Photo

Alternative Strategies for

Desert Development and Management

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Asit K. Biswas

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SOME INTERRELATIONSHIPS BETWEEN WATER MANAGEMENT LIVESTOCK, RANGELAND & CROP PRODUCTION IN THE ARID & SEMI-ARID AREAS OF THE NEAR EAST

Abdullah Arar
Regional Land & Water Development Officer
Donald L. Huss
Regional Range Management & Fodder Crops Officer

INTRODUCTION

The Near and Middle East's ecology and productivity is mainly determined by the total amount and seasonal incidence of rain-fall and to a more limited extent by soil type, topography and elevation. Rainfall is low, unpredictable, highly variable and extended droughts are more the rule than the exception. Temperatures and evaporation rates are high. Most of the countries are classified by FAO (1974 A) as low rainfall, in that most of their land could be termed either arid or semi-arid by Meig's definition. This is clearly displayed by the rainfall data in Table I. From this data it could be noted that the arid and semi-arid areas amount to about 96% of the total geographic area in North Africa and the Near East Region and about 48% in Sudan, and Somalia is in between.

Natural aridity is a major constraint to production and there is very little that can be done to alter it. However, man could balance his actions with respect to the hydrological cycle so that a given amount of water could serve his needs without undesirable side effects such as desertification. Water is the most manageable of the natural resources in that it can be transported, stored, diverted and recycled. However, the concept of managing the hydrological cycle involves more than hydrology and engineering; it also includes ecological and physiological factors, and forces beginning at the time the raindrop strikes the earth's surface, and ending when it re-enters the atmosphere.

The concept of managing the hydrological cycle is not new as it has been tried with success on some watersheds in the western United States. Water supply was in effect increased through the use of rainfall recovery techniques and the development of ecosystems with balanced and efficient water regimes. Water demand was also decreased through improved irrigation systems and techniques and vegetation manipulations on both the watershed and the irrigated areas.

We propose that the key to desertification control and rehabilitation and increased productivity within the Near and Middle East lies in the realm of management of the hydrological cycles. Space does not permit an exhaustive review of the various aspects and ramifications of this large subject. Therefore, we have

Table I. - Extent of Aridity in FAO Near East Region as Reflected by Rainfall Data

Region or Country	Total Area 1000 sq. km.	Amount of Rainfall				Total
		A Less than 100 mm		B 100 - 400		A + B % of Total
		Area (1000 sq. km	%	Area (1000) sq. km	%	
1. North Africa[1/]	5,751	4,864	85	653	11	96
2. Near East[2/]	3,705	3,033	79	589	16	95
3. Middle East[3/]	3,100	548	18	2,132	69	87
4. Sudan	2,625	764	29	500	19	48
5. Somalia	637	170	27	300	47	74
	15,818	9,379	60	4,174	26	86

1/ Algeria, Egypt, Libya , Morocco and Tunisia

2/ Bahrain, Cyprus, Iraq, Jordan, Kuwait, Oman, People's Democratic Republic of Yemen, Qatar, Saudi Arbia, Syria, United Arab Emirates, Yemen Arab Republic

3/ Afghanistan, Iran and Pakistan

limited this presentation to examples of some fundamentals, principles, and techniques which are applicable to the Region and which could be incorporated into an integrated land and water management system aimed at controlling the hydrological cycle. Emphasis has been placed upon the effects that this would have upon livestock and crop production.

2. CURRENT SITUATION IN BRIEF

2.1. Desertification

Desertification is degradation of both the living organisms and non-living environment of an ecosystem caused by man's interventions and abuses. The process is marked by increasing micro-aridity and declining productivity and the end product is a state in which total photosynthesis is of little use to man and beast.

Desertification is rampant throughout the Region on both rainfed and irrigated lands, and from all indications it has gone underground to include the aquifers as well. In spite of its severity, statistics relative to the results, rate of advance, and the area that has been affected are limited. The problem of desertification is great, however. For example, Lamprey (1975) compared reconnaissance surveys in 1958 and in 1975 in the Sudan and asserted that the desert's southern boundary had shifted south by an average of about 90-100 km. during the 17 year period. This represents a rate of between 5.3 and 5.9 kms. per year. In Tunisia, it was estimated that 18,000 ha. of productive lands are lost to the desert each year (FAO 1976).

In many countries of the Region, it is generally known that desertification manifestations of waterlogging and salinity of irrigated lands are major problems along with increasing salinity of underground water and falling water tables. In Saudi Arabia and the Gulf States, for example, the artesian flow of springs from time immemorial is decreasing, the water quality is deteriorating, and the water level is falling due to increased extraction by modern methods, and perhaps decreased recharge, thus causing sea water intrusion.

For the Near East Region waterlogging and salinity in irrigated areas constitute one of the most serious environmental problems. The most severe and direct cause of these two forms of degradation, however, is poor water management at the field level. They have been known since ancient times, when they led to impoverishment of farmers' communities and eventually to the abandonment of once fertile areas. Unfortunately, these problems do not belong to the past; they are found also at the present time. Considerable areas in Pakistan, Iraq, Iran, Syria and Egypt, to mention only a few, are added annually to those already affected. Here farmers still find that the introduction of irrigation water does not necessarily bring about a sustained increase in their standard of living; on the contrary irrigation - after an initial rise - often brings about a decrease in production and in quality of produce. In consequence, farmers' income drops and so does the general economic activity in the area.

Most of the countries of the Region are already suffering from a shortage of arable land (which is presently about 5 percent of the total geographic area) and opportunities for further expansion of the cultivated areas will have to be provided mainly through irrigation. However, any expansion in irrigated agriculture is faced with severe problems of natural salinity in the soils and irrigation water or both. As a result of intensive water application in the absence of efficient drainage systems, waterlogging becomes a problem in many countries of the Region. This problem was aggravated under the prevailing arid climate by soil salinity.

Quantitative data on the extent of present and potential salinity are only available for some countries of the Region. As an example, it is estimated that Pakistan is losing about 20,000 ha. per year of its irrigated land due to salinity and waterlogging. More emphasis should be placed on surveying and evaluating the productivity of these soils. However, the present and potential great losses of land resources in Pakistan, Iraq, Egypt, Syrian Arab Republic and other countries indicate that measures should be taken to overcome this menace. Salinization and waterlogging should not only be regarded as mechanisms through which land deteriorates, but their impact on the economy of the country and the social life of its population should also be realized and stressed.

It is gratifying to mention that many countries of the Region have initiated action programmes to overcome the problems of salinity and waterlogging. In Pakistan, through the techniques of tube well drainage and leaching of salts the land resources in this country are being saved, and thus the economic and social status of the people is being improved. In Egypt, the improvement of drainage, through horizontal tile drainage, and the improvement of the chemical and physical properties of the soil through leaching and the application of amendments (mainly gypsum) can increase income from salt-affected, sodic and waterlogged soils by at least 50 percent. It has also been demonstrated that drainage can pay back its cost at a rapid rate. Iraq has also started on ambitious drainage and land reclamation programmes to combat the problems of salinity and waterlogging (Arar and Dieleman 1975).

As the problem of salinity and waterlogging are common to the countries of the Near East, concerted group action of exchange of information should be adopted to the benefit of all. The Regional Project for Land and Water Use in the Near East and North Africa, which is operated by FAO and financed by some of the oil countries of the Region, has just been formulated and will become operational in the middle of 1977; it is an approach to such action and will obviously have greater impact if it is given full and continuous support.

These spectacular examples clearly illustrate that desertification is a serious and alarming problem in the Near East. Of equal importance is the desertification process on rainfed agriculture and rangeland which is not spectacular and which normally requires trained eyes to detect. In this case productivity is decreased because of soil structure deterioration which reduces rainfall infiltration and water retention capacity. Johnston et al (1971), for example, documented soil changes on an area heavily grazed for 17 years and found reductions in organic matter, less soil moisture and higher soil temperatures. They concluded that the soil changes made for a drier microclimate.

The effects of increasing micro-aridity on livestock and crop production is hard to determine, but it too must be great. Since aridity and productivity are inversly related, increased micro-aridity on either crop, pasture or forest land can only represent a reduction in crop, meat, milk or wood production. It cannot be otherwise, and therefore management aimed at reversing this downward trend must be a vital and the foremost consideration in any land use attempt.

2.2. Rangeland Utilization

If one were to see the vegetation of the Near and Middle East today, he would be hard put to believe that it once supported forest in areas and that in general it was characterized by highly productive native pastures (Pearse, 1971). Allred

(1968) and Draz (1976) described the vegetation of areas in Saudi Arabia and Syria (known as Al-Hima) which have been subjected to controlled grazing before the Prophet's time. These areas remain dominated by highly productive grasses, legumes and shrubs which are rarely found outside the protected areas.

While many of the Region's rangelands have been misused for hundreds of years, destructive utilization has only become acute and widespread within the past few decades. This is mainly because of explosive increases in livestock numbers. A regional study showed that the livestock population of nearly all the countries has increased several fold within the past few decades (FAO, 1972). In the Kordofan Province of the Sudan, for instance, livestock numbers increased nearly four fold from 1957 to 1966 (Anonomyous, 1976). And livestock numbers continue to increase regardless of the rangelands' ability to feed them.

Although undesirable, some sort of vegetation which provides some protection is usually attained with overgrazing, but this is not so in the Near and Middle East. Once a range reaches a vegetal stage in which cattle or sheep cannot survive, goats and camels are introduced which are less selective in their grazing habits and which cause further deterioration. Moreover, rangelands and forests also provide fuel for cooking and heating and the number of shrubs, many of them being invaluable fodder shrubs, that are destroyed for fuel is astounding. It is estimated that 182 million fodder shrubs are annually uprooted in Jordan (FAO, 1976) and that 548 million acacia shrubs are destroyed per year in the Sudan just to make tea and for cooking (Anonoymous, 1976). These estimates pertain only to shrubs destroyed by nomads and do not include fuel consumed by city and village dwellers. Clearly, there is a need for another source of energy.

The end result is that the Region's rangelands are in a deplorable condition. The Region's forests have fared no better and they too are in a deplorable condition, though vast reforestation programmes are being implemented in most of the countries. Considering that the Region's forest and rangelands are also its watersheds, it is obvious that their proper management must be an integral part of any attempt to manage the hydrological cycle.

2.3. Livestock Production

While some of the Region's livestock are grown under sedentary conditions on specialized farms or in mixed farming systems, the majority are produced under a migratory system of production. Two migratory systems are recognized; nomadic and transhumance (FAO, 1974 B). The pastoral nomads move continuously with their families in search of water and pasturage for their animals. While movements are as erratic as the rainfall, they are not haphazard wanderings as migration is usually confined within certain territorial limits. Nomadic grazing normally occurs in the very arid and desert areas and it is the only way in which the forage produced by sporadic rainfall can be utilized.

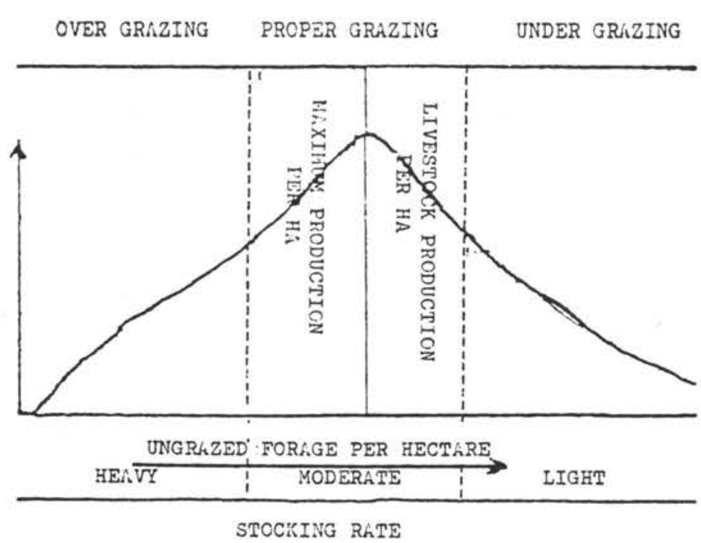
The transhumance system differs from nomadic in that the migrations are regulated by seasonal forage availability depending upon normal climatic conditions. This is the major system of livestock production and millions of animals move between dry and wet zones and from winter to summer grazing areas in the whole Near East.

The bulk of the feed consumed by the Region's livestock is produced on rangelands or natural pastures. The percentage of forage for livestock contributed by rangelands has been estimated at 90% in Iraq and Sudan, 86 to 88 in Jordan, Lebanon and Iran, 70 to 80 in Pakistan, 50 in Syria and as low as 34% in Cyprus (FAO, 1972).

Livestock production is greatly influenced by overgrazing because it reduces; (1) daily nutritional intakes and (2) quantity and quality of pasturage. Research in general has shown a curvilinear relationship between production and stocking rate, (Riewe 1961; Jones and Sandland, 1974; and Bement, 1969). This relationship is shown in Figure 1 and one can see from it that production declines rapidly when a stocking rate resulting in optimum production per unit area is exceeded. Stocking beyond the optimum creates animal competition for forage and as a consequence, all animals suffer from malnutrition. Jones and Sandland (1974) have calculated that zero gains per animal can be expected when the stocking rate is double that required for optimum gain/unit area. Clearly, the theory "more animals more meat" does not work.

Many of the Region's rangelands are grazed at two to three times their optimum carrying capacities. Consequently, production per animal and per unit area is very low. In the Sudan, for instance, annual offtake for cattle is 10-15% compared with 38 to 40% in the U.S.A. (Anonymous, 1976). It is estimated that annual sheep offtake for the Region as a whole is only 33% (FAO, 1972). The fact that production is not less is due to the ephemeral vegetation which grows following rains and which provides some sustenance, the occurrence of some shrubs with an amazing physiological resistence to over-grazing and the hardiness of the native animals. The most amazing thing is that these animals can live and even produce under conditions in which the improved European and American breeds could not survive.

Figure 1. Relationship between Livestock Production and Stocking Rate. This relationship has been described by several authors. (Adapted from Bement, 1969)



2.4. Cropland Production

Rainfed farming occurs mainly in the 250 to 300 mm and over rainfall zones and cultivation below these limits is extremely hazardous. In fact, attempts to cultivate the lower rainfall zones have been identified as major desertification causal factors in the Region. Most of the wheat and coarse grains are produced under rainfed farming leaving the land under irrigation for high value crops for local consumption or for export. In terms of actual food value (i.e. calories and protein) average yields per hectare in rainfed farming can approach these obtainable under irrigation if good care is taken of the crop.

Traditionally, about 50% of the cultivated area is annually fallowed for the purpose of improving soil fertility and accumulation of soil moisture from one year to another as a supplement for the next crop. However, there is evidence in some countries that fallow is not fully doing what it is supposed to do because long-term yields per unit trends are downwards (FAO, 1975, Draz, 1976 and Anonymous, 1976). In the Kordofan province of the Sudan, for instance, maize yields in 1973 were only 46 percent of that in 1961, sesame yields were down 23 percent and groundnuts 22 percent (Anonymous, 1976).

This is thought to be due to: (1) depletion of organic matter, (2) soil nitrogen deficiency in face of the fact that nitrogen fertilization is often uneconomical under rainfed farming, (3) decrease in overall fertility because of accelerated wind and water erosion, (4) deteriorated soil structure reducing infiltration and water retaining capacity and (5) increased weeds: e.g., increased micro-aridity and decreased fertility. Rainfed farming usually does not incorporate soil and water conservation practices such as water harvesting, chisel ploughing, contour ploughing, strip cropping, stubble mulch, green manure crops and others. Clearly, the adoption of these practices plus the planting of nitrogen-fixing, soil-building legumes in lieu of fallow are important.

All seven of the world's countries almost entirely (average 95 percent) in low rainfall areas, but very largely dependent on irrigation, occur in the Near and Middle East. One of the world's largest irrigation system occurs in Pakistan and the sum total of irrigated area in the Region is about 30 million hectares. These lands contribute significantly (about 70%) to the Region's food and fiber supply and it is important that their productivity be maintained at a high level.

The irrigation of arid and semi-arid lands is in fact the creation of a new ecosystem which in many respecs is just as fragile as the original. Since the objective of irrigation is to grow crops which could not be grown in the natural state, one direct result of the operation is an increase in transpiration. If the irrigation water is taken from outside the catchment basin and only enough is added to provide for additional transpiration, there will be no effect on the water budget of the area. There is, however, an effect on the soil which may have serious consequences. The irrigation water applied to the soil contains mineral salts, the vast bulk of which are left behind in the soil (Arar, 1970 and FAO, 1973). Since there is very little gravitational flushing in low rainfall areas, these minerals will likely remain.

Since it is difficult, under practical conditions, to determine the exact water requirements of a crop, there is a tendency for the farmer to make sure that there is enough water for plant growth by supplying more than an adequate amount of irrigation water. The water not required for transpiration or maintaining the field capacity of the soil will percolate down, thus giving a recharge to ground water that was not present in the natural condition. Such a rise is liable to bring about not only waterlogging of plants, but ultimately the development of a saline soil. (Arar, 1970 and FAO 1973).

These are all serious desertification problems which have been aggravated by the assumption that irrigation systems and methods applicable in other environments are also applicable in the Near and Middle East, which is not necessarily true.

Irrigation systems and methods including the provision of drainage to fit local conditions are needed along with determinations of water requirements and frequencies of irrigation required for maximum production of specific crops consistent with minimization of waterlogging and salinization. Innovative new cultural techniques, the use of low water requiring crops or crop cultivars must also be invented and implemented. Some of these and other possibilities are presented in more detail in the following sections, but it is appropriate to say here that they must be considered in an overall and balanced attempt to manage the hydrological cycle.

3. WATER YIELD AS RELATED TO GRAZING AND VEGETATION

This section deals mainly with rangelands merely because they constitute the Region's largest natural renewable resource and its major watershed. While forest lands only constitute about 5 to 6 percent of the Region's natural resources, it must be remembered that they are important as regards total watershed yields. Most of the fundamentals and examples mentioned here also apply to natural forests areas as well.

Most of the studies related to this subject have been conducted in the U.S.A. The studies are numerous and many of them have been used in the formulation of the publication "Rangeland Hydrology" by Branson et al (1972). We cite only a few examples here merely to illustrate certain points. Admittedly, the absolutes from the U.S. may not be applicable to the Near East, but the relationships, principles and fundamentals are as we have witnessed during the course of our work within the Region.

3.1. Influence of Grazing

Generally, infiltration decreases and runoff increases with grazing and the amount of runoff increases as grazing intensity increases. These relationships are illustrated in Figure 2. Runoff from heavily grazed plots was about 25% greater than runoff from moderately grazed plots and about 50% greater than from the ungrazed plots. This study also showed that the increase in runoff with moderate grazing was not accompanied by increased soil loss. Dragoun (1949) therefore concluded that moderate grazing was permissible if the resulting loss of water does not cause a critical shortage of moisture for plant development (as cited by Branson et al, 1972).

Hanson et al (1970) reported that heavily grazed watersheds produce runoff from both short and long duration storms whereas lightly grazed watersheds produced runoff from long duration storms only. In another study on desert shrub rangeland grazed by both cattle and sheep, there was 30% less runoff from the ungrazed watersheds (Lusby, 1970). On the other hand, and although the differences were small, Thompson (1968) reported that pre-runoff water absorption over a 10 year period was greater on ungrazed than on grazed plots but that the infiltration rate was higher on grazed plots. The percent vegetation cover remained essentially the same between the grazed and ungrazed plots in this study which suggest that an ecosystem can be properly grazed without disturbances of the water regime.

3.2. Influence of Vegetation Kind and Amount on Infiltration and Erosion

Changes in vegetal type or modification of cover on a watershed also result in a corresponding change in the hydrological regime. These changes may be beneficial

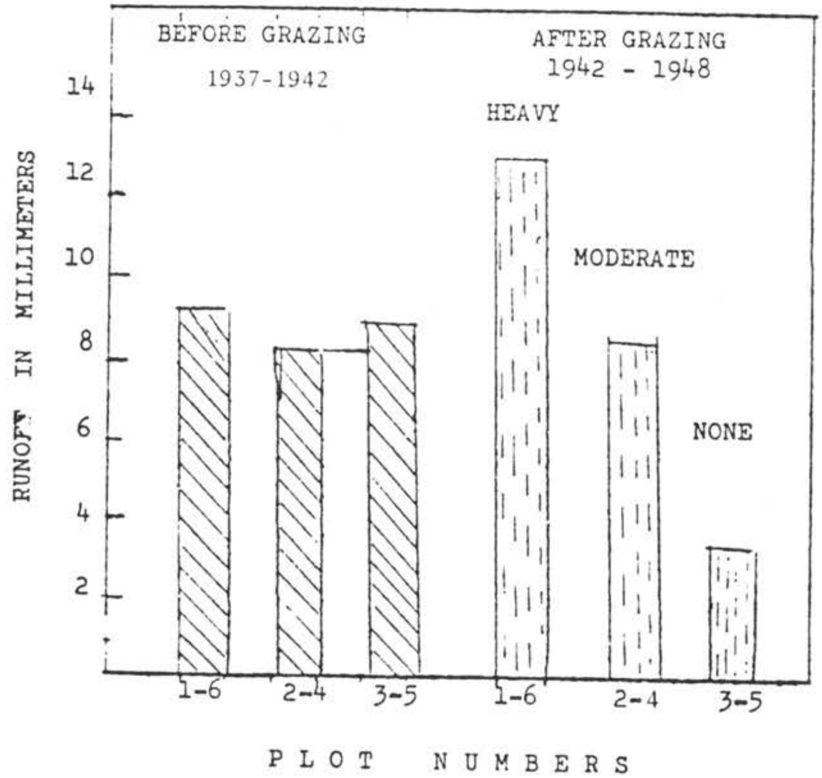


Fig. 2 - Average runoff, June to September, for Colorado Bunchgrass rangeland subjected to different intensities of grazing. (After Dunford,1949)

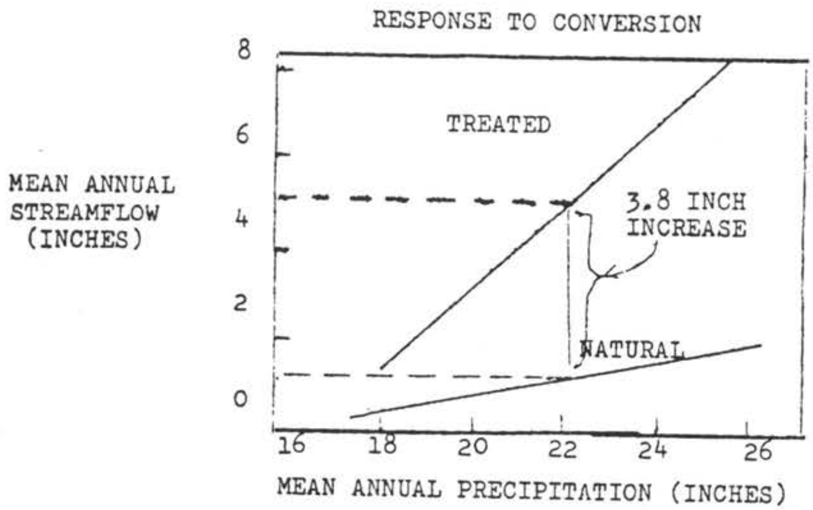


Fig.3. - Average water yield from natural and converted chaparral as a function of precipitation. Difference between lines is attributed to treatment (From Hibbert et al,1975)

or disastrous depending on the circumstances and objectives (Branson et al, 1972). We contend that the objective of increased runoff would be disastrous. Excessive runoff conditions invariably create peak flood possibilities which may cause more harm than good. Floods are always accompanied by erosion and the question becomes: "what is the lifetime of a silting dam?" Experiments have suggested that their "lifetime" could be greatly increased if the watershed is properly vegetated and managed.

Allred (1950) showed that the rainfed infiltration rate was drastically reduced with reduction in vegetation cover and organic matter (Table II). The infiltration rate on bare ground was only 0.5 inches per hour, compared with a rate of 1.0 inches per hour on rangelands protected by 750 pounds of forage and organic material per acre, and 9.4 inches per hour on rangelands with 5,800 pounds of vegetable material per acre.

Table II. - Relationship Between Forage and Organic Matter Content and Rainfall Infiltration Rate Per Hour. (From Allred, 1950)

Pounds of Forage and Organic Material/Acre	Inches of Infiltration per hour
0	0.5
750	1.0
2,150	8.5
5,800	9.4

Weaver and Nall (1935) reported that runoff on a 10° slope from 26.88 inches of rainfall during 15 months was 2.5% from overgrazed pasture and 15.1% from a range entirely bared by overgrazing. No measurable amount of soil eroded from the prairie, only a small amount from the pasture, but 5.08 tons per acre was lost from the bare area. Orr (1970) reported that the decline in runoff closely followed an increase in live vegetation and litter on a burned area seeded with a grass-legume mixture which approached stability when a ground cover of about 60% was reached.

The water consumption rates of a watershed's dominant species also influence water yields. In general, woody invaders are higher consumers of water than are herbaceous perennial grasses, legumes and forbs. For example, the shrub mesquite (*Prosopsis juliflora*) requires about five times more water per unit of growth than do perennial grasses (Allred, 1950). Dwyer and De Garmo (1970) showed that desert shrubs require about 2.5 times more water per unit of growth than do desert grasses and some grass species required more water than others.

Manipulations that reduce brush density and cover often increase watershed yields. In Arizona, streamflow increased on each of six experimental watersheds in which the chaparral brush cover was reduced and stream flow became perennial on four of them (Hibbert et al, 1975). Streamflow increases varied from 28 percent in open brush with low rainfall to more than 300 percent in dense brush with high rainfall. Average water yield from natural and converted chapparal as a function of precipitation as determined by Hibbert et al (1975) is presented in Figure 3.

This relationship between stream-flow and brush density undoubtedly occurs with many kinds of woody invaders. The second author has witnessed a case where the flow of a stream that had not flowed for about 50 years was restored with eradication of mesquite on its watershed.

Hibbert et al (1975) concluded that erosion would probably increase for a time following brush control, but that in time the replacement cover would protect the soil as well or better than the brush. Grazing capacity for both livestock and wildlife was increased considerably through conversion from brush to grass.

Runoff and erosion and downstream water quality are invariably related. Osborne (1956) classified various rangeland soils in the U.S. as to their inherent erodibility based upon certain soil characteristics and then conducted studies to determine their stabilization requirements. He found that the least erodible soils required about 1,500 pounds of vegetal material per acre for stabilization and the most erodible required 5,000 pounds. Except for the highly erodible soils, these levels of productivity were equivalent to those for properly utilized ranges in low good or high fair condition. The results of the study also suggest that some lands should not be utilized because of their watershed value, a point which any good land manager will readily admit.

Afforestation; e.g., establishing forests where forest never grew, is riding the tide of popularity as the means of arresting desertification, and many policy makers have advocated the appropriation of billions of dollars for this purpose. However, in respect to long-term water yields, the above data suggest that something other than afforestation would be a more desirable desertification remedy. Afforestation in these areas normally requires the construction of water harvesting contour terraces; protection from grazing which usually involves fencing; production, transport and land planting of seedlings; and supplemental irrigation for several years until the seedlings are established. The cost is high and is beyond the financial means of most countries.

This is not intended to say that reforestation where forests once grew should not be attempted; to the contrary, it is encouraged and is very necessary as regards the hydrological cycle. However, it appears logical to question afforestation from economical, ecological, hydrological and productivity viewpoints (sand dune stabilization excepted) as a satisfactory solution to desertification. Afforestation should not be confused with the planting of desert fodder shrubs, which is a range improvement procedure.

3.3 Runoff and Erosion on Ploughed Lands

Runoff and erosion from ploughed lands in semi-arid zones appears to be greater than on pasture, even overgrazed pasture (Weaver and Nall, 1935). Dragoun (1969) concluded that plant cover on cultivated areas seeded to perennial grasses resulted in a 90% reduction in surface runoff the second year after seeding. Upon conversion of a native prairie grass area to cultivation, surface runoff began to approach that of continuously cultivated areas. This, no doubt, is the reason why cultivation is a major factor causing desertification.

3.4. Phreatophytes

A phreatophyte is a plant which grows with its roots in water, and such species may require 3000 kilograms or more of water per kilogram of growth. In other words, they are "waterhogs." The planting of phreatophytes in connection with irrigation systems, especially along irrigation canals, is widely employed throughout the Region. This practice is questioned except in those cases where it is absolutely necessary to protect the fields from strong winds and sand encroachment. It would be interesting to know just how much water the introduced phreatophytes utilize and how much more water would be available for crop production in their absence. The water consumption/production ratios of plants associated with irrigation, but not normally considered as irrigated crops, could lead to inefficient and excessive use of the water resource. This aspect of plant water consumption must also be given due consideration in plans to manage the hydrological cycle.

RANGE IMPROVEMENT THROUGH NATURAL RESOURCES

While many of the Region's rangelands have deteriorated to the point of irreversibility as regards improvements through natural resources, the majority have not. These ranges have a remarkable "come-back" ability through natural secondary succession needing only the opportunity which can be provided through well designed and implemented deferred rotation grazing systems and proper stocking. We have observed trials in Pakistan, Iran, Syria, Jordan, Tunisia, Libya and the Sudan which clearly demonstrated that tremendous range improvement can be attained in only a few years after proper stocking or deferred rotation grazing begins.

Desirable perennial grasses and shrubs and annual grasses and legumes rapidly increase in both abundance and cover and the community is soon dominated by them to the benefit of livestock and the watershed. In one case in Tunisia, improvement was so drastic that the area could be identified by aerial photography three years after the trial began. In another trial in Tunisia it was reported that 200 ewes under a properly stocked deferred rotation grazing system accompanied with supplementation during the dry season produced 3000 more kilogrammes of lambs than 200 ewes under traditional management on rangelands adjacent to the station (FAO, 1976).

The beneficial effects of improved range was witnessed during a visit to the Khanasiri Range station in Jordan. The station, located in a 250 mm per year rainfall zone, is characterized by a rough topography and shallow soils, a situation highly subject to runoff and erosion. However, its vegetation cover was in good to excellent condition owing to years of controlled grazing and proper management. The erodibility of the adjacent lands was considerably less because of an undulating topography and the dominance of the deep and well developed Mediterranean terra rosa soil type. Some of this area was cultivated and the remainder was overgrazed rangeland in poor condition.

A rainstorm occurred prior to and during the visit. Runoff from the ploughed lands was tremendous and the waterways were soon overflowing with red water which was ample testimony as to the amount of erosion that had taken place. There was also considerable runoff from the overgrazed rangelands but erosion was less as was evidenced by the color of the water. However, runoff from the Station's rangelands was practically nil and the small amounts of water that did runoff were crystal clear.

5. WATER DEVELOPMENT AND MANAGEMENT PRACTICES

5.1. Water Development for Livestock and Human Consumption Through Rainfall Harvesting

The scarcer the water, the greater the need for technical and management skills. Methods of enhancing water supply and water conservation are being developed and refined. Rainwater harvesting is almost 4000 years old. It began in the Bronze Age, when desert dwellers smoothed hillsides to increase rainwater runoff and built ditches to collect the water and convey it to lower lying fields. The practice permitted agricultural civilizations to develop in regions with an average rainfall of about 100 mm, inadequate for conventional modern agriculture.

Water for human and livestock consumption and for limited agriculture can be provided through rainfall harvesting techniques. The water is usually impounded in ponds constructed in small depressions or in cisterns. Many of the cisterns constructed in Roman times in the Region are still functional today.

Rainfall runoff may be collected from untouched catchment areas, but often the catchment area needs modifications for the purpose of increasing the amount of runoff which usually entails making the soil surface more impermeable. There are many methods used for this purpose, such as: (i) land alteration by making ditches or rockwalls along hillside contours, clearing away rocks and vegetation and compacting the soil surface. When erosion is not excessive and when low-cost hillside land is available, land alterations can be a very economical way of harvesting rainwater in arid lands. (ii) chemical treatment involves the use of chemicals, such as sodium salts, silicones, latexes, asphalt or wax, that fill pores or make soil water repellent.

Water harvesting methods are site specific and before a system is installed one must know the soil (water holding, runoff, erodibility), the topography (slope), precipitation characteristics (amount, reliability) and the climate. Currently, developing water supplies by rainwater harvesting is for small scale use, for farms, villages and livestock. In Western Australia, a thousand hectares of shaped and compacted earth catchments supply water for both households and livestocks. In the Sudan and Botswana, catchment tanks have been introduced in technical assistance programmes.

The livestock carrying capacities of some arid rangelands is limited more by lack of drinking water than by a lack of feed and rainwater harvesting may be the only source of water development. Improving drinking water supplies in arid rangelands or other remote watershed areas increases the value of these grazing lands and allows the available feed to be used more fully.

However, livestock water development must be a part of an overall range management plan including control of livestock numbers. Indiscriminate water development has led to increased livestock numbers, overgrazing and desertification in many sections of the Region. The Sudan, for example, developed nearly 1000 water points between 1957 and 1969 without providing for proper grazing and the Sudanese scientists now realize that this contributed to an explosive increase in its livestock population (Anonymous, 1976). When water is a constraint to production, the pastoralists adjust accordingly which usually results in an ecological equilibrium between forage produced and forage consumed. Removal of the water constraint results in rapid increases in livestock number and the equilibrium is ruptured. Desertification begins as a circle around the water points and grows in diameter with years. The situation becomes extremely serious when the circles join each other.

No method of rainwater harvesting has been subjected to a long-term economic analysis. Large field trials in different areas are needed to build up a data base that could lead to a better understanding of economic viability of different methods in different economic environments. Developing countries particularly need the data because most of the technology was designed for developed countries such as Australia or the United States. With adaptive research to fit the needs, economies, and materials of developing countries, rainwater harvesting methods may be of exceptional and immediate value. The major technical research need is to reduce the costs of sealing catchment soils and to make the treatment practical for a wider variety of soils and situations.

5.2. Runoff Agriculture

The principle of rainfall harvesting can also be used for improving crop and rangeland productivity and for developing farming in areas where it is not naturally feasible. In this case, runoff from a larger areas is collected and concentrated in a small area where the water is stored in the soil. As a result, soil moisture in the small area for plant growth and development is increased considerably above the amount that would be available from rainfall alone. Runoff agriculture has particular promise in marginal areas as it lowers the risk of crop failure.

Runoff agriculture was once widespread over the whole region of the Near and Middle East, South Arabia and North Africa. It was the basis for civilization on many thousands of hectares in the desert of South Palestine. Today, runoff agriculture can be revived if care is taken in selecting the site, designing the system and selecting the crop. With good management it can make arid wasteland productive and can be an economically sound investment. Development of quick maturing crops will make runoff agriculture more effective.

Rainfall harvesting techniques are of particular importance to artificial seeding or revegetation of rangelands in low rainfall areas. It is the general consensus of range scientists that the conventional methods of range reseeding or revegetation will likely fail in areas of 300 mm of average annual rainfall and less. However, seeding and revegetation of rangelands in connection with rainfall harvesting techniques have been successful in many parts of the world in areas with less than 300 mm of rainfall.

The most promising runoff agriculture techniques are water spreaders, pits, contour borders and contour strip ploughing. We have highlighted these techniques here, but we refer those readers who desire more information to Vallentine's (1971) book; "Range Development and Improvements", and to the publication of the National Academy of Science - U.S.A., 1973 entitled "More Water for Arid Lands."

Waterspreading is a simple irrigation method for use of runoff water from intense storms, which are common in arid areas, in which flood waters are directed from their natural courses and spread over adjacent flood plains or retained on valley floors. The water is diverted or retarded along ditches, dikes, small dams, or brush fences. The wet flood plains or valley floors can thus be used to grow crops. Water spreading is also frequently practiced on range and pasture lands in connection with seeding or for the purpose of increasing productivity of the existing vegetation. Water spread pastures usually extend the season during which forage is succulant and nourishing and they provide green forage when it is especially needed.

Overgrazed areas can be revegetated and the carrying capacity greatly increased. For example, in South Wales Australia, the weighted average productivity of an

80-ha. water-spread area from 1968 to 1973 was 2.66 sheep per ha. Without water-spreading the carrying capacity of this region was 0.18 sheep per ha. Pastures established with water-spreading can be used in various ways. They can be used to relieve grazing pressure on adjacent rangelands or as special pastures to increase control over grazing, minimize losses of newly born animals or to hold the stock during the breeding season.

Pitting is the making of shallowpits or basins of suitable capacity and distribution on range to reduce overland flow from rainfall and snowmelt (S.R.M., 1974). Runoff water on the undisturbed land between the pits is captured by the pits in which either seed or seedlings are planted. Pitting does not require elaborate and expensive equipment as modified standard disk, wheatland or brushland ploughs are mainly used. The modifications consist of eccentric or deeply notched or cutaway disks. For example, the top portion of disks numbers 1 and 3 and the bottom portion of numbers 2 and 4 would be cutaway to convert a standard four disk plough into a pitter. Basins made by the disk pitters are about 3 to 5 feet long, 8 to 12 inches wide and 4 to 8 inches deep (Vallentine, 1971). To our knowledge, this relatively inexpensive and effective method of water conservation and range improvement has not been introduced into the Region. Pitting has also been used to increase soil moisture on croplands.

The beneficial effects of contour borders or terraces upon cropland production and soil and water conservation have been known for many years. Yet, the practice is not widely used in the Region. Although expensive, the concept of contour terraces also applies to rangelands. The practice is widely used throughout the Region in connection with fruit trees plantations and afforestations. We have observed, however, that the practice, plus protection from grazing also triggered the natural reseeding of desirable grass, legumes and browse species. Had these species been originally seeded, a productive and protective forage cover would have been rapidly established.

Contour stripploughing or furrowing also reduces runoff. The practice involves the construction of micro-furrows made 4 to 8 inches deep about 2 to 3 feet apart. In one study in the U.S., total average runoff from contour-furrowed plots was 3.36 inches compared with 16.15 inches on non-furrowed plots (Dragoun and Kuhlman, 1968).

5.3. Use of Brackish Water

Beneath many of the world's deserts there are huge reserves of brackish water and many surface waters, such as land-locked lakes and irrigation return flows, also contain fairly large amounts of salt. If saline water could be used for irrigation, more desert lands could be cultivated. The non-saline water now used in agriculture could be released for human consumption thus reducing the need for expensive desalinization schemes now contemplated for supplying urban areas.

New appreciations of soil science and plant physiology and new irrigation techniques show that with careful management, saline waters can be used to grow a variety of crops. In Abu Dhabi Emirate, deep in the desert, about 6000 ha. of forest plantations have been established using saline underground water (up to 10,000 ppm of salts) to irrigate salt-tolerant forest trees on deep sandy soils of undulating and sometimes steep slopes. This was possible by the introduction of the drip irrigation methods.

5.4. Recycling of Water

Reusing water can greatly lower the overall demand for water resources. Waste water can be used for irrigation, industry, recharge of ground water and in special cases, properly treated wastewater has been used for municipal supply. In the Gulf States big plans are being formulated for the use of sewage water for agriculture and one of these schemes is already operating in Kuwait involving about 800 ha. It is estimated that the use of sewage water of Cairo can increase the irrigated area by about 12,000 ha.

With careful planning, various industrial and agricultural demands may be met by purified waters, thereby freeing freshwater for municipalities which require better water suitable for human consumption. Water reuse may have greater impact on the future useable water supply in arid areas than any of the other technologies discussed before.

5.5. Underground Water

The use of local ground water in irrigation to supplement the rainfall and surface water supply can ensure sure and high yields. For this purpose, sprinkler or drip irrigation seems to be the most promising. The ground water would be exploited by shallow wells or canals to tap the shallow water table and by deep wells provided with motor driven pumps to extract deep groundwater reservoirs. The pumping of water, using solar energy, is being tested in the Region and it appears to have a very good potential, in isolated areas now, with a long-range objective of supplying energy for pumping and desalination of water on a commercial scale.

Many productive aquifers in arid regions of the world are storing large quantities of water that can be tapped. Development of such aquifers of this type is now proceeding in several parts of Egypt (the New Valley and other oasis), Algeria, Libya, Saudi Arabia, Jordan and the Gulf States. Since the recharge of such aquifers is either too small, or nil, its development must be undertaken with the full understanding that usually within a few decades the supply will be depleted and capital investment must be amortized within that time. To avoid ghost towns in the future, agricultural development under such conditions must be associated with industrial and/or tourism development.

In the near East Region there exists large international underground water aquifers, such as:

- (i) The Nubian Sandstone basin in Chad, Egypt, Libya and Sudan.
- (ii) The deep aquifers of the Arabian Peninsula.
- (iii) The Taoudani Basin in Mali, Mauritania, Algeria and Niger.
- (iv) The Northern Sahara Continental Inter-Calary Basin in Algeria, Tunisia and Libya.

There is a need to carry out studies on the utilization of these basins which will include, among other things, the optimum use of groundwater resources, control of over-extraction, alternative choices and time scale for exploitation of aquifers. There is a need for formulating an action programme for the execution of feasibility studies to arrive at an agreed approach in the development of the desert areas, aquifers, sociological and ecological aspects acceptable to the countries concerned.

5.6. Other Sources of Water

(a) Desalting

Desalting of underground and surface brackish water and sea water offers inexhaustable sources of water for arid areas in the Near East Region. The use of solar energy in place of the conventional sources of energy, (oil, gas and atomic) is very promising. At the present, reverse osmosis and electrodialysis are cheaper than the distillation methods for desalting of brackish water of soluble salts contents less than 5000 ppm. It is generally agreed that water from desalting plants will be too expensive for use in irrigation as practiced today. However, desalination of sea or brackish water could prove economically rewarding in special situations such as tourist centres and for the production of high value crops under protected agriculture.

Distillation plants producing up to several million gallons per day are already used for domestic and industrial purposes in some countries of the arid regions such as Kuwait, Saudi Arabia and the Gulf States where the local economy can afford it. In Kuwait, it has also been shown, that the production of out of season vegetables using desalted water under controlled environment can be a viable enterprise.

(b) Artificial Rainfall

Icebergs, dew and fog harvesting are potential additional sources for fresh water in arid areas.

6. WATER CONSERVATION MEASURES

In arid areas, measures that would increase the efficiency of the use of available water resources are as important as finding additional sources of water. Work has been carried out in different countries in this field and some of their measures are listed as follows:

(i) Reducing evporation from water surfaces in reservoirs and canals. This is based on the principle of providing a barrier on the water surface that inhibits vaporization by the use of liquid chemicals, wax, solid blocks, etc...

(ii) Reducing seepage losses by lining open canals or conveying water in pipes.

(iii) Reducing field application losses by the use of improved irrigation practices such as sprinkler and trickle irrigation.

(iv) Reducing percolation losses, particularly in sandy soils, by the use of underground moisture barrier.

(v) Reducing evaporation from soil surface by cover or mulches.

(vi) Reducing transpiration from plant leaves. About 99% of the water absorbed by plants roots is released to the air from leaf surfaces. If practical means to reduce this process can be found, but without affecting yield, major savings can be realized in the amount of water needed to raise a given crop.

(vii) Controlled environment. High agricultural productivity has been achieved with small amounts of water in very inhospitable regions such as El Saadyyat, Abu Dhabi and Kuwait with controlled environment procedures.

(viii) Hydrophylic soil amendments. This will reduce evaporation losses from soil surface and deep seepage losses. Soils mixed with hydrophylic (water attracting) chemicals can absorb water thus holding it safe from evaporation or deep seepage and keeping it available to plant roots for an extended period.

(ix) Artificial recharge of underground water. Rainwater harvesting can be used for recharging of groundwater. This is being experimented upon with success in Qatar. Runoff from local rain storms is being collected in depressions and artificially recharged to groundwater. This will result in minimal evaporation losses and protection from contamination. Groundwater replenishment also keeps neighbouring saline water from intruding into the aquifers.

7. INTEGRATING THE RANGE LIVESTOCK AND AGRICULTURE INDUSTRIES

Throughout the Region there is a traditional schism between the livestock growing people of the rangelands and settled agriculturists. Consequently, there are few examples of integrating the extensive use of rangelands with intensive livestock feeding and fattening on farmlands and using agricultural by-products in stratified animal production systems. This is a shame because integration of the range livestock and agriculture enterprises offers one of the best avenues for controlling overgrazing, increasing both crop and livestock production and arresting desertification.

Inadequate marketing and fattening facilities contribute significantly to overgrazing. It often requires 5 to 6 years for cattle and 12 to 18 months for sheep to reach slaughter weight. This means that the major portion of an animal population is growing or fattening animals. Practices which would siphon these animals from rangelands at weaning would help solve the overgrazing problem and would greatly increase livestock production.

The use of soil building nitrogen fixing legumes in lieu of fallow and in rotation with wheat or rainfed croplands is one means by which this can be achieved. In cereal-legume rotations, legumes boost cereal yields by raising soil nitrogen and suppressing weeds while providing more and better feed for livestock (CIMMYT, 1975). In a region where rain is highly erratic, the improved capacity of the soil to keep plants alive during droughts makes the odds on harvesting a crop much more favourable. Moreover, the nitrogen fixing by the legume allow the farmer to benefit from modern nitrogen-responsive wheat varieties without risking cash loss or putting himself in debt.

The use of the medic legumes (species of Medicago) in rotation with wheat has been successfully tried in the high rainfall Mediterranean climatic zones to the mutual benefit of both livestock and wheat. In Libya, for instance, wheat production increased from 400 kgs/ha under traditional farming methods to 1.6 tons/ha under medic-wheat rotation. Furthermore, the demonstration indicated that a grazing capacity of three sheep per hectare per year may be possible by using the legumes as pasturage and hay along with the wheat straw that is produced (FAO, 1976). The vetches (Vicia spp) have proved successful in the cold winter high rainfall areas. There is a need for legume species or cultivars suitable for cultivation in the drier and colder areas as well as the summer rainfall zones.

Drainage and soil leaching are the conventional methods of controlling water-logging and salinization. However, the possibilities that the severity of these could be reduced further in many situations through improved irrigation practices and through crop-pasture or crop-forage crop rotations warrants more consideration than at present. The possibilities are tremendous because many pasture and fodder crop species are both soil building and low water requiring. The idea is not new to the Region as the Egyptian farmer plants berseem clover in crop rotations for soil improvement purposes as well as for forage. Lal (1976) reported that fallowing with aggresive leguminous cover crops once in three or four years increases biological activity, aggregate stability, infiltration rate and aeration porosity. Legumes further improve soil fertility through their nitrogen fixation abilities.

Semple (1970) stated that grass is an important means of restoring soils that have become worn out by cropping. The grasses cover the soil and bind it with their deep and extensive fibrous root systems, adding organic matter and improving the tilth or physical conditions in the process. Rainfed farming systems involving grass "rotation pastures" are being employed in various parts of the world for the purpose of maintaining soil fertility and structure and sustaining crop productivity. Perhaps the same would be true on irrigated lands.

Furthermore, high producing low water requiring pasture plants exist. Burton et al (1959) determined the water required by five different grasses to produce one pound of forage (Table III). Common bermuda required 2.5 times more water than the other four and water requirements were reduced for all grasses except pangola with additional nitrogen. More important, however, is that Coastal and Sawanee bermuda required less water during the dry year compared with the wet year.

The use of drought resistant low water requiring plants such as these would reduce irrigation requirements which in turn should reduce salinization and water logging. Their use might also be the best use of limited water supplies; especially where only supplementary irrigation is possible. A search for pasture and fodder plants with minimal irrigation requirements is needed in the Region.

Other than Egypt, livestock production in general is not associated with irrigation in the Region because it is considered uneconomical and assumed to be a wasteful conversion of water to food. However, experiences in other countries have indicated that these assumptions are not always true. In Mexico, fattening on perennial irrigated pastures accompanied with supplementation resulted in 561 kgs. of live weight beef production per hectare in 101 days. The net profit per hectare was three times that for the traditional maize crop (Huerta, 1972). It was estimated that production and income could be doubled with two 100-day fattening periods. This was not an uneconomical nor wasteful conversion of water to food.

Greater use of rotation pastures and fodder crops in rotation with other crops would lead to the establishment of fattening and marketing facilities required to control grazing on rangelands. They will likely reduce desertification on ir-

Table III. Effects of Rainfall & Nitrogen Fertilization On Water Required to Produce One Pound of Dry Matter for Different Grasses (After Burton et al, 1957)

Species or Cultivars	Pounds of Water Required Per Pound Produced of Dry Matter			
	1953 (Wet Year)		1954 (Dry Year)	
	Nitrogen Fertilization		Nitrogen Fertilization	
	30 lbs/ac.	200 lbs/ac.	30 lbs/ac.	200 lbs/ac.
Coastal Bermuda	2478	803	1547	841
Sawanee Bermuda	1923	692	1107	432
Common Bermuda	4812	1546	9738	4436
Pensacola Bahia	2200	870	3103	1239
Pangola	2249	2240	2843	3016

rigated lands as well. Integrating the range livestock and agricultural enterprises would also create other possibilities for desertification control and increased livestock production.

Some of these are:

1. A land use system in which the range livestock are grazed in the cropland area during the major part of the growing season would greatly facilitate the deferment of rangelands during this important season which would result in range improvement and better dry season range.

2. Forage conservation and storage would provide supplement for critical periods. Supplemental stations could also serve to control livestock numbers as well as to facilitate development of marketing systems.

3. Forage conservation would also provide for emergency feed during droughts preventing huge death losses and reducing grazing pressure during this critical time of plant life.

8. SUMMARY AND CONCLUSIONS

1. Man can do very little to alter natural aridity but he can balance his actions with respect to the hydrological cycle so that a given amount of water can serve his needs without undesirable side effects such as desertification. Managing the hydrological cycle involves hydrological engineering, ecological and physiological fundamentals and forces beginning at the time the raindrop strikes the earth's surface and ending when it reenters the atmosphere.

2. Rangelands which constitute the Region's largest natural renewable resource, e.g. about 4 land units of range to one land unit of arable land, have not received the attention they deserve in national and international programmes. The range management practices and principles required for increasing their productivity, stability and water yields are largely known, needing only implementation, yet the problems of implementation have not been fully solved. Owing to the importance of rangelands as regards animal production and as a major element in the hydrological cycle, they should be given very serious attention. Livestock production could be increased several fold with proper range management and desertification would be arrested.

3. The present irrigated area amounts to about 25% of the total cultivated area, but it contributes about 70% to the total agricultural production. However, this contribution could be more than doubled if the fallow is reduced and the problems of salinity and waterlogging are kept under control together with the improved inputs, such as better irrigation practices, improved seeds, more use of fertilizers, weeds and pests control and improved cultural practices.

4. The potential productivity of rainfed agriculture has been seriously underestimated. This together with the fact that progress in rainfed agriculture is dependent upon a series of complex measures to be undertaken by Governments has until recently led to its neglect in many countries of the Near East Region.

In the Sudan, agricultural development in rainfed agriculture is being vigorously pursued by expanding the cultivated areas, where huge potential for expansion exists. However, the problem of raising or maintaining yields in the same plot of land has not received sufficient attention. While only in the Mediterranean regions limited possibilities exist for horizontal expansion, agricultural and livestock production and productivity per hectare of presently utilized areas can rise considerably through the abolition of fallow and the introduction of forage or other crops in its place and through the increased use of nitrogen and phosphorous fertilizers, together with other cultural practices such as early sowing and weed, pest and disease control.

5. In low rainfall areas the production of crops and livestock can be significantly increased by supplementary irrigation through using technical and management skills of the available scarce water resources, such as rainfall harvesting and runoff agriculture. The use of brackish water, recycling of water, underground water, and desalting of brackish and sea water are potential sources of water in the arid areas. In these areas measures that would increase the efficiency of the use of available water resources are as important as finding additional sources of water. These measures include reducing evaporation from water surface; reducing seepage losses by lining open canals or conveying water in pipes; reducing water application losses through improved irrigation methods such as sprinkling and drip irrigation; reducing evaporation from soil surfaces by covers of mulches; reducing percolation losses in sandy soils, by the use of underground moisture barriers; reducing transpiration from plant leaves without affecting the yields; the use of controlled environment; the use of hydrophylic soils amendments; and finally the artifical recharge of underground water from runoff water following intensive rain storms, which happens occasionally in arid areas and is normally lost by evaporation.

6. The traditional schism between the pastoralists and the settled agriculturists must be overcome because integration of the two enterprises offers one of the best avenues for increasing both crop and livestock production and arresting desertification. The integration should include both rainfed and irrigated croplands.

7. Development in agriculture depends on the availability of efficient government services for research, extension, soil conservation, range management etc. In order to ensure sustained production in agriculture, additional data is needed which can be supplied only by research. However, the research effort in the field of rainfed agriculture has in general not received adequate support. The drive for increased production presupposes the availability of efficient range management, extension, soil conservation and other government agencies. In many countries such agencies are either non-existent or are poorly organized.

8. In view of the above, and the fact that rainfed agriculture accounts for most of the land under range and under agriculture, a concentrated effort is called for by the governments concerned to remove the various obstacles in the way of progress and the formulation and resolute implementation of a policy for the development of rainfed agriculture. This may, within a relatively short time, not only double the volume of production from this sector of the economy, but will also protect the range and cultivated land from degradation. The effectiveness of the drive for raising production will be greatly enhanced if regional cooperation is established in the field of research, training and exchange of experience. With this in mind, the establishment of a Regional Agricultural Research Institute and Regional Range Management and Fodder Production Institute have been recommended by the previous FAO Near East Regional Conferences.

It is gratifying to report that the establishment of ICRADIA Institutes in Syria with Sub-Centre in Iran, together with three Regional Projects operated by FAO Regional Office and financed by the countries of the Region (Land and Water, Field Crops and Livestock Development) will play a major role in meeting the demand of the countries of the Region in maximizing their production, from irrigated areas as well as from range and rainfed agriculture.

9. Lastly, to achieve the above objectives by the member governments there is a need to establish a national policy for the development of range as well as rainfed agriculture, so as to reduce the growing socio-economic disparity between low rainfall areas and those with a more favourable environment. This will involve the solution of the problems of fragmentation and small size holdings, legislation to protect the rangeland from being put under marginal cropping, lack of marketing, infrastructure facilities and pricing policy and unfavourable input/output price relationships. This will also involve the strengthening of the government services for research, extension, soil conservation and range management for low rainfall areas.

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