Ecological Consequences of Bedouin Settlement in Saudi Arabia

Harold F. Heady
Professor of Forestry (Ecology)
University of California, Berkeley

Introduction

The primary purpose of this paper is to trace the use of the Arabian deserts for grazing by domestic animals. Ecological effects which have resulted from modernizing the Bedouin and which may result from changing pastoral nomadism to sedentary living are the central subjects. These effects were not planned, intended nor widely realized but unforeseen side-effects from the oil industry.

The Arabian case-history is likely to be unique within the context of this conference for three reasons. First, oil resources have relieved the Kingdom from the beggar's position in obtaining funds for development. Hence, limiting factors are scanty information and entrenched social customs. Second, the climatic harshness is extreme. More humid parts of the world have been the sites of nearly all development projects. Third, most changes to date in use of the Arabian desert are directly attributable to outside influences, as for example, the development of motor vehicles in the United States, and the accompanying oil industry in Arabia. Therefore, this paper examines a history of normal and slow changes by local peoples in response to materials and ideas brought to them through unpremeditated effort from a modern world.

Saudi Arabia's economy is based on revenues from the oil industry which are paid through royalties, salaries and local purchases. These moneys are used to develop other industries and to improve standards of living. Money has been used at a rapidly increasing rate for construction of schools, hospitals, roads, airports, laboratories, etc., and for the establishment of services in security,

education, agriculture, health, and communications. Interacting and unpredicted results from these developments have caused the Government of Saudi Arabia to embark on inventory, planning and feasibility studies during the last decade.

For the purposes of developing its water and agricultural resources, the Government has contracted with international consulting firms for natural resource inventories (Klemme 1965). Included are surveys of ground water quantity and quality, soil surveys and laboratory analyses of soils, range and livestock resources, and others. These studies, extending over three years and costing several million dollars, are feasibility studies upon which a program of development will be based. The first of these contracts was recently completed. During the study phase most small projects were postponed because piecemeal development was not giving satisfactory results from either ecological or economic standpoints. Development should proceed on a sound basis when all the survey contracts are finished.

This paper is based on reconnaissance of grazing resources in Saudi Arabia (Heady 1963) and later studies in the country amounting to eight months, nine weeks of which were used in desert safari.

Location

Saudi Arabia includes nearly four-fifths of the Arabian Peninsula, covering slightly more than 1.5 million km^2 (Fig. 1). Perhaps because of questionable boundaries, the area has been given as large as 2.1 million km^2. It is bounded on the north by Jordan and Iraq; on the west by the Red Sea; on the east by Kuwait and the Persian Gulf. Several sheikdoms or small states occupy coastal positions along the southeast and south from Qatar to Yemen. Accurate topographical, geographical and geological maps and aerial photographs of Saudi

Arabia have been prepared through joint effort by the U.S. Geological Survey, Arabian-American Oil Company, and the Kingdom of Saudi Arabia. These maps are variously available in scales ranging from 1:50,000 to 1:2,000,000, in both Arabic and English. The high quality of maps suggests that reliable inventory and census data of people, livestock, soils, vegetation, climate, land use, and water resources should be available. They are not. Statements about the quantity and location of these resources must be considered as estimates based on scarce data and informed guesses.

Geography

The topographic or physical appearance of Saudi Arabia is best described as a series of north-south belts that one crosses during west-east travel. The narrow (50 km) coastal plain along the Red Sea merges abruptly into the Asir Mountain chain composed of crystalline and metamorphic basement materials and volcanic rocks. Steep escarpments face the Red Sea with gradual slopes toward the east. The peaks seldom rise above 2,200 meters north of Mecca. Southward they are increasingly higher, attaining 3,760 meters in central Yemen.

Eastward of the western mountains lies the Arabian Shield. It is relatively narrow at either end but extends nearly 800 km into north central Arabia. The elevation is 1000 to 1300 meters and the rocks are pre-Cambrian crystalline basement with igneous intrusions toward the north. The Shield gives way to an escarpment region which is formed by six distinctive ridges with steep westward facing escarpments and gentle eastern slopes. The most prominent of these escarpments is known as the Tuwaiq Mountains, which are about 800 km long, 900 meters in elevation and rise 300 meters above the plains. Sedimentary deposits from the Paleozoic (outcropped in the escarpments) to the Quaternary period have covered the basement with increasing thickness from west to east.

In the northern part of the escarpment region is the Great Nefud, a sand desert of about 57,000 km^2. The sand is reddish and is variously sculptured into crescent dunes, parallel ridges and cones 100 to 300 meters high. A narrow belt of sand connects the Nefud in the north with the Rub' Al Khali or Empty Quarter in the south, which covers an area of 650,000 km^2. At least 80 percent of the Rub' Al Khali is covered with sand dunes and cones. Eastward from the sands is a gentle coastal plain which decreases to sea level at the average rate of approximately one meter per kilometer. Beneath this coastal plain are most of the oil resources. It is one of the richest oil deposits in the world.

Soils

Large areas of gravelly and rocky plains and lava beds without significant soil development occur in Saudi Arabia. There are agricultural soils in the wadis, near oases, and places where silts have been deposited, but agricultural crops in Arabia require irrigation with few exceptions. Soils studies and inventories are just now beginning. These include reconnaissance surveys and laboratory analyses based on standards used in the United States. Soil maps and the results of laboratory analyses are not yet available as the first laboratory for study of Arabian soils was established in early 1965.

Soils that are destined to remain useful for range forage production are those where irrigation and rainfall are inadequate for crops. This will probably be 98 to 99 percent of the Kingdom. Less than one percent is currently cultivated. The better range soils include the sands which have little profile development and the wadis which are usually mixtures of sand, silt and clay. Large, flat plains with extremely high clay and salt content are numerous. These are

barren but may be flooded occasionally. Exposed clay banks often show layering of salts and various textures of alluvium. In the escarpment region limestone is the principal parent material. Large areas of bare and sloping outcrops of both sandstone and limestone have little soil and are nearly devoid of vegetation.

Climate

Few weather stations have been established in Saudi Arabia. Data are scarce, and numbers are to be considered doubtful. Weather data are being collected systematically in conjunction with airline operations, but these records began too recently to produce reasonable averages and measures of variation (Meteorological Services 1959-1965).

The whole of the peninsula is arid except the mountains in the southwest. It is estimated that over 90 per cent of the country has less than 100 mm. average annual rainfall. Dhahran, over a 23-year period, averaged 89 mm. of rain, with a range between 17 and 176 mm. At Jawf, over a 5-year period (1957-61) the average annual precipitation was 56 mm. and the average number of days with rain per year was 5. There were 10 days during the 5 years that had over 10 mm. of rain. Similar data for Hail were 91 mm., 10 days of rain each year and 13 days with over 10 mm. Rainfall occurred on consecutive days once at Jawf and 6 times at Hail in 5 years. Local people in these two areas considered 1957-61 as a drought period. The high mountains in the southern Asir receive 300 mm. or more average rainfall. Rainfall occurs mainly during winter in the north and during summer in the south. However, it is irregular and often comes as downpours of high intensity.

Temperatures are extremely high during the summer months. Temperatures over 38° C. occur for weeks on end, with frequent days over 45°C., and occasionally

over 50°C. The winters are characterized by a few nights below freezing and daytime temperatures as high as 25°C. Humidity is very high on coasts of the Red Sea and the Persian Gulf and very low inland, with zero relative humidity frequently recorded. Evaporation has only recently been measured in Saudi Arabia. One year of measurement in Kuwait showed over 3,600 mm. from an open pan.

Many problems and uncertainties exist concerning the relation of rainfall to the total water resources of Saudi Arabia. Ecological consequences of haphazard water development and manipulation will be examined in later sections. Water is or can be as important as oil to the kingdom of Saudi Arabia. No elevation of living standard nor true social progress is possible until problems of water supply are solved.

Vegetation

Full description of the vegetation in Saudi Arabia must await detailed study. Broad vegetational types have been mapped and described by Vesey-Fitzgerald (1955, 1957a, 1957b) and by Tothill (1952). These authors have generalized but it is difficult to do otherwise in brief tours, mostly in areas long without rain, and without the aid of a published flora. All areas I visited in 1962 had vegetation, with the exception of the occasionally flooded mud flats. The gravel plains support a thin cover of annual grasses and herbs following rains, even though they appear bare of vegetation most of the time. The major vegetational types upon which grazing animals depend are as follows:

Areas of deep sand: These occur along both the Persian Gulf and Red Sea; in the Great Nefud, Dahna and Rub' Al Khali; and in smaller areas throughout Saudi Arabia. The principal grass is Thumam (Panicum turgidum) (Fig. 2). Following

rains, vast green carpets of annual grasses and herbs cover the sands. With exceptional rains, once in 10 years or more, the annuals form a dense cover as tall as a half-meter. The common shrubs are Calligonum and Artemisia, which are productive and are grazed extensively. These sands have an extremely high infiltration capacity and a very low water-holding capacity. As much of the rain comes in high intensity storms, these two soil characteristics prevent runoff and promote deep penetration of water. Thus, the sands store all the rainfall and support more vegetation than is normally expected with such low average rainfall. The Panicum type is best developed on the plains of the Red Sea south of Jeddah, where, the soil is so covered with vegetation that it disappears from view at a distance of 10 to 15 meters from the observer.

The wadi channels: The wadis are the most favorable habitats for range forage production throughout Saudi Arabia. These broad, flat valleys receive runoff water which brings silt and manure along with the additional moisture. Shrubs and grasses form a more dense cover than on surrounding uplands (Fig. 3). In the north, for example, the only plants available were in the wadis. Practices that might prevent the accumulation of water or its infiltration into the wadi fills could be damaging to this range type. The major wadi forage plants are species of Salsola, Artemisia, Atriplex, and Achillea. Annuals are abundant in the wet season. Some of the wadis are salty, in which case Haloxylon is the most common species. It also occurs on salty sites in sandy areas but is normally not extensively grazed.

Limestone plateaus: Outcrops of limestone have plants scattered in the pockets where soil has accumulated. If a sand layer covers the limestone, Rantherium forms a dominant cover and Stipa tortilis is a common associate along with many other annuals. This type, found principally in the north central

region, is grazed extensively.

The western mountains: Juniper (Juniperus procera) forest occurs high in the mountains. Below this are various combinations of species in the genera Olea, Acacia, Commiphora, Euphorbia and many others. The mountains have been very heavily grazed for many centuries so the vegetation which remains is largely unpalatable. The species of grasses in protected spots indicate that many palatable grasses were formerly abundant and have not completely disappeared.

One cannot travel far in this large and varied region without being impressed with the repetition of vegetational types as the various habitat conditions repeat. The vegetation is closely correlated with stratigraphy, sand, topography, drainage and salt. Except for the high mountains, the overall climate is much the same throughout Saudi Arabia, so the vegetational types are more closely related to soil conditions than to climate. The major variations are associated with the Mediterranean climatic influence in the north and the monsoonal effects in the south.

Grazing History

The Arabian Peninsula has been grazed by domestic animals for several thousand years. By piecing together from the records of early travelers (Krader 1959), and by observing as one crosses the deserts today, two conclusions are reached. Many settlements and even irrigated areas have existed which are now abandoned, suggesting times of crises throughout history. Relic areas of ungrazed vegetation suggests that vegetative cover in the past few decades was more dense than it is today. If one accepts these propositions, then it is interesting to examine the reasons for change.

When the late great Ibn Saud unified the Arab tribes in the first quarter of this century, numerous changes occurred in the use of the grazing land (Aramco 1960).

Tribal warfare was reduced. As this usually centered on raids for livestock, it is surmised that animal populations began to increase. Government policy to settle the Bedouin in order to control them, although not widely enforced, resulted in concentration of people and animals where permanent water occurred. These areas were already occupied by cultivators, so Bedouin settlement crowded and accentuated overgrazing near water. Extensive settlement awaited and has been very largely a consequence of the oil industry. Many Bedouins were employed directly by the industry and have successfully exchanged desert living for an urban environment. Others were attracted to the newly developed water within the oil fields and along the Trans-Arabian Pipeline (commonly called Tapline). Serious droughts between 1955 and 1963 intensified these movements toward settlement on permanent water. There was no other place to go. As many as 90 percent of some herds were lost in 1958-1961. This crisis added urgency to discussions and proposals for development of Saudi Arabia's water, grazing and agricultural resources.

Bedouins and Their Domestic Animals

There is no doubt that forage production has been and is sufficient to support many thousands of sheep, goats, camels and donkeys. As no reliable census data on numbers of animals were available in 1962, an attempt to determine numbers was made so that an appraisal of landscape effects caused by grazing could be made.

Counts and locations were recorded of all camels, sheep and goats combined, donkeys, and Bedouin tents during the course of 5,758 km. of desert automobile travel. Measurements of visibility along the roads indicated that the livestock were seen with reasonable completeness on a strip of land averaging about

2 km. wide. This would indicate the following average densities for the particular regions and particular season of travel:

	Number per sq. km.	Number per sq. mile
Bedouin tents	0.13	0.34
Camels	0.59	1.52
Sheep and goats	2.43	6.29
Donkeys	0.04	0.11

If one considers that 5 sheep and goats or two donkeys are equivalent to one camel in the amount of forage consumed, there is an average of 1.0 camel unit of grazing per sq. km. in the area visited. This is 2.8 camel units per sq. mile. It may be taken as an estimate of the stocking rate over much of Saudi Arabia. A later and more sophisticated aerial survey by one of the contractors in the Great Nefud in 1966 indicated 2.7 camel units per square mile. This is heavier grazing pressure than exists in much of the desert areas of southwestern United States.

These data also suggest that livestock numbers in Saudi Arabia as a whole are as follows. The calculated totals have been reduced by 20 percent to correct for low densities in the great sand desert (Rub' Al Khali) which was not visited.

Bedouin tents	227,000
Camels	1,004,000
Sheep and goats	4,158,000
Donkeys	75,000

These estimates indicate roughly twice as many camels, somewhat fewer sheep and goats and a similar number of donkeys in comparison with other estimates. Authors of previous estimates have not stated their procedures and no countrywide census is available.

Regions in which large numbers of animals were found include those near Nuayriyah, Ar'ar, Dahna sands in a 50 km. strip about 250 km. south of Rafha,

and the coastal plains south of Jeddah. These should not be considered areas of permanently high concentrations because all animals are migratory, except those maintained in or near villages. For example, counts for the first 100 km. southeast from Ar'ar along the Tapline road on two dates were as follows:

	31 October	14 November
Bedouin tents	26	109
Camels	61	106
Sheep and goats	200	1,683
Donkeys	4	14

Showers occurred between the two dates and migrations into the area were in progress on November 14. Another point of interest is that the only area where the number of tents equalled or exceeded the number of livestock was along Wadi Sirhan in northern Arabia. Three recent years of drought had caused severe livestock losses in the region. The longest distance travelled without observing animals was near Rafha where none were seen in 137 km.

Such a census as this has many chances of being inaccurate. These include biased estimates of animal numbers in groups that are too crowded for individuals to be visible, the fact that animals are more in the open during the morning and evening than during the middle of the day, topography resulting in widely varying distances of vision, people placing their tents out of sight, roads attracting people because of access, and roads being through villages and points of water may also be through areas of greatest livestock concentration. Some of these factors are compensating. Whatever the errors of the system, it does seem reasonable to conclude that the number of livestock is greater than has been previously stated. It may be increasing or decreasing. Only later counts of animals will determine which. If there are an average of 5.5 persons per tent, the population of Bedouins in Arabia is about 1,250,000.

The effects of livestock use on the vegetation is of special interest.

Many areas were in reasonably good condition. For example, the region halfway between Turayf and Qurayyat had excellent stands of Salsola and Poa sinaica, both highly palatable species. A 50 km. wide area of Panicum turgidum (Fig. 2) near Hadriyah along the Tapline road was in excellent condition, as were similar stands near Al Lith', south of Jeddah. The Rantherium type appeared generally to be in good condition. The headlands of many wadis were also producing forage in considerable quantity.

On the other hand, some locations had been overgrazed so severely that all plants had been destroyed. Wadi Ar'ar and its tributary, Wadi Ruthiyah, were lacking forage species. The damage in Wadi Ruthiyah was so recent that the dead Salsola plants were still present (Fig. 4). Yet 75 km. towards the headwaters of Wadi Ar'ar, there were abundant palatable species (Fig. 5). Similar areas of complete forage destruction around permanent water were seen at Khurais, Nuayriyah, the plains near Hail, and others. Wadi Sirhan had recently been used very heavily during three consecutive drought years. Palatable species were dead and shrubs that are not normally grazed had been very heavily used. Locally and commonly along the route travelled, areas of poor range condition were found. More land was producing below its potential than was in satisfactory condition. Overgrazing was gradually destroying much vegetation.

Hydrology

Saudi Arabia has no watercourse which continuously flows to the sea. Floods of a few hours or at most a few days reach the ocean but these are only from the Asir Mountains and short coastal streams. Water may flow in the wadis for a short time but it soon disappears into the sands and is stored in the wadi fill.

Runoff from large areas of impermeable outcrops and clays pans which

concentrates in the sandy wadis is a natural phenomenon. Much of this water is stored in alluviam at depths of 2-20 meters or more. It is within reach of hand digging and promotes vegetative growth beyond that which could be supported by the rainfall alone. The long, winding wadi strips are too narrow to show on most maps and may be ignored by the newcomer. However, they furnish water and forage which has supported wild animals, domestic animals and human populations for centuries. They are the life-lines of the desert.

The Asir Mountains and Arabian Shield, composed of pre-Cambrian crystalline rocks, do not contain large bodies of deep groundwater. Numerous aquifers and large groundwater reservoirs occur in the sedimentary basin which includes the eastern two-thirds of Saudi Arabia. They outcrop in the escarpment region and may be recharged from water in the wadis. As the sedimentary strata dip slightly to the eastward, water occurs as large flowing springs along the Persian Gulf. Many wells in the eastern region are artesian.

As a consequence of drilling for oil in eastern Arabia, flowing water-wells were developed and a drilling boom was underway by 1940 (Aramco 1960). Many wells were improperly completed so much waste occurrs. Two common mistakes were failure to cap the wells resulting in continuous flow and loss of control over artesian water. The second was improper casings which allowed mixing of waters from different acquifers with differing salt contents. Some aquifers produce high quality water but others have as much as 2000-4000 ppm of dissolved salts (Aramco 1961). As drilling for water expanded across Arabia, water control was not obtained so the consequences are widespread and affect all the land resources. The major problems are excess water, high salinity and poor drainage. Sand encroachment into irrigated areas is common (Fig. 6). Over 3,500 wells have been examined in northern Saudi Arabia during the last three years. Improved water

use is beginning through the plugging of some wells, control of flow, better conveyance of water to the place of use, and better irrigation practices.

There is little doubt that large bodies of water exist in the sedimentary basin of Arabia and that abundant water will be available for many years. However, it is just as certain that these water resources have limits. Pressures within the aquifers and water level in non-flowing wells have dropped. Recharge water may be entering the deeper aquifers but it is not keeping pace with discharge. More and more wells will need pumps. Evidently water accumulated in these aquifers over recent geological time and the supply could be mined and depleted.

Many water developments that are now used for livestock and domestic purposes have occurred largely as a consequence of the oil industry. These have unintentionally changed the patterns of nomadic grazing, as illustrated by the small community of Khurais which is east of Riyadh, and the pumping stations along the Trans-Arabian Pipeline at Ar'ar and Nuayriyah. These water sources are recent, too far from others to permit ready movement between watering points, and they are permanent, yearlong supplies. Grazing has changed near them from occasional nomadic use to year long grazing by livestock permanently based at these villages. The result is destruction of vegetation with bare soil near water and little vegetation closer than 50 kilometers from the three centers.

Dykes or low dams have been used to spread water laterally across wadis, to slow the runoff flow, and to promote infiltration in desert areas. Commonly, the dams are spaced 100 meters or so apart, depending upon the wadi gradient. They are open at alternate ends so that the water flows slowly in a zigzag fashion from one side of the wadi to the other. Numerous designs for water spreading systems are available.

This practice is of doubtful value in Saudi Arabia except where it can be

used as an irrigation system to raise planted crops, such as the ones employed in the Wadi Jizan and others of the southern Tihama coast. Several reasons for the questionable value of water spreading are: (i) Flowing water that leaves Saudi Arabia to the sea is almost none; therefore, it infiltrates into the wadi sands somewhere or evaporates. Since little water is lost, increased infiltration is not needed. Holding the water in one place would reduce the water in the wadi further down, where someone else needs it. (ii) Dams or dykes which slow the velocity of flow allow the silt and clay fractions to settle. These tend to seal the soil, prevent infiltration, and increase evaporation in the water held above ground. This has already been demonstrated in Saudi Arabia in the dam at Riyadh and at other places. Dykes in Wadi Kulays north of Jeddah are used for a few years to trap the silt. Ploughing, then, breaks the sealed surface and crops are raised on the improved land by irrigation from wells. Water spreading is not needed for floods to replenish stored water in the wadi sands, and is likely to increase the loss of water through evaporation. (iii) Water-spreading dykes are expensive to build and are likely to be destroyed by the large floods, in which case there is so much water that a spreading system is not needed, especially one which allows silt and clay to seal the sandy surface. When water is needed in times of drought, there is too little water to spread. (iv) Water spreading systems must be protected from livestock grazing at the beginning and carefully managed later. Indiscriminate livestock use will destroy them by trampling. With careful engineering and continuous care, water spreading systems will improve forage production, but these conditions are not available under nomadic grazing in Saudi Arabia.

Wildlife

Many species of animals and birds are natural components of desert eco-

on the best lands; employment in expanding industries such as the oil industry; water developments; rapid transport by auto on new roads; improved communications; extension of mechanized agriculture with incentives such as low rents, credit, technical aid, and veterinary services; localized health facilities; schools; and transfer of authority from the tribal chief to the central government. There is little doubt that tribal life holds back economic development and in the words of Helaissi (1959) "the nomads must catch up with the caravan of modern civilization." Present evidence is abundant that the Bedouins respond in modern society and many have forsaken their tents for permanent dwellings.

With more and more individuals selecting a sedentary way of life, there is the possibility that nomadic grazing will be greatly reduced or eliminated. This is undesirable because the vast areas that can only be so used will be eliminated from livestock production. Perhaps the best approach is to let these people take a new way of life as they desire it and at the same time to take steps to improve livestock production and living conditions in the range areas. Such steps include development of additional water, travelling schools, frequent communication of forage conditions and news, travelling stores, extension training in range management, veterinary services; improved marketing facilities, livestock fattening operations in the irrigated areas, and others.

To argue for not modifying the nomadic way of life is a futile exercise as it will continue to change. But modernization should be taken to the Bedouin as well as removing him to a new habitat. The arid climate cannot be changed. Irrigation in his habitat is possible on only a tiny fraction of the arid lands. Why waste the grazing resource of the vast areas? This is not to suggest that traditional migratory grazing should not be changed. It suggests that modernization of Bedouin life <u>in situ</u> with all the services available from technical agriculture and other aspects of modern society should be brought to bear on the

problems of livestock production in arid regions. The philosophy of "the desert is a waste land" should be replaced by one of "production at the full potential", however low or high it may be. More or less controlled nomadism is necessary for the use of desert grazing resources. That philosophy can prevail only if Bedouin life is promoted and improved. Intentional settlement of all Bedouins should be questioned. The unplanned, unintentional and often unrealized ecological influences which have invaded the deserts in Saudi Arabia because of Bedouin settlement need to be quantified and controlled before these fragile ecosystems are upset beyond repair.

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Figure 1. The Arabian Peninsula showing geographic regions and names used in the text.

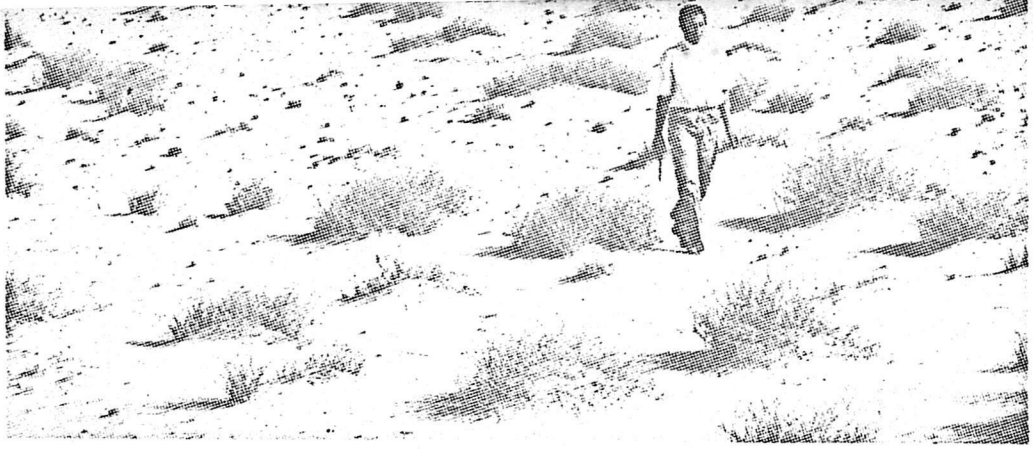
Figure 2. Little grazed grassland dominated by Panicum turgidum in northeastern Saudi Arabia. This shrub-like grass with perennial stems is common on deep sands. Annual plants are abundant in this type briefly following rains.

Figure 3. Haloxylon along a broad, flat wadi channel in northeastern Saudi Arabia. Runoff water permits increased density and growth of both shrubs and herbaceous plants. Water may be found in the wadi sands at 2-20 meters below the surface.

Figure 4. Dead shrubs of Salsola in Wadi Ruthiyah, caused by overgrazing and drought. This area is near recently developed permanent water where animals have concentrated.

Figure 5. At sixty km. from livestock water in Wadi Ar'ar the cover is fair to good and has a mixture of several palatable browse species.

Figure 6. Sand encroaching on irrigated land at the edge of the Hofuf oasis. Not only is crop land covered but irrigation canals are plugged and drainage reduced by moving dunes.



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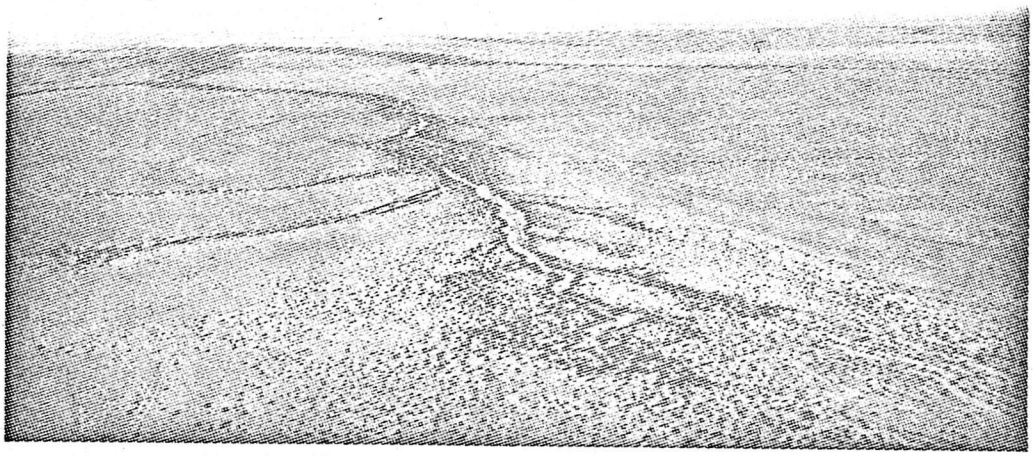

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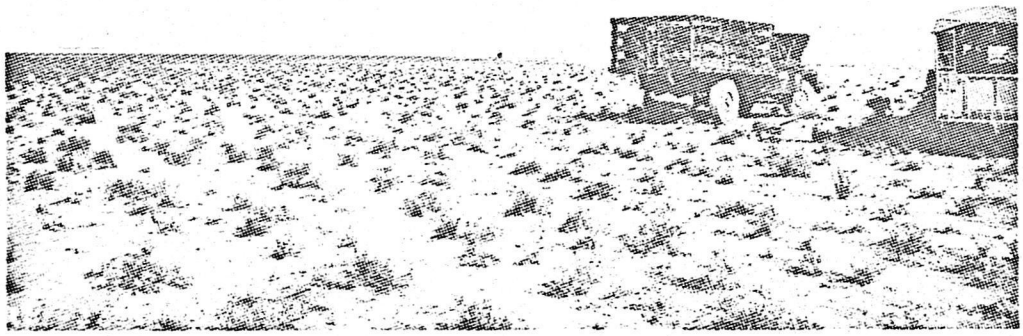

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