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Range Improvement by Waterspreading in the Gash Delta, Kassala Province: Democratic Republic of the Sudan

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RANGE IMPROVEMENT BY WATERSPREADING IN THE GASH DELTA, KASSALA PROVINCE: DEMOCRATIC REPUBLIC OF THE SUDAN

by

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INTRODUCTION

The area north of latitude 14° north in the Sudan is characterized by unreliable precipitation patterns and a high incidence of a drouth period following the first rain of the "rainy season." In this region it is not uncommon to have a completely dry year without a single rain shower. The damage occurring to the plant cover when a drouth period follows the first rain is great. This is especially the case for the annual plant species in that such precipitation distribution patterns tend to exhaust the seed supply in the soil and do not supply adequate moisture for seed germination. This factor has largely been responsible for development of sparse vegetal cover consisting mainly of shrubs with an occasional understory of early maturing annuals that are evident in years with a good rainy season.

If grazing is imposed under such conditions, the result is bare and depleted rangeland. The problem of providing additional livestock forage for the famine striken areas of the arid regions of the Sudan can be solved to a certain extent by establishing grazing areas through water-spreading. This has been shown in the Mukram Range Pilot Scheme (Annual Report, Range Management Section, Kassala, 1968), where the dairy herds around Kassala town were accommodated for about three months during the dry season.

REVIEW OF LITERATURE

Waterspreading on rangelands is the practice of diverting runoff water from stream channels or courses and distributing the water over nearby flood plains or valley floors. The main purpose of waterspreading is to slow the water and allow it to infiltrate into the soil.

The spreading of flood waters, for agricultural purposes, is an old practice in the Orient and in North America. Bennet (1939) mentioned that the early Indians in the Colorado Plateau Region used it extensively in crop production. Similarly, in the Gash Delta, the Beja tribes utilized the technique to produce grains that were famed for their quality in Arabia and elsewhere (Bolton, 1948). For generations, waterspreading was only associated with crop production and this concept is still in the minds of the semi-nomadic individuals of the Beja tribes.

Miller et al. (1969) stated that the watershed area above the spreading site should provide at least one flooding per year for satisfying the requirements of forage production, and additional floodings each year are advantageous. Where water is scarce and the area suitable for spreading is greater than the water supply, application of three to six inches of water per acre, when available,can be expected to produce more forage than heavier applications on smaller areas (Stockes, Larson and Pearce, 1954).

Miller et al. (1969) concluded that a runoff basin having a rainfall less than nine inches of average annual rainfall generally gives small forage yield responses on the spreading area and does not justify the construction of a waterspreading system.

It is important that there be a proper ratio between the size of the runoff basin and the spreading area. Hubbel and Gardner (1950) stated that a ratio of 10:1 has been considered correct on the average in the Four Corners area of the Colorado Plateau.

Monson (1958) mentioned that waterspreading has two main functions, (1) increasing forage production by spreading of water and its storage in the soil profile, and (2) reducing gully erosion and downstream flooding.

The best water spreading structures are not built to a pattern but are built to fit the terrain. In all cases, major mechanical operations such as levelling are expensive compared to the expected revenue from increased forage production. The common set of specifications for a waterspreading structure is discussed by Stokes, Larson and Pearce (1954) as:

1. Reservoir for temporary storage of flood water
2. Diversion structures for removing water from channel of reservoir
3. Conveyance structures for taking the water to the spreading site
4. Control structures on the spreading area
5. Disposal structures for removing excess water without erosion damage.

The most profound and often deleterious effect of waterspreading on the soil has been the change in soil texture due to sedimentation. This change generally varies with the distance from the diversion dike. Hubbel and Gardner (1944) showed that in New Mexico studies, the soil became more sandy over the first 1500 feet. Beyond this point, the texture either remained the same or became heavier as a result of the deposition. Analogous to this situation but on a larger scale are the soils of the Gash Delta. They are arranged in a sequence starting with the lighter soils in the south to heavier in the north, with stretches of fine alluvial silt in the center of the Delta.

Hubell and Gardner (1950) reported that rapid deposition of more than five inches of sediment greatly damages most grasses except western wheatgrass (Agropyron smithii). The deposition of sediment is a function of particle weight and velocity of the floodwater. They suggested that the slope of a spreading area should not be steeper than 2 percent in order not to have either sedimentation or extensive erosion.

Hubbard and Smoliak (1953) and Houston (1960) showed that there was an increase in forage production and carrying capacity from 150 to 500 percent over the entire spreading systems they studied. They attributed this increase to the responsiveness of the plant species to moisture increase. This increase can be significant only when the area involved is large enough to relieve grazing pressure from the surrounding rangelands for a certain critical period. Most of the plant species in the arid areas of the Sudan are responsive to the slightest moisture increase.

THE GASH DELTA WATERSPREADING EXPERIMENT, A CASE STUDY

Historical development of the project

In 1924, the Government granted the Kassale Cotton Company the right to cultivate the Gash Delta. In 1927 the company relinquished its concession in the Delta and a board representing the Government managed the area (Bolton, 1948). The pastoralist tribes of the Delta drove their livestock to the surrounding areas away from the cultivated lands. Overstocking of these surrounding ranges was inevitable and in 1947 the animal population increased even more due to the disease control program that was gaining momentum. Harrison (1955) reported that signs of overgrazing were observed in Kassale district. In 1964, the writer made a reconnaissance survey on the eastern regions of the Aroma district, east of the Gash Delta, and reported that the only perennials besides trees were *Calotropis procera* Ait. and *Panicum turgidum* Forsk. Several annuals were listed and the density was estimated as 38 plants of all species per square meter plot.

In 1968 a survey indicated the total absence of *Panicum turgidum* Forsk. from the eastern and western areas. In the northern areas, for a distance of 120 miles from the Delta not a single grazing area was to be found except around the ephimeral water courses. Encroaching sand dunes had reduced the whole northern area to completely bare soil. The nomadic migration pattern changed accordingly and reached out to River Atbara on the west (Figure 1), the Sudanese-Ethiopian borders on the east and the Red Sea Hills in the north. In the dry years, the routes of migration were

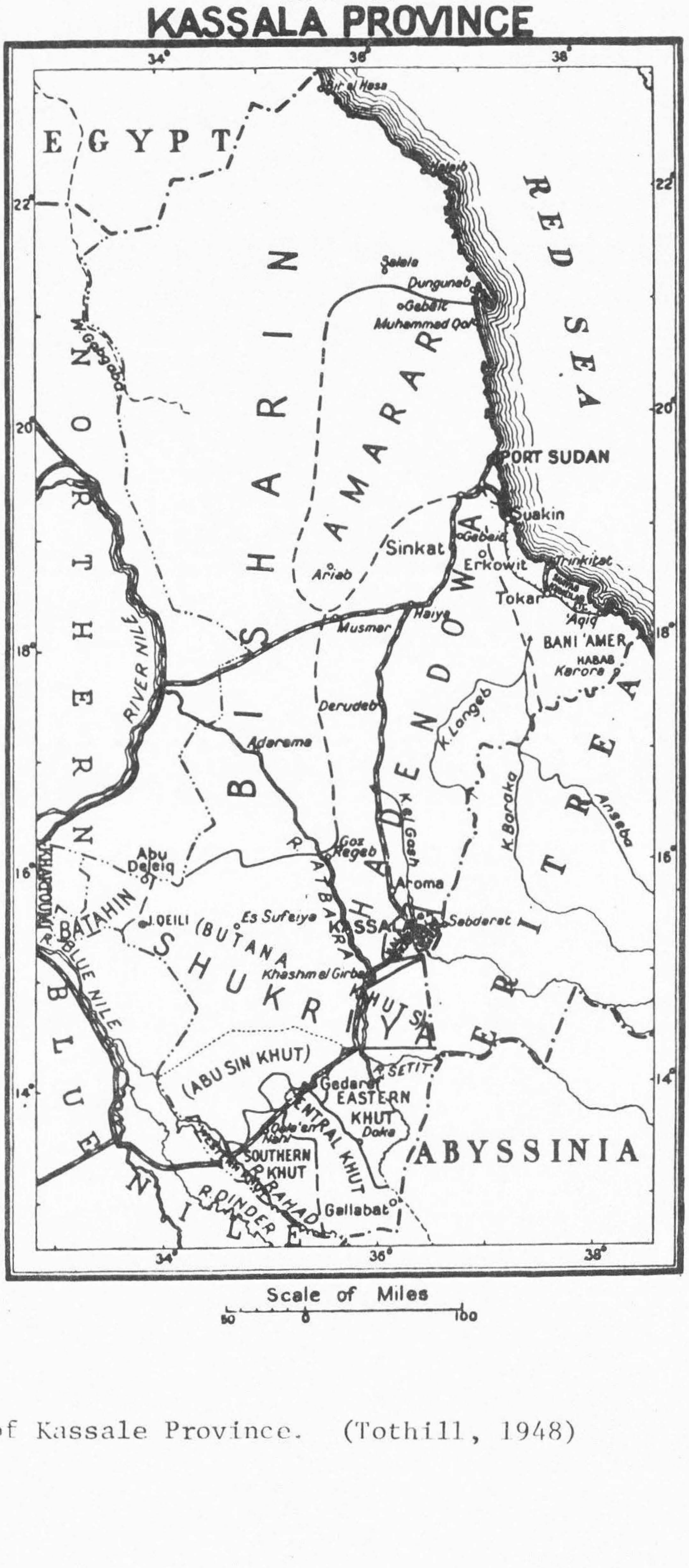

Figure 1. Map of Kassale Province. (Tothill, 1948)

confined to the Red Sea Hills and back to the Gash Delta. This pattern of movement was synchronized to make use of the winter ranges in the Red Sea Hills and the early summer ranges in the Gash area. Under such grazing pressure, the northern area between the Gash Delta and the Red Sea Hills became bare and subject to sheet erosion by the prevailing summer winds. As a result the nomads, favoring the survival of their livestock have continuously invaded the cultivated areas of the Gash Delta as early in the year as mid July and have caused considerable losses in the crop production. For example, in 1968 this loss was estimated as high as 25,000 Sudanese Pounds ($70,000) in the Hadaliya section of the northern region of the Gash Delta. According to authorities, the total loss in crops approaches 150,000 Sudanese Pounds annually. If we considered this value as an opportunity cost or the cost that can be avoided by developing and improving the rangelands of the Gash Delta, then we can have an economical justification for providing alternative sources of forage to the livestock in quantities large enough to decrease the loss in crop production.

The northern part of the Delta was chosen in 1962 as a potential site for additional forage development, as it would block the entrance of the nomadic herds to the cultivated areas of the Gash Delta. In 1964 a proposal was submitted to the Ministry of Finance to establish a pilot range improvement scheme at Eitama. Due to the technical difficulties, execution of the project was postponed until 1969.

Description of study site

Location and topography. The project covers the eastern part of squares 252 and 266 of the Gash Delta (Figure 2). It is roughly between latitude 16°15' and 16°30' north and longitude 36°0' and 36°15' east.

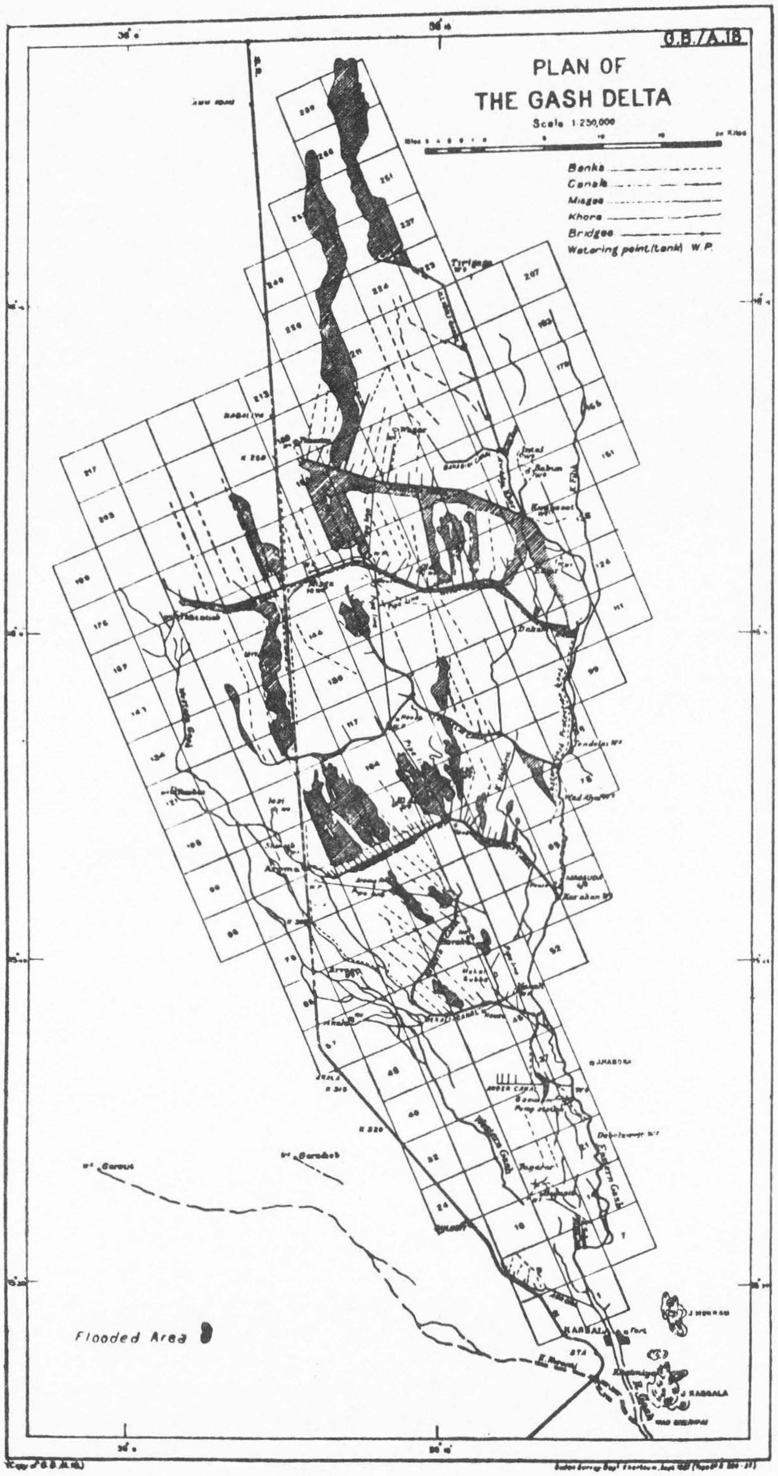

Figure 2. Plan of the Gash Delta showing the Experimental Range Improvement Scheme. (Tothill, 1948)

There is a gentle slope from south to north and a steeper one from west to east. Part of the project area forms a higher strip running from south to north.

The total area of the project is about 6933 feddans (11.2 square miles) of which 1,050 feddans are located in the higher strip previously mentioned. Another 4,457 feddans are demarkated as part of the original basin that used to be flooded to grow sorghum. This area received its last flood in 1958 and since that time it has neither been flooded nor cultivated. The other 1,426 feddans are covered by thickets of trees and shrubs with sparse stands of herbaceous species confined to the depressions.

Soils. Greene (1948) described the Gash soils as recent, still-forming material of coarse sand, finer sandy loam, and clay loam as one proceeds from the head of the delta in the south to the edge of the deltaic fan in the north. The project area being in the northern part of the Delta, is located on the dark cracking clay soil type. Upon drying the soil cracks below the loose upper surface that is subject to sheet erosion by the wind during summer. This soil type suggests a low infiltration rate which is not the case in other clay soils of the Gash Delta. Water travels through these cracks to great depths even before the wetting of the upper soil. Mackinnon (1948) reported that the moisture penetration reaches 13-18 feet and that only the top two feet appear to be affected by evaporation. Wetting at these depths is achieved only when floodwater is applied at rates in excess of 8,000 cubic meters per feddan.

Vegetation. According to Andrews (1948) the project falls in the "Acacia Desert Scrub" vegetational region, which has an average annual rainfall of 100-200 mm. Annual flooding of the delta forms a unique type of vegetation that is not typical of the vegetational region according to Andrews (1948) classification. The plant associations in some areas within the Gash Delta suggest stable conditions, and in my opinion it can be considered as climax because the earlier surveys (1948-1958) and the later ones (1964-1968) did not seem to differ in the species list indicated by these surveys. These undisturbed areas are located on the east central part of the delta, where the Gash River forms marshes and swamps that are flooded for eight months annually. These areas are not accessible to grazing, as the dominant species is the thorny Acacia mellifera (Benth). From these areas arises the weed problem of the cultivated areas. From here arises the water-borne seeds that provide for a crop of invading species year after year. Due to the weeds and grazing problems, the cultivated area has shrunk from 120,000 feddans down to 80 to 90,000 in area. Low floods may still reduce the acreage to 40 to 50,000 feddans.

The original agricultural plan, initiated in 1928, suggested that areas flooded in excess of 18 days should be put under cotton or castor and those in excess of 10 days flooding should be allotted to grow sorghum. Areas with less than 10 days flooding were left uncultivated and support a natural plant cover that was grazed mainly by goats and donkeys. As expected, these areas were scattered and to gain access to them, the livestock trespassed on the cultivated areas.

Study method

A species list of all the weeds reported by the Gash Delta authorities was prepared and the species were discussed with the nomads as to their value as forage species. Most of the plants were described by the nomads as good forage species that were once dominant in the Gash Delta. The logical conclusion was that there was a seed source that continually provided viable seeds to flood water. We then proceeded to investigate the patterns of invasion and to determine the plant parts by which the various species propagate. Seeds and stolons were found to be the main parts by which most grasses and forbs dispersed in the delta. Reseeding of the bare areas was then ruled out and our recommendations were made to encourage the natural invasion of these plant species. We introduced five species that were tested in the Kassala nursery to study their behavior under flooding conditions. These species were: Clitoria ternatea L., Sorghum vulgare L., Sorghum sudanense (Piper) Stapf, Pennisetum purpureum (Schumach) and Panicum viragatum.

The following species are considered to invade naturally by seeds:

A. Shrubs: Calatropis procera Ait. (noxious shrub)
Indigophera oblingifolia Forsk. (camel browse species)

B. Grasses and grass-like species:

1. Perennials: Sporobolus festivus Hochst.
Cenchrus ciliaris Linn.
Cenchrus setigerus (Vahl)
Cyperus rotundus Linn.
Panicum coloratum Linn.

2. Annuals: Aristida sp.
Chloria villosa Pears.
Dactyloctenium aegyptium Beaur.
Brachiaria mutica Stapf.
Echinochloa colona Link.
Cenchrus biflorus Roxb.

3. Forbs (all annuals):

Ipomea obscura (L) Ker-Gawl.

Rhynchosia memnonia (Del) DC.

Tribulus terrestris L.

Corchorus sp.

Trianthema pentandra L.

Cassia tora L.

Cassia senna L.

Ludwigia parviflora Roxb.

Colocynthis vulgaris Schra.

The only grass that propagated by stolons was:

Paspalidium desertorum Stapf.

In the northern part of the project area, the following shrubs and trees were found:

Acacia nubica Benth.

Acacia mellifera (Vahl) Benth.

Acacia tortilis Forsk.

Acacia radianna Savi.

Balanites aegyptiaca Del.

Cadaba rotundifolia Forsk.

Capparis decedua Forsk.

Calotropis procera Ait.

Indigofera oblongifolia Forsk.

Ziziphus spina-christi (L) Willd.

The project area was divided into three main basins according to their topography. Basin (1) was the high land area of 1,050 feddans (1.64 square miles); Basin (2) was the low area west of Basin (1) and consisted of 4,457 feddans (6.96 square miles); and Basin (3) was the northern shrubby part of 1,426 feddans (2.23 square miles). Each basin was surrounded by a main dyke that had an average height of 1.5 meters. Within each basin minor dykes were constructed on the contour lines to have a maximum of 6 inches difference between the lowest and highest points in these plots.

Basin (1) was that area that had not received any floods since 1956 when silting up of the basin prevented flooding. Accordingly this basin was completely bare of vegetation and was eroded. Since this basin presented itself as the most likely area to study the natural invasion of the species previously mentioned, we constructed checking dams and raised the sides of the feeding canal. A spillway was constructed at the eastern end of every plot to drain excess flood water to the following plot. Disking was necessary to prepare a seed bed and prevent seed-loss in the soil cracks. This practice was carried out only on the 400 feddans which were allotted to the introduced plant species.

The plots were flooded from their western end and once the water reached the eastern low end, the inlet was closed. Different flooding periods ranging from one day to 16 days were imposed to detect the proper flooding period required for establishing forage species in the whole basin.

In Basin (2) there was an area completely dominated by Sporobolus festivus Hochst. which, according to the nomads is the least desirable forage grass in the Gash area. To control it we set three plots: the first was ploughed, the second was burned, and the third was burned and then ploughed. None of these treatments seemed to affect this species as the plants recovered after flooding. Later our observations indicated that this species is palatable prior to flowering but due to successive dry years, it had failed to regenerate and was avoided by livestock. The nomads, reaching the Delta at the time when the species was dormant, developed the idea that it was unpalatable.

FINDINGS

We designed our experiments in a way to study the vegetation before and after flooding. Our first experiment was carried out by irrigating small areas to observe the date of germination and the species composition. The same observations were taken after flooding the basins. Species composition was not recorded due to the grazing of the nomadic livestock in October 1969.

Irrigated plots

To test the hypothesis that perennial species of the Gash Delta invade the flooded area by water-borne seeds, we chose ten plots of 4 square meters and irrigated them in May 1969 at weekly intervals. Since it was impossible to identify the grass seedlings, a tag with the date of emergence was attached to a wire circle and punched in the soil around the plants. Forbs were easy to identify. Continuing irrigation until the first week of August of the same year, we found that the germinating species were annuals with the exception of one perennial species (Cyperus rotundus) an d it occurred in only two of these plots at a frequency of 20 percent. The annuals were ranked according to their germination date in the following groups:

1. Ipomea obscura and Sorghum lanceolatum germinated at the same time after three days from the first irrigation.
2. Trianthema pentandra and Brachiaria mutica appeared on the fifth day.
3. Cyprus rotoundus appeared on the sixth day.

4. Aristida sp., Schoenefeldia gracilis, Eragrostis minor and Tephrosia sp. appeared on the ninth and tenth day or after two and three days from the second irrigation.

5. Solonaum dubium, Cassia senna and Iponea obscura were the last to appear in the third week after the first irrigation.

None of the perennial forage species previously mentioned appeared in any of the ten plots. Cassia senna had a frequency of 30 percent as it was encountered in three plots only. The other annual species had a frequency as high as 100 percent. The density was determined for the plots. Ipomea obscura and Aristida sp. had the highest density among the annual species. Ipomea obscura continued to germinate until the third week and no new plants were recorded after this period.

Flooded basins

After flooding, the annuals did not differ as for their germination sequence from the pattern shown in the irrigated plots and the greatest amount of germination was in the areas flooded for 1 to 5 days. In areas flooded for 6 to 16 days, annuals were associated with perennials but with a lower density for the annuals.

Ipomea obscura and Sorghum lanceolatum were the first to germinate following the retreating water-line. Cyperus rotundus occurred in the water-logged areas. Trianthema pentandra, Brachiaria mutica and Chloris villosa were the second group to germinate. Sporobolus festivus, Ludurigia parviflora, Colocynthis vulgaris and Tribulus terestris were the third group to germinate. Rhynchosia memnomia and Solanum dubium germinated at the same time. This group was followed closely by Cenchrus ciliaris, Cenchrus setigreus and Panicum coloratum (Gash). In the areas flooded for six or more days, this sequence was rather continuous as soon as the water infiltrated and germination of these species occurred at the same time. Cassia tora and Corchorus sp. started to germinate after one month when most of the annuals were flowering. Cassia senna completely failed to show in our post-flood reconnaissance survey, probably because of its rareness in the area.

As for the seeded and transplanted species, most of them succeeded and reached the flowering stage with the exception of Pennisetum purpureum which failed to grow above 1.5 feet height and showed signs of water stress.

Range inventory was delayed until all species were in flowering stage but it was never done because the nomadic herds invaded the area and grazed all the standing crop.

We still believe that if all the northern part of the Gash Delta is developed for forage production, the invasion of the cultivated areas in the central and southern parts of the delta will be minimized together with the expected improvement in animal production. The development of similar areas north of latitude 14° north through water spreading is quite promising once the areas are large enough to stand the migrating herds' impact.

CONCLUSIONS AND RECOMMENDATIONS

1. The total flooded area of 1.47 square miles supported 8,000 AU for 12 days according to Alama's Report (1969). He showed that the standing crop was completely reduced to bare soil within 12 days. If we assume that the forage consumption per animal unit is 24 pounds dry matter (Skerman, 1966), then the production is estimated roughly to be 2,443 pounds dry matter per feddan. At this level of production, three feddans can support an animal unit for 10 months or 214 AU/sq. mile. The other two months were deducted to cater for flooding and establishment of the plant species. In this vegetation zone, the Special Fund Report (1966) recommended a stocking rate of 10 AU/sq. mile in Kordofan province. Due to the special conditions in the Gash Delta, we would expect this figure to reach 20 AU/sq. mile (Baasher, 1961) and our studies indicate that by improving the ranges of the Gash Delta we can achieve an increase of 640 percent in the stocking rate, taking into consideration that utilization under proper management is approximately 60 to 70 percent.
2. It is possible to use protected areas or exclosures in watersheds as seed sources that can reseed adjacent barren areas. The plant species and location of such exclosures should be thoroughly investigated before applying them in a certain watershed.
3. Since the nomadic herds will be directed towards the best grazing areas, migrating routes can be modified by range managers using range developments and water points as tools to alternate these routes. The nomads usually select a migrating route that will

bring them close to water points within a two-days distance from another water point in the case of sheep and a one-day distance in the case of cattle. By closing a water point, the nomads will avoid areas as large as 100 square miles and if they should pass through it, they will drive their herds as quickly as possible to reach a water point, exerting only minimum damage to the range.

4. It has been a general agricultural policy in the Sudan to exclude animals from the cultivated areas. In the Gash it is quite feasible to accommodate animals in the delta and reduce the losses in crop production due to grazing.

5. Under low rainfall regions as is the case in the Gash area, live-stock suffer heavy losses each year due to famine. By developing highly productive forage schemes, we can reduce such a loss and can improve animal production with the hope that in the future we can convince the nomads to keep fewer highly productive animals rather than numerous ones low in productivity.

6. It will be easier for the different agencies in the government to render their services to the nomads if the migrating routes are determined in advance.

7. There should be a continuous effort to develop a system for pricing forage other than using the opportunity cost which will only be applicable in the agricultural schemes. Increases in animal production can be a criterion once the nomadic herds are kept in one place long enough to collect the necessary data.

SUMMARY

Waterspreading has been regarded for a long time as a tool for range improvement. When rainfall is sporadic, the plant species face drouth periods long enough to either stop their growth or cause them to die. Annual plant species that propagate by seeds usually suffer the greatest loss compared to perennials. Supplying adequate moisture by waterspreading will allow both the annual and perennial plant species to survive and complete their life cycles.

In the northern parts of the Sudan, ranges have suffered from drouth, fire and overgrazing to the extent that seeding, although expensive, seems seems to be the only solution. This type of range improvement has its own drawbacks since the factors that initially caused range deterioration are still prevailing. Unless provided with adequate moisture and proper management, seeded ranges are doomed to deteriorate and disappear just as their native predecessors.

The data obtained in the experimental range improvement scheme in Kassale Province in the Sudan, proved the advantages of using waterspreading in establishing a productive range that may be preserved by proper management.

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