

## IRRIGATION AND AGRICULTURAL DEVELOPMENT IN DROUGHT PRONE AREAS OF IRAN : A WATER BALANCE APPROACH

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**ABSTRACT:** An endeavour is made here to study the irrigation potential of drought-prone areas of Iran and to evaluate the possible ways of utilising the available surface and ground-water resources.

### INTRODUCTION

Drought is a real problem in nearly all parts of Iran and it limits agricultural yield everywhere. The present and future demands for food and fibre of the coun-  
necessitate further increase in agricultural development. The adverse effects of drought need be minimised by developing irrigation. Further development of irrigated agriculture particularly in the semi-arid areas is of paramount importance. Although the data available on the water resources and water use in drought prone areas of Iran is limited, yet, the available data roughly indicates the potential for development.

#### The Distribution pattern of Water deficiency in Iran

The problems of the arid or semi-arid regions of Iran are climatic in origin and stem from the imbalance between the water supply and the water need. The physiological effects of drought on plants are complex as explained comprehensively by Richards and Wadleigh (1952). In general, the essential factors that cause loss of yield and output of crops are :  
(i) the magnitude of water deficiency

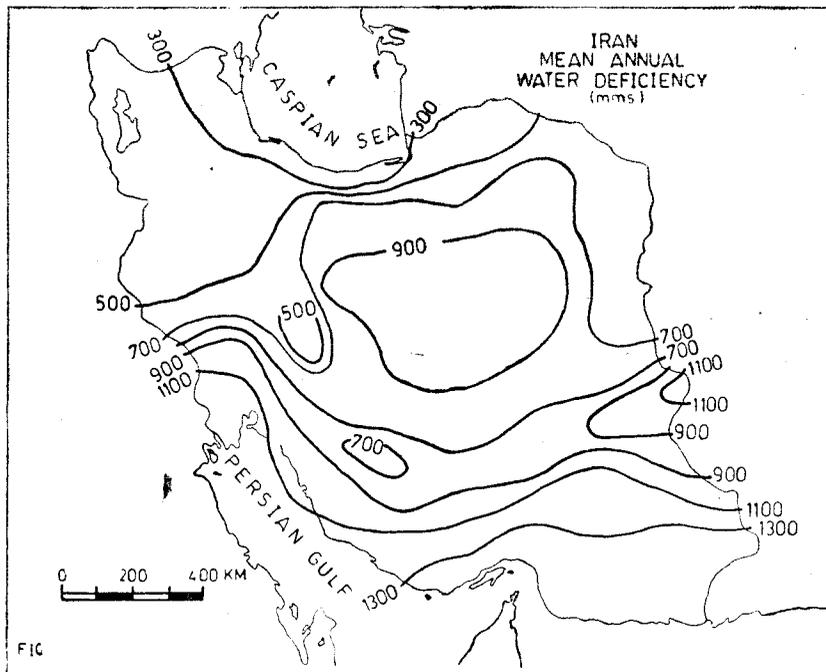
and (ii) the time of its occurrence during the growing season.

While the water deficiency distribution indicates the amount of water needed for supplemental irrigation in different parts of the country, the distribution of water surplus gives the amount of water that is available from individual regions for conservation and subsequent utilization by proper planning of irrigation projects. Thus, from a comparative study of water deficiency and water surplus, the regions that are potentially suitable for agriculture can be identified. Specifically, water deficiency represents the amount by which precipitation fails to meet the demands of evapotranspiration after all the available soil moisture has been used up. It is thus a crude measure of supplemental irrigation required for the efficient growth and development of crops. To have a clear understanding of moisture problems of Iranian agriculture, it is essential to assess the distribution of water deficiency in different parts of country.

Fig. 1 shows the distribution of mean annual water deficiency over Iran based on computations for about 43 selected stations. The occurrence of even the limit-

ed precipitation is highly seasonal and is concentrated in a short period of three to four months while the rest of the year is practically rainless. No area in Iran has surplus water. The area of the largest water-deficiency is found in arid region of the South Coast which includes, Khozestan, Bushehr, Hormozgan, and Sistan and Baluchestan provinces. Most

of the semi-arid regions have deficiencies of about 700 mm, and the area of the lowest water deficiency is in the humid regions of Gilan and Mazandaran provinces. The deficiency gradually increases from North-West to South-East. The highest values of water deficiency are observed in Hormozgan and Sistan and Baluchestan provinces.



Since, in many parts of the semi-arid region of Iran, it is not temperature but only the moisture which is the limiting factor which determines the growing period of crops, agriculture is practised only during the rainy season in all unirrigated areas. In areas where water is available for supplemental irrigation, crops are grown almost throughout the year. In most parts of Iran, the available water resources are insufficient to meet the irrigation requirements of the cultivated land. Hence, it is necessary to utilise the available water in these areas

in such a way so as to secure the maximum crop production per unit of water. Adoption of the best technique of irrigating the field, minimising waste of water in storage and conveyance and adoption of suitable cropping patterns are necessary to minimise the utilization of scarce water.

The hard-core drought areas of the semi-arid region of Iran have a different set of considerations in the use of their very scarce water resources. Here, not only the rainfall is very scanty but its

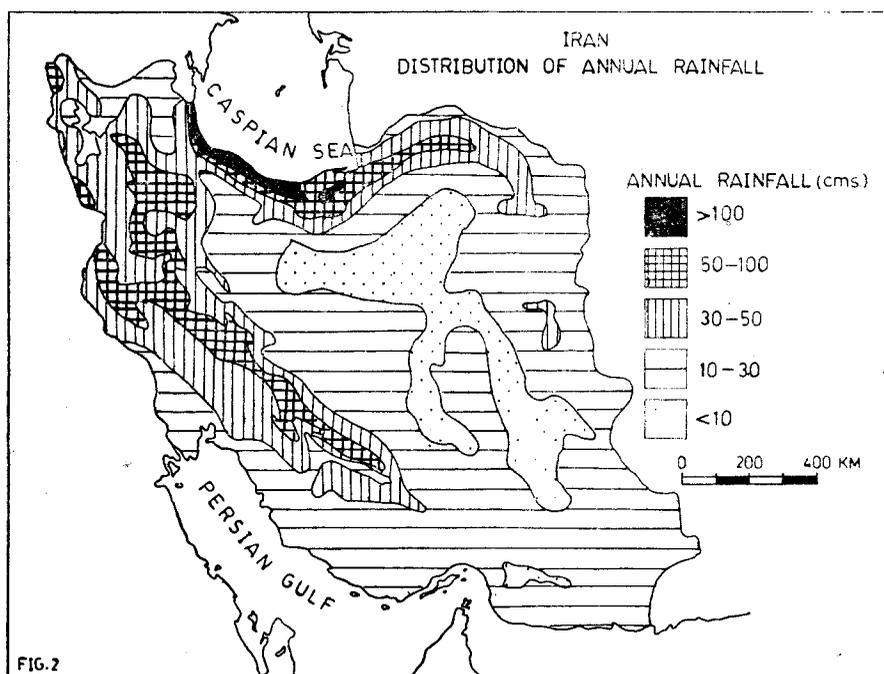
year to year variation is more pronounced than elsewhere. Moisture conservation practices assume greater importance in these areas. Here, irrigation with only local water resources is precarious unless surface water is brought in from other basins with better moisture conditions.

### 1. Surface Water Resources

More than 90 percent of Iran falls within the arid and semi-arid zones receiving an annual precipitation of less than 500 mm. Practically, all the rainfall occurs during October-May or during the winter months due to the passage of westerly depressions from the Mediterranean. Due to high annual variability and erratic distribution of rainfall cultivation of crops is hazardous without irrigation. In the Gilan and Mazandaran region, summer rainfall is generated by the depressions following a more northerly route from the Mediterranean, whilst in the south-eastern area of the country

occasional monsoonal rainfall may occur.

The Ministry of Agriculture and Natural Resource (MANR), Iran (1975) recognized that the deep seated limestone aquifers in the mountain zones provide the base-flow of most rivers, but the main volume of run-off is derived from snow-melt which usually commences towards the end of March and continues into June. In the Central plateau, river discharges are small and generally confined to ephemeral streams. Groundwater recharge too is limited. Recharge may only occur during the periods of heavy rainfall or where surface run-off is concentrated in low lying depression. Precipitation in the Alborz and Zagros mountainous regions is undoubtedly the major source of water availability in Iran. Surface water run-off is usually negligible in areas with an annual precipitation of less than 250 to 300 mm. In most parts of Iran, rainfall is confined mainly to the winter season. During the remain-



ing months the water requirements have to be met from ground or surface water resources. Irrigation is required not only in low rainfall areas as well as during non-rainy season, but also during the long breaks of rainfall in good rainfall areas.

It is already mentioned that in Iran, evaporation is extremely high, while the rainfall in most areas is low and restricted to the winter season. On the northern part of the plateau the average annual rainfall is above 200 mm., and it decreases to less than 120 mm. in the southern part. The general distribution of rainfall is shown in the following table and Fig. 2.

**Table — I : Rainfall Distribution in Iran**

Annual Rainfall (mm)	Recipient area (millions of hectares)	Ratio of Recipient area to Total area of the Country (in percent)
Less than 100	22	13
100-250	100.5	61
250-500	28	17
500-1000	13	8
Over 1000	1.6	1

Some 13 percent of Iran receives less than 100 mm. of rainfall annually, and a further 61 percent less than 250 mm. Only 9 percent of the country receives more than 500 mm.

As a result, Iran has sever water problems. Precipitation in Iran is mainly due to the Mediterranean depressions which govern the weather patterns of the country throughout the winter spring seasons. During their passage, these depressions

cause rain at low altitude and snow at high elevations. When these Mediterranean Cyclones fail, Iran faces severe drought. Of the total rainfall received in Iran, it is estimated that 60-65 percent evaporates or lost below the ground, 15 percent seeps underground and the remaining 20-25 percent remains at or near the surface.

Successful agriculture without irrigation requires at least 240 mm. of annual precipitation and an inter-annual variability of not more than 87 percent. However, about 75 percent of the total area of the country receives annual rainfall of less than this amount (Table 1 and Fig. 2). Those regions where annual precipitation is the highest are the highland areas, where farming is difficult due to shallow soils, rugged terrain, steep slope and restricted growing season. Most of the precipitation occurs during the period from October to March in the form of snow. Snow-melt begins in spring, swelling the streams and rivers to provide maximum water discharges during April and May, a time which coincides with the beginning of the growing season. Water supply is thus not out of phase with the season of maximum crop growth. However, once the early summer discharge peak has passed, the availability of water from surface sources diminishes rapidly. Unfortunately, this is at a time when water demand for the growing crops reaches a maximum. Where water cannot be supplied from alternative sources during this period arable farming is impossible.

Annually the country receives an average of  $400 \times 10^9$  Cubic meters ( $M^3$ ) of water from precipitation inf'owing rivers (Table 2). Of this total, about  $78 \times 10^9 \times M^3$  (19%) is utilized, the remainder evaporates or flows out of the country.

Table II General Locational Distribution of Water Resources in Iran, 1983-84

No. of the Zone	Name of the Area	Area Km. <sup>2</sup>			Average Annual Rainfall mm.	Volume of Precipitation Million m <sup>3</sup>	Surface stream on plateau Million m <sup>3</sup>	Ground-water Million m <sup>3</sup> (per annum)
		Mountain	Plateau	Total				
1	2	3	4	5	6	7	8	9
1.	Gilan	9000	4000	13000	1200	1500	4500	1500
2.	Mazandaran	22000	5000	27000	800	20000	6500	1500
3.	Gorgan	6500	7500	14000	500	7000	1000	900
4.	West Zagros	32000	6000	38000	500	19000	7500	1500
5.	West and Khozestan	115000	41000	156000	475	74000	29000	6000
6.	Sefid-Rud (upper basin)	45000	11000	56000	450	25000	6500	1500
7.	Oromeyeh Lake	37000	15000	52000	420	22000	6000	1900
8.	Aras Basin	30000	10000	40000	350	14000	2500 + 7500	700
9.	Maharlu Bakhtaran Jam-Rud	20000	15000	35000	315	11000	1500	1000
10.	Kashaf-Rud	28000	14000	42000	285	12000	500	1750
11.	Houz-O-Soltan	60000	34000	94000	280	26000	3600	3000
12.	Moundan Chareh-Aghage	45000	24000	69000	250	17000	3000	1300
13.	Gavekhoni	15000	24000	39000	245	9500	1400	1400
14.	Atrak	20500	6500	27000	240	6500	1000	900

Table II Continued

1	2	3	4	5	6	7	8	9
15.	Garmsar (Semnan)	19000	11000	30000	220	6500	1000	400
16.	Dasht-e-Kavir	63000	80000	143000	175	25000	3000	2000
17.	Namakzar-e- Khavaf	16000	15000	31000	175	6000	500	400
18.	Shour-Mehran	42000	20000	62000	155	9500	1200	750
19.	Jerof and Rudbar	20000	14000	34000	150	5000	600	600
20.	Minab & Badar Abbas	10000	10000	20000	150	3000	400	400
21.	Abargho-Sirjan	25000	38000	63000	140	8000	600	800
22.	Kavir-e-Namak	20000	28000	48000	125	6000	500	1000
23.	Kavir-Bafegh	60000	52000	112000	110	12000	1000	1500
24.	Iranshahr Delkan	17000	21000	38000	105	3500	200	250
25.	Bahre Oman	55000	16000	71000	100	7000	1000	300
26.	Kavir-Lout	55000	90000	145000	90	12500	600	1000
27.	Hamon Sistant	19000	21000	40000	90	3500	150 + 1500	100
28.	Mashkilil Tohlab	27000	15000	42000	85	3500	250	250
29.	Kavir-Tabass	16000	28000	44000	80	3500	200	400
	Total	949000	676000	1625000	—	392500	96200	35000

Source: Budget and Plan Organization of Iran, Water, in "First Five Year Plan, 1983-87," Vol. 2, pp. 5-14.

Of a total area of about 6.5 percent of annually cultivated land in 1982-83, approximately 45.1 percentage is irrigated 40 percent of which receives water only in the spring when river discharges, run-off from winter rains and snow feeds are high.

The actual use of water in agriculture is at a low efficiency level and hence is a high need to practice improved irrigation practices to reduce wastage. Accurate knowledge of water requirements of crops and controlled application of water are essential.

The Ministry of Agriculture and Natural Resources recognized that surface water resources in Iran are estimated to be about 85 to 90 thousand Mm<sup>3</sup> (Million Cubic Meters). This estimate is based on discharge records at gauging stations together with estimates of upstream water abstraction.

Estimates of reliable surface water yield or the proportion of total surface surface water run-off which can be utilised in drought-prone areas of Iran are not available. Table 2 presents an estimate of overall surface and groundwater resources as prepared by the Ministry of power, cont. of Iran (1983). Adjustments must be allowed due to the differences between the natural catchment boundaries and agricultural zones.

The zonal allocation of surface water resources is calculated on a zonal basis of 81.6 milliards cubic meters according to 1972-73's estimation. 1983-84's estimation too is presented in Table 2 as 96.2 Milliards cubic meters. The estimates are essentially inductive. Detailed statistics on the use of surface water specifically for the semi-arid region are not available. Estimates of irrigation water use at province level are made by the Ministry of Agriculture and Natural Resources

(MANR) on the basis of crop cultivated. The MANR estimates are subjective in that crop consumption requirements and irrigation efficiencies are not supported by sample surveys. The Ministry of Energy maintains records of water diverted to government irrigation projects which serve about 25 percent of the total irrigated land in Iran. It is difficult to extrapolate from this base because of the variation in water supply between government and non-government irrigated areas.

## 2. Groundwater Resources

Precipitation and ground water is the main source of water supply in dry regions. In general, groundwater reservoirs are in dynamic balance with precipitation, evaporation, and drainage to the sea. Normally, the drier a region is, the smaller will be the proportion of natural precipitation that will reach the groundwater reservoir. In regions with less than 200 mm annual rainfall, rain usually falls on non-saturated ground. Practically no precipitation will infiltrate to a water-table due to very large moisture deficiency in the soil coupled with very low precipitation. The groundwater recharge depends on the total amount of rainfall as well as the rain intensity, composition and texture of the soil, the underlying rock, geomorphic features, the depth of the zone of saturation, vegetation, etc.

### Influence of geology on groundwater

The occurrence of groundwater in Iran is determined by geological conditions and the availability of recharge. Dewan and Famouri (1964) classified the whole of Iran into seven broad geological zones of which the strata of particular interest from the hydrological point of view are the alluvials, limestones and saline

deposits. The alluvial aquifers occur in three basically different physiographic types, which are reflected in the nature and potential of their groundwater yields. The limestones, often form mainly the high relief areas of the mountain chains and are not suitable for large scale exploitation by wells except where located near the surface or in the immediate vicinity of alluvial plains. The saline deposits and the numerous salt domes tend to make both groundwater and surface water resources saline. Groundwater quality poses a major problem in Iran, due to the occurrence of saline formations, internal drainage basins and marine influence in the coastal areas of the Caspian Sea and the Persian Gulf. In coastal areas, the depth of wells is limited to avoid saline water. The upstream removal of water reduces the amounts available downstream reducing the quality of the water to unsafe levels. The development of new wells affects the output of the older wells that depend on the same underground reservoir. Transfer of water from one region to another may limit future development of the donor region. In the coastal areas, uncontrolled development of groundwater is likely to result in irreversible invasion of saline water.

### Zone-wise Distribution of Ground Water

Both the Plan Organisation of the Government of Iran (1972) and its Ministry of Water and Power (1973) (now Ministry of Power) have carried out calculations of groundwater recharge for the whole of Iran, by means of surface water-balance. The two estimates of recharge are remarkably similar, being 35,000 and 33,000 Mm<sup>3</sup> per annum respectively.

Many of the basins of the zone are highly suitable for groundwater abstrac-

tion with high-capacity drilled-wells. For instance, the average annual production per drilled-well in Zone I (Markazi and Semnan provinces) is 0.41 Mm<sup>3</sup>, that is, about 50 m<sup>3</sup> per hour. With likely operating factors of 0.25 to 0.5, it is certain that most of the drilled-wells pump at a discharge rate of between 100 and 300 m<sup>3</sup> per hour. In Zone II (Gilan and Mazandaran) of the humid region the average yield of shallow wells is low. Most of them probably discharge between 10 and 5 m<sup>3</sup> per hour. The average yield of deep-wells is high and their production capacities are probably between 100 and 300 m<sup>3</sup> per hour. Much of the area is suitable for installation of high capacity drilled-wells. In Zone III (Azerbaijan Sharghi, Azerbaijan Gharbi, Kurdestan, and Zanjan which belong to the semi-arid region) the average yield of wells appears to be variable. In Eastern Azerbaijan the average production rates of both shallow and deep wells are low, suggesting that aquifers of low permeability predominate. In Western Azerbaijan and Zanjan the yields of drilled-wells are exceptionally good and even the shallow wells are more productive. In Kurdestan there has been very little groundwater development. In Zone IV (Bakhtaran, Hamedan, Lorestan, and Elam) which mainly belongs to the semi-arid region, it is difficult to determine credible values for production rates of drilling wells. But the Ministry of Water and Power has suggested that there are some extremely productive shallow wells in Lorestan with average yields in excess of 100 m<sup>3</sup> per hour. In khozestan province, average yield of a shallow well is estimated at almost 15 m<sup>3</sup> per hour and that of a deep well about twice that of a continuous discharge basis. Allowing for operating factors of 25 percent, this would make average discharge rate of shallow well some 60 m<sup>3</sup> per hour and

that of a deep well 120 m<sup>3</sup> per hour. Furthermore, in Zone VI (Esfahan, and Yazd of the arid region) the average well yields appear to be highly variable but it seems that some areas (e.g., the Yazd and Ardekan Basin) are suitable for high capacity drilled-wells. The average yields of drilled-wells are reasonable and many of the basins are supposed to be suitable for deep wells in Zone VII (Fars, Chaharmahal, and Kohgiluyeh). The flow rates of high

yielding **ghanats** and springs are much greater. Busher and Hormozgan zones have very little potential for further groundwater development. The average yields of wells are low in Zone IX (Kerman and Sistan and Baluchestan). In fact, the most productive structures in the zone appear to be **ghanats**. Nevertheless, it is likely that some of the basins are suitable for high-capacity drilled-wells. In Khorasan province, the average yield of deep wells is high.

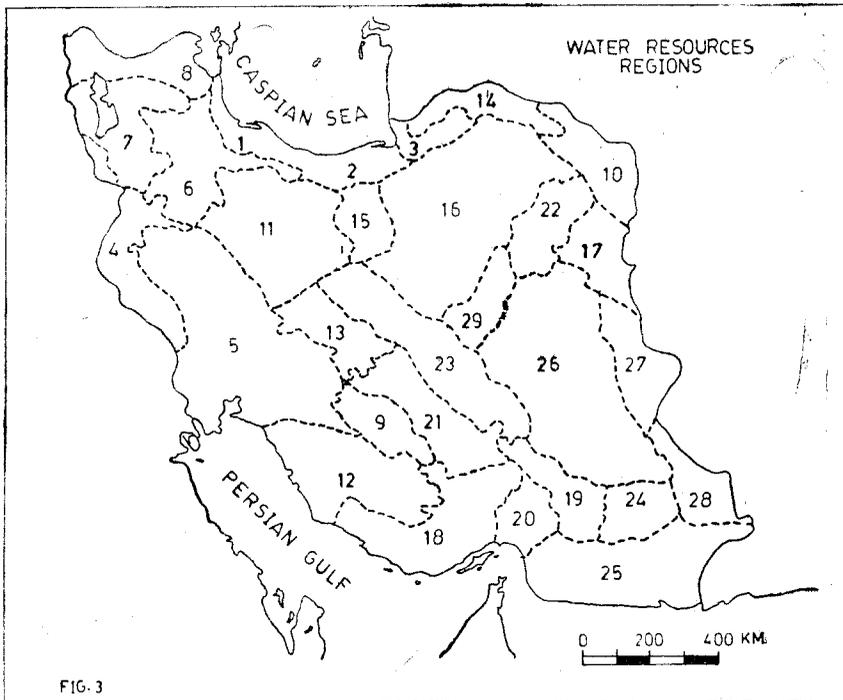


FIG. 3

In many regions there are potential water resources which could be developed. Much additional water can also be made available by improving water conservations and rational utilization. In Iran there exist thousands of **ghanats**, which are the sole water-suppliers for numerous villages besides irrigating extensive areas. The largest drawback is

that the water discharge from **ghanats** is uncontrollable which means that water runs to waste during the winter season when irrigation is not required. Even during the summer months, water flow during the night is unused, unless a storage reservoir is constructed down-slope.

Table — III : Water Use in Iran: Milliard Cubic Meters

	Abstraction m <sup>3</sup>	Water Use m <sup>3</sup>
Controlled surface water diversions	41	
Ground-water abstraction	17	
	—	
	58	
Consumptive use of irrigated crops		17
Seepage, evaporation and surface run-off losses		41
	—	—
	58	58

#### Need of Groundwater Development Programme

If careful planning of the groundwater development programmes is not made, it will result in over-exploitation in some areas causing deleterious effects like water-logging in other areas.

Much of the loss occurs in conveyance of

water and from escape of canal discharges, particularly in the winter months. Similarly, spring and **ghanat** discharges go waste during the winter months, and possibly upto 5.0 Milliard m<sup>3</sup> is lost in this manner. Estimates of field irrigation efficiency are always difficult to make but the estimated field efficiency is in the range of 45 to 50 percent.

Table — IV : Groundwater Used in Agricultural Sector

Sources	Abstraction	Used by crop	Percentage used by crop
<b>Ministry of Water and Power</b>			
Ghanats & Springs	9	5	55.5
Wells	8	6	75.0
<b>Plan Organization</b>			
Ghanats & Springs	20	5.7	28.5
Wells	10	7	70.0

At present, more than 35 percent of all groundwater produced in Iran comes from **ghanats** and 15 percent from minor springs. The Ministry of Water and Power and the Plan Organization have given, the following figures for groundwater use in Millions  $m^3$  per annum.

Deep wells on the other hand always have the flexibility of discharge to meet peak agricultural demand without any waste when not needed. There will of course be areas, where **ghanats** exist. An increase in overall water resources must, in the long run, depend upon the development of surface water resources. Additional groundwater development may yield up to 9.0 Million  $m^3$  but this will not be sufficient to provide for more than the immediate demand for increased agricultural production (table V).

### 3 Irrigation Development

The main purpose of irrigation in drought-prone area is to counteract drought by making certain that the plants are not deprived of water at any time during their growth. The amount of precipitation is the principal factor influencing crop-yields in drought-prone areas. But the precipitation may be distributed unevenly: during the growing season itself, it is often excessive and sometimes too low. The reaction of plants to drought is different to different types of drought and to soil-moisture deficiency, and it also depends on the stage of development at which drought occurs. Supplemental irrigation is a safeguard against droughts. It increases yields, permits production of products of higher quality, provides earlier maturity, and maintains grazing capacities of pasture especially in late summer and fall. Responses from other improved practices, such as application of fertilizer etc., are also good with supplemental irrigation.

The zonal net sown area and the cultivated areas which were irrigated by various surface and groundwater resources in 1972-73 and 1982-83 are given in the Table VI. Due to lack of detailed information about the surface and groundwater potential utilised in the drought prone areas of Iran, our study may not show quantitative results. As per the Table, in both the years 1972-73 and 1982-83, a very low percentage of the net sown areas of the semi-arid provinces of Iran (those are included in Zones III and IV) were irrigated. In spite of the availability of considerable amount of surface water in the semi-arid region, the agricultural yield and production in this region suffered from the course of drought-effect. A comparison between 1972-73 and 1982-83 shows that some of the semi-arid provinces lightly increased their irrigation level which is not the maximum utilisation of the amount of available water. It should also be noted that the main volume of the run-off in Iran is generated by springs and snow-melt, and is concentrated in the period between March and May. The irrigation of many crops commences during this period, but critical water requirements may occur in May-June or June-July, when river flows are at their lowest. The cultivation of high-value summer cash-crops therefore requires a high volume of storage capacity in order to provide timely water supplies. Generally speaking, the rivers flowing from areas of high precipitation, e.g., from the Alborz or Zagros mountains, have a higher reliability than those flowing from catchments with low annual precipitation. The reliability of water-supply for individual irrigation projects is related to the type and economic conditions of spate irrigation based on low cost production. Intensive irrigated crop production requires a reliability of at least 80 to 90 percent probability for

commercial cash-crops. During the drought, shallow wells go dry or yield meager quantities of water. Water management during droughts depends on, a) assessment of the water to be conserved at the beginning of the drought so as to satisfy the prescribed demand at an acceptable risk rate, and b) estimation of the risk rate and modification of releases if the observed drought is more severe than forecasted. A strategy for better use of water-resources for irrigation consists of two important steps:

- i) adoption of a cropping pattern which would provide maximum coverage of crop per unit of water (or optimum protection from drought), and
- ii) introduction of improved methods of irrigation like sprinklers and drip irrigation, and lining of canals to minimise the loss of water due to evaporation, transpiration and seepage.

So far as stream flow is dependent on surface run-off from rains the drought effect is immediate and continuous throughout the rainless periods or periods when precipitation is less than the rate of infiltration. The effects of droughts on soil moisture are shown directly by the growth of plants whose roots penetrate the moisture zone. Shallow-rooted grasses may be able to draw moisture only from a soil zone containing 1 or 2 inches of water. Such supplies are quickly exhausted during the summer, and rainless periods of short duration result in a tendency for such grasses to wither. Deep-rooted vegetation draws from a large reserve and is therefore more drought-resistant. In general, groundwater is the last to reflect drought effects and also the last to reflect the cessation of a drought.

**Irrigation Requirement:** The total amount of water that has to be applied, accord-

ing to Arnon (1972), in order to replace effectively the soil moisture deficit in the root-zone is called the "irrigation requirement"<sup>12</sup>

For rice, the water requirement for puddling before transplantation is substantially higher than in subsequent stages and for good yield the transplantation has to be completed in a period of about four to six weeks. In the case of cotton there has to be sufficient supply to enable the crop to be sown in a reasonably short period of about four weeks. For wheat watering is needed three weeks after sowing at crown root initiation stage, and it is crucial that this should be completed in a period of about six weeks. The C.W. Thornthwaite method includes all meteorological factors which affect water need of a crop and has as such a great advantage over other methods.

Irrigation schemes in Iran are of two types, namely, diversion schemes which draw their supply from the run-of-the-river, and storage schemes where the irrigation channels get their supply from a reservoir or dam. In the first type, the supply of water in non-rainy season is limited by the river flows which vary from year to year. Any additional requirement in a particular period of crop growth can be met only from a supplemental source like groundwater.

National Commission on Agriculture of India<sup>13</sup> pointed out, in order to make the optimum use of the available water resources, certain policies will need to be observed. Briefly these are:

- i) making the maximum use of rainfall for raising crops, utilising irrigation for making up deficiencies;
- ii) adoption of the most suitable cropping pattern from consideration of soil, climate and availability of irrigation supplies;

- iii) making the most efficient use of irrigation supplies by minimising losses in conveyance by lining and adopting scientific methods of irrigation on properly prepared fields;
- iv) deployment of irrigation supplies for maximum overall production and not necessarily maximum yields;
- v) reuse of water to the extent feasible; and
- vi) conjunctive use of surface-water and groundwater.

Under irrigation even rice can be grown in an arid area like Esfahan and Zahedan regions but it is not the best use of available water. If the water resources which are available for irrigation in various parts of the country are to be put to the maximum productive use, then suitable cropping pattern should be evolved.

In spite of water being such a scarce asset, there is a regretful wastage of the limited resources available for development. Efficiencies of water use are low

in all phases of conveyance, delivery, distribution and field application. Partly it is due to the poor construction of canals, ditches and structures, but even more important, the low standards of management in irrigation. This can be explained by the lack of education and training of farmers and the absence of economic incentives to regard water as a costly input in farm production. This accounts for the often extremely low efficiencies in irrigation systems in which sometimes only 20 to 50 percent of the water delivered is actually used for production. With the rapid expansion of pump irrigation and the mounting costs of extracting water from increasing depths. The scarcity of fully irrigated lands is the most important factor that limits the agricultural development of Iran. Full development of the existing water resources and efficient land and water management, in combination with other factors for high yields is the key for increasing agricultural production. Available water resources are limited and crop production should be planned to maximise returns to water.

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Table V : Approximate Annual Abstraction from Groundwater Resources of Iran, 1972-73

Consisted provinces	Climatic Regions	Covered Areas '000 Km <sup>2</sup>	No. of Abstraction			Yield (M <sup>3</sup> x 10 <sup>6</sup> )			Estimated Additional Potential (M <sup>3</sup> x 10 <sup>6</sup> ) per annum		
			W	G	S	T	W	G		S	
Markazi Seman	(Semi-Arid) (Arid)	173.0 (10.6)	6927	3283	551	10761	2065	1468	237	3770	500
Gilan Mazandaran	(Humid) — do —	62.0 (3.8)	8629	545	1096	10270	993	148	602	1743	1000
Azerbaijan East (Sharghi)	(Semi-Arid)										
Azerbaijan West (Charbi)	— do —	157.6 (9.7)	2867	1800	611	5278	325	431	313	1069	1000
Kurdestan Zanjan	— do — — do —										
Dakhtaran Hamedan Loreotan Elam	(Semi-Arid) — do — — do — — do —	158.5 (9.7)	2462	1255	684	4401	295	556	915	1766	1000
Khozestan Eafahan Yazd	(Arid) (Arid) — do —	152.0 (9.3)	24064	2032	558	4654	263	622	64	949	200

Table — V : Continued.

Consisted provinces	Climatic Regions	Covered Areas '000 Km <sup>2</sup>	No. of Abstraction			Yield (M <sup>3</sup> x 10 <sup>6</sup> )			Estimated Additional Potential (M <sup>3</sup> x 10 <sup>6</sup> ) per annum				
			W	G	S	T	W	G		S	T		
Fara,	(Arid)												
Kohgiluyeh	— do —	152.0	5626	928	260	6814	1145	812	1163	3120	1000		
Chaharmahal	(Semi-Arid)	(9.3)											
Bushehr	(Arid)	90.0	794	4	11	809	42	2	4	48	Very little		
Hormozgan	— do —	(5.5)											
Kerman	(Arid)	374.5	2340	1738	156	4234	612	1108	86	1806	1000		
Sistan & Baluchestan	(Arid)	(22.9)											
Khorasan		313.0	3000	1895	213	5108	1712	1039	163	2914	500		
All-Iran		1632.6											
		(100)											

(Value in the brackets indicate percentage)

W — Wells, G — Ghanata, S — Springs, T — Total.

Source: The Ministry of Agriculture and Natural Resources, Agricultural Census of Iran, 1973

Table VI : Area Irrigated by Surface and Groundwater Resources, 1972-73 to 1982-83

No. of the zons	provinces Consisted	Climatic Regions	Covered Areas '000 Hect.	Net Sown Area '000 Hect.		Area Irrigated '000 Hect.	
				1972-73	1982-83	1972-73	1982-83
1	2	3	4	5	6	7	8
I	Markazi	(Semi-Arid)	6095.6	683.40	638.55	353.80 (51.8)	406.58 (63.7)
	Semnan	(Arid)	8956.8	27.94	97.03	19.98 (71.5)	74.54 (76.8)
	Gilan	(Humid)	1471.1	211.23	246.85	154.60 (73.2)	173.71 (70.4)
II	Mazandaran	— do —	4736.5	740.65	943.90	287.50 (38.8)	322.27 (34.1)
	Azərbayjan East (Sharghi)	(Semi-Arid)	6710.4	1083.92	1007.67	281.83 (26.0)	417.78 (41.5)
	Azerbaijan West (Charbi)	— do —	3921.6	654.47	621.86	293.86 (44.9)	299.05 (48.1)
III	Kurdestan	— do —	2499.8	837.40	527.79	113.02 (13.5)	87.68 (16.6)
	Zanjan	— do —	3639.8	500.85	762.08	90.29 (18.0)	217.98 (28.6)

Table VI Continued

1	2	3	4	5	6	7	8
	Bakhtaran	(Semi-Arid)	2366.8	499.10	459.44	81.45 (16.3)	70.32 (15.3)
	Hamedan	— do —	2017.2	511.12	517.48	138.52 (27.1)	148.76 (28.7)
IV	Lorestan	— do —	3138.4	546.54	290.69	128.91 (23.61)	112.89 (38.8)
&	Elam	— do —	1904.5	120.32	142.52	20.24 (16.8)	19.29 (13.5)
V	Khuzestan	(Arid)	6466.4	914.54	870.48	398.36 (43.6)	397.98 (45.7)
	Eofahan	(Arid)	10545.9	207.58	308.67	139.33 (67.1)	279.50 (90.5)
VI	Yazd	— do —	5689.6	13.08	37.08	13.08 (100.0)	37.08 (100.0)
	Faro	(Arid)	13329.9	670.78	909.112	310.99 (46.4)	513.04 (56.4)
VII	Kohgiluyeh	— do —	1426.1	101.57	86.95	15.50 (15.3)	17.12 (19.7)
	Chaharmahal	(Semi-Arid)	1482.0	138.02	152.16	52.32 (37.9)	85.36 (56.1)

Table VI Continued

1	2	3	4	5	6	7	8
VIII	Bushehr	(Arid)	2765.3	178.22	162.43	8.63 ( 4.8)	13.32 ( 8.2)
	Hormozgan	— do —	6847.2	38.21	47.82	12.75 (33.4)	41.72 (87.2)
IX	Kerman	(Arid)	19297.8	99.20	214.41	94.58 (95.3)	210.27 (98.1)
	Sistan & Baluchestan	— do —	18157.8	76.48	166.60	71.27 (93.2)	162.36 (97.5)
X	Khorasan	(Arid)	31333.5	1570.65	1525.58	481.98 (30.7)	736.67 (48.3)
	All-Iran		164800.0				

Note: Value in the brackets column 7 and 8 are as a percentage of column 5 and 6 respectively, which are indicated percentage irrigated areas.

Sources: The Ministry of Agricultural, Annual Report on Agricultural of 1972-73 and 1982-83.