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GEOMORPHOLOGY OF THE MIDDLE LUNI BASIN OF WESTERN RAJASTHAN, INDIA

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ABSTRACT

The geomorphology of the Middle Luni Basin of arid Western Rajasthan has been discussed. The region consists of 11 geomorphic units. The geomorphic features of the region are the products of both fluvial as well as aeolian actions. The condition of ground water are favourable in piedmont plains, recent flood plains, eroded rocky surface, Siwana alluvial plain and Kundal-Ramania alluvial plain. The depths of wells in these units vary from 15 to 21 m. The measurements of the dunes have indicated that they have increased and decreased by 6 to 10 m since 1934. The dunes occuring in this region are of aeolian origin. The region is drained by the Luni river and its tributaries. The total length of the Luni river with its tributaries is about 843 km, the highest being in the piedmont zones. The drainage patterns developed in this region are linear, sub-parallel, sub-dendritic and radial. The largest concentration of streams is in the piedmont zone where the basins of 4th order are found and the lowest number of the streams is found in Pachpadra salt basin and undulating alluvial plains with sandy hummocks. The total area of the basins is the highest in the alluvial plain and the lowest in the Kundal-Ramania intermontane alluvial plain.

The wind erosion is more conspicuous than water erosion. The water erosion is confined to the piedmont zones and gullies have occasionally formed. The wind erosion is more widespread in sand dunes, sandy plains and ploughed alluvial plains.

To check the water and wind erosion several conservation measures have been suggusted.

INTRODUCTION

In the arid Western Rajasthan the Luni is the only important river which drains into the Rann of Kutch. Almost all the year round its bed remains dry except during rainy season when flashing seasonal flows take place occasionally for a few days. In the past geological periods when the climate of the region was somewhat better than the present the Luni with its tributaries must have done their job in sculpturing the landscape. One peculiar feature of the basin is that there are several tributaries on the left of the river namely, the Lilri, Raipur Luni, Guhiya, Bandi, Sukri, Jawai and Jojri. These streams have built up the plain features except a few remnants of old rocks. These are mainly hill torrents drying completely during the offseason. On its right bank there are a very few tributaries traversing through wind swept landscape.

In the present paper a composite geomorphological study of landforms of 15222 sq. km. falling in the middle part of the Luni Basin has been compiled from the detailed studies of landforms made with the help of aerial photo-interpretation and field traverses of various Panchayat Samiti Blocks falling in this region. Previously such type of study was made only in 1100 sq. km area of this region by conducting reconnaissance geomorphological survey (Ghose *et al.* 1966).

MATERIAL AND METHOD

First, the aerial photographs on the scale of 1:25,000, 1:31,000 and 1:40,000 representing different parts of the region were laid down in respective runs to get a composite view of the landscape of the entire region and to make the photo patterns representing different landform features. Each stereo-pair of photographs was studied under mirror stereoscope and the annotations were marked on the back of the photographs. The query points were marked in different photo-patterns for field traverses and investigation. The survey party carried out the detailed reconnaissance surveys and noted down relevant points and information. The boundaries of geomorphological units already drawn on photos in the laboratory were checked and new boundaries were drawn for micro-relief features. In the laboratory the boundaries of different landform features were transferred on the base map of 1:126,720 scale by Zeiss Sketch-master by the method described by Ghose and Singh (1966). The final geomorphological map of the region was prepared on 1: 253,440 scale (Fig. 1). After finishing the mapping and analysis of sediments the description of each geomorphic unit was written.

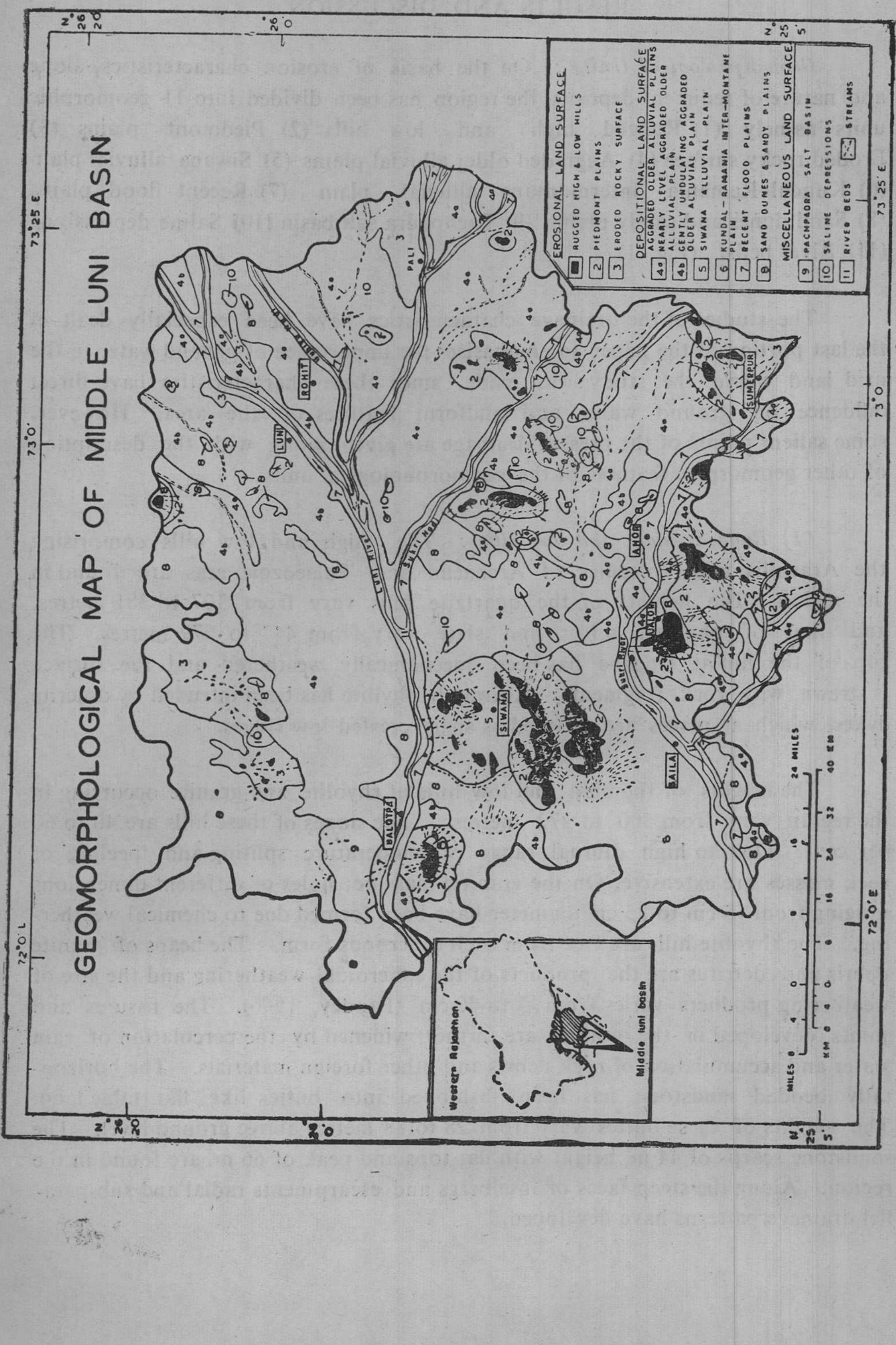
GEOMORPHOLOGICAL MAP OF MIDDLE LUNI BASIN
EROSIONAL LAND SURFACE
1 RUGGED HIGH & LOW HILLS
2 PIEDMONT PLAINS
3 ERODED ROCKY SURFACE
DEPOSITIONAL LAND SURFACE
4a AGGRADED OLDER ALLUVIAL PLAINS
4b NEARLY LEVEL AGGRADED OLDER ALLUVIAL PLAIN
4c GENTLY UNDULATING AGGRADED OLDER ALLUVIAL PLAIN
5 SIWANA ALLUVIAL PLAIN
6 KUNDAL – RAMANIA INTER-MONTANE PLAIN
7 RECENT FLOOD PLAINS
8 SAND DUNES & SANDY PLAINS
MISCELLANEOUS LAND SURFACE
9 PACHPADRA SALT BASIN
10 SALINE DEPRESSIONS
11 RIVER BEDS
STREAMS
PALI
ROHIT
LUNI
SIWANA
BALOTRA
JALOR
AHOR
SUMERPUR
SAILA
Luni River
Sukri Nadi
Sukri River
Western Rajasthan
Middle luni basin
MILES
KM
Cartographic Laboratory C.A.Z.R.I. Jodhpur.
26° 20' N
26° 0'
25° 5' N
72° 0' E
73° 0'
73° 25' E

Fig. 1

RESULTS AND DISCUSSION

Geomorphological Units : On the basis of erosion characteristics, slope and nature of sediment deposits, the region has been divided into 11 geomorphic units namely (1) Rugged high and low hills (2) Piedmont plains (3) Eroded rocky surface (4) Aggraded older alluvial plains (5) Siwana alluvial plain (6) Kundal–Ramania intermontane alluvial plain (7) Recent flood plains (8) Sand dunes and sandy plains (9) Pachpadra salt basin (10) Saline depressions (11) River beds. (Fig. 1)

The studies of the drainage characteristics have been especially dealt in the last portion of the paper to emphasise the importance of ground water in the arid land where the study was made, since these characteristics have direct influence on ground water and landform features of the area. However, some salient points of the present drainage are given along with the description of other geomorphic features of the geomorphological units.

(1) Rugged high and low hills : The high and low hills comprising the Aravallis and Volcanics of Archaean and Palaeozoic eras are found in the region. The heights of the quartzite hills vary from 307 to 381 metres, and that of phyllite, schist and slate vary from 447 to 579 metres. The top of the hill at Dugana has been mechanically weathered and the surface is strewn with rock fragments. Khiwandi phyllite has been intruded by dolerite dykes, which at places are exposed as sharp crested low ridges.

The heights of the high and low hills of rhyolite and granite occurring in the region vary from 300 to 972 metres. The slopes of these hills are 40 to 60 per cent. Due to high diurnal range of temperature spliting and 'peeling' of rock masses are extensive. On the granitic mass pot holes of different dimensions ranging from 15 cm to 25 cm diameter have been formed due to chemical weathering. The rhyolite hills are free from such cavernous form. The heaps of granite debris and detritus are the products of the spheroidal weathering and the size of weathering products varies from 3 to 60 cm (Pandey, 1966). The fissures and joints developed in the granite are further widened by the percolation of rain water and accumulation of rock debris and other foreign materials. The horizontally bedded sandstone has been fashioned into buttes like flat table land. The heights of these buttes vary from 28 to 88 metres above ground level. The sandstone scarps of 44 m. height with flat tops and peak of 66 m. are found in the region. Along the steep faces of inselbergs and escarpments radial and sub-parallel drainage patterns have developed.

(2) Piedmont plains : The piedmont plains are situated in the foot of the hills. The upper part of the plain is degradational and the lower part is aggradational. Unlike Beaty's piedmont plains (1963) this geomorphic feature of the region has been formed by scarp-retreat process. According to Pandey (1955), Ghose and Singh (1965), Ghose and Pandey (1965), Singh *et al.* (1966), Ghose *et al.* (1966) and Pandey and Singh (1968) the piedmont plains occurring in the central arid Rajasthan have been formed due to scarp-retreat. The slope of the plains is convex and declivity varies from 3^0 to 6^0. The sediments of the plains are poorly graded and assorted. Ghose (1965) stated that gravel layers in the piedmont plains were laid down by torrents and the fine aggregates were laid down by sluggish sheet floods. The piedmont plains are composed of heterogeneous materials such as sands, gravels, pebbles, cobbles and boulders. The deposits are coarser at the head and finer at the base. The piedmont plains of the Aravalli hills are gently sloping and covered with debris and detritus of 50 to 100 mm diameters.

In this unit the condition of ground water is good and the water table varies from 3 to 5 m. in the upper part and 5 to 8 m. in the lower part depending on the thickness of the material. The lime concretions are generally lacking or poorly developed, the subsurface water may pass under the concretion layer and thus contributes recharge to the deeper ground water. In this unit sub-dendritic and sub-parallel patterns are found.

(3) Eroded rocky surface : The surface consists of weathered mantle and at places solid rocks have been exposed due to subsequent erosion of wheathering products. This unit lies in the northeast of Sumerpur, west and northeast of Thob and north and northeast of Pali. The eroded surface of granite is found more extensively. The granitic outcrops of domal shape with 1 to 2 metres height are present here and there. The deposition of soil of varying thickness is found in low-lying pockets. Due to granular disintegration the surface is strewn with rock fragments. The slope of the surface is irregular. In the weathered zone of granite water is found at shallow depths. Numerous short channels have been found.

(4) Aggraded older alluvial plains : The alluvial plains are very extensive and cover about half of the total area of the region. The alluvium was deposited during the Pleistocene and sub-Recent periods by sheet wash. Some parts have been developed *in situ* due to two cycles of erosion (Pandey *et al.* 1967). The *kankar pans* are met at varying depth ranging from 30 to 170 cm. According to Ghose (1965) the extensive alluvial plains of the Central Luni Basin have been formed by the prior drainage system of the region. The field boundaries are clearly

N 36°W. Shrub-coppice dunes have been formed against shrubs and bushes. The active barchan dunes are found near the villages. The dune sand is light yellow to brown in colour. The dunes of various types occurring in the region are of old and new systems. The high stabilised dunes belong to the former system while unstabilised to the new system.

The heights of the low, medium and high dunes are 1.5 to 5 m, 5 to 15 m. and 15 to 30 m. respectively. The slope of the crest is 32 to 40 per cent. The slopes of the flanks, leeward and windward sides are 7 to 15 per cent, 20 to 25 per cent and 3 to 5 per cent respectively. The dunes formed on piedmont slopes have been dissected by short channels of 3 to 16 m depth. The heights of these dunes vary from 9 to 10 m. In old dunes lime nodules and concretions are found on crests and flanks. The $CaCo_3$ content varies from 3.8 to 5.5 per cent. In fresh dunes no concretions or nodules of lime are found and calcium carbonate content is 1.5% (Pandey *et al.* 1964). The comparative studies of the heights of the selected dunes indicated on the survey of India toposheets published in the year 1934 and the heights calculated from the air photos taken in the year 1958 have indicated that the heights of these dunes have increased and decreased by 6 to 10 metres since 1934. The ground water condition in the interdune areas is good.

The study of the shape and size of the sand grains of the dunes and river beds have indicated that the dune sands are of aeolian origin. In majority of the cases the sand grains are well rounded to rounded and very few are angular to subangular. The grain size distribution of dune sands is given in Table 1.

Table 1. Percentage distribution of sand grain diameter, in mm.

S. No	Site of the dune	Sand grain diameter in m m. 0.48	0.42	0.25	0.18	0 15	0.12	0.07	0.06
1.	Katari village	7.09	1.27	10.63	—	—	63.29	17.72	—
2.	Jhumba village	—	—	—	14.20	29.92	29	26.59	—
3.	Tapra village	—	—	4.89	25.88	23.05	17.60	23.96	4.92
4.	Asotra village	—	—	—	71.80	25.85	2.35	—	—

From the table it is evident that the dune situated near Katari village has 60 to 70 per cent sand grains of 0.12 mm diameter and 14 to 18 per cent grains of 0.07 mm diameter. Asotra dune has about 72% sand grains of 0.18 mm diameter. The dunes of Jhumba and Tapra villages have more percentage of finer grains than others.

(9) *Pachpadra salt basin :* This unit lies in the northwest of Balotra town. It has been established (Ghose, 1964 and Ghose and Singh, 1968) that the formation of Pachpadra salt basin and similar other basins is related to the prior drainage channels. Gypsum and other salts were formed by chemical transformation of minerals and by reaction of salts in solution brought down into shallow channels of the prior drainage system where they were precipitated in stages according to their differential solubilities. The less soluble minerals calcium carbonate and calcium sulphate were deposited in the upstreams while sodium chloride which is comparatively more soluble has been deposited near the confluence, Pachpadra salt basin has been formed by the channels coming from Kailana–Mandor plateau and meeting the Luni river near Soda-Ki-Dhani. In the past, these channels brought enormous salt and silt which were deposited at the confluence. As aridity set in. there were continuous capillary rise and evaporation of saline water for a long time. These have turned the confluence into a salt basin. This basin constitutes the highest percentage of sodium chloride i. e. 85.7 followed by magnesium sulphate 9.5 per cent calcium sulphate 2.9 per cent and magnesium sulphide 1.9 per cent (Ghose, 1964). The surface is highly saline and does not allow any crop to grow. This unit is surrounded by *high* to *very high* stabilised sand dunes except in the eastern side. The deposits of the basin are clay to sandy clay loam. The slope of the basin is 1 to 2 per cent. The sand mounds of 4 to 6 metres height are found here and there. The intermittent and disorganised channels are present.

(10) *Saline depressions :* Shallow to deep saline depressions are situated near the confluences of the tributary channels of the trunk stream. The prominent depressions of the region are Thob Ka Rann, Sanwarla Ka Rann, Samuja and Didas. Like the Pachpadra salt basin the formation of these saline depressions is from the past drainage system. New saline depressions are being formed in the lower reaches of the dead tributaries of the Jawai and the Sukri rivers. The depressions of Didas and Samuja are the relics of Sukri-Bandi drainage system.

(11) *River beds ;* The beds of the Luni, Khari, Bandi, Sukri, Jawai, Phunpharia, Mitri, Jojri and Golasni are graded. The river beds constitute sand,

gravel and grits. The mean diameter of the grains of the river material varies from 0.44 to 0.45 mm. The sand bars of different dimensions have been formed. The sand bars in the Luni river are of 500 to 700 m. length and 250 to 300 m. width. The average width of the Jawai and the Khari beds is 88 m. with sandbars of 600 to 700 m. length, about 300 to 400 m. width and 1 to 2m. height. The beds of Reria and Agria are rocky and unsuitable for cultivation. The average depths of tha Luni river from the surface are 4 and 3 m. in upper and lower reaches respectively. The longitudinal gradients of the Luni, Jawai, Sukri and Khari rivers are 1: 600, 1: 500, 1: 600 and 1: 550 respectively. The longitudinal gradients of the courses of the Jojri, Mitri, Reria and Golasni rivers are 1: 700, 1: 700, 1: 500 and 1: 400 respectively. The banks of the rivers have been cut by heavy floods during the rainy season. The amount of dissection varies from 7 to 10 metres. Whenever, there is torrential rain the rivers are incapable of giving passage to the full discharge of runoff water and thus bank erosion and occasional floods in new flood plains take place. The different layers of deposits exposed due to bank cut erosion near Purara village have been given in table 2.

Table 2. Profile description of vertical bank cut erosion near Puara village

Layers	Depth in metre	Deposits	Size of deposits
I	0 to 1.5	Rounded rock fragments gravels and coarse sand.	Rock fragments 25 to 80 mm. diam, gravel 5 to 10 mm diam.
II	1.5 to 2	Subrounded rock fragments small pebbles & silty clay.	Rock fragments 40 to 45 mm. dia. pebbles 20 to 30 mm. diam.
III	2 to 3	Gravelly deposits with alternate layers of calcium carbonate.	Calcium nodule 3 to 5 mm. diam.
IV	more than 3	Silty clay with grits.	0.02 to 0.06 mm.

From the above table it can be inferred that the precipitations were localised, infrequent and occasionally torrential when these deposits were laid down layer by layer.

DRAINGE CHARACTERISTICS IN DIFFERENT GEOMORPHOLOGICAL UNITS

The geomorphic properties of drainage channels in different geomorphological units are given in table 3.

Table 3. Drainage characteristics in different geomorphic units

S. No.	Geomorphic units	Basin order	No. of streams	Stream-length in km.	Area in sq. km.	Drainage density in km per sq. km.	Constant of channel maintenance in sq. km.	Stream frequency
1	Piedmont plain	4	405	931.81	955.24	0.98	1.02	0.42
2	Nearly level aggraded older alluvial plain	3	86	384.24	4743.14	0.08	12.28	0.02
3	Gently undulating aggraded older alluvial plain	2	8	96.56	2602.80	0.04	6.96	0.03
4	Sand dune and sandy plains	3	121	315.44	3289.05	0.09	10.43	0.04
5	Eroded rocky surface	4	142	236.59	785.37	0.30	3.32	0.18
6	Siwana alluvial plain	4	162	386.62	317.22	2.21	0.82	0.51
7	Kundal-Ramania Inter montane alluvial plain	4	150	305.77	121.92	2.51	0.40	1.23
8	Pachpadra salt basin	2	16	28.97	172.06	0.17	5.94	0.09

The table shows that the highest concentration of streams is in the piedmont zones, eroded rocky surface, Kundal-Ramania and Siwana alluvial plains where the basins of 4th order are found. The basins of 3rd order are found in alluvial plains and sandy plains adjacent to piedmont zones. In Pachpadra Salt Basin and undulating alluvial plains with sandy hummocks basins of 2nd order are found. The number of streams also decreases in the same fashion. The highest total stream length is in piedmont zones and the lowest in Pachpadra Salt Basin. The highest total area of the basins is in the alluvial plain and the lowest in the Kundal-Ramania intermontane alluvial plain. The largest area of 26.96 sq. km. is required to maintain 1 km. length of stream in the undulating alluvial plain and the lowest area is required in Kundal-Ramania intermontane alluvial plain where two ranges of hills are closely situated.

EROSION HAZARDS AND CONSERVATION MEASURES

The region has been affected both by water and wind erosion but the damage caused by the latter is more severe and conspicuous. The water erosion is confined to the hilly and piedmont zones. The western and north western parts of the region have been affected by slight to very severe wind erosion which has turned the fertile land into wasteland. Ghose *et al* (1968) have studied with the help of air photos the soil erosion and its effects on landuse in the Central Luni Basin, Western Rajasthan.

Water Erosion

The areas affected by water erosion can be put under different uses by taking into account the following conservation measures—

1. Semi-circular rock bunds should be constructed to check the headward extension of the gullies.

2. The river bank cut erosion should be checked by constructing spurs at 45^0 angle with the banks.

3. To check the velocity of water the ridges should be constructed across the courses of the channels and impound water for livestock consumption.

4. Sheet flow should be checked by putting contour furrows.

Wind Erosion

1. *Dunes* (i) The grazing and cultivation should not be allowed on the sand dunes. They should be put under cultivation after fencing the area.

(ii) The wind velocity should be checked by putting wind breaks at right angle to the wind direction.

(iii) The trees, shrubs and grasses should be planted for firewood and forage reserves. The ground coverage will reduce blowing of soil particles.

2. *Cultivated fields* (i) The land should be ploughed across the prevailing wind.

(ii) Wind strip cropping by farming and stubble mulching should be practised.

(iii) Before sowing, the compost should be applied in sufficient quantity.

(iv) The improved types of tillage implemnts suggested by Chepil *et al* (1961) should be used.

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INTEGRATED APPROACH FOR DEVELOPMENT OF NATURAL RESOURCES IN SANTALPUR BLOCK OF GUJARAT STATE

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ABSTRACT

Integrated survey of natural resources of Santalpur Panchayat Samiti block which falls in arid zone of Gujarat State was carried out to frame developmental programme for overall improvement of the economic conditions of the people. It covers an area of 1356 sq. km and gets 400 to 500 mm average annual rainfall during southwest monsoon period. The landscape of the block is almost flat with light textured soils over major part of the area. Some areas are saline. The scarcity of water is acute. Ameliorative measures have been suggested for development of water resources, agriculture, pasture, animal husbandry, etc.

INTRODUCTION

About one-fifth of the total arid zone of India falls in Gujarat State confined mainly in its western part. The major problems of the area, as commonly found in the arid zones of the world, are scarcity of water caused by low and uncertain precipitation, saline flats with saline soils, saline underground water, severe soil erosion caused by wind of high velocity, scanty vegetation and poor pasture-all resulting in very low production of food and fodder. These problems require careful handling for gainful utilization of natural resources, particularly land and water. An integrated survey of Santalpur Panchayat Samiti block in Banaskantha district which represents the arid zone of the State was carried out so as to ascertain the main problems, make an assessment of the various natural resources namely climate, topography, soils, water and vegetation and recommend how best these resources could be utilized for the development of the block. The results of the survey are presented briefly in this paper.

PHYSICAL FEATURES

Climate : Santalpur Panchayat Samiti block extends from 23°31′ to 24°01′ N latitude and 71°01′ to 71°31′ E longitude and covers an area of 1356 sq. km.

The average annual rainfall varies from 420 to 500 mm. The southwest monsoon season (June to September) accounts for 96 per cent of the total annual rainfall. The monsoon usually starts sometime during the last week of June and withdraws by the middle of September. Probability of rainy day during the period from November to April varies from once in five to once in ten years.

A significant factor of climate is the prevalence of high wind velocity during the period from May to August. There are two distinct wind direction regimes i. e. wind blowing from any direction between north and east during October to March period, and from any direction between south and west during rest of the year.

The hottest month of the year is May with a mean maximum temperature of 41.8°C. The minimum temperature ranges from 10.5°C during January to 27.1°C during June.

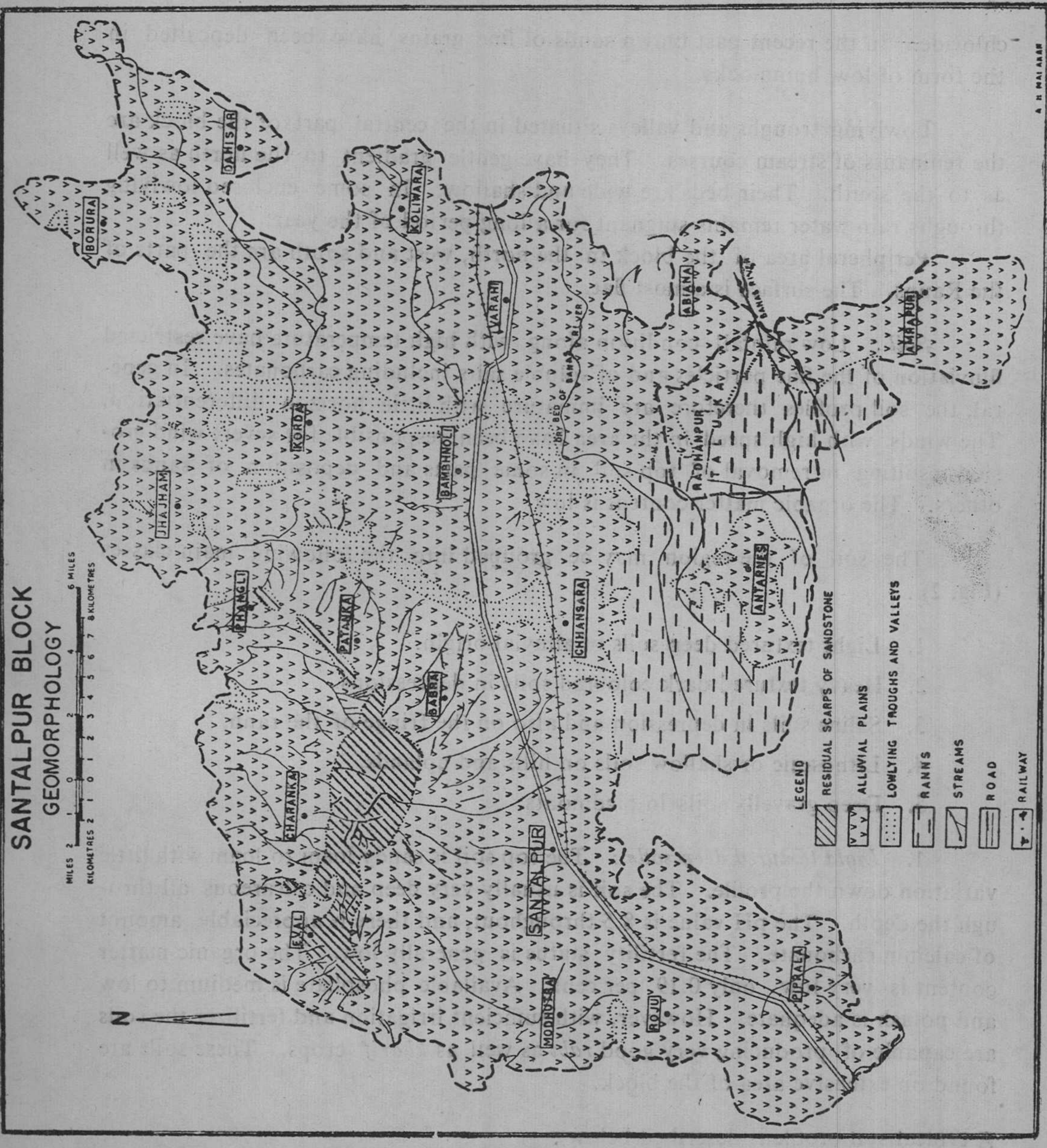
Topography : The block is surrounded on three sides by the Rann of Kutch-the Great Rann in the north and west, and the Little Rann in the south. Both the Ranns are practically saline flats and are the remnants of the past sea. The Banas river passes adjacent to the southern boundary of the block. It is an ephemeral river. There are a few seasonal hill-streams (Fig. 1).

The area can be divided into 4 landform units, namely, 1. residual scarps of sedimentary rocks, 2. alluvial plain, 3. lowlying troughs and valleys and 4. ranns.

The scarps are made of sandstone, shale and conglomerate. They are generally low in height and small in area. The highest of them is about 57 metres from the ground level at Eval. The scarps have been dissected in isolated individual outcrops. In the wide valleys the present streams have narrow and deep courses, and the runoffs from the highlands take place through these courses.

Piedmont slopes around rocky outcrops are gravelly. There are several low mounds of gravels and shattered rocks in Phangli, Patanka, Bakutra and Eval.

About 80 per cent of the total area of the block consists of alluvial plain. It is an extension of the extensive alluvial plain of the State. The plain is made of alternate layers of pervious coarse sands and grits and impervious fine silts and clays. The silts and clays contain cognate salts, predominantly sodium


SANTALPUR BLOCK
GEOMORPHOLOGY
MILES
KILOMETRES
LEGEND
RESIDUAL SCARPS OF SANDSTONE
ALLUVIAL PLAINS
LOWLYING TROUGHS AND VALLEYS
RANNS
STREAMS
ROAD
RAILWAY
BORURA
DAHISAR
KOLIWARA
VARAHI
ABIANA
AMRAPUR
RADHANPUR
KORDA
JHAJHAM
BAMBHNOLI
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PAYANKA
CHHANSARA
ANTARNES
BABRA
CHARANKA
EVAL
SANTALPUR
MODHUTRA
ROJU
PIPRALA
N

Fig. 1

chloride. In the recent past blown sands of fine grains have been deposited in the form of low hummocks.

Lowlying troughs and valleys situated in the central part of the block are the remnants of stream courses. They have gentle gradient to the north as well as to the south. Their beds are wide and shallow. In some enclosed lowlying throughs rain water remains stagnant for a long period of the year.

Peripheral area of the block in the north, west and south are the parts of the Ranns. The surface is almost flat.

Soil : Low rainfall condition along with high temperature have restricted illuviation of the fine particles and of soluble salts including carbonates. In general, the soil profiles therefore are immature with little horizon differentiation. The winds with high speed in the area have been responsible for severe wind erosion resulting in removal of top soil in some parts and deposition of sands in others. The organic matter content is low.

The soil of the region may be grouped into the following main classes (Fig. 2) .

1. Light textured deep soils of alluvial origin.
2. Heavy textured dark coloured soils in depressions.
3. Saline soils in depression and also on the fringe of the rann.
4. Lithosolic or shallow soils on hills and uplands.
5. Deep gravelly soils in piedmonts.

1. *Light textured deep soils :* The top soil is sandy loam to loam with little variation down the profile. The soil is usually very deep and calcareous all through the depth. The pH value is 8.5 throughout, and there is appreciable amount of calcium carbonate. The fertility status is generally low. The organic matter content is very low. only 0.19 per cent. Available phosphate is medium to low and potash is adequate. However, with sufficient irrigation and fertilizer the soils are capable of producing very good *rabi* as well as *kharif* crops. These soils are found on extensive area of the block.

A typical soil profile is described below :

Situation : Located in village Nawagam on cultivated field of bajra, now fallow. Level land, water table at about 5 metres depth.

0.35 cm Yellowish brown (10 YR/ 5/4, D) to brown (10 YR 4/3 W) loam, single grained, dry and loose, strong effervescence with HCl,

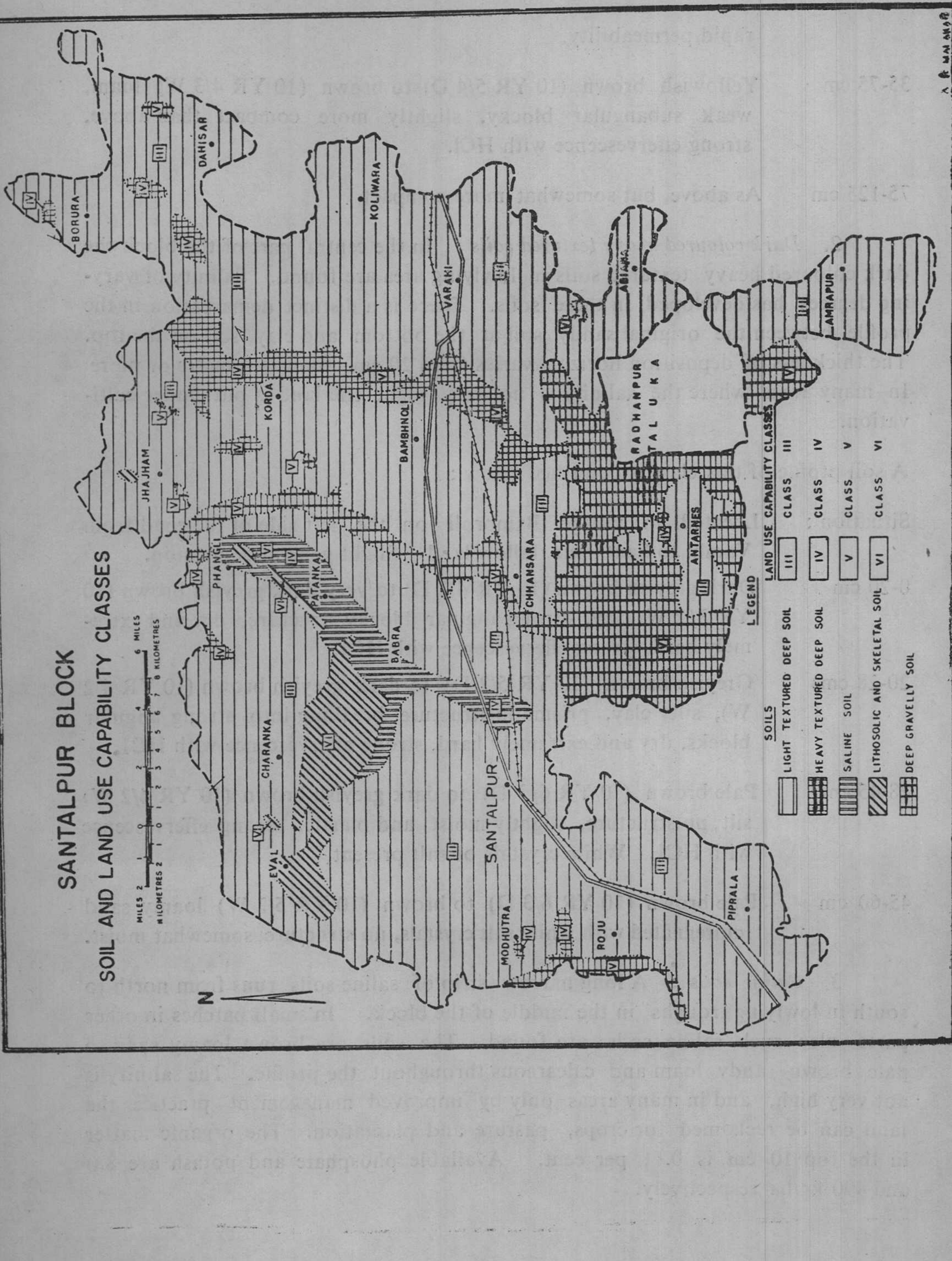
SANTALPUR BLOCK
SOIL AND LAND USE CAPABILITY CLASSES
MILES
KILOMETRES
N
BORURA
DAHISAR
KOLIWARA
ABIANA
AMRAPUR
VARAKI
JHAJHAM
KORDA
BAMBHNOLI
RADHANPUR
TALUKA
PHANGLI
PATANKA
CHHANSARA
ANTARNES
BABRA
CHARANKA
EVAL
SANTALPUR
PIPRALA
MODHUTRA
ROJU
LEGEND
SOILS
LIGHT TEXTURED DEEP SOIL
HEAVY TEXTURED DEEP SOIL
SALINE SOIL
LITHOSOLIC AND SKELETAL SOIL
DEEP GRAVELLY SOIL
LAND USE CAPABILITY CLASSES
III CLASS III
IV CLASS IV
V CLASS V
VI CLASS VI

Fig. 2

rapid permeability.

35-75 cm Yellowish brown (10 YR 5/4 D) to brown (10 YR 4/3 W) loam, weak subangular blocky, slightly more compact than above, strong effervescence with HCl.

75-125 cm As above, but somewhat more compact.

2. *Dark coloured heavy textured soils :* In the central part of the block the dark coloured heavy textured soils in lowlying area are found. Salinity of varying degrees has developed in these soils. There is a distinct demarcation in the profile between the original sandy soil at the bottom and clay soil on the top. The thickness of deposition horizon varies from 20 cm. to even a metre or more. In many areas where the salinity is not very high, the land is put under cultivation.

A soil profile of this class is described below :

Situation : Located in village Bambroli on the left side of the road from Varahi to Santalpur, fallow land Slight general depression.

0-20 cm Dark greyish brown (10 YR 4/2 D) to very dark greyish brown (10 YR 3/2 W) clay, strong angular blocky structure, dry and extremely hard, strong effervescence with HC1.

20-28 cms Greyish brown (10 YR 5/2 D) to dark greyish brown (10 YR 4/2 W), silty clay, prismatic structure breaking into strong angular blocks, dry and extremely hard, strong effervescence with HC1.

28-45 cm Pale brown (10 YR 6/3 D) to dark greyish brown (10 YR 4/2 W) silt, no structure, slightly moist and plastic, strong effervescence with HC1. White crystals of salt present.

45-60 cm Pale brown (10 YR 6/3 D) to brown (10 YR 5/3 W) loamy sand impregnated with white salt crystals, no structure, somewhat moist.

3. *Saline soils :* A long narrow strip of saline soils runs from north to south in lowlying troughs in the middle of the block. In small patches in other parts also such saline soils are found. The soils are brown loamy sand to pale brown sandy loam and calcareous throughout the profile. The salinity is not very high, and in many areas only by improved management practices the land can be reclaimed for crops, pasture and plantation. The organic matter in the top 10 cm. is 0.11 per cent. Available phosphate and potash are 8.0 and 490 kg/ha respectively.

4. *Shallow skeletal or lithosolic soils :* The skeletal and lithoslic soils are found in Phangali, Aluvas, Patanka and Bakutra. These are reddish brown shallow soils of light texture. In pockets, however, the soil is of sufficient thickness to permit cultivation.

5. *Deep gravelly soils in piedmonts :* Below the hilly uplands in lower piedmonts zone lies fairly deep gravelly soils of sandy loam texture. These soils are found in Patanka, Babra, Bakutra and Dhokawada. The water holding capacity is low.

Land use capability classes I and II are absent in this block. The major part consisting of light soils on flat land is class III land. The gravelly undulating lands belong to class IV. The heavy soils somewhat saline in the lowlying areas also belong to this class, whereas saline soils belong to class V. Class VI lands occur on piedmont slopes and on the fringe of the Rann.

VEGETATION

Natural vegetation on the hills comprises of *Acacia senegal*, *Commiphora wightii*, *Salvadora oleoides* and *Maytenus emarginatus*. On sandy loam soils *Capparis decidua* and *Salvadora oleoides* are the dominant species while on saline soils *Salvadora persica* is more prominent: On the riverbed near Gokhantar *Acacia Jacquemontii*, *Tamarix* sp. and *Salvadora oleoides* have been recorded. Regeneration of *Tamarix* is very good on the islands of these rivers. Where the soils are sandy *Prosopis cineraria* and *Salvadora oleoides* form the common association with various psammophytic scrubs like *Leptadenia pyrotechnica*, *Calotropis procera* etc. On the tank and field boundaries *Acacia nilotica* sp. *indica*, *Azadirachta indica* and *Ficus bengalensish* are the common species planted. Near the Rann of Kutch (village Modutra and Rozu) typical halophytic succulents like *Suaeda fruticosa*, *Atriplex* sp. *Cressa cretica* without any natural tree species are present. Amongst the introduced vegetation *Prosopis juliflora* is the only species so far tried successfully, although near the Rann at Rozu the performance of this species is rather poor. On sandy loam soils, on hills and in dry river beds, where good moisture is available, this species has practically dominated the entire landscape. *Euphorbia caducifolia* has been used extensively for field boundaries and as tree girdle for roadside plantations. The native vegetation is extensively used as firewood, and hence is under constant pressure of cutting and lopping as top-feed for animals.

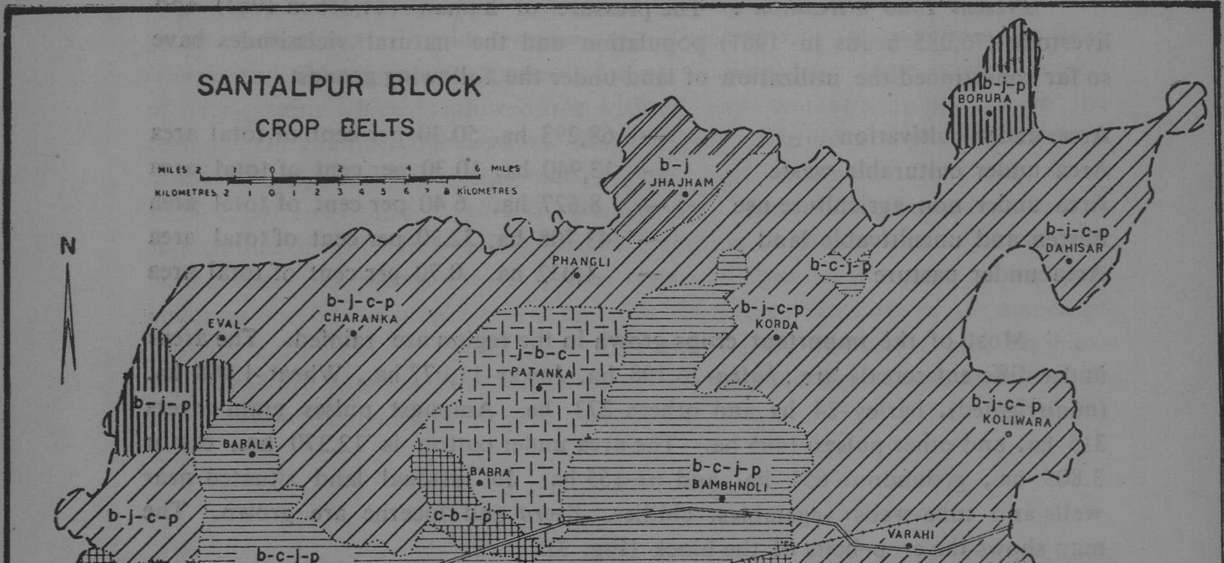
SANTALPUR BLOCK
CROP BELTS
MILES 2 1 0 2 4 6 MILES
KILOMETRES 2 1 0 1 2 3 4 5 6 7 8 KILOMETRES
N
b-j-p
BORURA
b-j
JHAJHAM
b-j-c-p
DAHISAR
b-c-j-p
PHANGLI
b-j-c-p
CHARANKA
EVAL
b-j-c-p
KORDA
j-b-c
PATANKA
b-j-p
b-j-c-p
KOLIWARA
BARALA
BABRA
b-c-j-p
BAMBHNOLI
b-j-c-p
c-b-j-p
b-c-j-p
SANTALPUR
VARAHI
c-b-j-p
b-c-j-p
b-c-j-p
GOKHATAR
CHHANSARA
b-j-c-p
c-b-j-p
ROJU
b-c-j-p
ABIANA
j-b-c
b-j-p
ANTARNES
RADHANPUR
TALUKA
b-c-j-p
PIPRALA
b-j-c-p
LEGEND
CROP BELTS
CROPS
BAJRA, COTTON, JOWAR, PULSES
BAJRA, JOWAR, COTTON, PULSES
BAJRA, JOWAR, PULSES
COTTON, BAJRA, JOWAR, PULSES
JOWAR, BAJRA, COTTON
BAJRA, JOWAR
b — BAJRA
c — COTTON
j — JOWAR
p — PULSES
c-b-j-p
AMRAPUR
A. R. MALAKAR

Fig. 3

domestic use but also for minor irrigation. Water of the existing tube-wells should be judiciously used keeping in view their recharge capacity, so as to ensure availability of water for a longer period.

2. *Soil conservation and afforestation in denuded and depleted habitats :* In order to control high wind speed and consequent soil erosions, strip-cropping, stubble mulching and field fencing by *Euphorbia caducifolia* may be adopted. In strip-cropping protecting grass strips should be established at right angles to the direction of the prevailing wind. Crops in protective strips may be rotated. Crop stubbles should be left in the fields during summer season. Field bunds may be constructed and farm forestry encouraged. This will provide timber and fuel and also act as windbreak On sloping lands contour bunding and furrowing should be practised. Construction of suitable drainage channels in areas inundated during and after the monsoon may be made, so as to drain off excess water into the Rann. This, for example, may be practised near Modhutra village where about 1,000 acres of land with good soils remain inundated for the greater part of the year. This will provide more area for cultivation.

Under the afforestation programme shelter-belts may be raised along the fringe of the Rann, roadside and field boundaries. Woodlots may be raised near village tanks.

The following plant species are recommended for plantation in different habitats :

1. Rocky sites near Eval, Phangli and Aluvas

Acacia senegal, *Commiphora wightii*, *Maytenus emarginatus*, *Salvadora oleoides* be planted in pockets with sufficient soil depth i. e. at least 45 cm, Plantation of economically important species such as *Acacia senegal* and *Commiphora wightii* may be engouraged for gum and *gugul*.

2. Semi-rocky or gravelly areas

Acacia senegal, *Zizyphus nummularia*, *Albizzia amara*, *Azadirachta indica*, *Feronia elephantum*, *Holoptelea integrifolia*, *Parkinsonia aculeata*. Barbed wire fancing should be provided for protection of plants.

3. On riverbed of the Banas and its tributaries

Tamarix dioica, Acacia nilotica sp. *indica, A. leucophloea, A. jacquemontii, Salvadora oleoides, S. persica, A. tortilis.*

4. On roadsides

Azadirachta indica, Albizzia lebbek, A. cupressiformis, A. tortilis.

5. On irrigated field boundaries and tanks

Azadirachta indica, Albizzia lebbek, Parkinsonia aculeata, Nerium indicum, Tamarix articulata, Ailanthus excelsa, Acacia cupressiformis.

6. On sandy soil at Piprala and adjacent areas :

Acacia jacquemontii, Calligonum polygonoides, Prosopis cineraria and *A. tortilis.*

7. On sandy loam and medium heavy soils

Prosopis cineraria, Salvadora oleoides, A. nilotica ssp. indica. Zizyphus nummularia, A. leucophloea, S. persica. (on saline areas).

8. On the peripheries of the Rann (near the Ranns)

Prosopis juliflora

Successful establishment and increased growth of the tree species in this habitat can only be obtained by perforating the hardpan to a depth of 60-90 cm and keeping the plantation floor clear by carrying out atleast two cross harrowings a year for the first three years after planting in the inter-row spaces by tractor drawn harrow.

3. *Improved agricultural practices :* It is suggested that improved varieties of crops may be tried in the demonstration plots in different soil groups. New crop varieties like hybrid bajra, Nadia 207, wheat NP 824, Sonara 64, Cotton Kalyan and other similar varieties may be adopted in irrigated areas. Farmyard manure under dry farming is quite useful and should be applied. Increased fertilizer doses particularly nitrogen and

phosphate are also recmmended.

There is a great need for evolving suitable cropping patterns so that underground water can be efficiently utilized.

Irrigation channels should be lined with bricks to check loss of water through seepage. The most efficient means of transporting water would be the pipes.

4. *Development of pastures :* There is a great scope for pasture development in a major part of the block which is at present barren, uncultivable and culturable waste. Hilly areas with suitable protection and soil conservation practices may be opened for grazing according to the carrying capacity which varies from 0.5 to one hectare per sheep on year long basis. Foothill with moderately deep soil may be reseeded with high yielding perennial grasses like *Cenchrus ciliaris*, *Cenchrus setigerus*, *Dichanthium annulatum* and *Sehima nervosum*.

Alluvial plains may be put under strip-cropping by raising forage or grain crops along with perennial grasses. Strips of perennial grasses may be established, and a legume crop (guar, moth, mung etc.) may be grown in between the grass-strips. This will form a stable base for animal husbandry. Where irrigation is available hybrid Napier and lucerne may be raised.

The gravelly undulating lands in village Patanka, Debra, Dhokawada, and Bakutra belonging to Class IV are marginal land where cultivation of crops is possible only under very careful management practices. Much of these lands could preferably be converted into pasture lands. Class VI lands of Fangli, Patanka, Aluwas and Eval may better be put either under pasture or under forest.

Waterlogged and saline areas, consisting of Class V lands, may considerably be improved by soil conservation practices, and be utilised on controlled or deferred rotational grazing system. It has been observed that *Dichanthium annulatum* gradually starts taking the place of *Sporobolus* under suitable grazing practices and soil conservation methods.

There is considerable scope for improving the animal husbandry in the block. Establishment of cottage wool industry and cattle and sheep breeding centres will go a long way in enhancing the economic condition of the people.

ACKNOWLEDGEMENT

The authors wish to thank the District Development Officer, Palanpur and his staff for the help and cooperation extended during the survey.

MOISTURE STORAGE CAPACITIES IN RELATION TO TEXTURAL COMPOSITION OF WESTERN RAJASTHAN SOILS

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ABSTRACT

Two hundred soil samples were collected from various parts of Western Rajasthan and analysed for mechanical composition, moisture equivalent and water holding capacity. There are significant relationships between silt, clay, silt + clay and these two moisture constants. Silt has greatest effect on both of these moisture constants, clay being the next and silt + clay last.

INTRODUCTION

Information on water absorption and storage capacity of soils is of great importance to agronomists, soil scientists and agricultural engineers. Considerable attention has been given to the effect of texture and also organic matter on soil water relationship. In many soils moisture equivalent. total water holding capacity or sticky point frequently serve as good indices of soil texture or vice versa. The correlations with texture are not always perfect, due to the varying contributions of the organic matter and inorganic fractions of the colloid to the total. However, provided that these are restricted to the soils within closely related groups and to soils within these groups having similar amounts of organic matter, the correlations are sufficiently good to warrant the use as indices especially in survey works where frequently the approximations are required to characterise the soils and classify them for use in general croppings (Piper 1957).

'Moisture equivalent' was first used by Taylor (1936) as a rapid means of determining the approximate clay content of soils for certain irrigation areas. Veihmeyer and Hendrickson (1931) reported that moisture equivalent gives fairly good measure of field capacity and now it is frequently used for determination of this value. Another soil moisture constant frequently used in soil studies is water holding capacity determined by Keen-Reezkovski boxes.

More information is needed on the relationships of soil texture and water storage capacity especially in the arid areas. The results out of the soil survey works conducted in various parts of western Rajasthan in this regard are presented here. The soils studied thus far are mostly coarse to medium textured and fairly low in organic matter contents. The clay mineral in these soils is dominantly illitic.

MATERIAL AND METHODS

200 soil samples were collected during surveys from various parts of arid western Rajasthan and mechanical analysis was conducted by International Pipette method (Piper 1950). Moisture equivalent for all these samples was determined with the method of Briggs and McLane as modified by Viehmeyer (Piper 1950). Water holding capacities were determined with Keen-Reezkovski boxes as described by Piper (1950). Organic matter content was determined by Walkley and Black's rapid titration method (Piper 1950) and calcium carbonate by calcimeter. Statistical correlation coefficients were worked out between clay, silt and silt+clay and these two moisture constants.

RESULTS AND DISCUSSION

Texturally soils varied from loamy sand to clay loam, majority number falling in fine loamy sand to fine sandy loam groups. Calcium carbonate contents varied from nil to 3.5 per cent, majority of soil samples having it around 1 per cent. Organic matter content was more or less similar in all the samples having a range from 0.6 to 1.2 per cent. Values of moisture equivalent ranged from 3 to 24 per cent majority of samples falling in 9 to 16 per cent. Values of water holding capacity ranged from 22 to 50 per cent majority falling in 24 to 40 per cent.

Table 1. Broad textural class and the range in moisture constants

Textural Class	*M. E. %*	*W. H. C%*
Sand	3 - 6	22 - 24
Loamy sand	6 - 8	24 - 28
Sandy Loam	8 - 11	28 - 32
Loam	11 - 16	32 - 38
Clay loam	> 16	> 38

Results of correlation analysis is shown in Table 2. The regression lines between moisture equivalent and textural separates are shown in Fig. 1 and between water holding capacity and textural separates in Fig. 2.

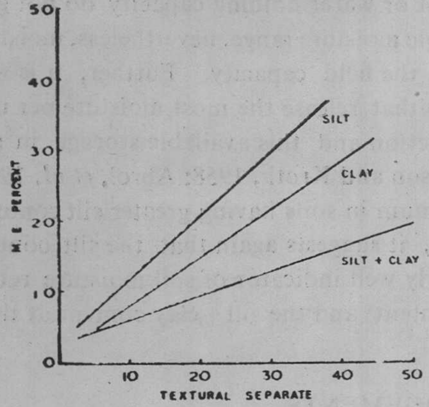

Fig 1

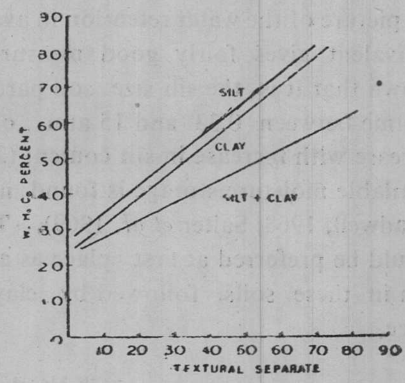

Fig. 2

Table 2. Correlation between texture and moisture constants

S.No.	Variables	Correlation Coefficients
1	Moisture equivalent × clay per cent	0.6734*
2	Moisture equivalent × silt per cent	0.7304*
3	Moisture equivalent × silt + clay per cent	0.6129*
4	Water holding capacity × clay per cent	0.8235*
5	Water holding capacity × silt per cent	0.6131*
6	Water holding capacity × silt + clay per cent	0.5772*

*Significant at 1% level

It is interesting to note that clay and silt individually as also in combination significantly influence both, the moisture equivalent as well as water holding capacity in these arid zone soils From statistical point of view the silt content gives highest correlation coefficient r = 0.7304 with moisture equivalent; followed by clay content and further followed by silt + clay. As regards water holdtng capacity, however, it seems, it is closely associated with clay fraction alone and silt content takes intermediary posit ion between clay and silt + clay.

It is worthwhile to note, however, from the regression lines that silt has the greatest influence on both the moisture constants as seen from the influence of a unit per cent increase in silt on both the moisture constants. Clay content has also similar influence on water holding capacity alone; as both the curves run parallel (Fig. 2). Thus it is suggested that silt content alone could be preferred first for moisture consideration in these soils.

Although either moisture equivalent or water holding capacity do not give the picture of the water retention in available moisture range, nevertheless, moisture equivalent gives fairly good measure of the field capacity. Further, it is well known that it is the silt size soil particles that release the most moisture per unit volume between 0.33 and 15 atm. of suction and this available storage in soil increase with increase in silt content (Jamison and Kroth, 1958; Abrol, *et al.* 1968). Available moisture storage is found maximum in soils having greater silt contents (Gradwell, 1968, Salter *et al.* 1969). Thus, it suggests again that the silt content should be preferred at first place as a fairly well indicator of soil moisture retention in these soils, followed by clay content and the silt+clay content at third place.

ACKNOWLEDGEMENTS

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EFFECT OF SALTS ON SEED GERMINATION OF SOME DESERT GRASSES

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ABSTRACT

Effect of five salt concentrations on the germination of eight grass species has been studied in perti-dishes in the laboratory. *Dactyloctenium aegyptium, Dichanthium annulatum* and *Chloris virgata* showed germination of 50, 14 and 22 percent respectively in a solution of 13.6 g/lit salt concentration. Permutaion and combination of the three types of salts in more than one ways would throw more light on the effect of individual salts and in combination. From this study it is clear that the above three species are relatively better salt tolerant than other species studied. *Dactyloctenium sindicum and Cenchrus setigerus* are highly sensitive to saline media. Maximum percentage germination is recorded under the first treatment (1.7 g/lit) in *Dactyloctenium aegyptium.*

INTRODUCTION

Soil salinity has varying effect on the seed germination and seedling growth. These studies have been undertaken with a view to study the effect of varying salt concentrations on the germination in some grasses. Though various aspects of germination and seedling growth in crop plants have been studied (Bhumbla *et al.* 1965, Ayers *et al.* 1952, Wahab *et al.* 1961 and many others) grasses have not received much attention. Present studies, therefore evaluate the salt tolerance of some fodder grasses of Rajasthan at the time of their germination.

MATERIAL AND METHOD

Seeds of eight common grass species were selected after a preliminary survey of the flora of saline areas (Saxena and Gupta 1970). Fifty seeds of each grass species were placed in petri dishes lined with moist filter paper. Five concentrations of NaCl, Na_2SO_4 and $CaCl_2$ salts viz. 1.7,3.4,6,8,10.2 and 13.6 g/lit. as suggested by Bhumbla *et al.* (1965) were used. Five replicates of each treatment were studied and the data are recorded in tables 2 and 3. Care was taken to keep enough quantity of solution in the dishes to maintain the filter papers moist.

OBSERVATIONS

The amounts of salts used in preparing solutions of different concentrations, their osmotic pressures and Ec are given in table 1. The estimation of osmotic pressure was made with the relation $OP=0.36\times Ec\times 10^3$ from conductivity measurements as described in USDA Hand Book No. 60 (1954). Germination of different grass species at different time intervals is given in table 2. Table 3 records the total percentage germination at the end of the experiment.

Table 1. Amount of salts used for preparing solutions of different concentrations

Soln. No.	NaCl gms/lit.	Na_2SO_4 gms/lit	$CaCl_2$ gms/lit	T. S. in gms/litre	E. C. in m. mhos/ cm at 25C°	Osm P. in Atm
I	0.85	0 425	0.425	1.70	2.6	0.93
II	1.70	0.85	0.85	3.40	4.9	1.76
III	3.40	1.70	1.70	6.80	8.6	3.09
IV	5.10	2.55	2.55	10.20	13.1	4.71
V	6.80	3.40	3.40	13.60	16.6	4.97

DISCUSSION AND RESULTS

A perusal of table 2 shows that germination of grasses in treatments with relatively low salt concentration did not increase appreciably beyond 144 hours of sowing except in *Dactyloctenium sindicum* and *Chloris virgata*. *Cenchrus setigerus*, *Dichanthium annulatum* and *Chloris virgata* show higher germination appreciably after 144 hours of sowing especially at high salt concentrations. This observation is in conformity with those reported by Bernstein and Haywards (1958). Germination of *Lasiurus sindicus*, *Dactyloctenium sindicum*, *Digitaria adscendens* and *Chloris virgata* seem to be activated by chloride and sulphate ions present in solutions of high salt concentrations. It may, however, be worth mentioning that during the first 48 hours no seedling emergence was observed in the first three grasses and it is only after 48 hours that the germination process becomes active. *Dactyloctenium aegyptium* seems to be more salt tolerant throughout its germination period which is followed by *Dichanthium annulatum* and *Chloris virgata*. Though *Dactyloctenium aegyptium* is a palatable grass it may not contri-

…ing salt concentrations on germination of different grass species at different time intervals

Plant species / T.S.S	GERMINATION COUNTS (Total of Replications) Within 98 hours of sowing C	I	II	III	IV	V	Within 144 hours of sowing C	I	II	III	IV	V	Within 192 hours of sowing C	I	II	III	IV	V	Total
1. D[illegible]	[illegible]	[illegible]	[illegible]79	167	133	125	189	186	181	169	133	125	189	186	181	169	133	125	983
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	43	24	18	7	—	—	53	56	32	12	—	2	155
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	140	117	112	55	32	22	140	117	112	55	33	24	481
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	43	39	36	32	13	10	45	40	42	38	19	10	194
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	171	169	142	86	68	27	176	178	148	93	79	35	709
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	84	138	97	104	97	33	85	144	106	119	111	55	620
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	52	33	37	38	13	81	52	33	37	38	13	18	191
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8	5	13	9	9	11	8	6	14	9	10	11	58

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PASTURE PRODUCTION AND ITS USE IN THE ARID AND SEMI-ARID AREAS OF RAJASTHAN (INDIA) AND KAZAKHSTAN (U.S.S.R.)

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ABSTRACT

Animal husbandry is the major occupation of the people living in the arid and semi-arid zones of India and Kazakhstan. Improvement of the grazing resources is therefore the key point in development of animal husbandry. Forage production from natural grasslands varies from one to 30 quintals per hectare in Indian arid and semi-arid zones whereas the same varies from 2 to 5 quintals per hectare in similar areas of Kazakhstan. Production from natural grasslands of the arid zone of India was increased by 60 per cent by soil working and seeding with *Cenchrus ciliaris* and of Kazakhstan was increased by soil working and seeding with *Agropyron desertorum* and *Kochia prostrata*. Grazing stress in the pastures of the arid zone of India is comparatively higher than that in Kazakhstan.

INTRODUCTION

Agriculture in the Indian arid zone which forms part of the 'Thar' desert of the Indo-Pakistan subcontinent suffers very much due to scanty and erratic rainfall. But the soils and climate of this part of the country are well adapted to animal husbandry rather than crop culture. Similarly in Kazakhstan the principal farming occupation of the people living in semi.arid and arid zones is animal husbandry and in particular sheep breeding. One of the main problems in animal husbandry in the arid region is to create a firm fodder base. Scientists in both India and Kazakhstan have undertaken the task of development of fodder and pasture resources of the arid and semi-arid regions in their respective countries (Kaul and Chakravarty, 1968, Chakravarty, 1969). Although the two areas differ both geographically and ecologically the basic approach in development of pastures is almost the same and therefore the results are comparable. On this background the pasture production of both the countries have been discussed in the present paper.

AREA, CLIMATE, SOIL AND VEGETATION

India : Area included in the present study lies between 23°3′ and 30°12′ north latitudes and 69°30′ and 78°17′ east longitude covering an area of 2.5 million hectares. The average annual rainfall varies from 300 500 mm in the semi-arid and 100 to 300 mm in the arid zone. The temperature ranges from 50°C in summer to below freezing in winter. Rainfall, which is only seasonal and occurs from July to September is very erratic. Soil ranges from sandy to sandy loam in texture. Hard pan of calcium carbonate or gypsum occurs at various depths. Saline and Saline-alkali lands occur where drainage is impeded.

The grassland observed in the area is *Dichanthium–Cenchrus–Elyonurus (Lasiurus)* type (Dabadghao, 1960) which includes the principal perennial grasses such as *Cenchrus ciliaris, C. setigerus, Cymbopogon jwarancusa, Cynodon dactylon, Dactyloctenium sindicum, Desmostachya bipinata, Dichanthium annulatum, Eleusine compressa, Eremopogon foveolatus, Isilema laxum, Lasiurus sindicus, Panicum antidotale, P. turgidum, Sehima nervosum* etc. and the annual grasses such as *Aristida adscencionis, A. funiculata, Brachiaria ramosa, B. bizantha, Chloris virgata, Cenchrus biflorus, Echinochloa* sp. *Elyonurus royleanus, Eragrostis ciliaris, Perotis indica, Tragus biflorus* etc. (Chakravarty, 1968 b). In spite of the wealth of indigenous grasses the average production from the natural grasslands is about 3 quintals per hectare due to severe grazing stress and unplanned use (Kaul and Chakravarty. 1968), Among these grasses, *Cenchrus ciliaris, C. setigerus, Dichanthium annulatum* and *Lasiurus sindicus* are the key species for pasture development because of their comparatively higher forage yield (1-4 tonnes per ha) combined with higher carrying capacity (Chakravarty, 1968c).

Kazakhstan : The areas of this state in U. S. S. R. was classified into northern and southern desert; the former is located in 48° latitude and above and the latter area is in 45° latitude and below. The average annual precipitation is 200 mm in the northern desert and it rains mostly in summer with a little in spring and in winter. The average annual rainfall in the southern desert is about 135 mm. 80 per cent of the precipitation fall in spring and the rest in winter and autumn. There may be occasional snow fall in winter but the snow cover seldom exceeds 8-10 cm. The north is semi-arid and the south is arid (Zikov, 1966) and the boundary line between the two lies between 43° latitude north. Northern semi-arid zone is characterised by dry steppes with chestnut soil whereas the southern arid zone is characterised by clay and loamy grey soil with varying degrees of salinity. Area of northern semi-arid zone is 118 million hectares and that of the southern arid zone is 75 million hectares out of which about 53 and 56 million hectares respectively are pastoral areas in the northern semi-arid and southern arid zones. The maximum temperature goes upto 30°C and 45°c respectively, in the northern and southern zones during summer. The vegetation cover consists of semi brush species i, e, *Artemisia* spp. *Atriplex* cana, *Anabasis salsa*, *A. ramossisima*, *Kochia prostrata*, *Nanophyton erinaceum*, *Salsola* sp. etc. perennial grasses viz., *Agropyron desertorum*, *A. sibiricum*, *Avenastrum desertorum*, *Festuca beckeri*, *F. sulcata*, *Lasiagrotis caragane*, *Stipa capillata*, *S. sareptana* etc. annuals and ephemerals (including bulbous plants) in different association of *Stipetum Festucum-Artemisiosum* or *Agropyretum-Artemisiosum Festucum*.

PASTURE PRODUCTION

The forage production from the pastures of Indian and Kazakh arid zones are low as compared to the production from the humid areas of the respective countries. Both inspite of their environmental differences, have the nucleus of high yielding forage species which if encouraged could increase the forage production tremendously.

Table 1. Forage production from different desert grassland communities, India (Kaul and Chakravarty, 1968) and Kazakhstan (Zikov, 1966)

Grassland Communities	Forage production in quintal per ha.
India	
Lasiurus sindicus - Eleusine compressa-Aristida spp.	4-16
Eleusine compressa - Aristida spp.	1-5
Cenchrus - Eleusine compressa - Aristida spp.	4-17
Cenchrus - Heteropogon contortus - Aristida spp.	13
Sporobolus - Cyperus - Aristida spp.	2-11
D. annulatum - Eremopogon faveolatus - Aristida spp.	7
D. annulatum - Hateropogon contortus - Aristida spp.	11-30
Kazakhstan	
Stipatum - Festucum	4-5
Stipatum - Festucum - Artemesiosum	3-4
Festucum - Artemesiosum	2-3
Agropyretum - Artemesiosum - Festnucum	4-5

The forage production (Table 1) from natural pastures of the India arid zone (1-30 Ql/ha) is comparatively higher than that from pastures of the arid zone of Kazakhstan (2-5 Ql/ha). In both the countries alround efforts are being made for radical improvement of the natural pasture resources by soil working, fertilization followed by reseeding with high yielding forage species.

Soil woıking followed by seeding increased the forage yield of the natural pastures from 47 to 60 per cent and from 20 to 88 per cent in India (Chakravarty, 1968a) and in Kazakhstan (Prianishikov, 1966) respectively. In Jodhpur station (India), the high yielding perennial grass species viz., *Cenchrus ciliaris, C. setigerus, Lasiurus sindicus* and *Panicum antidotale* were fertilized with NPK fartilizers @ 22.4 kg.ha either singly of in combination. There was an increase in yield from 15 to 38 per cent over the control where nitrogen was applied singly or in combination with Phosphorus and Potash (Dabadghao *et. al.* 1965). Fertilizer experiments in arid and semi-arid areas of Kazakhstan with 60 kg. of Nitrogen, Phosphorus and Potash each indicated about 10.3 per cent increase in yield over the non fertilized plots. Fertilizer application was only effective in years of good rainfall (Prianishnikov, 1966).

Table 2. Average harvest of hay from perennial forage plants in desert areas in Ql/ha.

Species	*India (Chakravarty, 1968a)*
Cenchrus ciliaris	16.2
C. setigerus	10.6
Lasiurus sindicus	19.5
Panicum antidotale	22.3
Natural pasture	3.2
	Kazakh astan (Prianishnikov, 1966)
Agropyron desertorum	12.1
Elymus juncus	7.0
Kochia prostata	16.9
Medicago sativa	7.8
Onobrychis arenaria	11.9
Natural pasture	2.3

Forage production was increased by 3 to 8 times in Indian and Kazakh arid zones by the introduction of high yielding and perennial forage species in the pasture.

UTLIZATION OF PASTURES

The grasslands of the arid and semi-arid zones of Rajasthan are under severe stress of grazing by 4.74 million cattle 5.66 million sheep, 3.38 million goats and 0.5 million of other kinds of livestock (Kaul and Chakravarty, 1968) in an area of about one million hectare. There is however good flush of annual grass due to seasonal rainfall in July to September. But this growth is utilised by the grazing stock immediately after the flush and subsequently the animals have to migrate from the arid to the humid zone in search of fodder. In years of drought the situation worsens further and large scale migration of animals takes place. The carrying capacity of native pastures under protection was estimated as one to 2.5 sheep per hectare and one cattle per 2.4 to 6 hectares, on the basis of 60–70 per cent utilization of forage and under continuous grazing throughout the year. But the relative carrying capacity of the pastures increased by three times in perennial pastures of *Cenchrus ciliaris*, *C. setigerus*, *Dichanthium annulatum* and *Lasiurus sindicus*.

Nomadic in the past, the Kazakh people has long ago studied and used the properties of each type of animals, primarily the ability of consuming different grasses and associations of grasses. A natural proverb in the country says "breed horses on turf grasses, camels on the solonets, sheep on the sands and cattle on the valley" (Elemanov, 1966). Many of the achievements of range livestock breeding is the heritage from the peoples experience. Many years experience has proved that continuous use of pastures decreases their carrying capacity from year to year. In order to avoid this and keep the harvests steady and even increase them it is necessary to make use of the pastures following a certain rotational scheme (Prianishnikov, 1966). According to the experiences of Betpakdala sheep breeding experimental station the introduction of plot grazing increased the productivity of animals by 11.2 per cent besides the productivity of different pastures was increased by 14–21 per cent in comparison to non systematised grazing. Under Indian condition however continuous grazing according to carrying capacity indicated higher gains in body weight of the animals.

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EFFECT OF DIFFERENT NITROGENOUS FERTILISERS IN RAINFED RAGI

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ABSTRACT

Studies were undertaken from 1966 to 1968 with *Ragi* variety H22 under rainfed conditions at the University Farm, Bangalore. The effect of continuous application of four types of nitrogenous fertizers viz. Ammonium sulphate nitrate. Ammonium sulphate, Urea, Calcium nitrate, all at 2 levels, viz. 33.3 Kg and 100 Kg N per hectare, on the grain yield was investigated. The entire dose of fertilizers was applied to soil at the time of transplanting. Calcium ammonium nitrate was the best source of nitrogen for increased ragi yields. Although the yields were maximum at 100 Kg N, there appears to be no large benefit through increased grain yield due to 100 Kg N per hectare as compared to 33.3 Kgs N per hectare. With Calcium ammonium nitrate the original soil pH was increased to 6.6 from 5.1.

INTRODUCTION

Investigations on the fertiliser application to rainfed ragi (*Eleusine coracana* Gaertn. has been under way since long and these studies have clearly indicated the beneficial effects of fertilisers in increasing the yield, (Sirur 1960, Khureshi, 1964, Krishnamurthy, 1967, Krishnamurthy *et al.* 1968, Venkat Rao, 1964). Further, these earlier studies with regard to nitrogen fertilisers to rainfed ragi have been confined mostly to the use of lmmonium sulphate. In some cases, however comparison of Ammonium sulphate has been made in Mysore State with Chillian nitrate (Venkat Rao, loc cit) and elsewhere with calcium ammonium nitrate (Chinnaswamy *et al.* 1967). Several other nitrogenous fertilisers are however available. In order to fill in this gap of information, studies were undertaken on the relative differenc nitrogenous fertilisers on rainfed ragi.

MATERIAL AND METHODS

Studies were taken up under rainfed condition, with H.22 ragi on red sandy loam soil with a pH of 5.1 at the Main Research Station of the University of Agricultural Sciences, Bangalore. These studies were made in the same plots for a period of three years from 1966-1968. The following treatments were included in the study :

1. Control. No fertiliser application

2. Ammonium sulphats at 33.3 Kg N per hectare

3. Ammonium sulphat at 100 kg N per hectare

4. Urea at 33.3 Kg N per hectare.

5. Urea at 100 Kg N per hectare

6. Calcium ammonium nitrate at 33.3 Kg per hectare

7. Calcium ammonium nitrate at 100 Kg N per hectare

8. Ammonium sulphate nitrate at 33.3 Kg N per hectare

9. Ammonium Sulphate nitrate at 100 Kg N per hectare.

A level of 33 Kg N per ha has shown to be optimum for rainfed crop; and with the idea of extracting some more information at a very high level 100 Kg N has been included.

Trial was laid out in a randomised block design with four replications. Plot size was 4 cm by 2.5 cm with 10 rows per plot spaced 25 cm apart. Four week old seedlings were transplanted with 2 seedlings per hill at a plant to plant distance of 20 cm during the last week of July each year. All the fertiliser was incorporated in the soil before transplanting. At maturity ragi grain yield was recorded and subjected to statistical analysis. During the year 1966 out of the total rainfall of 105.3 cm, 84.4 cm. was received in 47 rainy days during the crop period (July to November). The corresponding figures for 1967 were 63.7, 36.2, 26 and or 1968, 70 ,9 50.4, 38 respectively, At the end of the third year pH of the the soil was estimated.

RESULTS AND DISCUSSION

The data on grain yield for three years is given in Table.

Table 1: Grain yield of H22 rainfed ragi in relation to different forms and levels of nitrogenous fertilisers during different years in Kg/hectare

Sl. No.	Treatment	1966	1967	1968	Av	pH of the soil at the end of 3rd year
1	Control	977	1012	1045	1011	5.8
2	Ammonium sulphate at 33.3 Kg N per hectare	1219	1348	1525	1364	5.6
3	Ammonium sulphate at 100 Kg N per hectare	1114	1496	1610	1407	5.6
4	Urea at 33.3 Kg N per hectare	947	1712	1014	1224	5.5
5	Urea at 100 Kg N per hectare	1910	1204	1217	1162	5.6
6	Caicium ammonium nitrate at 33.3 Kg N per hectare	1222	1692	1797	1570	6.2
7	Calcium ammonium nitrate at 100 Kg N per hectare	1086	1775	1944	1602	6.6
8	Ammonium sulphate Nitrate at 33.3 Kg N per hectare	1078	1412	1481	1324	5.6
9	Ammonium sulphate Nitrate at 100 Kg N per hectare	1239	1600	1569	1469	5.7
	C. D. (5%), Kg/ha	20.0	13.0	12.0	—	—

The results indicated that in general, all the sources of nitrogenous fertilisers have increased the grain yield over control. Further, there was not much benefit through increased grain yield due to 100 Kg N/hectare as compared to that of 33.3 Kg N/hectare with all the fertilisers. In general, there was marked decrease in the yield in 1966 as compared to 1967 and 1968. This was due to the rampage of yellowing disease of the ragi crop. Nevertheless in 1966, there was definite indication of higher yield with calcium ammonium nitrate at 33.3 kg N per hectare (1222 kg/hectare). Although Ammonium Sulphate Nitrate at 100 Kgs N gave the maximum grain yield (1239 kg per hectare), yet the difference with calcium ammonium nitrate at 33.3 Kg N was negligible (17 Kg). Ammonium sulphate at 33.3 Kg N per hectare was the 3rd best treatment (1219 Kg/hectare). All these were significantly higher than control.

The grain yield of 1967 also showed the beneficial effects of calcium ammonium nitrate. The yield was maximum when calcium ammonium nitrate was applied at 100 kg N hectare (1775 Kg). This was followed by urea at 33.3 Kg N per hectare (1712 Kg). Due to better climatic conditions, the yield in general were better in 1968 than the previous years. Once again calcium ammonium nitrate at 100 Kg N (1944 Kg per hectare) and 33.3 Kg N (1797 Kg/hectare) gave significantly higher yield over all the treatments. The next best treatment was ammonium sulphate at 100 Kg N/hectare level (1610 Kg).

Based on the average results of three years, calcium ammonium nitrate at 33.3 Kg N was best from all consideration. The explanation that could be offered for the improved yield with the application of calcium ammonium nitrate was due to the beneficial effect of calcium. It could be recalled that the original soil had a pH of 5.1. At the end of the third year cropping, the pH of soil increased to 6.6. This is near to neutral soil reaction. There will be better utilisation of nitrogen and phosphorus at the neutral range than in the acidic range. This must have added to the higher yields with calcium ammonium nitrate.

Further, it could be seen from the yield results that application of calcium ammonium nitrate at 100 Kg N level, did not increase the yield to any appreciable extent, over calcium ammonium nitrate application at 33.3 Kg N level. This clearly indicates that there is no use in applying calcium over the required dose needed to neutralise the soil acidity. Further, when once the soil pH nears neutral range, the rate of reaction of lime slows down, (Ananthanarayana, 1969),

Viswanath (personal communication, 1969) has also observed that calcium ammonium nitrate was superior to ammonium sulphate and ammonium nitrate in increasing the ragi yield, on a red soil having a pH of 4.67. However, Iruthyaraj and Rajarathnam (1955), Chinnaswami *et al* (1967) have reported that calcium ammonium nitrate was as efficient as sulphate of ammonia and urea for ragi. Variations in yield observed in diffirent years in this study might be due to seasonal vagaries which is normally expected under rainfed conditions.

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RESPONSE OF UNIRIGATED WHEAT TO NITROGEN AND ITS METHOD OF APPLICATION

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ABSTRACT

The results of field experiment conducted at Regional Research Station, Basawara during *rabi* 1967–68 and 1968–69 to study the response of unirrigated wheat to nitrogen and its method of application have been discussed. Average yield of grain and straw of wheat increased by 14.5 and 12.5 per cent respectively with the application of 20 kg N/ha over control. Basal application of nitrogen full in soil gave higher yields than in splits (1/2 as basal + 1/2 as foliar application, Variety RS 31–1 proved superior to local wheat.

INTRODUCTION

Wheat is an important cereal crop grown under heavy black soils of South Eastern part of Rajasthan and occupying nearly twelve thousand hectares. The crop is predominantly rainfed and is entirely grown on the limited quantity of conserved soil moisture during rainy season. Fertilizers are generally not applied to this crop under such conditions Chandnani (1955) and Bathaka (1965), obtained highest yield of wheat under unirrigated conditions by nitrogen fertilization. A pa t of this nitrogen when applied through foliar spray contributed toward higher yields (Anon, 1969). Hence, a study was taken to find out an optimum dose and suitable method of nitrogen application under unirrigated condition for two varieties of wheat,

MATERIAL AND METHODS

The experiment was laidout in a randomized block design with twelve treatments, consisting of three levels of nitrogen (0,20 and 40 kg N/ha), two methods of its application (full at sowing and half at sowing + ¼ as foliar application at tillering + ¼ as foliar application at boot leaf stage) and two wheat varieties (local and R S 31-1). There were four replications. A basal dose of 20 kg P_2O_5/ha through triple superphosphate was also applied to all treatments. Nitrogen spray was done through urea with 2 per cent concentration. Total rainfall during kharif in each year and monthly rainfall during the growth period in rabi seasons is given in table 1,

Table 1, Rainfall (mm) during the growth peried

Months	1967-68	1968-69
Kharif total	994.83	743.2
October	—	—
November	—	—
December	141.10	—
January	—	—
February	—	—
March	57.0	—
April	—	—

During rainy season the fiield was kept follow and was harrowed four times to conserve moisture, The total rainfall upto the time of sowing of wheat crop during the year 1967 and 1968 was 994.83 and 743.2 mm respectively (Table 1).

RESULTS AND DISCUSSION

Table 2. Effect of varieties, nitrogen levels and method of nitrogen application on grain and straw yield in kg/ha

Treatments	Grain yield			Straw vield		
	1967-68	1968 69	Mean	1967-68	1968-69	Mean
Varieties						
Local	983	293	638	1480	723	1101.5
RS 31-1	1037	419	728	1449	965	1206.5
S. Em ±	100	18	—	152	99	—
C. D at 5%	NS	37	—	NS	203	—
Levels of nitrogen						
O kg N/ha	968	254	611	1427	617	1049
20 kg N/ha	1018	386	702	1445	913	1179
40 kg N/ha	1023	377	700	1505	859	1182
S Em ±	100	42	—	152	99	—
C D at 5%	NS	86	—	NS	203	—
Method of application						
Soil application	1015	400	708	1476	906	1191
Soil + Foliar	1026	364	695	1474	867	1170
So Em ±	100	30	—	152	99	—
C. D at 5%	NS	62	—	NS	203	—

Response of varieties : During both the years RS 31-1 proved superior over local strain. In the year 1968-69, grain and straw yields of Rs 31-1 were 42 3 and 32.3 per cent higher than the local and differences were significant while in the year 1967-68 differences in these varieties could not reach the level of significance. Although 5.5 per cent increased grain yield was obtained over local.

Response to nitrogen : A non significant increase in grain and straw yields was observed with nitrogen application in 1967-68 while in 1968-69, significant differences in grain and straw yields were obtained. The increases in grain and straw yields were 52.2 and 35.7 per cent by the application of 20 kg N/ha over the control.

Method of applictation : Methods of nitrogen application did not significantly affect the grain and straw yields in 1967-68 while in 1968-69 significant difference in grain and straw yields were observed and per cent increase being 9.8 and 4.5 respectively with soil application of total nitrogen at sowing over split application of nitrogen. Results are in close conformity with Singh (1957) and Tisdale and Nelson (1956) they also reported that soil application is more effective than spray solution. There was a negligible difference between the soil application and soil + foliar during 1967-68, the later being slightly effective in case of grain yield. This appears to be impact of soil moisture stress.

Higher yields of grain and straw were obtained during the first year than that of second year. It might have been due to more soil moisture available as there were winter rains during the growth period of wheat in the month of December and March. While in the second year there were practically no winter rains and total rainfall in preceding season was also less.

Better response of crop to nitrogen in first year might be due to more available soil moisture, resulting higher plant population per heactare and more ear bearing tillers per plant. Low soil moisture during second year adversely affected, the plant population and number of tillers that resulted in lower yields, Kanwar and Bhumbla (1949).

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CORRELATION OF AVAILABLE COPPER VALUES OBTAINED BY DIFFERENT METHODS TO COPPER UPTAKE BY MAIZE

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ABSTRACT

For determining the availability of copper in soils of Tarai region of U. P., extractions were made from 10 different soils of this region by five different reagents viz. (a) Water, (b) 0.1 HCl, (c) 0.05 M EDAT, (d) N ammonium acetate (pH 4.6, and (e) N ammonium acetate (pH 7.0). Maize plants were grown in pots containing all significant correlations between neutral ammonium acetate ($r=+0.812$) and 0.05 M EDTA ($r=+0.993$) extractable copper and copper uptake by maize plants were obtained.

Simple correlation coefficients were also worked out between each of several soil factors and extractable copper. The results showed no significant correlation of extractable copper with soil pH, clay, organic matter and calcium carbonate except between neutral ammonium acetate extractable copper and per cent clay in soil.

INTRODUCTION

Coopper present in a soil can be divided into three catagories–water soluble. exchangeable and non-exchangeable or fixed. Soils vary widely in their copper supplying capacity regardless of the amount of copper in non-exchangeable form. A variety of soil extractants including water, salts, acids or chelate forming agents have been used by different workers to determine available copper. Iyer and Satyanarayan (1958) and Neelkantan and Mehta (1961) found that ammonium acetate gave the maximum predictability of copper uptake by *Jowar* plants. Agarwala (1963) reported that 0.1 N HCl is not an efficient soil extractant for predicting the copper in the tissues of paddy and maize. However, Pickett and Dinius (1954) reported that 0.1 N HCl gave a better indication of available copper content of the soil than N ammonium acetate (pH 7). There is no unanimity about the suitability of these extractants.

In the present paper, study was made to evaluate the methods by comparing copper extracted by each method with copper taken up by maize plants from Tarai soils of U. P.

MATERIALS AND METHODS

Bulk samples of plough layer soils were collected from 10 sites in Tarai area of U. P. Soils were air dried, ground with a wooden roller. After grinding, the soil was passed through 2 mm sieve. Some characteristics of soil pertinent to this investigation were determined as follows : clay by international pipette method; pH in 1 : 2 soil to water suspenion with Beckman pH meter; calcium carbonate by rapid titration method, organic carbon according to Walkley and Black mothod; and total copper as described by Jackson (1958).

Available copper was determined in the extract by 2, 2′-biquinoline method (Black, 1965) after extracting copper with five extractants : (a) water, (b) 0.1 N HCl, (c) 0.05 M EDTA, (d) N ammonium-acetate (pH 4.6), and N ammonium acetate (pH 7.0).

Green-house studies : The soil as processed above was potted in polythene pots (18x20 cm) each containing 5000 gm of soil. Nitrogen, phosphorus and potassium as basal dose were applied at the rate of 120 Kg N, 60 Kg P_2O_5 and 30 Kg K_2O per hectare through reagent grade ammonium sulphate, diammonium phosphate and potassium chloride in all pots.

The pots were seeded with maize (Zea-mays, L. var. Ganga-2) at the rate of 4 seeds per pots. These pots were maintained at field capacity with distilled water. When the plants were one week old, they were thinned to 2 plants in each pot. The plants were allowed to grow for 7 weeks and the above ground portion of plant was harvested, washed dried at 70°C and powdered. One gram of powdered material was digested with nitric-perchloric acid mixture and analysed for copper.

RESULTS AND DISCUSSION

In table 2 are given the values of copper extracted by five different reagents viz., water, 0.1 N HCl, 0.05 M EDTA; N ammonium acetate (pH 4.6) and N ammonium acetate (pH 7.0) from ten different soils. The amounts of copper extracted by maize plants from these soils are also given. The amounts extracted by the five reagents in order of decreasing quantities are given as follows : 0.1 N HCl > 0.05M EDTA > N ammonium acetate (pH 4.6) > N ammonium acetate (pH 7.0) > water.

The content of total copper varied from 14 to 49 ppm most of the soil containing more than 25 ppm (table 1). However, only a small fraction of this quantity could be extracted by any of the extractants.

Table 1. Total copper and other soil properties

Sl. No.	Location	Total copper (ppm)	Percent clay	Percent organic matter	Percecnt calcium carbonate	pH
1	West zone, G Block Matkota	28 2	14.30	2.07	4.14	6.8
2	Tarai Model farm, Rudrapur	18.4	11.09	1.97	5.22	8.5
3	West zone, D Block Matkota	14.1	13.10	0.91	4.87	8.0
4	West zone, C Block Matkota	19.2	7.60	2.07	4.52	7.9
5	Crop research station H Block, Pantnagar	25.1	36.23	2.53	5.22	8.1
6	Livestock research station, Nagla	29.3	21.59	2.73	4.55	7.8
7	H Block Pattnarchatta	37.0	22.13	2.28	4.52	8.1
8	West zone, E Block, Matkota	27.2	15.19	1.42	4.52	8.1
9	Crop research station D-5 Block, Pantnagar	49.0	14.77	2.07	4.26	7.0
10	Eastern zone, K Block, Beni	30.1	8.23	2.10	4.48	7.8

Table 2. Extractibility of copper in soils by different reagents and uptake of copper by maize plants

Sl. No.	Extractable copper in soil (ppm)					Copper content in maize top (ppm)
	Water	0.1 N Hcl	0.05 M EDTA	N ammonium acetate (pH4.6)	N ammonium acetate (pH7.0)	
1	Trace	0.96	0.60	0.50	0.000	8.0
2	Trace	1.35	0.71	0 44	0.096	10.5
3	Trace	0.92	0.72	0.41	0.074	9.2
4	Trace	1.08	0.64	0.34	0.082	8.2
5	Trace	1.50	0.75	0.47	0.280	10.3
6	Trace	1.65	0·65	0.29	0.082	9.2
7	Trace	1.48	0.89	0.50	0.300	12.1
8	Trace	1.50	0.96	0.48	0.321	13.0
9	Trace	1.50	1.20	0.52	0.212	15.3
10	Trace	1.32	0.90	0.45	0.261	12.6

Water along extracted negligible quantities of copper from the soils. Ammonium acetate (pH 7.0) extractable copper was very small. These solutions extracted water soluble and exchangeable copper respectively. In the soils analysed here, water soluble copper was absent and exchangeable copper was low as compared to other forms of copper. Ammonium acetate (pH 4.6) extracted larger amounts, because H+ ions in this extractant determined copper from exchangeable as well as some from non-extracting form. EDTA is better extractant because its extracting property is based upon both ion-exchange and chelation capacity. HCl extracted largest quantity among all the extractants used in this investigation. It may be because of larger extracting capacity of this reagent for fixed as well as exchangeable copper.

There exists a positive correlation between available copper (HCl, ammonium acetate, pH 4.6 and 7.0 and EDTA extractable copper) and copper