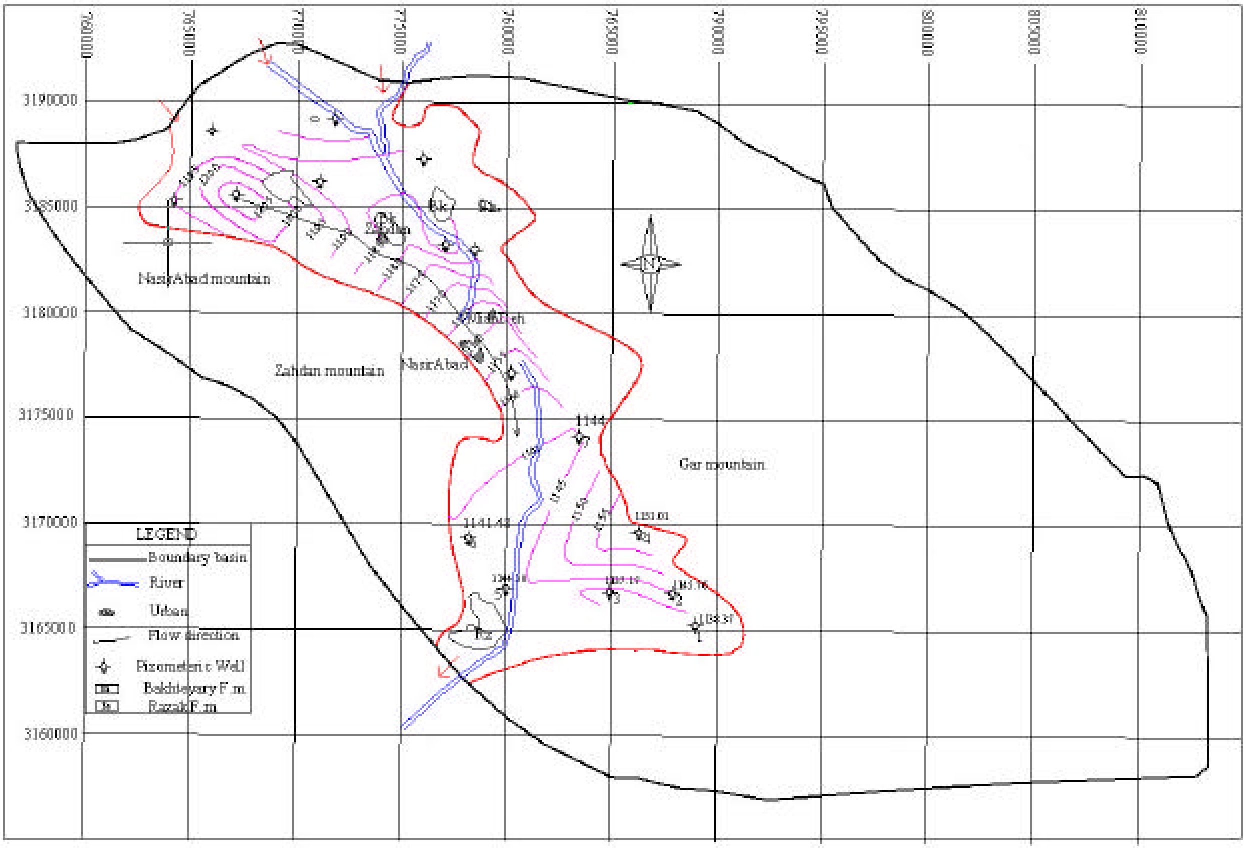

Fig.7 . Isopotential lines of the Gareh Bygone Plain aquifers.

Table 11. Date, amount of rainfall, maximum flow rate, and flow duration for the Bisheh Zard River, and the volume of floodwater diverted from it.

Date	Rainfall, mm	Max.flow rate, m^3s^{-1}	Flow duration, hours	Diverted floodwater,m^3
22Dec.2002	35	30	8.5	450000
5Feb.2003	26.5	50	20	1800000
25Feb.2003	20	25	7	400000
23Mar.2003	21	45	5	1100000
26Mar.2003	35	100	25	25000000
23July.2003	32	19	1	160000
16Aug.2003	25	29	2	417000
Total where applies	260.5		68.5	6,827,000

Table. 12. Response of watertable to the artificial recharge of groundwater in the Gareh Bygone Plain.

	Height of watertable from mean sea level, (m)				
Year	Well No.1	Well No.2	Well No.3	Well No.4	Well No.5
May 1996	1138.37	1145.76	1137.17	1151.01	1144.38
Nov 1995	1133.72	1143.68	1136.62	1150.4	1143.5
Difference (m)	+ 4.65	+ 2.08	+ 0.55	+ 0.61	+ 0.88

Water quality

The presence of gypsum veins in the Agha Jari Formation affects water quality in the seepage springs and the runoff from the watershed. The water in the ARG system is classified as sulfatic-calcic- magnesic. Those on the vicinity of the recharge site are sodic-sulfatic .

Electrical conductivity (EC) of the Bisheh Zard flow ranges 0.25 – 4.0 ds m^{-1}; the lower figure belongs to floodwater; the higher belongs to the seepage springs in summer.

The EC of well water ranges 1.6-1.8 dsm^{-1} in the ARG systems. As one proceeds downstream from the systems, the EC increases up to 8.0 dsm^{-1}. A very positive effect of the ARG appeared in the EC of the domestic well of the Rahim Abad Village. The EC was 4.941 dsm^{-1} in 1988 ; it decreased to 1.520 dsm^{-1} in 1993 , a difference of 323% (Pooladian and Kowsar, 2000).

A possible reason for the high EC of the wells outside the influence of the ARG systems is an intrusion of saline water from a thrust fault to the SW of the ARG systems. It is only through keeping a high head in the freshwater aquifer that we can hinder the encroachment of saline water into it.

Soil formation and their characteristics

Of the five soil forming factors in the Gareh Bygone Plain (GBP), the parent material is the most important. The aridic precipitation regime (the control section is dry more than 180 days per year), and the hyperthermic temperature regime (the mean annual soil temperature is 22±2°C), have not facilitated the physico-chemical and biological weathering. Therefore, the soils of the plain are limited to the orders Aridisols and Entisols. The very low organic matter content of the soil is mainly due to the scant precipitation and the very high temperature.

The presence of loose sand on the plain is due to the erosion of the Agha Jari sandstone, deposition of the sand in streambeds, and their subsequent transportation by wind to the settling areas.

Four physiographic units are recognized in the study area:

1. Plateaus and old alluvial fans. These landforms are located at the highest elevation on the foothills. The soils on this landform have been developed under climatic conditions more favorable to weathering, and are relatively old; therefore, they have acquired genetic horizons. As these soils contain calcic horizons, they are categorized in the Typic Haplocalcids subgroup, which consists of 3 families:
   - Soil No.1.Sandy,carbonatic,hyperthermic;
   - Soil No.2.Loamy over sandy skeletal, carbonatic, hyperthermic;
   - Soil No.3.Coarse loamy over fragmental, shallow, carbonatic, hyperthermic.

   A typical profile is described below:

Description of soil profile No. 10 in the Gareh Bygone Plain.

Classification:	Typic Haplocalcids, coarse loamy, over sandy skeletal, carbonatic, (hyper) thermic
Location:	Ahmad Abad, Gareh Bygone Plain.28° 33' 54'' N, 54° 00' 28? E
Physiography	Old fan
Topography and aspect:	Gentle, north-facing, <1% slope
Drainage:	Somewhat excessively drained
Vegetation:	*Artemisia sieberi, Stipagrostis plumosa, Helianthemum salicifolium*
Parent material:	Calcareous sandstone
Sampled by:	H. Hassanshahi, M. Pakparvar, 16 Sept.2003
Remarks:	The watertable is below 30-m

Ap 0-12 cm (0-5 in). Pale brown to very pale brown (10YR 6.5/3, dry), brown (7.5YR4.5/4, moist), sandy loam; cloddy structure; slightly hard (dry), friable (moist), slightly sticky (wet); few fine roots; strongly effervescent; clear, smooth boundary.

Bk_1 12-25 cm (5-10 in). Pale brown to very pale brown (10YR 6.5/3, dry), brown (7.5YR4.5/4, moist), sandy loam; weak structure; hard (dry), friable (moist), slightly sticky (wet); 5% gravel by volume; few fine roots; few carbonate powdery pockets; strongly effervescent; gradual, smooth boundary.

Bk_2 25-40 cm (10-16 in). Brown to light brown (7.5YR5.5/4,dry), brown (7.5YR4.5/4,moist) sandy loam; medium angular blocky structure; slightly hard (dry), friable (moist), slightly sticky (wet); few carbonate powdery pockets; 10% gravel by volume; few fine roots; coarse and medium pores; strongly effervescent; gradual, smooth boundary.

BK_3 40-60 cm (16-20 in). Brown to light brown (7.5YR5.5/4,dry), brown (7.5YR4.5/4,moist), sandy loam; medium angular blocky structure; slightly hard (dry), friable (moist), slightly sticky (wet); few carbonate powdery pockets; few carbonate mycelia; strongly effervescent; abrupt smooth boundary.

C >60 cm (>25 in). Coarse and fine gravel, few carbonate mycelia; strongly effervescent.

Table 13. General characteristics of soil profile No. 10 in the Gareh Bygone Plain.

Parameters	Horizon and depth (cm)				
	Ap 0-12	Bk_1 12-25	Bk_2 25-40	Bk_3 40-60	C >60
Sand, %	75.12	71.12	72.12	66.12	68.12
Silt, %	17	16	18.0	16.0	16.0
Clay, %	7.88	12.88	9.88	17.88	15.88
Texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam
Organic carbon, %	0.332	0.211	0.155	0.146	0.137
$CaCO_3$,%	41.62	40.87	40.62	48.5	46.25
Saturation, %	31.14	33.2	45.23	57.43	52.73
pH	7.5	7.27	7.64	7.61	7.56
EC, ds/m	0.572	3.25	1.65	1.128	1.61
Available K, mg/kg	264	226	276	176	18.0
Available P, mg/kg	11.0	1.2	1.0	0.6	1.0

2. Gravelly alluvial fans. The soils on this landform cover the area between the plateaus and plain. Being relatively young, they show no development. They contain a considerable amount of gravel and rock fragments, and have sandy textures. These soils are categorized under the Typic Torriorthents subgroup, and contain one family:
   - Soil No.4. Sandy skeletal, carbonatic, hyperthermic.

A typical profile is described below:

Description of soil profile No. 7 in the Gareh Bygone Plain.

Classification: Typic Torriorthents, sandy skeletal, carbonatic,(hyper) thermic

Location: Ahmad Abad, Gareh Bygone Plain

Physiography: Gravelly alluvial fan

Topography and aspect:: Gentle, north facing, 1-2% slope

Drainage: Excessively drained

Vegetation: *Artemisia sieberi, Stipagrostis plumosa, Helianthemum salicifolium.*

Parent material: Calcareous sandstone

Sampled by: H. Hassanshahi, M. Pakparvar,16 Sept.2003

Remarks: The watertable is below 20-m

A_{11} 0-5 cm (0-2 in). Pale brown (10YR 6/3, dry), yellowish brown (10YR 5/4, moist), loamy sand; massive structure; loose (dry), very friable (moist), nonsticky (wet); 10% gravel by volume; few fine roots; strongly effervescent; clear, smooth boundary.

A_{12} 5-20 cm (2-8 in). Pale brown (10 YR 6/3, dry), dark yellowish brown (10YR 4/4, moist), loamy sand; massive structure; loose (dry), very friable (moist),slightly sticky (wet); few fine roots; violently effervescent; clear, smooth boundary.

C_1 20-30 cm (8-12 in). Pale brown (10 YR 6/3, dry), loamy sand; massive structure; loose (dry), very friable (moist), slightly sticky (wet); few fine roots; 40 % gravel by volume; strongly effervescent; clear, wavy boundary.

C_2 30-50 cm (12-20 in). Pale brown (10 YR 6/3, dry), sand ; single grain;loose (dry /moist), nonsticky (wet); very few fine roots ; 60-70 % gravel by volume; ; strongly effervescent; abrupt, smooth boundary.

C_3 50-70 cm (20-28 in). Pale brown (10 YR 6/3, dry), yellowish brown (10YR6/4, moist), sand; single grain; loose (dry /moist), nonsticky (wet); strongly effervescent; abrupt, smooth boundary.

C_4 70-110 cm (28-44). Pale brown (10 YR 6/3, dry), sand; single grain; loose (dry /moist); nonsticky (wet); strongly effervescent.

Table 14. General characteristics of soil profile No. 7 in the Gareh Bygone Plain.

Parameters	Horizon and depth (cm)					
	A_{11} 0-5	A_{12} 5-20	C_1 20-30	C_2 30-50	C_3 50-70	C_4 70-110
Sand, %	77.12	78.12	85.14	90.12	89.04	82.12
Silt, %	17	14	10	5	7	10
Clay, %	5.88	7.88	4.96	4.88	3.96	7.88
Texture	Loamy sand	Loamy sand	Loamy sand	oamy sand	Sand	Sand
Organic carbon, %	0.545	0.198	0.174	0.062	0.062	0.050
$CaCO_3$, %	37.87	44	56	57.75	52.5	50.75
Saturation, %	28.64	26.43	29.99	29.41	37.87	28.75
pH	7.39	7.54	7.76	7.72	7.85	7.81
EC, ds/m	0.829	0.316	0.303	0.398	0.193	0.316
Available K, mg/kg	160	138	70	84	40	128
Available P, mg/kg	14	1.2	11	1.4	3.2	3.6

3. Floodplains. The soils on this landform cover the downstream of alluvial fans. They are presently under fallow. They show signs of erosion. They contain a considerable amount of gravel and rock fragments, and have a coarse sandy texture. These soils are categorized under the Typic Torriorthents subgroup, and contain 3 families:

- Soil No. 5. Sandy, carbonatic, hyperthermic;
- Soil No. 6. Sandy, skeletal, carbonatic, hyperthermic;
- Soil No. 7. Coarse loamy over sandy, carbonatic, hyperthermic

A typical profile is described below:

Description of soil profile No. 2 in the Gareh Bygone Plain.

Classification:	Typic Torriorthents, coarse loamy over sandy, carbonatic, (hyper) thermic
Location:	Ahmad Abad
Physiography :	Floodplains
Topography and aspect:	Gentle, north facing, 1.5% slope.
Drainage:	Somewhat excessively drained
Vegetation:	*Peganum harmala, Lactuca echinops*
Parent material:	Calcareous sandstone
Sampled by:	H. Hassanshahi, M. Pakparvar,15 Sept.2003
Remarks:	The watertable is below 30-m

Ap_1 0-7 cm (0-3 in). Pale brown (10YR 6/3, dry), brown (10YR 4.5/3, moist), sandy loam; massive structure; slightly hard (dry), friable (moist), slightly sticky (wet); very few fine roots; strongly effervescent; gradual, smooth boundary.

Ap2 7-30 cm (3-12 in). Pale brown (10YR 6/3, dry), brown (10YR 5/3, moist), sandy loam; weak structure; slightly hard (dry), firm (moist), slightly sticky (wet); very few fine roots; strongly effervescent; gradual, smooth boundary.

BC 30-65 cm (12-25.5 in). Brown to pale brown (10YR 5.5/3, dry); brown (10YR 4.5/3, moist); sandy loam; weak structure, slightly hard (dry), firm (moist); sticky (wet); very few fine roots; strongly effervescent; clear, smooth boundary.

C_1 65-75 cm (25.5-30 in). Yellowish brown to dark yellowish brown (10YR 4.5/4, dry), brown (7.5YR 4.5/4, moist), sandy loam; massive structure; loose (dry), friable (moist), slightly sticky (wet); 50% gravel by volume; moderately effervescent; abrupt, smooth boundary.

C_2 75-115 cm (30-45 in). Brown (10YR 6/3, dry), brown (10YR 4.5/4, moist), sandy loam; massive structure; loose (dry), friable (moist), non-sticky (wet); 50% gravel by volume; moderately effervescent.

C_3 >115 cm (>45 in). Gravelly layer.

Table 15. General characteristics of soil profile No. 2 in the Gareh Bygone Plain.

Parameters	Horizon and depth (cm)				
	Ap_1 0-7	Ap_2 7-30	BC 30-65	C_1 65-75	C_2 75-115
Sand, %	65	34	59	76	92
Silt, %	27	31	24	11	3
Clay, %	8	15	17	13	5
Texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam
Organic carbon, %	0.257	0.276	0.174	0.146	-
$CaCO_3$, %	42.5	42.5	37.25	20.75	55.25
Saturation, %	32.98	39.55	41.10	39.26	35.59
pH	7.7	7.79	7.72	7.31	7.74
EC, ds/m	0.398	0.731	1.014	0.815	0.738
Available K, mg/kg	180	150	66	52	30
Available P, mg/kg	4.8	1.6	1.4	1.6	1.6

4. Piedmont alluvial plains. These soils occupy the lowest elevations in the study area. They are mostly used for dryland farming. They have developed horizon, and contain a considerable amount of gravel and rock fragments in the subsoil, and have a coarse sandy texture. These soils are categorized under the Typic Haplocambids subgroup, and contain one family.
   - Soil No. 8. Coarse loamy, carbonatic, hyperthermic

Description of soil profile No. 13 in the Gareh Bygone Plain.

Classification:	Typic Haplocambids, coarse loamy, carbonatic, hyperthermic
Location:	28° 33' 55'' N, 53° 59' 56? E
Physiography :	Piedmont alluvial plain
Topography and aspect:	Gentle, north facing, 1-2% slope
Drainage:	Somewhat excessively drained
Vegetation:	
Parent material:	Calcareous sandstone
Sampled by:	H. Hassanshahi, M. Pakparvar, 15. Sept.2003.
Remarks:	The watertable is below 30-m.

Ap 0-20 cm (0-8 in). Brown to pale brown (10YR 5.5/3, dry), yellowish brown to dark yellowish brown (10YR 4.5/4, moist), sandy loam; massive structure; loose (dry), very friable (moist), slightly sticky (wet); few fine roots; strongly effervescent; gradual, smooth boundary.

BC 20-40 cm (8-16 in). Light yellowish brown (10YR 6/4, dry), yellowish brown to dark yellowish brown (10YR 4.5/4, moist), sandy loam; weak angular blocky structure; soft (dry), very friable (moist), slightly sticky (wet); few fine roots; strongly effervescent; gradual, smooth boundary.

C_1 40-60 cm (8-16 in). Brown (7.5YR 4/4, moist), sandy loam; massive structure; very friable (moist), slightly sticky (wet); very few fine roots; few very fine pores; strongly effervescent; gradual, smooth boundary.

C_2 60-110 cm (16-44 in). Brown (7.5YR 4/4, moist); sandy loam; massive structure; very friable (moist), slightly sticky (wet); strongly effervescent; gradual, smooth boundary.

Table 16. General characteristics of soil profile No. 13 in the Gareh Bygone Plain.

Parameters	Horizon and depth (cm)			
	Ap 0-20	BC 20-40	C_1 40-60	C_2 60-110
Sand, %	62.12	64.12	66.04	78.12
Silt, %	23	19	21	12
Clay, %	14.88	16.88	12.96	9.88
Texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam
Organic carbon, %	0.471	0.276	0.138	0.118
$CaCO_3$, %	45	44	49.5	44.37
Saturation, %	39.72	39.47	35.79	34.23
pH	7.67	7.73	7.77	7.76
EC, ds/m	17.86	8.21	8.38	5.21
Available K, mg/kg	196	176	82	100
Available P, mg/kg	5	0.6	3.2	1.4

Land classification for surface irrigation

Description of classes and subclasses

The major objective of land classification in this study site was to assess suitability of different areas for surface irrigation, as the very high cost eliminates sprinkler irrigation as a viable alternative. In this assessment several limitations, namely high amount of gravel and stone fragments in the surface and the entire profile, effective depth, the presence of pans, salinity and alkalinity, and also slope, unevenness of the land (high relief), erosion hazards and deposition of sediment (on lower fields) are considered (Table 17).

Of the 6 classes of land capability, the first 3 are suitable for irrigation.
The following symbols apply to our study site:
A: Limitations due to salinity and alkalinity;
S: Limitations due to permeability, soil surface texture, amount of gravel and stone fragments in the surface and subsoil;
T:Limitations due to topography, slope, water and wind erosion;
W: Limitations due to high watertable and inundation hazards.
The area intended for implementation of the artificial recharge of groundwater and irrigated agriculture are in class II, which covers 758.74-ha, and class ???, which covers 1106.30-ha, of the total expanse of 2092.74-ha.

The subclasses are:
IIS.Surface soil contains up to 10% gravel by volume with very high permeability. They cover 200.72-ha.
IIST.High permeability, slightly undulated, little wind and water erosion, without wind deposited materials. They cover 274.47-ha.
IISTW. High permeability, surface and subsurface gravel and stones (low to relatively high amounts); water erosion hazards; some wind deposited materials; inundation hazards. They cover 244.98-ha.
Limitations of class III for irrigation are as follows:
the subclasses are :
IIIA. High salinity and alkalinity with EC>8ds m^{-1}. They cover 68.97-ha.

IIIS.A large amount of gravel and stone fragments in the subsoil. They cover 577.19-ha.
IIIST. A large amount of gravel and stones (15-35% by volume); shallowness (35-50 cm); high relief and steep slope. They cover 404.81-ha.
IIITW. Intense water erosion and inundation. They cover 55.37-ha.

Table 17. Soil units, land classification symbols and the area of each unit.

Work unit No.	Soil unit No.	Land classification symbols	Soil profile No.	Area, ha	Area,%
1	6	$\frac{3gL(f)}{A\text{-}(d1)\text{-}E_1\text{-}F_1}$ IISTW	3	25.48	1.22
2	7	$\frac{2gL(f)}{A\text{-}(d_1)\text{-}E_1\text{-}F_1}$ IISTW	2	219.50	10.49
3	2	$\frac{2GL(g)}{A_1\text{-}(d_1)\text{-}E_0}$ IIIS	1	228.15	10.90
4	4	$\frac{2GL(g)}{A_1\text{-}(d1)\text{-}E_1}$ IIIS	7	241.95	11.56
5	5	$\frac{2L}{A\text{-}E_2\text{-}F_2}$ IIITW	12	55.33	2.64
6	3	$\frac{2gLg3\text{-}Z}{Baz\text{-}E_1}$ IIIST	_	363.55	17.37
7	8	$\frac{2gLf}{A_1\text{-}(d_1)\text{-}E_0}$ IIS	6	200.32	9.57
8	8	$\frac{2L}{A_1\text{-}(d_1)\text{-}E_1}$ IIST	4	93.91	4.49
9	8	$\frac{2LS_2}{A\text{-}E_0}$ IIIA	13	68.97	3.30
10	6	$\frac{2GL(g)}{A_1\text{-}E_1\text{-}F_1}$ IIIS	11	71.88	3.43
11	3	$\frac{2gLg3\text{-}Z}{Bb_2\text{-}E_1}$ IIIST	8	41.26	1.97
12	8	$\frac{2L(g)}{A\text{-}E_0}$ IIS	9	38.97	1.86
13	1	$\frac{2L}{A_1\text{-}E_0}$ IIST	5	180.56	8.63
14	2	$\frac{2GL(g)}{A_1\text{-}E_0}$ IIIS	10	35.21	1.68
15	?	Hills	?	202.47	9.67
16	?	Villages	?	25.23	1.21
Total				2092.74	100.00

General remarks

The surface soil in the study area is sandy, with some wind-deposited materials. Salinity and alkalinity cause problem only in a very small percentage of the area. These soils contain a small amount of gravel and stone fragments in the irrigated and dry farming areas. Other lands have a considerable amount of gravel and stone fragments, particularly in the subsoil. Water and wind erosion presents a limitation in this area. A considerable portion of the area has a low gradient. Slope maybe a limitation on foothills. Permeability is very high, i.e., porosity is high in these soils, which makes them suitable for floodwater spreading. It is worth mentioning that the floodplain is inundated almost every year. A detailed soil map for the study site is presented in Appendix B.

Land use change during the 1984-2002 period in the Gareh Bygone Plain

Availability of satellite imagery, computers and relevant programs has enabled us to accurately analyze the changes that have occurred since 1984, 19 months after initiation of the artificial recharge of groundwater (ARG) project in the Gareh Bygone Plain (GBP). A Landsat-4, a 7-band imagery of 16 July 1984, a Landsat-5, again a 7-band imagery of 20 May 1998, and an ASTER 3-band imagery of 26 July 2002 were used in this study. The first two images had been acquired by the thematic mapper (TM) in whom each pixel covered 25×25-m. The area of each pixel in the ASTER images was 10×10-m.

The required corrections were made on these imageries and all of them were digitized to facilitate data collection. These were achieved by employing the Optimum Index Factor (OIF) and using the bands, which had the most regression at exact locations. The false color composites were then prepared with these images of the study area.

The most important criterion employed for delineating the plain was an 8% slope of the foothills. Different land use of the study area was polygonized using the visual interpretation method by digitizing them on the screen. The output was the area, and the percentage of each of the land use types. These data were then statistically analyzed using the integrated land and water information system (ILWIS ver-3.1).

The area of 9 categories of land use for the years 1984, 1998, and 2002 are presented in Table 18, figure 8, and two maps (Appendix C).

- A very prominent change of bareland from 2971- ha in 1984 to 983.6-ha in 1998 has been due to floodwater spreading (FWS).
- FWS on some bareland not only decreased the total area, but also provision of forage on the spreading area decreased the grazing pressure on the rangeland.
- The FWS area, which covered 475-ha in 1984, increased to 2445-ha in 1998. No new FWS system for the artificial recharge of groundwater has been constructed since 1998.
- The area of irrigated farm fields increased from 148.0-ha in 1984 to 1193-ha in 1998. An increase of 1504-ha of bareland in 2002 had been due to a drought during the 1996-2000 period. A decrease of 462-ha in irrigated land in 2002 relative to 1998 had been due to the drought, and a decrease in natural and artificial recharge of groundwater.
- A very encouraging observation in the wheat fields of the GBP is their relatively high yields (up to 5 ton ha^{-1}) in a loamy sand (> 72% sand) irrigated at a 3- week interval. This points to the potential of sandy deserts for food production.

Table 18. Land use changes during the 1984 – 2002 period.

Land use type	Years					
	1984		1998		2002	
	ha	%	ha	%	ha	%
Bareland	3137	21.13	1067	7.19	2571	17.32
Cultivated-irrigated	147	0.99	1193	8.04	731	4.92
Cultivated-rainfed	335	2.26	831	5.60	158	1.06
Fallow	304	2.05	182	1.23	393	2.65
Floodwater spreader	475	3.20	2445	16.47	2445	16.47
Forested with spate irrigation	0	0.00	87	0.58	87	0.58
Poor rangeland	217	1.46	1972	13.29	2917	19.65
Urban	3	0.02	18	0.12	44	0.30
Very poor rangeland	10224	68.89	7047	47.48	5497	37.04
Total	14842	100	14842	100	14842	100

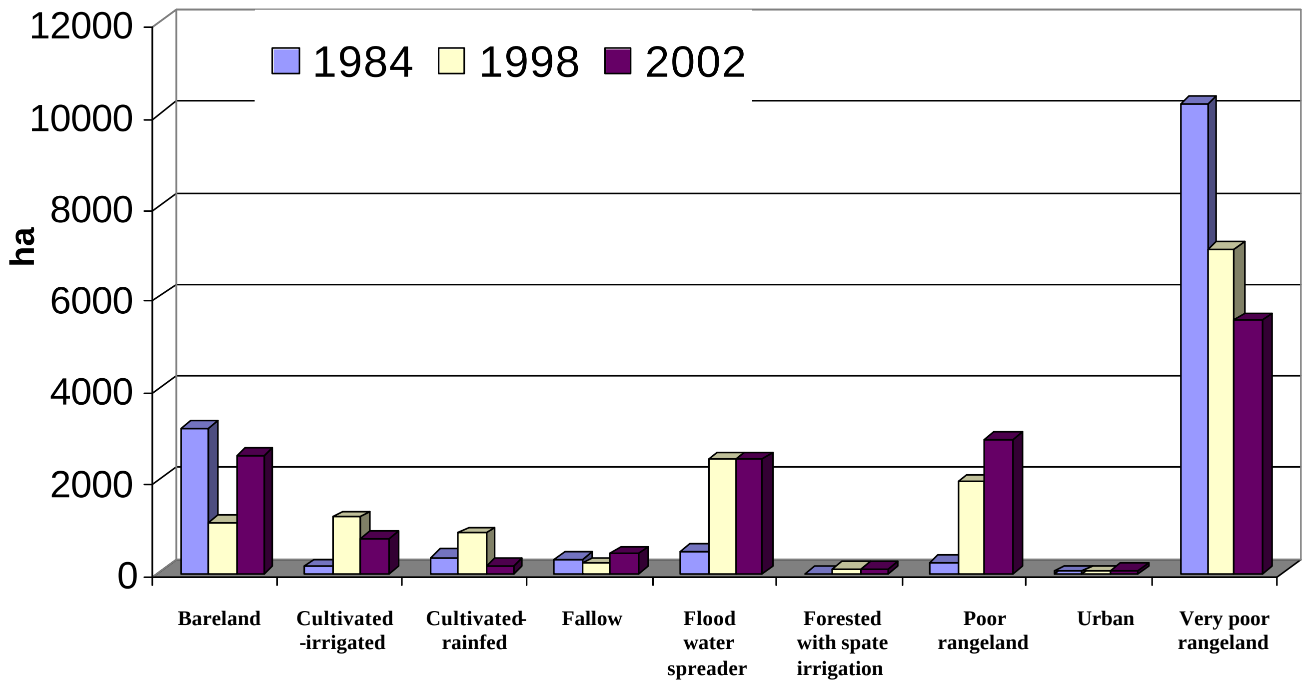

Fig. 8. Land use changes during the 1984 – 2002 period.

Hydraulic conductivity of sedimentation basins

A major determinant of the success of the ARG projects is the hydraulic conductivity (HC) of the floodwater spreading sites. As floodwaters are turbid by nature, the HC drastically decreases even after the very first operation. The main reason for this problem is translocation of very fine clay minerals in the vadose zone. Figure 9 presents a TEM of clay species sampled at a depth of 7.5-m in a sedimentation basin planted with river red gum *(Eucalyptus camaldulensis* Dehnh.*)*. Therefore, a valid question of "what happens to the system when the soil becomes impervious?" is repeatedly asked.

To answer this question, the HC was determined at 3 site and at 5 depths with 3 replications. Our control was outside of an ARG system. A sedimentation basin devoid of plants, and one planted to river red gum constituted the other treatments. The double-ring method was employed to determine the HC at 50, 100, 150, 200, and 250-cm. The data for each site was averaged and presented as a single figure.

The HC for the control, and sedimentation basins with and without tree were 7.7,9.3, and 3.8 cm hr^{-1}, respectively. A 50% decrease in the treeless site relative to the control was logical, as the thickness of the freshly laid sediment exceeded 60-cm. A 20% increase in the afforested site, however, looked anomalous at first. Close examination of the soil profile, however, revealed the presence of numerous root channels and biopores. It is to the credit of a sowbug (*Hemilepistus shirazi* Schuttz) that water enters the crusted surface soil. Mean infiltration rate for the sowbug infested area and the control, using the double ring method, was 7.7 and 2.7-cm hr^{-1}, respectively. As their burrow is 60-100-cm deep, root channels take over at those depths. Since the roots have reached the phreatic zone, and their decomposition after death is a perpetual process, therefore, there is no hindrance to water movement in the vadose zone. To decrease the very high water consumption rate in the afforested basin, a thinning trial is being conducted. Moreover, studies for replacement of eucalypts with less water consuming trees are under way.

Fig.9. TEM of palygorskite-sepiolite fibers in a sediment-clay assemblage with kaolinite, smectite and other minerals in a sample at

Floral biodiversity

The inhabitants of the dry and semi-dry zones of Iran had found from time immemorial that rainfall in their habitat was insufficient for agriculture. Therefore, they chose the nomadic livestock systems that are well adjusted to the ecosystems of most of the land of Iran. Unfortunately, the forced sedentarization of nomads in the 1930s, and the encroachment of farm fields and orchards onto the rangelands, have made livestock herding an unattractive business for the majority of nomads. This applies to the Arabs who presently inhabit the Gareh Bygone Plain (GBP) too.

Concentration of man and livestock in a place of very low carrying capacity has delivered a serious blow to the natural resources of the GBP. Conversion of a scrubland into farm fields in an area with 243-mm mean annual precipitation, and a low reserve of groundwater, turned a beautiful haven of gazelles and houbara bustards into a desolate land. Now, we are faced with a degraded land, most of it covered with sand, and try to rehabilitate it through the artificial recharge of groundwater (ARG).

In the following sections we try to present the state of natural resources for the area we intend to implement our SUMAMAD project, and their mutual relationships at other geographic scales. It is imparative to realize that this study covers an area between the contours of 1300-1120-m above the mean sea level.

.? State of the rangeland

Methods

The following criteria have been considered in an assessment of the vegetative cover: Type mapping, biomass determination (grazing capacity), and species richness.

Table 19. Yield and crown cover of spate-irrigated and control range plants at the Kowsar Station during the 1992-2000 period.

Year	Annual rainfall*, mm	Spate irrigated: Yield, kg ha^{-1}	Spate irrigated: Crown cover, %	Control: Yield, kg ha^{-1}	Control: Crown cover, %
1992	273.5	655.0	49.0	85.6	20.1
1993	556.5	437.6	38.0	88.3	27.4
1994	165.0	317.8	37.8	87.0	15.7
1995	285.0	432.2	35.2	90.0	20.3
1996	514.0	721.5	36.4	125.6	18.3
1997	208.5	581.0	32.1	105.0	14.6
1998	273.5	457.0	23.6	98.0	12.6
1999	188.0	330.7	20.3	83.0	11.0
2000	83.0	257.3	19.0	78.0	9.7
2001	141.5	260.0	19.5	80.0	12.2

*Baba Arab Meteorological Station, 15.7-km to the WSW of the Kowsar Station.

Table 20. Yield and crown cover of spate-irrigated and control range plants during the wet and dry periods, 1992-2000.

Parameter	Wet years		Dry years		Entire period	
	Yield, kg ha^{-1}	Crown cover ,%	Yield, kg ha^{-1}	Crown cover, %	Yield, kg ha^{-1}	Crown cover, %
Spate irrigated	540.6	36.4	349.3	25.7	445.0	31.0
Control	97.5	19.5	86.6	12.6	42.0	16.0
Significance	**	**	**	*	**	**

* and ** significant at the 1 and 5% level

Please note that as this range inventory has been peformed in August and September 2003, when the air was hot and the surface soil was dry, presenting accurate data, particulary for the annuals, is risky, indeed. We shall perform this inventory in the spring of 2004, and collect more reliable data. Moreover, we shall establish permanent plots both inside and outside of the floodwater spreading (FWS) sites to minitor the changes in the vegetative cover in the coming years.

a.Type mapping

The mosaic of a large composite picture was assembled from selected portions of 1:25000 and 1:10000 scale aerial photographs. The physiognomy method, based on the life forms, was used in this study. The land forms and ecotones were delineated on the photographs, and the types were determined within each boundary.

These boundaries were then superimposed on a topographic map, which was used in the field along with the photographs. Phyto-geographically, the GBP is located between two major habitats of the Irano- Turanian domain and the Persian Gulf - Omani group. Vegetation types are as follows:

1. Foothills and sloping land

Occasional, isolated bushes of *Amygdalus liciodes* Spach, *Amygdalus scoparia* Spach, and *Pistacia khinjuk* Stocks occupy crevices hard to reach; otherwise they had been cut down. The undercover is composed of *Ebenus stellata* Boiss., *Astragalus arbusculinus* Gauba Bornm. *Aretmisia sieberi* Besser., *Centanrea intricata* Boiss., and *Convolvulus acanthocladus* Boiss.

2. Rocky, undulated land

Of perennials, *Convoluulus acanthocladus* Boiss., *Ebenus stellata* Boiss., *Platychaete aucheri* (Boiss.) Boiss., *Anvillea gracini* (Burm.) DC., *Gymnocarpus decander* Forsk., *Helianthemum lippii* (L.) Pers. , *Centanrea intricata* Boiss., *Acantholimon bracteatum* (Girard) Boiss., *Noaea mucronata* (Forsk) Asches. et Schweint.,*Scariola orientalis* (Boiss.) Sojak, and *Salsola* sp were determined in this landform. Of annuals, *Stipa capensis* Thunb., *Medicago radiata* L. *Medicago rigidula* (L.) All., and *Onobrychis cristagalli* (L.) Pam. were observed in this landform.

3. Low sloping plain

A major portion of this area has been plowed for dryland agriculture. Therefore, there has been a major change in species composition and density in this part of the plain between Ahmad Abad, Tchah Dowlat, and the Tchah Qootch River. However, isolated patches of vegetative cover are found where tractors could not maneuver. The major species are: *Artemisia sieberi* Besser., *Centanrea intrieata* Boiss.,*Peganum harmala* L., *Anvillea garcini* (Burm.) DC., and *Stipa capensis* Thunb. Some forbs and annual grasses are also observed in this section.

Ziziphus nummularia (Burm. f.) Wighth & Arn. is the prominent bush of the plain, which sometimes is found along with *Pteropyrum* sp in dry washes. Isolated stems of *Noaea mucronata* (Forsk), *Scariola orientalis*, *Carthamus oxyacantha* M. B., *Alhagi* sp., *Prosopis farcta* (Banks & Soland) Macbr. *Stipagrostis plumosa* (L.) Munro ex I.Anders. , and *Cymbopogon olivieri* (Boiss.) Bor. are also observed in this section.

b. Biomass production

As the carrying capacity of rangelands depends on the above ground biomass production, two permanent, 100-m transects, one parallel to slope and another on the contour, have been established to monitor the changes during the project duration. Ten 2×1-m plots, every 10-m on the transects, will be selected every year and the area covered by crown, litter, gravel and rocks will be determined. Dry matter yield of each plot will be determined, too.

As we have been monitoring the floodwater spreading (FWS) areas and the control for the past 20 years in an adjacent expanse, we present some of the collected data for 1992-2000 in Tables 19-21.

c. Species richness

Species richness is defined as the number of different species in a vegetative type. As it is practically impossible to count all individual plants, one resorts to the random or systematic sampling. This inventory is performed in 10 random plots in each working unit. The density and distribution of species is determined using the jackknife estimate as follows:

S = S + (n –1 / n) K , where
S = species richness
S = Number of species in n quadrats
n = Total number of samples in quadrats
K= Number of single species

d. **Practical implications**

Spate irrigation of rangelends increases forage yield many fold. We have observed up to 11-fold increase as compared with the control. In a 5-year study of the effects of FWS on a rangeland, Mesbah et. al (1994) has reported a 6-fold increase in yield, and a 2-fold increase in vegetative cover. Please note that these studies considered only the indigenous vegetation. If the yield of the planted quailbush [*Atriplex lentiformis* (Torr.) Wats] is also added to this figure, the yield will in crease up to 23-fold, enough to graze 4 sheep yearround in one hectare in the GBP.

II. State of the afforested area

The various species of Eucalyptus and Acacia genera have been widely used in afforestation and plantation programs throughout the world. These species are tolerant to drought and harsh conditions, and their poles, fuelwood and other by-products are used by local people, as well as by different industries.

Planting of Eucalyptus species, mainly *Eucalyptus camaldulensis* Dehnh.was started in 1982. Several species of acacia were also planted in the floodwater spreading area in 1985. Selection of these species were based upon the results obtained in species elimination and species growth trials, as well as the species plantation trials. These trials had been established earlier or were carried out simulataneously in several arid and semi-arid regions, including the Gareh Bygone Plain (GBP) floodwater spreading areas.

Table 21. The presence (+) and absence (-) of plant species in 2 spate-irrigated and control at the Kowsar Station, 1994-1998.

Plant species	Part1	Part2	Control
Aaris minor	+	+	-
Acantholimon bracteatum (Girard) Boiss.	+	-	+
Aegilops kotschyi	+	+	+
Alhagi pseudoalhagi	+	+	+
Artemisia sieberi Besser.	+	+	+
Astragalus tritoloides	+	-	+
Atriplex lococlada Boiss	+	-	+
Avena fatua L.	+	+	+
Bromus danthoniae	+	+	+
Bromus tectorum L.	+	+	+
Carex stenophylla Wahl.	+	+	+
Ebenus stellata Boiss.	+	-	-
Echinops sp.	-	-	+
Euphorbia sp.	-	-	+
Helianthemum lippii (L.) Pers.	+	-	+
Hordum sp.	+	+	+
Lolium sp.	-	+	-
Medicago radiata L.	+	+	+
Noaea mucronata (Forsk).	+	-	+
Onobrychis cristagalli (L.)	-	-	+
Peganum harmala L.	+	+	+
Poa sp.	-	+	-
Scariola orientalis (Boiss.) Sojak.	+	+	-
Stipa capensis Thunb.	+	-	+
Stipagrostis plumosa (L.) Munro ex I Anders.	+	-	+
Trigonella stellata	+	+	+
Vicia sp.	+	+	-
Ziziphora sp.	+	-	-

- Survival and growth performance of the trees were quite satisfactory in the GBP. The average yield at the age of 8 years in a sedimentation basin with an area of about3.6 ha planted in 1986,which had received more water during the years of establishment was 60-m^3 $ha^{-1}$of stem wood, and 18-m^3 $ha^{-1}$of fuelwood (9.8-$m^3ha^{-1}year^{-1}$ for total wood production). In less flooded area (6-ha). The average yield for stemwood and fuelwood per ha was 39.0-m^3 and 11.7-m^3, respectively (6.4-$m^3ha^{-1}year^{-1}$ for total wood production). Results of a measurement and survey of 18-year old trees, which was carried out in 2003, are presented in Table 22. The above ground carbon sequestration potential of an 18-year old, spate-irrigated *Eucalyptus camaldulensis* Dehnh. is 3.699-tons $ha^{-1}yr^{-1}$.This for *Acacia salicina* Lindl. is 3.392- tons ha^{-1} yr^{-1}.

Table 22. Total stemwood, fuelwood, and leaf production of two spate-irrigated sites and (yield per ha of each) in kg at the Kowsar Station.

Category	Site	Site1 3.6-ha,morefloodwater	Site2 6-ha,lessfloodwater
Stemwood		388800(107280)	371830(61970)
Fuelwood		66550(18360)	6540(10908)
Total leaf production(fresh)		15720(4337)	14890(2480)

Simple analysis of the income generated by these plantation after 18 years are presented in Table23.

Table 23. The income generated in an 18-year old eucalyptus plantation at the Kowsar Station in US $.

Parameter	Average yield of sites1&2, kg ha^{-1}	Price kg^{-1}	Total income ha^{-1} after 18 years
Stemwood	79232	0.0602	4770
Fuelwood	13750	0.024	330
Leaf (fresh weight)	3188	0.036	115
Grand total			5212

According to these calculations, the total income from stemwood, fuelwood and fresh leaf after 18 years amounts to $5215, that is, $290 ha^{-1} yr^{-1}. This amount, regarding the low risk and very low capital investment (as compared to agriculture), is quite considerable.

If 3000 -ha in the area can be allocated to tree plantations, then the annual income will amount to $ 870,000. Moreover, such incomes may potentialy be increased in two ways:

- Many species, including *E.camaldulensis* are vigorous coppicer, and 3 successive coppice rotations are applicable for them.
- Establishment of wood-processing industries enhances the added value of the forest products.

It should be noted that there would be other noticeable incomes from the afforestation by-product, such as forage, food products, pharmaceuticals, honey, beeswax, etc. Therefore, it is reasonable to conclude that, taking into account all of these benefits, allocation of such lands to tree plantations is quite rational, and may even lead to generation of higher revenues as compared to agriculture.

To achieve this goal, each product must be studied separately and evaluated in terms of the present and future consumption and economic values. Furthermore, other multipurpose trees must by introduced to investigate their adaptation and performance. Carbon sequestration allowance could be added to the incomes as well.

Faunal diversity

Many birds and mammals that inhibit the GBP have come to the area after the floodwater spreading activities were started. Therefore, it cannot be claimed with certainty that they are all indigenous. The birds are: houbara bustards [*Chlamidotis undulata* (Jaqu.)], rock doves [*Columba liva* (Gm.)], turtle doves [*Steptopelia turtur* (L.)], common babblers [*Turdoides caudatus* (Drapiez.)], white-eared bulbuls [*Pycnonotus leucotis* (Gould.)], blue-cheeked bee-eaters [*Meripus superciliosus* (L.)], Indian rollers [*Coracias benghalensis* (L.)], rollers [*Coracias garrulus* (L.)], hoopoes [*Upupa epops* (L.)], black-bellied sand grouses [*Pterocles orientalis* (L.)], see-see partridges [*Ammoperdix griseogularis* (Brandt.)],house sparrows [*Passer domesticus*(L.)], sparrow hawks [*Accipiter nisus*(L.)] and mallards [*Anas platyrhynchos*(L.)]. The mammals are gazelles [*Gazella subgutturosa* (Guldenstaedt.)], rabbits [*Lepus capensis* (L.)], foxes [*Vulpes vulpes* (L.)], jackals [*Canis aureus* (L.)], wolves [*Canis lupus* (L.)], pigs [*Sus scrofa* (L.)] and numerous species of rats and mice.

Soil microbiology

Microorganisms constitute less than 0.5 percent (w/w) of the soil mass; yet, they have major impacts on soil properties and processes. As human activities have caused a decline in the quality of soil resources, a considerable effort has recently been made in the study of soil microbial processes associated with maintaining the ecosystem.

Organic matter and water are the two major determinants of the microorganism life in soils. Soil organic and inorganic components may be oxidized or reduced as energy sources or electron acceptors for the microbial community. All nonphotosynthetic microorganisms must oxidize their growth substrates for energy production. The commonly considered reaction is the oxidation of ammonium to nitrite or nitrate, i.e., nitrification (Tate III, 1995). These oxidative reactions are catalyzed by two mutually exclusive groups of organisms, ammonium and nitrite oxidizers.

Nitrification as it occurs in soils is a strictly biological process due, so far as is known, to a few genera of chemoautotrophic bacteria. These are the nitrifying bacteria, or nitrifiers. They carry out the process in two steps: one group of nitrifiers oxidizes NH_4^+ to NO_2^-; another group oxidizes the NO_2^- to NO_3^-. The primary reactions involved are as follows (Tate III, 1995):

$$2\ NH_4^+ + 3\ O_2 \rightarrow 2\ NO_2^- + 4\ H^+ + 2\ H_2O + \text{Energy (66 kCal.mol}^{-1}\text{)}$$

$$2\ NO_2^- + O_2 \rightarrow 2\ NO_3^- + \text{Energy (20 kCal.mol}^{-1}\text{)}$$

Nitrite, the intermediate in the process, rarely accumulates to detectable levels in soils (Schmidt and Belser, 1982). The NH_4^+ oxidizers are comprised of five genera, and the NO_2^- oxidizers of two genera (Tate III, 1995).

The importance of the nitrifying microorganisms rests to a great degree on their capacity to produce the nitrate, the major nitrogen assimilated by higher plants (Alexander, 1983). Nitrate, although an important ion in plant nutrition, may be a significant environmental pollutant. It is deemed to be undesirable because of its potential role in eutrophication, infant methemoglobinemia (blue baby syndrome) and cancer in adults associated with consumption of nitrate-rich water or vegetables, and animal methemoglobinemia (Alexander, 1983; Follet and Walker, 1989). In these instances, the initiators of the problem are the nitrifying populations, the end product of their activity being often unwanted, in certain concentration at least, in water, food and feed (Alexander, 1983).

To control nitrate contamination in groundwater, the nitrate sources must be identified before appropriate and effective management actions could be taken. Nitrate sources could be divided into natural and anthropogenic (Madison and Brunett, 1985; Hallberg and Keeney, 1993; Spalding and Exner, 1993). Rainwater, forests, grasslands, agricultural lands, organic wastes (e.g., farm manures, sewage sludges, food-processing wastes and crop residues), row crops, vegetable crops, and livestock production are all potential nitrate sources in groundwater (Timothy et al., 2002). The previous work (Yazdian and Kowsar, 2003) indicated that the Agha Jari Formation, in which the Gareh Bygone Plain has been formed, contains NO_3^- and NH_4^+ (geologic-N).

The purpose of this study was to evaluate the importance of nitrifying bacteria in nitrate production in the Gareh Bygone Plain.

Materials and Methods

This study was conducted on a Typic Haplocalcids, coarse-loamy over loamy skeletal carbonatic, (hyper) thermic soil (alluvium-derived) at the Kowsar Station, 200 km to the southeast of Shiraz, Iran. Four composite samples of surface soil (0-20 cm depth) were collected from: (1) The first two sedimentation basins (SBs) of the Bisheh $Zard_1$ artificial recharge of groundwater (ARG) system, which was planted with *Eucalyptus camaldulensis* in Jan-Feb 1983(EUCA). (2) An adjacent site without floodwater spreading was chosen as the control. (3) SB_2 and SB_3 of the Rahim Abad, which formed the third treatment were under native pasture and irrigated with floodwater. (4) Farm fields located in south-west of Bisheh Zard (AFAR) formed the fourth treatment. These samples were used for enumeration of total microorganisms and nitrifying bacteria by the Most Probable Number (MPN) method (Schmidt and Belser, 1982). Also, different forms of soil inorganic nitrogen in these sites were measured.

Results and Discussion

The total number of microorganisms is shown in Fig.10. It is observed that the total population of the soil microorganisms increased by about 34 and 24-fold at the site which was planted with *Eucalyptus camaldulensis* and covered with native pasture along with floodwater spreading, respectively, in comparison with the control.

Two former sites had about 6 and 4-fold more microorganisms as compared with the farm fields. Apparently, an increase in moisture and substrate supply for the biotic community at these sites, are the two major determinants. Amount of organic matter in the site, which was planted with *E. camaldulensis*, has increased by about 2-fold in comparison with the control and farm fields (1.40 versus 0.63 and 0.73, respectively). The number of ammonium oxidizers in EUCA and AFAR sites increased significantly (Fig.12). Analysis of different forms of inorganic nitrogen in soils of the sites under study and in Agha Jari Formation (AJF) showed the higher amounts of nitrite (NO_2^-) in the control and nitrate in farm fields (Fig.11). Accumulation of nitrite in control may be due to oxidation of NH_4^+, which came from the AJF, and mineralization of native organic matter, deposition from atmosphere and non-leaching conditions. The higher amounts of nitrate in AFAR site may be due to fertilization. The activity of both ammonium and nitrite oxidizers (nitrifiers)(Fig. 12 and 13) increased in the site which was planted with *E. camaldulensis* as compared with the other sites. It may be concluded that cultivation of *E. camaldulensis* stimulates the growth and activity of nitrifier bacteria and subsequently, nitrification.

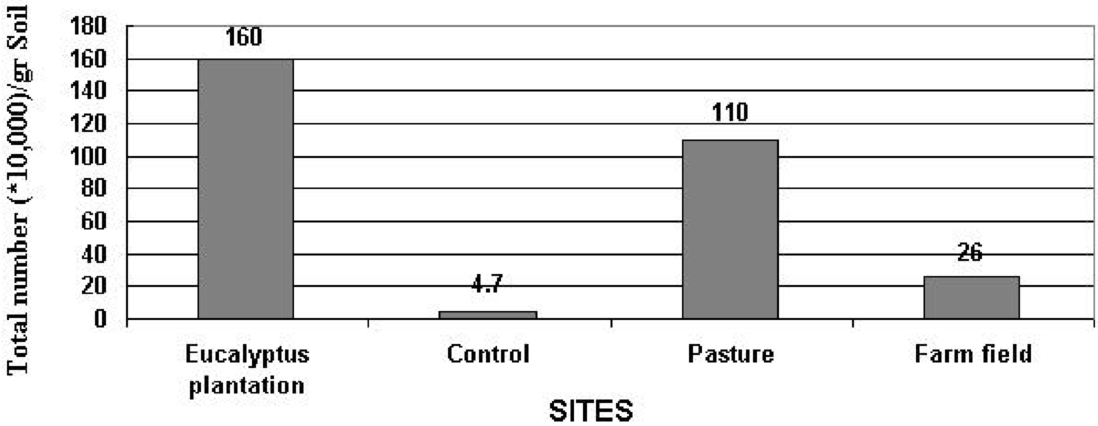

Fig. 10. Total number of microorganisms in different sites .

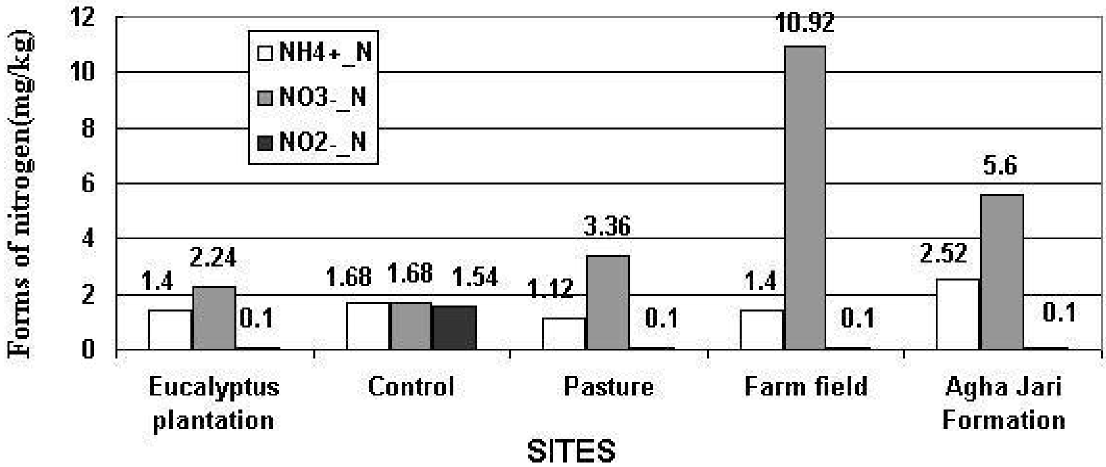

Fig.11. Different forms of nitrogen in different sites.

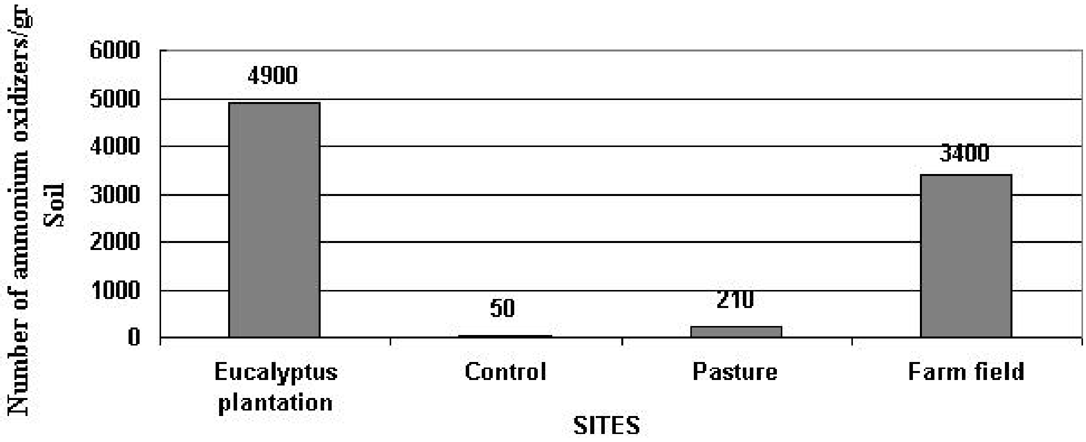

Fig. 12. Number of ammonium oxidizers in different sites.

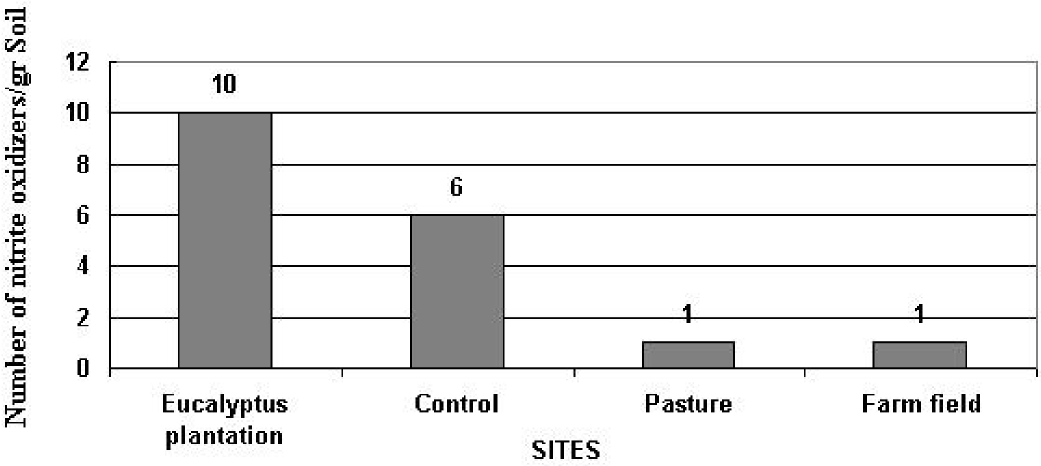

Fig. 13. Number of nitrite oxidizers in different sites.

B. Characterization of stresses

Assessment of desert livelihoods on the part of development practitioners and policy-makers needs to be harmonious with the realities of nomads' percieved risks and worries

The theory that humans are a product of their environment sounds logical when we ponder over the behaviour of the present day population of the Gareh Bygone Plain. These people are the descendants of the warlike nomads of the *Khamseh* Confederation, which was created by the *Qavam* clan of Shiraz in the middle of the 19th century. This was done to balance the power of the *Qashqai* Tribe, and also to enforce the will of that clan to intimidate the central government, and to wrest wealth from powerless citizens. In fact, Ahmad Abad, the closest village to the project site, was the den of a feared bandit who had been offered an amnesty by the

Government of Iran in the 1950s. The mentality, that 'if I don't take it somebody else will', still resides in the mind of the populace. We hope to teach the children of young couple to respect the right of others, particularly to safeguard the natural resources that are common property.

Demography

There are 4 villages in the Gareh Bygone Plain (GBP) with a total population of 2127, as of September 2003. The annual population growth rate, based on the latest five-year data, is 1.7 percent. The in-migration, although significant due to water avaiability, was not recorded. The out-migration in the past 5 years ,due to joining the armed services and going to college, has been 2.5% of the population. Population data for the GBP are presented in Table 24.

Table 24. Demographic data for the Gareh Bygone Plain.

Village name	Total population	Percentage of Total population	number of households	Persons per household
AhmadAbad	220	10.34	27	8.14
Bisheh Zard	486	22.8	80	6.07
Tchah Dowlat	801	37.66	148	5.41
Rahim Abad	620	29.2	107	5.79
Total	2127	100	362	----------------

Three of these villages have road and access to safe water, electricity, fossil fuels, radio and television programs, school and public health facilities (Table 25).

Table 25. Infrastructure and services received by the Gareh Bygone Plain villagers.

Village name	Access to safe water*	Electri City	Fuel	Radio &TV	Public health	School	Road **
Ahmad Abad	-	+	Kerosene	+	-	Primary	Dirt
Bisheh Zard	+	+	Kerosene	+	+	Primary	Dirt
Tchah Dowlat	+	+	Kerosene	+	+	Primary and Secondary	Dirt
Rahim Abad	+	+	Kerosene	+	+	Primary	Dirt

* . + Positive - Negative

** . Paved roads connect Bisheh Zard, Rahim Abad and Tchah Dowlat to the city of Fasa.

Poverty line

Taking the poverty level in Iran as the criterion, 68% of the households in the GBP live below the lowest standard poverty line. Only 32% of the population live just above the poverty line. It is probable that 80-90% this group (32%) descend beneath that line in bad times. Some pertinent data regarding annual income in these 4 villages and the way they spend it are presented in Table 26. The itemized cost of living for an average household are presented in Table 27.

Table 26. Annual per capita income of the villagers in the Gareh Bygone Plain for 2003 in US $ purchasing power parity.

Description	Average annual Income	Standard deviation	Maximum annual income	Minimum annual income
Income of people below the poverty line	1061	328	1750	456
Income of people above the poverty line	3044	1742	7425	1767
Average income of the villagers	1558	1372	7425	456

Means of earning livelihoods

Mixed farming (raising wheat, barley, cotton, sugar beets, alfalfa, tomatoes, cantaloupe, melon and watermelon, and herding sheep and goats), plus a minor amount of citrus fruits, make the bulk of the people's income. About 49.3% of the households are mixed farmers, 50.6% are herders, and 80% are service workers. About 29.3% raise farm and horticultural crops and herd as well; 36.0% of farmers raise horticultural crops, and herd livestock, and do service work; 37.3% are herders and service workers. Please note that there are many overlaps in these percentages, as men, who are the bread-winners try their hands in many businesses, even become common laborers as the need arises. As of women workers, very few in each village weave carpets and rugs, more as a hobby than a regular occupation. On the whole, 69.4% of the population of the 4 villages depend on agriculture for their livelihoods.

Table 27 . Itemized annual cost of living per household in the 4 villages in US dollar purchasing power parity.

Description	Household expenses	Percentage of the total
Health	575.8	8.53
Education	531.1	7.87
Water, electricity, fuel	275.9	4.09
Rent	6.00	0.09
Food	4288.3	63.55
Clothing	921.7	13.66
Transportation	22.8	0.34
Telephone	90.3	1.34
Miscellaneous	35.3	0.52
Total	6742.2	100.00

It is observed that 63.55% and 13.66 of the income of households is spent on food and clothing (the maximum), and 0.09% and 0.34% on rent and transportation (the minimum).

Human Development Index (HDI) For The Gareh Bygone Plain

This index, which has been introduced by the UNDP in 1990, is a very useful criterion that has proven its utility and validity in evaluating the level of human development in different countries.

By definition, development is a process, which enhances humans' ability to select among alternatives. As there are unlimited needs and they vary in different periods, the following three major criteria, which better assess development in human societies, have been selected:

1. A long and healthy life, which is measured by the life expectancy (LEI);
2. Access to essential information, which is measured by the education index (EDUI);
3. Earning enough income to live a relatively comfortable life, and it is measured by income according to the dollar purchasing power parity (YI).

These three indices have equal weights in HDI.

A very important characteristic of this index is its worldwide utility; therefore, the development of all nations could be compared with each other by the HDI. In a detailed survey of the 4 villages in the GBP, we interviewed 75 families (about 20 percent of population) and collected comprehensive data, of which only a condensed form is presented here.

Life Expectancy Index

This is defined as the number of years an infant can live assuming the conditions that dictated death at the time of his/her birth remain unchanged. Life expectancy in the GBP is 64.5 years as compared to 64.8 for the country (I.R.Iran) as a whole. Life expectancies for men and women are 57.3 and 64.8 years, respectively. These figures for the country are 68.5 and 71.3 years. Of the 3 major causes for death, old age, diseases and accidents cover 65.0, 23.5, and 11.5 percents, respectively. Eliminating the accident as a cause of mortality, the average life expectancy is 66.6 years; 64.8 for men, and 67.6 for women.

The LEI (life expectancy index) for the Gareh Bygone Plain is therefore:

$$\mathrm{LEI} = \frac{64.5 - 25}{85 - 25} = 0.658$$

Education Index

This index is calculated by giving 2/3 of its weight to the literacy rate of individuals over 15 years of age, (adult literacy), and 1/3 of its weight to gross enrolment in school, or its equivalent, the average of years spent at school. As there is no secondary and high school in the area (GBP) to obtain the gross enrolment number, we used the average years spent at school (Tables 28 and 29).

Please note that either of these two, i. e., the number of years spent at school, or gross enrolment indicates the quality of education.

Table 28. Literacy rate in Iran and the Gareh Bygone Plain (values in percentages).

Description	Above 6 years old	Above 6 years old, (men)	Above 6 years old, (women)	Above 15 years old	Above 15 years old, (men)	Above 15 years old, (women)

Iran (urban & rural)	*	*	*	77.1	83.8	70.2
The Gareh Bygone Plain	76.0	82.0	69.0	71.4	83.0	63.4

*. No data are available or not calculated

Table 29. Average number of years spent at school in the Gareh Bygone Plain (values in years).

Description	Above 6 years old	Above 6 years old, men	Above 6 years old, women	Above 15 years old	Above 15 years old, men	Above 15 years old, women
The Gareh Bygone plain	5.00	4.82	5.17	5.80	6.91	4.60

Taking the percentage for literacy rate of above 15 year olds as 71.4 , and 5 years spent at school, the education index (EDUI) is:

$$LRI = \frac{71.4 - 0}{100 - 0} = 71.4$$

$$AYSSI = \frac{5 - 0}{15 - 0} = 0.333$$

Where LRI is the literacy rate index, and AYSSI is the average years spent at school index. Therefore, the education index (EDUI) is:

$$EDUI = [\frac{2}{3} * 0.714] + [\frac{1}{3} * 0.333] = 0.587$$

Income Index

This index shows the earning level according to the dollar purchasing power parity (PPP). A difficulty in arriving at this index is that the exchange rates according to the Government policies and the free market-floating rate are not equal. Therefore, to arrive at a common ground, it is converted to the local cost of living ,as instructed by the International Comparison Project (ICP).This index is annually measured and reported for every country in the world.

A large percentage of the rural income in Iran is from mixed farming. Carpet weaving and rug making are another source of revenue, especially for women.

To arrive at this index, the entire income of the sampled population was itemized according to their gross earnings from crop yields (both dry - farmed and irrigated), orchard produce (dry - farmed and irrigated), hay making, animal husbandry, earning rent, selling stubble, working as a common laborer, trading, earnings from charity foundations, scholarship for the children, prizes, dividends from savings, selling carpets and rugs, etc. Costs of crop production or caring for the livestock were then deducted from the gross earning to arrive at the net income. As the per capita dollar PPP of the population was lower than the average world income, the Atkinson Utility Relationship was not applicable for deflating.

The income per capita for the Gareh Bygone Plain is $1558.00 for 2003. Therefore the income index would be:

$$YI = \frac{\log(1558) - \log(100)}{\log(40000) - \log(100)} = 0.458$$

It is imperative to realize that the income per capita in terms of dollar PPP for Iranians in 2001 had been $6000.00.

Human Development index

This index is dimensionless, and it is the weighted mean of the three indices described. It is comparable with the same index worldwide. According to the UNDP, countries with the HDI of < 0.5 are underdeveloped. Those with the HDI of 0.5-0.8 are developed. And those with the HDI of >0.8 are well developed.

As HDI for the Gareh Bygone Plain is:

$$HDI = \frac{YI + EDUI + LEI}{3} = \frac{0.658 + 0.587 + 0.458}{3} = 0.568$$

Although, theoretically, this index places the people of the Gareh Bygone Plain in the “developed” category, they are near the lowest rank. Iran ranks 106th among 175 countries.

Some of the other major stresses are as follows:

Land degradation due to: wind and water erosion; overgrazing; salinization due to irrigation with saline groundwater; misuse of farm machinery and inappropriate implements (e.g., moldboard plows);

Groundwater depletion and salinization due to over-exploitation;

Denudation due to clearing of a scrubland for farming, and hills and mountains for fuelwood and fencing;

Low interest credit availability (the loan shark dilemma);

Low and erratic annual rainfall, high evapotranspiration, strong winds, sand storms.

- Large landholders and commercial operators who rent the farm fields have access to water, while small operators and landless peasants can hardly obtain their needed water. Water must be treated as a common property. All inhabitants of a watershed, including flora and fauna, are entitled to receive their fair share of water. The landless should acquire the right to sell their share to the highest bidder.
- Intended farm fields are extremely poor in organic matter (OM). As the floodwater loses most of its OM in sedimentation basins, therefore, addition of manure to the soil is essential. Provision of portable corrals, and night stabling of livestock flocks on a systematic basis on the fields,

should be arranged. This plan is implemented in fair weather, particularly when the flocks are grazed on wheat and barley stubble.

C. Description of Indigenous, Adaptive and Innovative Approaches

Transhumant pastoralists are first rate ecologists, otherwise they could not have lived that life for millennia. They had known it from time immemorial that rainfall in their habitat was insufficient for agriculture. They adjusted their trekking with the season to optimize their enterprise. Therefore, it is not surprising to find out that what Iranian transhumant pastoralists had learned through thousands of years of experience, only recently has been proven true under similar environmental conditions: nomadic livestock systems are well adjusted to the ecosystems of the southern Sahel (Breman and de Wit, 1983). This has been proven even for the Himalayan environment; continuance of transhumance within the carrying capacity of the Niti valley (Nanda Devi Biosphere Reserve buffer zone) has been advised for effective management of available resources (Nautiyal et al., 2003). Nomads spread their herds evenly across the landscape, thus cause less damage to the soil (Coughenour et al., 1985). On the contrary, concentration of humans and livestock into small areas degrades the soil, decreases the productive capacity of the land, and causes a decline in water resources and their quality.

Forced sedentarization of some Arab nomads in the GBP disrupted this environmentally sound practice. They tried dryland farming in an area with a mean annual precipitation of 243-mm, and Class A pan evaporation of 3200-mm. Using the farm tractor (inappropriate technology), they converted a scrubland into farm fields that yielded a meager harvest in good years. Therefore, they left the fragile land to nature. Needless to say, wind eroded the topsoil; a sandy expanse is a reminder of our ignorance.

Irrigation was the next technology implemented in the GBP. They hit watertable (WT) at about 10-m. Diesel pumps extracted water many times the natural recharge. Irrigated farms covered 168-ha in 1967, the heyday of the GBP. When the WT receded to 20-m, and the pumps were inoperative, they left the fields to nature, and wind erosion resumed. Out-migration to Fasa, and other nearby communities was the result of application of inappropriate technologies. *Therefore, neither dry- nor irrigated-farming had been sustainable for the nomad herders in the long-term.*

The situation was radically changed in Jan.1983, when the Government stepped in to develop the area. The main theme of the innovative project, financed by the Government and a few Good Samaritans, was floodwater spreading (FWS) for the artificial recharge of groundwater (ARG). Construction of 2445-ha of the ARG systems has drastically changed the lives of the GBP inhabitants. The mean annual diversion for the past 20 years has been 10million m^3 (mm^3), of which about 7-mm^3 reach the aquifer. The irrigated area exceeded1193-ha sometimes between1983 to 1992; however, a 5-year drought (1996-2000) decreased it to 731-ha.

Land tenure is a precarious situation in the GBP. All people do not own land. An absentee landlord claimed to having owned 1200-ha, while the Government proved him wrong. The former peasants somehow get along with him. As for our UNU-supported project site, the land belongs to the Government. Each member of the cooperative is entitled to farm 4-ha of irrigated land, 4-ha of FWS system for raising forage crops, and 0.5-ha of woodlot and orchard. The land will be endowed to the cooperative. The members cannot sell the land. If a member decides to leave the cooperative, he/she shall receive the market value of his/her share.

We believe that forced sedentarization of nomad herders in the GBP was wrong. A nomadic way of life has been, and still is, ecologically sound for this part of the world. However, it seems that the recent intervention, implementation of the ARG activities, may become sustainable if we could convince the younger generation to accept responsibility for the expansion and maintenance of the systems. We believe that there is no better way to raise awareness and build capacity than to think, plan, and work together.

Thirty research scientists and technicians will share their knowledge and experience with 40 young couples. So far, we have been relatively successful in our endeavour in an action-research project. The nomads-turned-mixed-farmers have already benefited from the ARG activities. Therefore, we hope to change their frame of mind, and influence the Government's policy that we have developed a technically practicable, an environmentally sound, a financially viable, and a socially acceptable method for sustainable desertification control.

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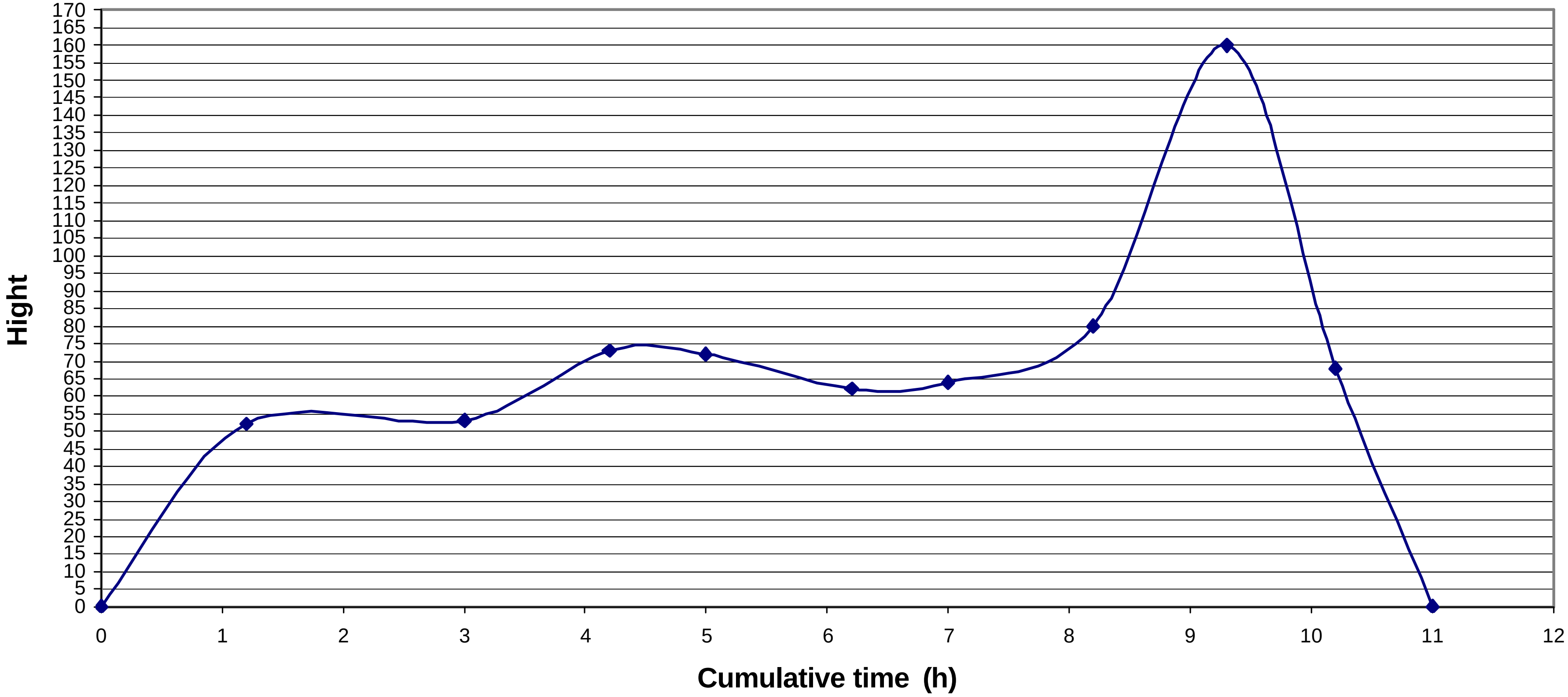
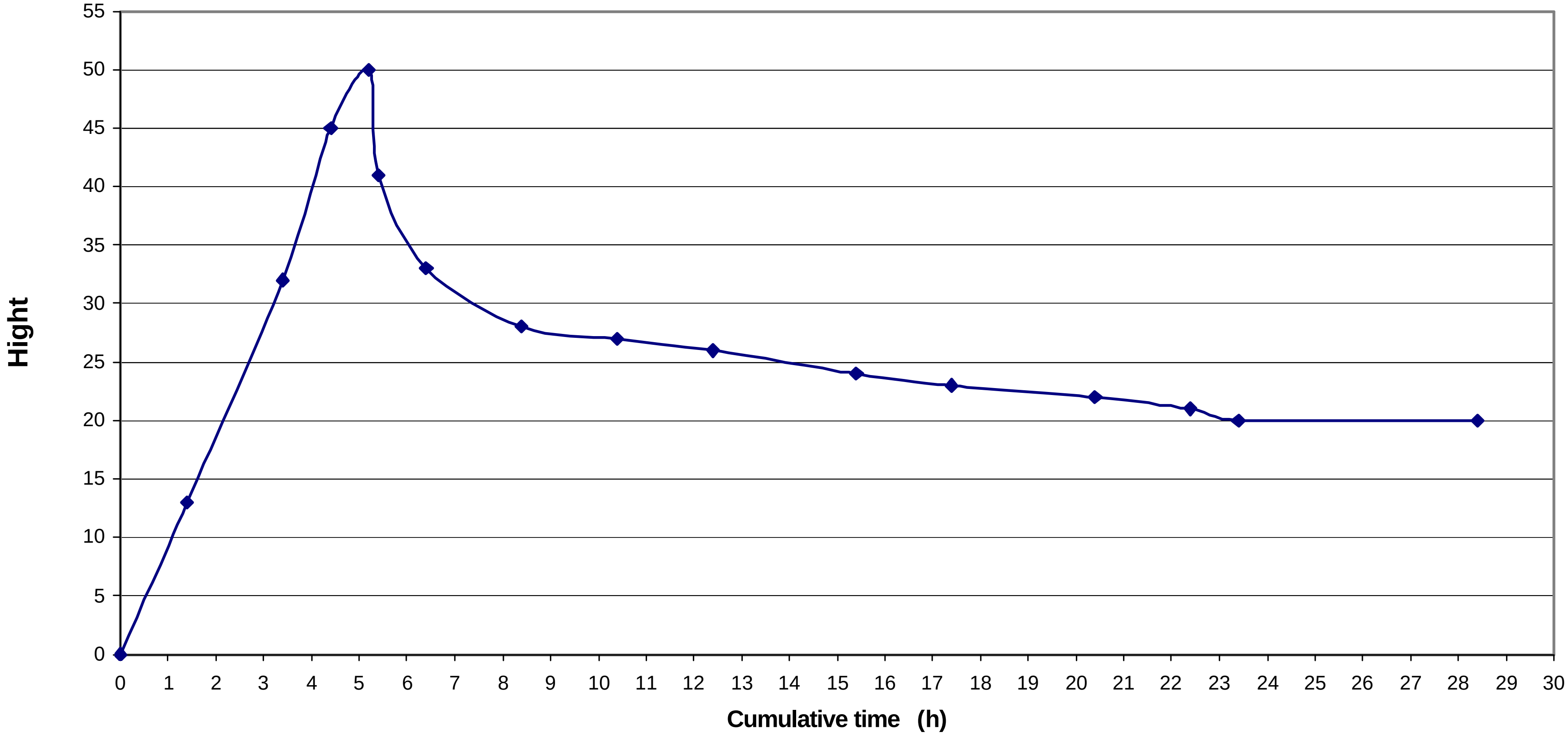
Appendix A

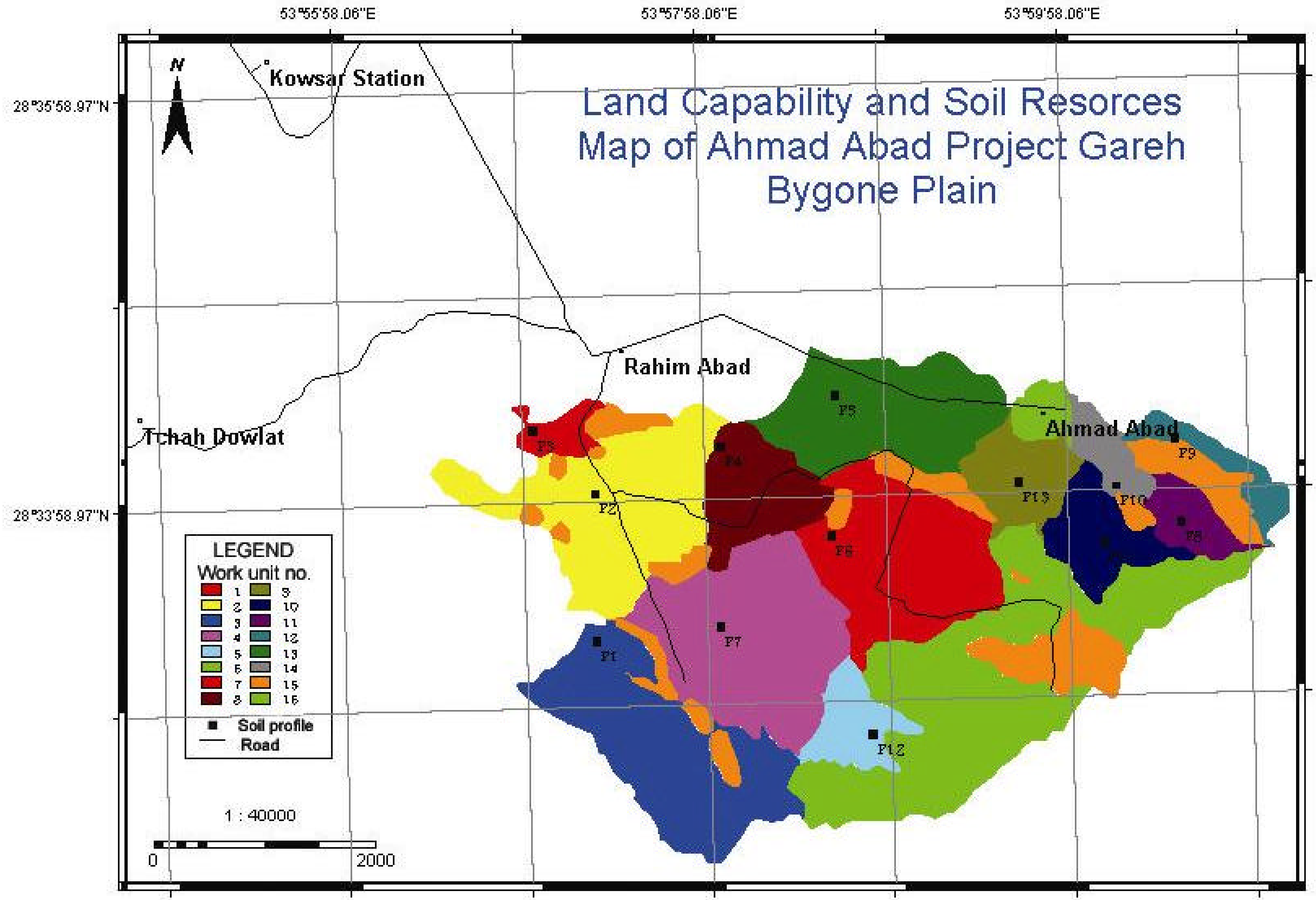
Flood Hydrograph of the Bishehzard River(Feb.25,2003) beginning time :13:00



Flood Hydrograph of the Bishehzard River(July.23,2003) beginning time :13:20



Appendix B



53°55'58.06"E
53°57'58.06"E
53°59'58.06"E
28°35'58.97"N
28°33'58.97"N
N
Kowsar Station
Land Capability and Soil Resorces
Map of Ahmad Abad Project Gareh
Bygone Plain
Rahim Abad
Tchah Dowlat
Ahmad Abad
LEGEND
Work unit no.
Soil profile
Road
1 : 40000
0
2000

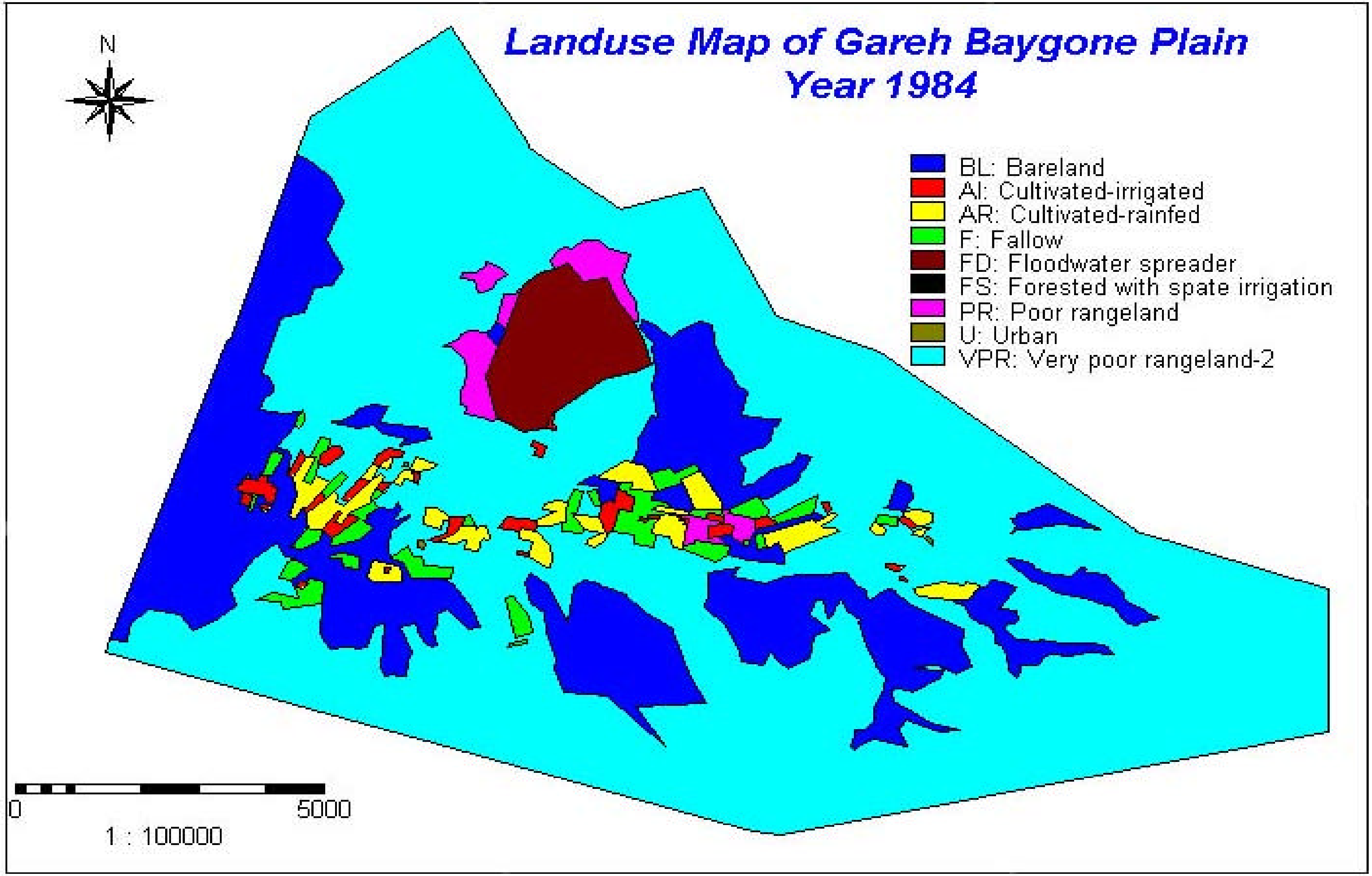
Description of soil classification and land capability symbols

Work unit No.	*Soil unit No.*	*Land classification symbols*	*Soil profile No.*	*Area*		*Soil characteristic*
				ha	*%*	
1	6	$\frac{3gL(f)}{A\text{-}(d1)\text{-}E_1\text{-}F_1}$ IISTW	3	25.5	1.22	Sandy, skeletal, carbonatic, hyperthermic,Typic Torriorthents
2	7	$\frac{2gL(f)}{A\text{-}(d_1)\text{-}E_1\text{-}F_1}$ IISTW	2	220	10.49	Coarse loamy over sandy, carbonatic, hyperthermic,Typic Torriorthents
3	2	$\frac{2GL(g)}{A_1\text{-}(d_1)\text{-}E_0}$ IIIS	1	228	10.90	Loamy over sandy skeletal, carbonatic, hyperthermic,Typic Haplocalcids
4	4	$\frac{2GL(g)}{A_1\text{-}(d1)\text{-}E_1}$ IIIS	7	242	11.56	Sandy skeletal, carbonatic, hyperthermic,Typic Torriorthents
5	5	$\frac{2L}{A\text{-}E_2\text{-}F_2}$ IIITW	12	55.3	2.64	Sandy, carbonatic, hyperthermic,Typic Torriorthents
6	3	$\frac{2gLg3\text{-}Z}{Baz\text{-}E_1}$ IIIST	_	364	17.37	Coarse loamy over fragmental, shallow, carbonatic, hyperthermic,Typic Haplocalcids
7	8	$\frac{2gLf}{A_1\text{-}(d_1)\text{-}E_0}$ IIS	6	200	9.57	Coarse loamy, carbonatic, hyperthermic,Typic Haplocambids
8	8	$\frac{2L}{A_1\text{-}(d_1)\text{-}E_1}$ IIST	4	93.9	4.49	Coarse loamy, carbonatic, hyperthermic,Typic Haplocambids
9	8	$\frac{2LS_2}{A\text{-}E_0}$ IIIA	13	69	3.30	Coarse loamy, carbonatic, hyperthermic,Typic Haplocambids
10	6	$\frac{2GL(g)}{A_1\text{-}E_1\text{-}F_1}$ IIIS	11	71.9	3.43	Sandy, skeletal, carbonatic, hyperthermic,Typic Torriorthents

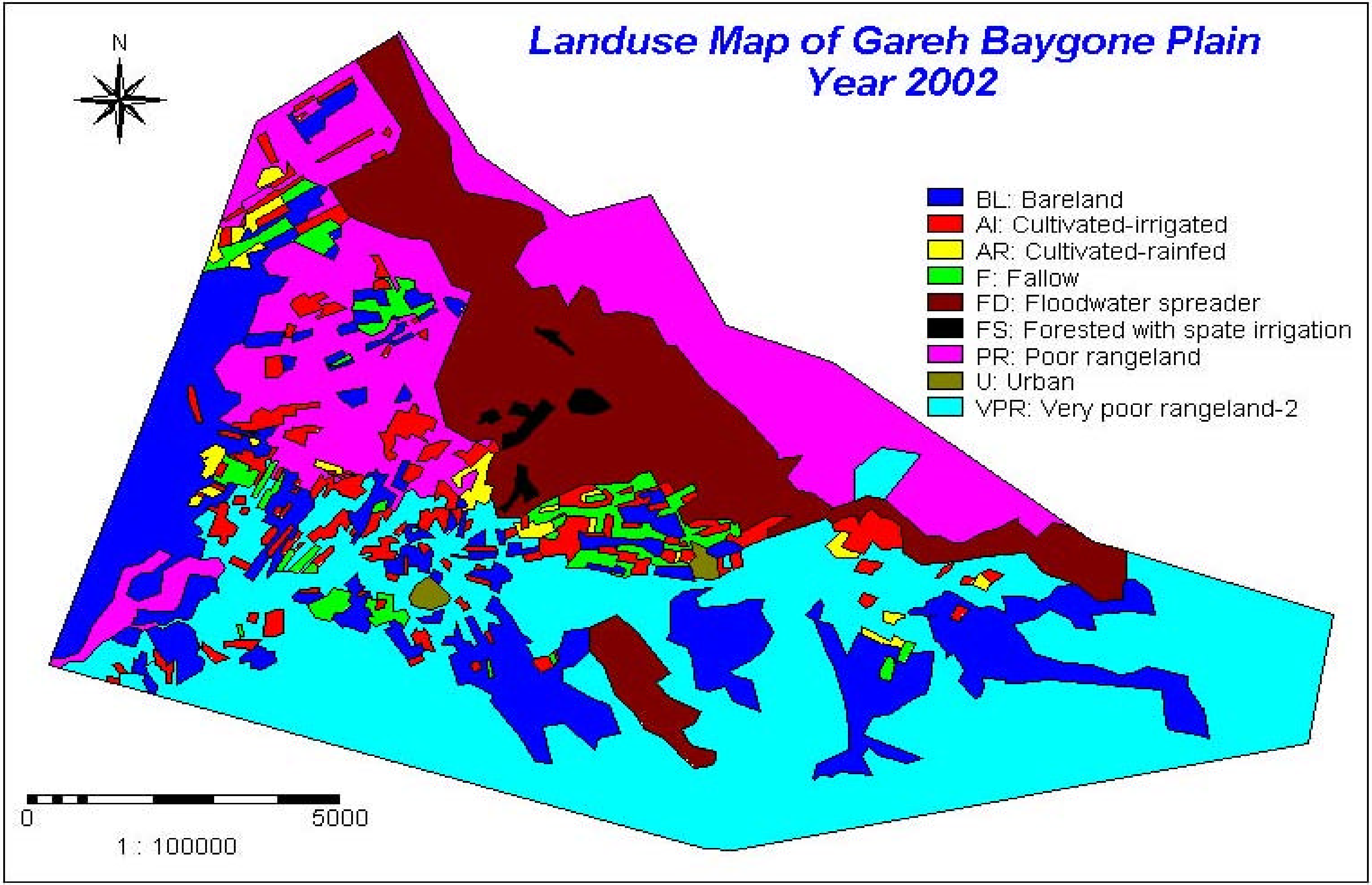
continued

11	3	$\frac{2gLg3\text{-}Z}{Bb_2\text{-}E_1}$ IIIST	8	41.3	1.97	Coarse loamy over fragmental, shallow, carbonatic, hyperthermic,Typic Haplocalcids
12	8	$\frac{2L(g)}{A\text{-}E_0}$ IIS	9	39	1.86	Coarse loamy, carbonatic, hyperthermic,Typic Haplocambids
13	1	$\frac{2L}{A_1\text{-}E_0}$ IIST	5	181	8.63	Sandy,carbonatic,hyperthermic,Typic Haplocalcids
14	2	$\frac{2GL(g)}{A_1\text{-}E_0}$ IIIS	10	35.2	1.68	Loamy over sandy skeletal, carbonatic, hyperthermic,Typic Haplocalcids
15	?	Hills	?	202	9.67	Gentel hillslopes
16	?	Villages	?	25.2	1.21	
Total				2093	100	

Appendix C



Landuse Map of Gareh Baygone Plain
Year 1984
N
BL: Bareland
AI: Cultivated-irrigated
AR: Cultivated-rainfed
F: Fallow
FD: Floodwater spreader
FS: Forested with spate irrigation
PR: Poor rangeland
U: Urban
VPR: Very poor rangeland-2
0
5000
1 : 100000


Landuse Map of Gareh Baygone Plain
Year 2002
N
BL: Bareland
AI: Cultivated-irrigated
AR: Cultivated-rainfed
F: Fallow
FD: Floodwater spreader
FS: Forested with spate irrigation
PR: Poor rangeland
U: Urban
VPR: Very poor rangeland-2
0
5000
1 : 100000