LAND USE CLASSIFICATION SYSTEM IN INDIAN ARID ZONE

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ICAR

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PREFACE

Land use survey and mapping deals with the classification of lands according to their present use. This is an obvious requirement to assess the use and misuse of land which is the prerequisite to plan the utilisation of resources. In the arid zones, where the resources have either not been fully assessed or the available resources are not being properly utilised, the need for this survey and mapping has been strongly felt. To deal with the problem, the Basic Resources Studies Division of the Central Arid Zone Research Institute, Jodhpur is carrying out land use survey and mapping, as a part of integrated basic resources surveys in different arid and semi arid regions of India since 1967. This monograph deals with the problems of land use classifications in the arid zone and the methods and techniques evolved and standardised by this Institute for land use survey and their cartographic expressions.

I hope this monograph will be useful to research workers and land use planners working in the arid zones.

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INTRODUCTION

Assessment of use and misuse of land is the prerequisite to plan the utilisation of resources. Land utilisation survey and mapping is the obvious requirement to make such estimates. In the Arid Zone of India, where the resources have not been fully assessed yet and whatever resources are available are not being properly utilised, the need for this study has been strongly felt.

A review of the land utilisation units classified by various organisations-significances of correlated research :

Various organisations and the geography department of the universities in this country are now doing land utilisation survey and mapping. The central organisations which are of course, conducting such surveys on regional levels are only considered here.

The first to be considered are the small and medium scale maps prepared by National Atlas Organisation on 1:1,000,000 and printed on 1:5,000,000 (1957) and Diagnostic survey of the Damodar Valley region (1968) prepared on 1:500,000 and printed on 1:1000,000. In both the cases the work was conducted under the guidance of Dr. S.P. Chatterjee and the mapping units adopted are based on the scheme earlier followed by him in Howrah land utilisation survey and the scheme recommended by the commission on land use of I.G.U. The schemes worked out are given in Tables I and II.

The two maps however present the broad variation of land use classes and can only pinpoint the problem areas which deserve further attention for detail surveys. The schemes worked out however may not be applied to indicate the actual pattern. The classification of arable lands with trees, alpine grass and scrub besides scrub and glaciated region as applied by the N.A.O., unproductive land orchards including smaller water features as drawn out by the diagnostic survey

of D.V. region may not have universal appeal. Important units need classifications like double cropped land, pasture or grazing ground, etc are often missing.

Directorate of Economics and Statistics and the settlement departments of various states collect detailed informations of land use on village wise which are further compiled on tehsil or police stations, districts and state basis. Although the organisations do not prepare any land use map as such but provide valuable mappable informations to prepare both detailed maps on village basis and choropleth maps on tehsil, district or statewise. The classification adopted is shown in Table III. The scheme however proposes, too many units and demand further modifications. Viewing the practical purpose and for cartographical work land utilisation units as given were modified earlier by Sen (1957) and Sen and Chakravarty (1958) for detailed land utilisation survey and mapping conducted by the State Agricultural Research Institute of West Bengal. These schemes (Table IVa and IVb) were further reviewed by the standing committee of All India Soil and Land Use Survey who suggested a separate scheme (1960, Table Va) for detailed land use survey. This scheme was followed by the various soil correlation units of All India Soil and Land use survey and the experience gained resulted further modification of the Scheme of land utilisation units (1970, Table Vb). Viewing all aspects the scheme proposed may have an appeal so for as All India level is concerned although the scheme is subjected to severe criticism for having classification like terraced lands in land utilisation unit. The great draw back of the classification of the settlement department and soil and Land use survey is the complete overlook of the human aspects of land use as evident in not providing any classifications for the villages, towns etc. as done by the D.V. diagnostic survey and West Bengal Agricultural department. Land utilisation map demands 'geographic' analysis of land and as such analysis of human aspects are also to be considered. The above review indicates that a correlation between the schemes discussed is needed to standardise the mapping units of land utilisation surveys for India. A tentative scheme of the mapping units of land utilisation survey for India has accordingly been proposed (Table VI).

Systematic mapping of Land utilisation on various scales, depending on the nature and Problem of surveys, is being conducted by the Basic Resources Studies division of Central Arid Zone Research Institute since 1967. To start with and on the basis of data available the

scheme proposed by the Directorate of Economics and Statistics was modified (Sen and Gupta, 1971, Table VII) for choropleth mapping. For reconnaissance mapping, particularly when the works are conducted for certain problems like estimation of waste lands and the mapping is based mainly on the interpretation of aerial photographs, a separate scheme was worked out (Sen, 1972, Table VIII). Since 1971-72 detail reconnaissance land utilisation surveys in the various districts of Western Rajasthan have been taken up.

This has been evident, that considering the problems of arid zone, the scheme (Table VI) does not work satisfactorily to map the land utilisation units. Accordingly, a project was undertaken to standardise the methods of land utilisation mapping in Arid Zone. This monograph records the findings of this research.

TABLE I

LEGENDS OF LAND UTILISATION MAP (PLATE 16)
NATIONAL ATLAS ORGANISATION, 1957.

1. a Dense forest
   b Open forest
2. Scrub
3. Arable land
4. Arable land with trees
5. Plantation
6. Pasture
7. a Rocky waste
   b Sandy waste
8. Alpine grass and scrub
9. Glaciated region

TABLE II

LAND UTILISATION UNITS--(MAP NO. 18) SHOWING LAND USE REGION. DIAGNOSTIC SURVEY OF DAMODAR VALLEY REGION

1. Field crops
2. Orchards including smaller water features and land of non-agricultural uses

3. Dense forest
4. Light forest
5. Non-agricultural use of land-mines and quarries (working and abandoned)
6. Unproductive land
7. Water features-Tanks
8. Larger villages with houses 300 and above
9. Culturable waste-small
10. Culturable waste-Large
11. Smaller villages
12. Cities and towns
    a—Administrative-Commercial & Industrial
    b—Residential
    c—Industrial
    d—Mining
    e—Mining and industrial
    f—Agricultural and administrative.

TABLE III

DIRECTORATE OF ECONOMICS AND STATISTICS (LAND UTILISATION UNITS)

1 Forest

2. Land not-available for cultivation
   a) Land to non-agricultural use
   b) Barren and uncultivable land

3. Other uncultivable land excluding fallow and
   a) Permanent and other grazing ground
   b) Lands under miscellaneous tree crops and groves

4. Fallow land
   a) Culturable waste
   b) Fallow land other than current fallow
   c) Current fallow

5. Cultivated land
   a) Net area sown
   b) Area sown more than once.

TABLE IV

IV a	IV b
a Land utilisation units (detailed maps)	
Scheme proposed by Sen (1957) for Mayurakshi commanded area (scale–4″ – 1 mile and above) West Bengal	Scheme proposed by Sen and Chakravarty (1958) for West Bengal (4″ = 1 mile and above)
1. Settlement	A) Settlement
a) Settlement-Compact	i) Settlement
b) Settlement-Scatterd	ii) Settlement with orchards
c) Community Institutions	iii) Cultural and community institutions
2. Water features	B) Arable land
a) Natural	i) Single cropped area
b) Artificial	ii) Double cropped area
	iii) Permanent pasture
3. Fallow	C) Forest
a) Culturable waste	i) Reserved
b) Uncultivable waste	ii) Un-reserved
4. Industry	D) Fallow
	i) Culturable
	ii) Un-cultivable waste
	iii) waste
5. Cultivated land	E) Water features
a) Double cropped area	i) Natural
b) Single cropped area	ii) Artificial
c) Mixed farming	
6. Permanent pasture	F) Industry

TABLE V

SCHEME OF LAND UTILISATION UNITS PROPOSED BY ALL INDIA SOIL AND LAND USE SURVEY

V a 1960	V b 1970
Forest areas	Forest areas
F1-Thin forest	F1-With no canopy
F2-Moderately dense forest	F2-Thin forest
F3-Dense Forest	F3-Moderately dense forest
	F4-Dense forest and fully stocked top canopy
Cultivated land	Cultivated land
C1-Single cropped	C1-Single cropped
C2-Double cropped	C2-Double cropped
C3-Triple cropped	C3-Triple cropped
C4-Occasionally cultivated	
	Terraced land
	T1-Poorly bunded lands
	T2-Poor terracing measures
	T3-Bench terraces
Waste land	Waste land
W1-Waste land fit for cultivation	W1-Fit for cultivation
W2-Unfit for cultivation	W2-Unfit for cultivation
Pasture land	Pasture land
P1-Plantation	P-Pasture and grazing land
T--Thorns, weeds and shrubs	H-Haylands when the grass periodically cut
	Plantation
	P1-With young shrubs
	P2-With well grown
	T--Thorny plants and heavy canopy shrubs; Weeds

TABLE VI

TENTATIVE SCHEME OF MAPPING UNITS PROPOSED FOR LAND USE SURVEY ON ALL INDIA BASIS

1. Settlement		
A. Rural sertlement		a) Villages with compact settlement b) Villages with scattered settlement c) Linear Villages d) Temporary villages e) Deserted Villages
B. Urban Areas		a) Administrative b) Residential c) Mining and industry d) Agricultural e) Religious centre
2. Water features		a) Rivers b) Lakes c) Wells d) Tanks e) Canals
3. Forest	A Natural B Reserved	a) With no canopy b) With no canopy c) Dense forest
4. Cultivated land		a) Single cropped b) Multiple cropped
5. Waste land		a) Fit for cultivation b) Unfit for cultivation but suitable for pasture c) Unculturable waste
6. Pasture land		a) Permanent pasture b) Haylands where the grass is periodically cut c) Thorny land covered by thorns, weeds and shrubs
7. Plantation		

TABLE VII

LAND UTILISATION MAPPING UNITS SCHEME PROPOSED BY CAZRI FOR CHOROPLETH MAPPING (1971)

1. Forest
2. Settlement and other non-agricultural lands including settlements. roads, publice buildings and water features.
3. Land not available for cultivation (Permanent grazing land, orchards, barren land; tree groves).
4. Fallow land-available for cultivation (Cultivable waste, fallow land other than current fallow, and current fallow)
5. Cultivated lands-Single cropped area (net area sown) and double cropped area.

TABLE VIII

LAND UTILISATION MAPPING UNITS PROPOSED FOR AERIAL PHOTO INTERPRETATION (SEN, 1968, '72)

1. Forest
2. Settlement
3. Roads & Railways
4. Land not available for cultivation
   - i) Sandy waste
   - ii) Rocky waste
   - iii) Gravelly waste
5. Hills
6. Slopping hill sides
7. Fallow lands
8. Cultivated lands.

CHAPTER 1

Land use and types of land use maps

Definition and necessity:

Land use survey deals with the classification and mapping of the lands according to their present utilization. Assessment of use and misuse of land is the prerequisite to plan the utilization of resources. Land utilization survey and mapping is the obvious requirement to make such estimates.

Land use maps:

A land use map shows the distribution and extent of different lands, as classified, according to their present use. The level on which the different land use classes are classified and cartographed is based on the type of survey undertaken, viz., reconnaissance, detailed-reconnaissance or detail. It also depends on the materials, data and informations available. A land use map tends to evaluate the lands actually used on the one hand and also the lands available for further use on the other. The map should be helpful to predict the use and misuse of land and to recommend its suitability for better use like farming, forestry, pasture growing, settlement, etc. under different systems of management. Hence the ultimate purpose of land utilization survey and map is to arrive at systems of land use and management best suited to the kinds of resources and capabilities of the land composing it.

Types of land use maps:

Depending upon the data, materials and informations available; the intensity of survey and the resulting details, two broad types of land use maps are distinguished.

a) General land use maps: These are small scale maps, often 1:2,000,000 or less but never exceed to 1:1,000,000, and prepared on the basis of available data. Mostly the data are collected from revenue or settlement records of government departments. Choropleth maps are often designed and the areas under different categories of land use and sometimes their changes are shown in graphical forms. The extent and pattern of land use classes cannot be depicted in these maps, but, these maps are often helpful to visualise the different types of present land use, their comparative analysis and thus provide good indications to formulate the mapping units to be drawn for land use surveys and their consequent mapping.

b) Land use maps based on survey and remote sensing device: Based on the intensity of survey, topographical maps and aerial photo interpretations and collection of field data, local informations, etc., three types of land use maps can be prepared from the resulting details viz; reconnaissance; detailed reconnaissance and detail land use maps. These are large scale maps being 1:250,000; 1:100,000 to 1:50,000 and 1:15,000 or more in general in cases of reconnaissance, detailed reconnaissance or detail maps, respectively. These maps show the extent and degree of land use classes and thus depict the actual pattern of land use. These are helpful to delineate or find out problem areas, planning and execution works.

CHAPTER II

Types of land use Survey and Mapping of Present land use

The level on which the different land use classes, as standardised, are cartographed is based on the type of survey to be undertaken and on the mapping scale. The methods, now being followed in this Institute, are summarised here under.

Reconnaissance survey and mapping

Reconnaissance land use surveys are carried out mainly to pinpoint problem areas to find out the extent of major land use classes in order to assess use and misuse of land; to select the areas where detailed land use surveys are to be carried out; to recommend future land use planning and to chalk out broad land transformation programmes. The scale of base maps are suggested as 1:250,000 or more, and that of the final maps 1:250,000 to 1:500,000. Accordingly any units having more than 25 sq km in area should be shown in the map. For example the details of the land use classes as mapped in course of reconnaissance surveys in Bikaner district are presented in Table I.

It is evident that the settlement in details, urban area, permanent pasture lands cannot be mapped vividly on this scale. But the survey successfully brings out the intensity of cultivation and waste lands. But in waste lands too, it has been evident that some more details like rocky and gravelly wastes cannot be mapped.

The CAZRI is conducting this survey only where aerial photographs are not readily available.

TABLE IX

LAND USE OF BIKANER

CULTIVABLE AND CULTIVATED LANDS (area in sq km) INCLUDING CURRENT AND LONG FALLOWS

(Figures within bracket indicate percent to total area)

Tehsil	Intensity of cultivation						Total
	60 to 80%	40 to 80%	30 to 50%	20 to 30%	10 to 20%	Below 10%	
	Cultivation and current fallow			Cultivation and long fallow			
Bikaner	1317.4 (14.28)	307.8 (3.33)	278.3 (3.02)	848.3 (9.20)	421.0 (4.59)	666.8 (7.23)	3039.6 (41.65)
Lunkaransar	974.7 (15.29)	—	335.6 (5.27)	284 8 (4.47)	6.2 (0.09)	738.9 (11.59)	2338.8 (36.71)
Kolayat	2437.0 (30.66)	117.3 (1.48)	507.4 (6.38)	473.1 (5.96)	133.4 (1.68)	390.4 (4.91)	4058,6 (51.07)
Nokha	1393.6 (36.71)	657.2 (17.31)	118.1 (3.12)	189.9 (4.48)	460.8 (12.14)	127.2 (3.35)	2926.8 (77.11)
Bikaner district (Total)	6126.6 (22.41)	1082.3 (3.96)	9230.4 (4.53)	1775.5 (6.50)	1021.4 (3.73)	1922.4 (7.02)	13167.8 (48.15)

Table IX (*Contd.*) WASTE LANDS AND PASTURE LANDS

Tehsil	Sandy waste	Saline waste	Rocky and gravelly waste	Total
Bikaner	5326.7 (57.79%)	51.8 (0.56%)	—	5378.5 (58.35%)
Lunkaransar	3951.6 (62.01%)	81.6 (1.28%)	—	4033.2 (63.29%)
Kolayat	3138.20 (44.76%)	32.3 (0.16%)	319.0 (4.01%)	3889.5 (48.93%)
Nokha	869.0 (22.89%)	—	—	869.0 (22 89%)
Bikaner district (Total)	13685.5 (50 05%)	165.7 (0.60%)	319.0 (1.20%)	14169.2 (51.85 %)

Detailed reconnaissance survey:

Detailed reconnaissance survey is being conducted mostly on the basis of aerial photo interpretation. The scale of the base map selected is 1:50,000/1:63,360 and that of the final map 1:250,000 or more. Units having 5 sq km or more can be mapped. Such survey forms the very basis for planning land use and land transformation programmes. Recently a detailed reconnaissance land use survey was conducted in Jodhpur district and the results are illustrated in Fig. I and Table X. It will be seen that land use classes are shown in more details. The actual problems of use and misuse of lands are more elaborately brought out.

TABLE X

LAND USE OF JODHPUR

CULTIVABLE AND CULTIVATED LANDS (area in sq km and percent) INCLUDING CURRENT AND LONG FALLOWS

Tehsil	Intensity of cultivation							
	Cultivation and current fallow in percent			Cultivated and long fallow in percent				
	100% double cropped	80 to 100%	60 to 80%	30 to 60%	20 to 30%	10 to 20%	Below 10%	Total
Bilara	138.3 (4.3%)	1183.0 (36.5%)	124.4 (3.8)	670.0 (20.7)	—	—	—	2115.7 (65.3)
Jodhpur	8.9 (0.3)	1572.2 (47.8)	978.6 (27.7)	67.3 (2.0)	—	—	—	2627.0 (79.8)
Osian	43.9 (1.0)	367.3 (8.8)	1126.6 (27.1)	739·9 (17.8)	235.9 (5.7)	216.5 (5.2)	—	2729.1 (65.6)
Shergarh	8.8 (0.2)	— —	357.9 (9.4)	762.3 (20.0)	449.6 (11.8)	161.5 (4.2)	99.3 (2.6)	1839.4 (48.2)
Phalodi	—	—	946.6 (12.3)	1744.4 (22.8)	716.2 (9.3)	936.8 (12.2)	114.7 (1.5)	4458.7 (44.4)
Total	199.9 (0.9)	3122.5 (11.1)	3534.1 (15.9)	3983.39 (17.9)	1401.7 (6.3)	1314.8 (5.9)	214.0 (1.1)	13769.2 (62.1)

WASTE LANDS (in sq km and percent)

Tehsil	Sandy waste B_1	Saline waste B_2	Rocky & stony waste B_3	Rocky & gravelly waste B_4	Undifferentiated B_1–A_4	Undifferentiated B_1–A_5	Total
Bilara	13.4	63.5	462.4	54.3	215.0 (6.6)	87.7 (2.5)	891.3 (27.4)
Jodhpur	108.5 (3.3)	41.4 (1.3)	190.1 (5.3)	25.6 (0.8)	—	—	365.6 (11.2)
Osian	520.1 (12.5)	8.0 (0.2)	308.8 (7.4)	142.8 (3.4)	—	—	979.2 (23.5)
Shergarh	1580.0 (41.4)	—	101.3 (2.7)	41.0 (1.1)	—	—	1722.3 (45.2)
	1608.6 (21.0)	131.8 (1.7)	168.9 (2.2)	960.2 (12.5)	—	—	2869.5 (51.1)
Total	3830.6 (17.3)	244.7 (1.1)	1231.0 (5.6)	1223.9 (5.5)	215.0 (0.9)	87.7 (0.4)	6827.9 (30.8)

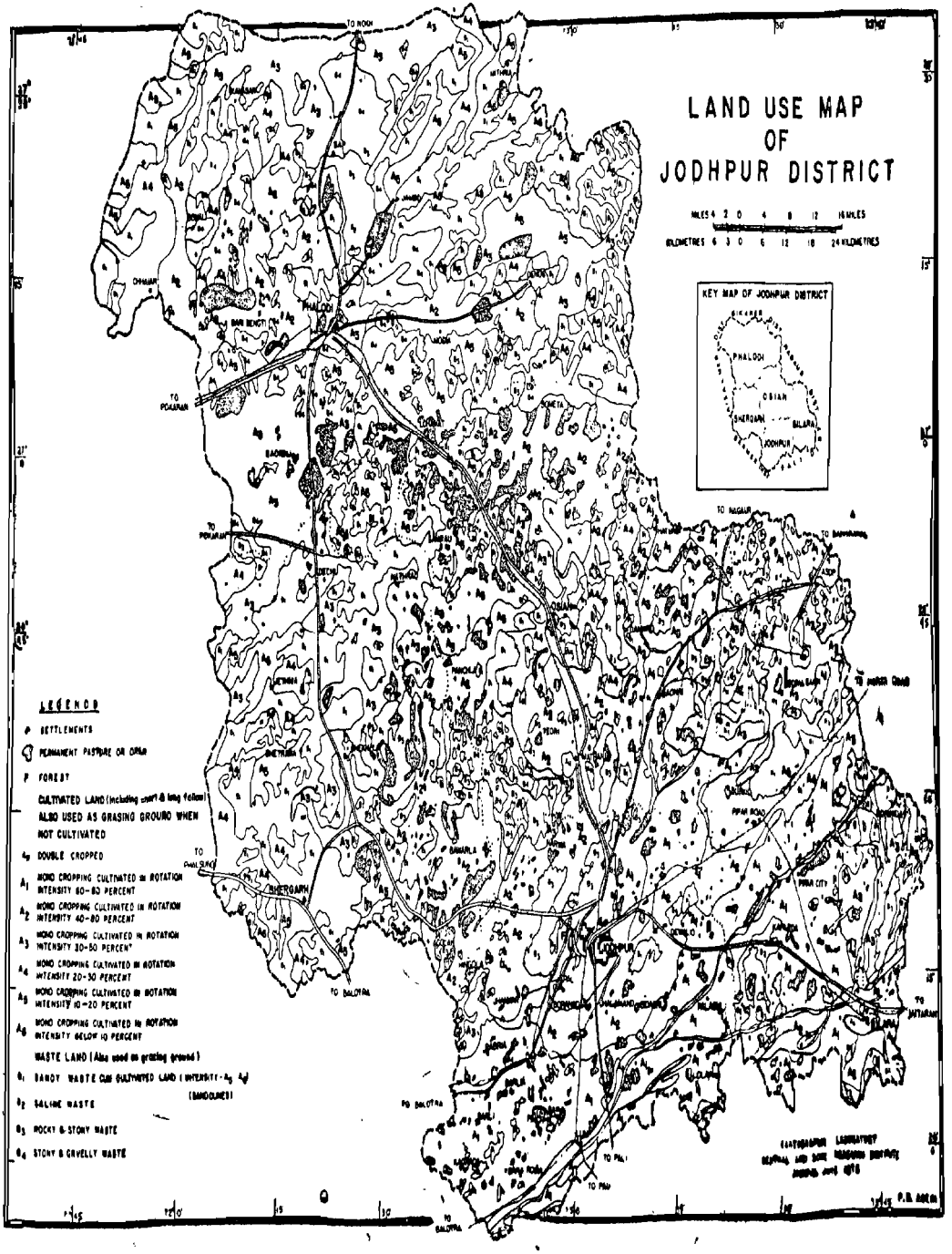

LAND USE MAP
OF
JODHPUR DISTRICT
MILES 4 2 0 4 8 12 MILES
KILOMETRES 6 3 0 6 12 18 24 KILOMETRES
KEY MAP OF JODHPUR DISTRICT
BIKANER
PHALODI
OSIAN
SHERGARH
BALOTRA
JODHPUR
LEGEND
SETTLEMENTS
PERMANENT PASTURE OR GRAZ
FOREST
CULTIVATED LAND (including short & long fallow)
ALSO USED AS GRAZING GROUND WHEN
NOT CULTIVATED
DOUBLE CROPPED
MIXED CROPPING CULTIVATED IN ROTATION
INTENSITY 60-80 PERCENT
MIXED CROPPING CULTIVATED IN ROTATION
INTENSITY 40-80 PERCENT
MIXED CROPPING CULTIVATED IN ROTATION
INTENSITY 30-50 PERCENT
MIXED CROPPING CULTIVATED IN ROTATION
INTENSITY 20-30 PERCENT
MIXED CROPPING CULTIVATED IN ROTATION
INTENSITY 10-20 PERCENT
MIXED CROPPING CULTIVATED IN ROTATION
INTENSITY BELOW 10 PERCENT
WASTE LAND (Also used as grazing ground)
SANDY WASTE CUM CULTIVATED LAND (INTENSITY-
(SANDDUNES)
SALINE WASTE
ROCKY & STONY WASTE
STONY & GRAVELLY WASTE
TO NOKH
TO POKARAN
TO NAGAUR
TO MERTA
TO PHALODI
TO BALOTRA
TO PALI
TO JAITARAN
TO PIPAR ROAD
TO MARWAR JUNCTION
SHERGARH
JODHPUR
BALOTRA
PIPAR CITY
EARTHQUAKE LABORATORY

Fig.1

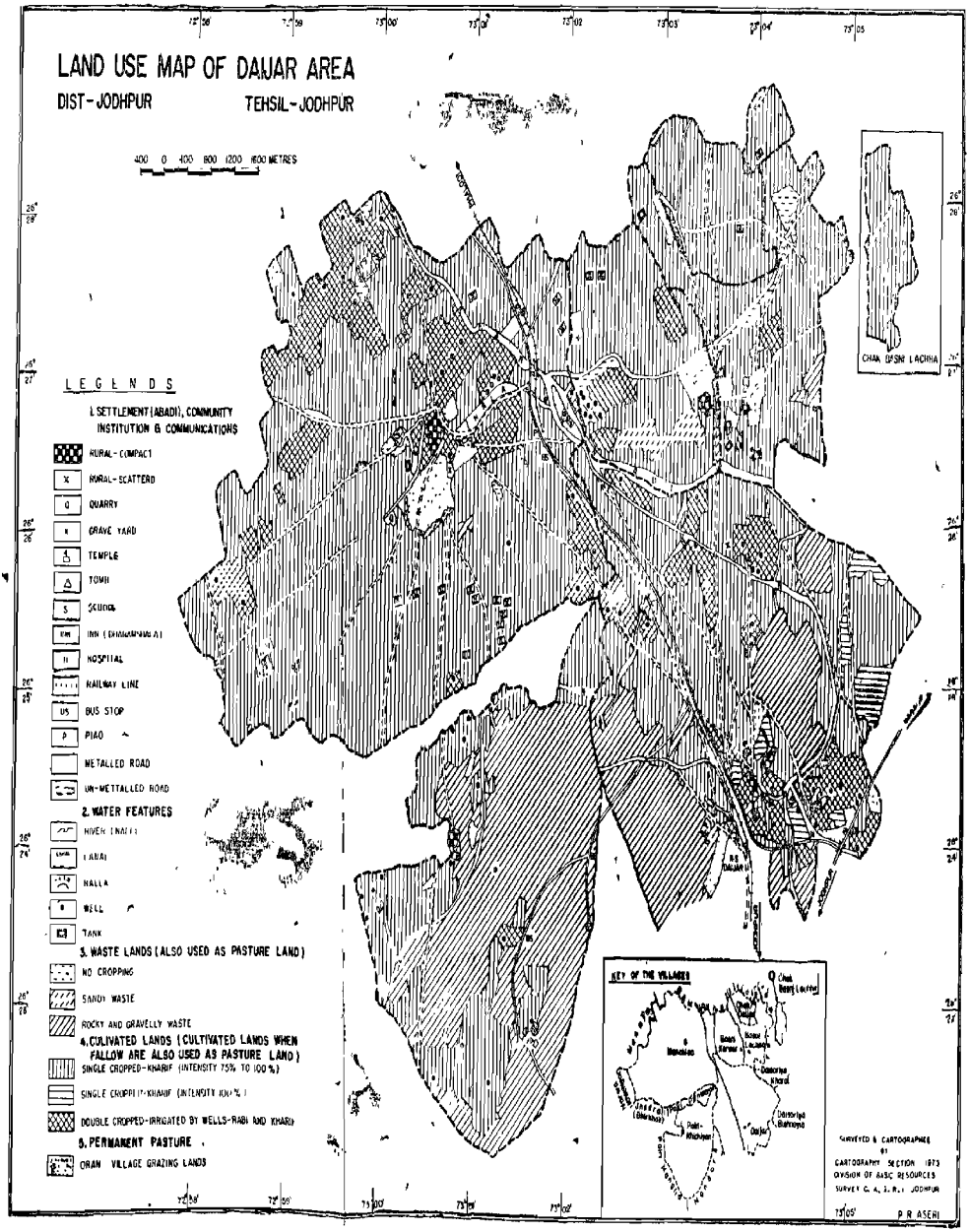

LAND USE MAP OF DAJAR AREA
DIST - JODHPUR
TEHSIL - JODHPUR
400 0 400 800 1200 1600 METRES
LEGENDS
1. SETTLEMENT (ABADI), COMMUNITY INSTITUTION & COMMUNICATIONS
RURAL - COMPACT
RURAL - SCATTERD
QUARRY
GRAVE YARD
TEMPLE
TOMB
SCHOOL
INN (DHARAMSHALA)
HOSPITAL
RAILWAY LINE
BUS STOP
PIAO
METALLED ROAD
UN-METTALLED ROAD
2. WATER FEATURES
RIVER (NADI)
TALAI
NALLA
WELL
TANK
3. WASTE LANDS (ALSO USED AS PASTURE LAND)
NO CROPPING
SANDY WASTE
ROCKY AND GRAVELLY WASTE
4. CULIVATED LANDS (CULTIVATED LANDS WHEN FALLOW ARE ALSO USED AS PASTURE LAND)
SINGLE CROPPED - KHARIF (INTENSITY 75% TO 100%)
SINGLE CROPPED - KHARIF (INTENSITY 100%)
DOUBLE CROPPED - IRRIGATED BY WELLS - RABI AND KHARIF
5. PERMANENT PASTURE
ORAN VILLAGE GRAZING LANDS
CHAK BESNI LACHHA
KEY OF THE VILLAGES
SURVEYED & CARTOGRAPHED BY CARTOGRAPHY SECTION 1973 DIVISION OF BASIC RESOURCES SURVEY G. A. & R. I. JODHPUR
P. R. ASERI

Fig. 2

Table X (*Contd.*) OTHERS (area in sq km and percent)

Tehsil	Oran	Settlement	Forest	Total
Bilara	214.0 (6.6)	24 0 (0.7)	— —	238.0 (7.3)
Jodhpur	246.1 (7.5)	42.0 (1.3)	8.3 (0.2)	296.4 (9.0)
Osian	368.6 (8.9)	85.1 (2.0)	— —	453.7 (10.9)
Shergarh	201.9 (5.3)	51.4 (1.3)	— —	253.3 (6.6)
Phalodi	304.4 (4.0)	34 4 (0.5)	— —	338.8 (4.5)
Total	1335.0 (6.0)	236 9 (1.1)	8.3 —	1580.2 (7.1)

Detailed surveys:

These are necessary for project execution, extension and operational research work. These are carried out on an extensive scale; survey and mapping are exclusively based on aerial photographs. The scale of the base maps is either 1:6,000 or 1:20,000. These bring out all the details including water features, types and nature of settlement pattern, etc. Results of such a detailed survey, in five villages round Daijar, (the area selected for Institute's operational Research work) are illustrated in Table XI and Fig. 2. Even details of 0.5 sq km can be mapped.

TABLE XI

LAND USE UNITS IN DAIJAR AREA (area in Hectare and percent)

(26°22′30″ N to 26°28′30″ N and 72°58′ E to 73°05′ E)

	Daijar	Manaklao	Palri-Khichiyan	Basni Lachha	Basni Kharwar	Total
	1	2	3	4	5	6
Total area in ha	2283.63	2911.72	1440.63	649.92	525.59	7811.59
Settlements	23.72 (1.03%)	33.40 (1.14%)	5.77 (0.40%)	1.86 (0.28%)	11.25 (2.14%)	76.00 (0.97%)
Water Features	82.97 (3 63%)	55 62 (1.91%)	36.72 (2.54%)	29.21 (4.49%)	33.59 (6.38%)	238.11 (3.04%)
Permanent pastures	34.06 (1.50%)	85.31 (2.95%)	15.78 (1.10%)	14.06 (2.18%)	20.00 (3.83%)	169.21 (2.19%)
waste land						
Sandy waste	2.81 (0.12%)	5.47 (0.18%)	—	7.97 (1.23%)	39.06 (7.43%)	55.31 (0.71%)
Rocky & gravelly	407.97 (17.86%)	3.75 (0.12%)	957.36 (66.45%)	13.28 (2.14%)	5.94 (1.12%)	1388.39 (17.77%)
No croping	—	8.75 (0.31%)	—	29.69 (4.57%)	11.40 (2.17%)	49.84 (0.63%)
Total waste	410.78 (17.98%)	17.97 ((0.61%)	957.36 (66.45%)	50.94 (7.8%)	56.40 (10.72%)	1493.45 (19.11%)
Cultivated Land						
Single cropped kharif (intensity 75 100%)	1417.08 (62.05%)	2277.08 (78.20%)	417.50 (28.98%)	538.54 (82.86%)	345.07 (65.64%)	4995.27 (63.94%)
Single or kharif (Intensity 100%)	71.27 (3.12%)	—	—	—	—	71.27 (0.91%)
Double cropped	243.75 (10.69%)	442.34 (15.19%)	7.50 (0.53%)	15.31 (2.35%)	59.38 (11.29%)	768.28 (9.84%)
Total cultivated	1732.10 (75.86%)	2719.42 (93.39%)	425.00 (29.51%)	553.85 ((85.21%)	404.45 (76.93%)	5834.82 (74.69%)

CHAPTER III

Land use Classification in Arid Zone Mapping Units

The efficiency of land use maps depends on a scientific selection of the mapping units. The land use practices differ in different eco-system. The arid zone or the desert has its own problems. Considering these problems (Sen, 1974 a), the mapping units for land use surveys in arid zone was tentatively standardised (Table XII) on the basis of a correlation with the land utilization units classified by other organisations. The scheme proposed was, however, extended to map the land use in different areas of the arid zone since 1972.

The concept of classifying the mapping units depends on following factors:—

i) Assessment of the use and misuse of land.
ii) Visualising the extent and pattern of different types of land use-both agricultural and non-agricultural.
iii) Identification of problems and pinpointing problem areas.
vi) Estimation of the physical and socio-economic aspects affecting the land use.
v) Impact of man on environment.
vi) Suggestion for further improvements.

With the background of these principles, the specific problems of the arid zone were considered to standardise the mapping units for land use survey. The problems of arid zone are many and were well discussed and summarised in the proceedings of the symposium on Problems of Indian Arid Zone (1964, '72). Considering the land use, the problems can be summarised as follows :—

i) Aridity and drought.
ii) Low water table-low fertility of soil.
iii) Absence of surface drainage.
iv) Salinity hazard-increase of salinity with depth.
v) Extensive sandy and rocky lands.
vi) Movement of desert sands and sand dunes.
vii) Sparse and scanty vegetation-absence of forest-less arable land.
viii) Large cattle population and livestock.
ix) Nomadism and semi-nomadism.
x) Temporary and deserted villages.
xi) Absence of fuels.

The following arid zone problems should also be added to this list:—

a) In general the cultivated lands are not regularly cultivated in all the years. Many of the lands are cultivated in rotation after putting into fallows from 1 to 5 years. These are short or current fallows and should be considered as cultivable lands.
b) Many of the lands are kept fallow for lack of water. They are cultivated only in the years of very favourable rainfall. These are long fallows and for mapping purpose should be classed as 'cultivable' in order to avoid survey and mapping in every year.
c) The grazing lands not only comprise the lands under permanent pasture but waste lands and long and short fallow lands as well.
d) The classification of settlements and forests require separate treatment.

All these problems are of unique character, requiring special treatments and necessitating the following demarcations in the land use maps:—

1) *Pasture and grazing land*

a) Permanent pasture
b) Other pasture lands.

2) *Waste lands*

a) Sandy waste

b) Rocky and gravelly waste
c) Saline waste.

3) *Water features*

a) Wells:	i)	Deep,
	ii)	Moderately deep,
	iii)	Shallow
	iv)	Unused;
b) Tank	i)	Permanent,
	ii)	Seasonal
4) Settlements:	i)	Permanent,
	ii)	semi-permanent
	iii)	deserted.
5) Cultivated lands:	i)	permanently cultivaled
	ii)	short fallow
	iii)	long fallow

Considering these problems and on the basis of experiences drawn while conducting land utilization mapping in the arid zone, the scheme for classification of land use units for land use maps as worked out (Table XII) has subsequently been modified (Table XIII).

TABLE XII

TENTATIVE SCHEME OF LAND UTILIZATION UNITS PROPOSED FOR ARID ZONE

1. *Settlement*

A) Rural settlement
   a) Villages with compact settlement (unplanned)
   b) Villages with scattered settlement (unplanned)
   c) Linear compact villages
   d) Temporary villages
   e) Deserted villages

B) Urban areas.
   a) Administrative
   b) Residential
   c) Mining
   d) Commercial
   e) Religious centre.

2. *Water features.*

   a) Rivers
   b) Playas and depression-ssalt lakes
   c) Wells: i) Deep
      ii) moderately deep
      iii) shallow
   d) Tanks: i) Permanent
      ii) Seasonal

3. *Waste lands* (Also come under pasture land)

   a) Sandy waste including shifting sand dunes
   b) Rocky waste
   c) Saline waste
   d) Gravelly waste.

4. *Pasture land and grazing ground*

   a) Permanent pasture (Oran)
   b) Waste lands and current fallows
      (Suitable representation is to be made so that both are indicated)
   c) Hay, thorn, weeds and shrubs-where the grasses are periodically out.

5. *Forest land*

   a) Natural forest
      i) Thin
      ii) Dense
   b) Afforested land
   c) Planation (road side. railway side etc.)

6. *Cultivated land*

i) Single cropped area
ii) Double cropped area
iii) Current and long fallow (also fall under pasture land and grazing ground).

Cultivated lands, as mapped, are not necessarily cultivated each year and include short and long fallows. In order to avoid annual survey and mapping, it has been proposed to map these three categories into one unit. In order to asses the actual land cultivated in general, it has been further decided to classify the cultivated or cultivable lands into sub units according to the intensity of cultivation. This is being done by the calculation, Cropped area/Total area × 100, taking a continuous group of lands as the total area identified as cultivated or cultivable lands. Total cropped area is calculated on the basis of systematic grid sample studies. The pattern of grid is determined by the mapping scale or the extent of cultivated area identified and mapped. This is being followed in the case of detail or detailed reconnaissance surveys. In case of reconnaissance mapping the method of stratified sampling is followed, taking the topographic divisions as the units. The range of cultivation intensity, as tentatively standardised for mapping is presented in Table XIII.

TALBE XIII

INTENSITY OF CULTIVATION

Mapping Symbol	Percentage Cultivable	Remarks
A11	100	Very good intensity, double cropped land.
A1	80 to 100	Good intensity, mostly permanent cultivated lands, also include short fallow.
A2	60 to 80	Cultivated and current fallows. Fair intensity.
A3	30 to 60	Cultivated and current fallow. Moderate intensity.
A4	20 to 30	Moderate to poor intensity. Cultivated, current and long fallows. Marginal lands.
A5	10 to 20	Poor intensity. Long fallows in marginal lands.
A6	Below 10	Very poor intensity. Long fallows.

CHAPTER IV

Aerial Photo-Interpretation Techniques to Prepare Land Use Maps

Basic principles:

For planning purposes a land use map should depict the distribution and extent of different land utilization units of the area under consideration. Field surveys are conducted to prepare such maps. But this is a time consuming device. To expedite the survey and to increase the efficiency of mapping, aerial photographs are now being extensively used to prepare land use maps. Land use mapping concerns the classification of lands according to use. The different land use units can be interpreted in aerial photographs by studying the pattern and variation of the image characteristics of the objects in the photographs. The correct interpretation is based on three basic considerations viz.

a) Similar land use in photographs is likely to appear in similar pattern. Any two land use units arising due to different cultivation practices, like double cropping, irrigation, different crops cultivated or due to grazing, or waste lands derived from rocky, saline or sandy nature of terrain, etc. have similar characteristics and appear in the photograph in similar patterns.
b) Dissimilar land use is likely to appear in dissimilar patterns.
c) Once the photographic images are correlated with the type of land use in field, the sequence of events which form a particular land use unit can often be delineated by means of photo interpretation and many important aspects of land use like cropping pattern or type of waste land or type of settlement, etc. can be inferred.

Successful interpretation of land and their uses entails evaluation of man's adaptation to environment. (Frost *et al.*, 1960). The land use

features of an area are created by human needs and anthropo-geogra phical processes, understanding of which enables the photo-interpre tater to classify land use units according to their properties. Wells for example are constructed in the agricultural lands for irrigation. I the photo-interpretater can recognise the relation between the agri cultural land and the wells, which he can determine by examining the size, shape, pattern and relationship of the wells and lands, he can easily and more efficiently demarcate irrigated and non-irrigated lands in detail. Similarly types and forms of settlements can also be demarcated by studying the relationship and pattern of the images.

Prerequisites:

The mapping of land use requires the knowledge on various land use in practice as well as the terrains and socio-economic conditions of the region under study. To gain knowledge of these aspects is the pre-requisite for photo interpretation for land use mapping. Hence it is necessary—

a) To study the revenue records. This will help to understand the land use system of the region and enable the photo interpretaters to chalk out, in general, the units to be mapped. Photo- interpretaters will, however, work out the units in more details.
b) To study the terrain and socio-economic conditions from existing maps and documents. This will help subsequently to analyse the terrain more efficiently by photo-interpretation.
c) To conduct a rapid traverse throghout the terrain to understand the different systems of land use, so that the tentative mapping units are framed prior to interpretation work.

Photographic-factors:

Choice of photographs: Vertical stereoscopic photographs with 6% side lap and 20 to 30% end lap are used for land use mapping. Vertical photographs are often assembled in mosaic, on which the natural and cultural landscapes of the region can be easily identified and mapped.

It has already been said that the primary technique of photo interpretation for land use is based on image classification of the object.

Hence the photographs which bear maximum contrast in images or total contrasts are best suited for land use studies. Hence photographs with good tone density and adequate tone range are needed. In India, panchromatic photographs taken with a minus-blue filter are used. Colour photographs, however, have proved more efficient in many of the western countries. Infrared photographs are often valuable in demarcating irrigated land and classifying waste lands in details. But in India these two photographs are not still available.

Scale factors:

There is no single scale of photography which will satisfy all the requirements of land use studies. For identifying various detail different scales of photographs are needed. In case of detail land use maps-scale 1:10,000 to 1:25,000 is suggested. In case of semi-detail 1:30,000 to 1:40,000 is recommended. In crop rotation, type and forms of settlement or urban land use is to be shown and the scale should not be lessthan 1:15,000. The scale requirement for various details has been presented in Table XIV.

TABLE XIV

SCALE REQUIREMENTS FOR VARIOUS DETAILS

A. *Cultivated and cultivable features.*

Scales 1:60,000 to 1:30,000

i) Outline areas of cultivated lands including short and long fallows
ii) Outline areas of fenced cultivated lands
iii) Outline general areas of extensive and intensive agriculture.

Scales 1:30,000 to 1:15,000

i) Specific land uses in areas of extensive cultivation
ii) Long and short fallows
iii) Irrigated lands-types of irrigation
iv) Outline areas of double and multiple cropped lands.

Scales larger than 1:15,000

i) Specific crops
ii) Specific use of farm buildings
iii) Types of farming like strip farming, etc.

B. *Waste lands*

Scales 1:60,000 to 1:30,000

i) Outline areas of waste lands
ii) Outline areas of sandy or rocky wastes.

Scales 1:30,000 to 1:20,000

i) Outline areas of saline wastes
ii) Outline areas of gravelly wastes
iii) Water logged areas.

C. *Settlements-rural*

Scales 1:60,000 to 1:30,000

i) Outline areas of transportation by types like railway, canal, road (metalled or unmetalled or foot tract, camel tract, etc.)
ii) Outline of the built up area of villages
iii) Scattered, compact or linear forms of settlements
iv) Planned or unplanned settlements
v) Rural industry.

Scales 1:30,000 to 1:20,000

i) Rural public, semi-public and residential buildings
ii) Forms of buildings or house types
iii) Commercial buildings
iv) Types of rural industries.

Scales larger than 20,000

i) Functional classification of buildings

ii) Identification of different quarters (like *Para* or *Niwas* based on cast segregations or other social factors)
iii) Specific characters of rural non-agricultural features.

D. *Settlement-Urban*

Scales 1:60,000 to 1:30,000

i) Total built up area
ii) Major transportation lines
iii) Major physical characteristics
iv) Hinterlands of the urban area.

Scales 1:30,000 to 1:20,000

i) Total built up area into urban suburban parts
ii) Kinds of transportational areas
iii) Outline of open spaces and recreational areas
iv) Outline of main industries
v) Outline of functional areas
vi) Street pattern
vii) Effective urban area.

Scales larger than 20,000

i) House types
ii) Identification of areas developed in different times-History or time scale
iii) Individual structures and installations.

E. *Water features*

Scale requirement 1:60,000 or more

F. *Forest*

Scales 1:60,000 to 1:30,000

i) Outline area of well defined forests.

Scales 1:30,000 to 1:20,000

i) Thin forest and
ii) Plantation areas.

Stock 1:20,000 or more

i) Stock mapping.

G. *Pasturing*

Permanent pasture (scales 1:40,000 and above)
Others-as in 'wasteland'.

Methods and techniques of photo interpretation for land use mapping

Principles:

The following procedures can be used for land use mapping. At the outset we must remember the following considerations:—

i) All the elements of land are registered on the photographs. Their identifications and interpretations depend on the logical classification of images, which is done through study of the texture (in a photo image, the frequency of changes of tones is called 'texture', some descriptive objectives are fine, medium or coarse) and structure (this refers to the arrangement of dot particles or tones; descriptive adjectives are like stippled or mottled) and form of the images (photo image-the representation of an object produced by optical or chemical means or both) and their correlations. This study–study and correlation of structure and texture of the images or variation of tones is often called *'edge gradient'* study (Rabben *et al.*, 1960).

ii) Certain aspects can be identified directly from the photographs and the others are deducted by systematic studying and correlating the photo elements of the images, like shape, size, tone, height, shadow, relationship, images, etc. The identification of problems through this system of interpretation is know as 'direct' interpretation. This is also known as function of *'fishing expedition'* and *'brobability* (Rabben *et al.*, 1960).

iii) Many objects are interpreted and identified by means of logical search and resorting to probabilities by studying and correlating photo-elements and existing knowledge and documents. This comes under the study of *'indirect'* interpretation and is know as *convergence of evidence* (Rabben *et al.*, 1960).

iv) Photo interpretation or photo mapping does not mean complete elimination of field work. Sample checking is always necessary.

The study of land use is mostly 'direct', but indirect analysis is also needed to identify and interpret many a items like types of settlements; cropping practices, etc.

Handling of photographs

a) In the first step the aerial photographs in question should be studied. A mosaic, preferably semi-controlled, is always helpful. A good practice is to lay down overlapping run of the photographs and to scan the group before stereoscopic examinations.

b) Second practice is to delineate effective area (Rabben *et al.*, 1960) of photographs, which included all images closer to the centre of that photograph than to the centre of the other. It is the area in which objects can be viewed with the least relief displacement. This is generally done by radial line or slotted template methods. In traditional surveys, only the middle section of each photograph is used. In order not to damage the photographs, transparent overlays are used as working map for plotting.

Now the photographs are ready for stereoscopic analysis to classify and interpret the images.

Study of Regional aspects

First task is to analyse and classify the regional aspects in the photographs and to prepare a map accordingly. A physical map or an erosion map or a slope map can be prepared. The identification of these are important as they have significant bearings on land use practices. Similarly drainage maps, including wells and canals may also be prepared. This has a bearing to understand the irrigation practices in the area under question. The climate of the area is known or to be

obtained from literatures. The influence of climate is evident in aerial photographs in erosional, drainage and vegetation patterns.

To sum up, in this group of study a photo interpreter is involved to get himself acquainted with the factors affecting land use. Most of the items or informations are to be obtained from the study of the existing literatures or maps, but many of them can be studied also from aerial photographs. It is, however, essential to work out the different relief features from the photographs as the land use often differs in different physiographic units.

Study of pattern elements

Having thus classified a regional unit, which has the most significant bearing in land use of the area under question, the photo interpretater should study the broad local pattern to classify the major land use groups. In reconnaissance mapping the unit as a whole is considered but in case of detail or detailed reconnaissance mapping, often a grid is employed (grid is proportional to scale of map to be cartographed) to study in more details. Agricultural lands are often distinguished by "check board pattern" which indicates the individual holdings. Similarly, "check board pattern" with wells or channels indicates irrigated crop land. Built up areas or settlements are distinguished from density pattern. Radial pattern of roads help to identify trading or marketing centres. Waste lands can be distinguished on the photographs by lands covering small or large areas in a continuous manner having irregular or diffused boundary. Permanent pasture lands or *orans* are often marked by a pattern having irregular or traingular boundary. Urban areas are often marked by pattern having sharp angular corners.

In short, several patterns can be distinguished in photographs which can be easily delineated. Each pattern element suggests certain land use. The type of land use can often be deduced directly by 'fishing expedition' or 'probability' techniques. Alternately, a 'key' for the patterns identified on a 'transect' or sample basis and thus a broad reconnaissance photo map of land use can be made (Sen, 1972; Sen and Gheesa Lal, 1974).

Study of photo-elements

In this stage, the photo-interpretation is involved to classify and analyse the images in details in each 'pattern' as distinguished in the

first interpretation. Here, we are to deal with logical classification of images for which a careful stereo-study is needed. A mirror stereoscope with binocular attachment should be used for the interpretation work. The photo elements which indicate land use are shape, size, tone and colour, texture, structure, shadow and height, etc. Each element should be studied independently and then correlations of the results are needed. If all the findings agree, then land use can be identified and mapped with reasonable accuracy.

i) *Shape:*

Shape of the image distinguishes orchards, plantations and forests. Shapes of the images are also helpful to distinguish used and unused land and help to identify cultivated and fallow lands, pasture lands having irregular shape.

ii) *Size:*

Size is also an important photo element to identify land use. Irrigated lands are of large size. Regular cultivated fields are large. Size and shape should be studied and correlated carefully.

iii) and iv) *Colours and tone:*

This refers to the brilliance with which the sunlight is reflected and registered in the photo image. Tones are helpful to identify and distinguish cultivated, short fallow and long fallow lands; saline lands; waterlogged areas; recent and old quarters of built up areas in settlements, etc. Saline waste lands can be identified by greyish white or ash coloured tone.

v) and vi) *Structure and texture:*

This refers to the rapid alteration of colour tone and arrangements of dots and are very helpful to identify many difficult items. With the correlation of structure and texture of images, it is possible to identify even, one year, two years or three years fallow lands. These enable us to classify short and long fallows. Through

the study of structure it is possible to classify rocky and gravelly waste lands. Texture is a good indication to classify saline and sandy waste lands, shrubs and woodlands, etc. For forest classification (medium, dense, thin), these photo elements give good indications. Terraced lands can be identified by analysing structure of the image.

vii and viii) *Shadow and height:*

Heights and shadows are important to distinguish orchards, plantations or forests. It is also helpful to identify different crops when aided with shape and size study. Thus sugarcane, rice, bajra, etc. can be easily distinguished in medium scale photographs. Shadow helps to determine the height of trees and give indications to classify forest lands.

Correlation of the photo elements:

Correlation or the relationship of the images and other objects of the photographs like roads, etc. is to be made after all the photo elements described above are studied. By correlation we may reach to an accepted agreement. Different crops require different management practices. This is often reflected in the sizes, shapes and arrangement of the fields. The irrigated crops, downstreams of tanks and around shallow wells or tubewells can be recognised very easily in this way. Orchards or cultivation of vegetables around settlements can also be distinguished in similar way. Recently, reclaimed areas have regular shape and size. Terrace contour bund fields can also be identified by correlation work.

It is necessary to prepare photo interpretation chart for verification, if required.

Key:

When the above interpretation is completed, it should be checked with literatures and legends prepared earlier for verification and corrections. The images identified along with the type of land use deducted for each image should be charted or drawn up to prepare the key of

the interpretation. This 'key' is required to be verified in the field on 10% sample basis in case of detailed reconnaissance and 15% in case of detail mapping. Random sampling is done in case of reconnaissance mapping. The sampling may be done along transect lines. This however depends on the efficiency and experiences of the interpretaters.

Correlation with field survey:

Field survey is to be carried out only to establish the relationship of the images identified and the corresponding land use on the ground. Once the relationship is established and confirmed, no further field work is necessary. The findings can be extended to areas having similar or identical pattern and photo elements.

Final interpretation and mapping:

The field studies should be followed by final study of the photographs. The previous interpretation is corrected if necessary and completed. The details marked in the photographs along with land use boundaries can be transferred to the base map, if available by vertical sketch master or by similar photogrammetric equipments like radial line plotter, stereotop, etc. In our Institute, we often use a 'musk' and a proportional compass which is made in proportion to the scale of the photographs and the base map (Sen, 1967). If no instruments are available and details are made in all the photographs, map can be prepared by radial line or slotted template method on the same photographic scale. With the help of some 'control points' (control point : any system in a horizontal or vertical position that is identified on photographed and is used for correlating data shown on the photoraph) the planimetric map (a map which presents only the horizonal portions of represented features) prepared by radial line method can be converted into a 'map' having geodetic control. This then can be reduced to the required scale. The map thus prepared, require cartographic compilation and editing for finalisation.

CHAPTER V

Photo Interpretation of Major Land Use Groups in Arid Zone: Standardisation of Photo Images

This chapter deals with the photo interpretation of the major land use units of arid zone, viz. cultivated land, waste land, waste land and sand dunes. On the basis of the land use survey and mapping conducted so far in different parts of arid region of India, particularly in Jodhpur, Jalore, Barmer, Bikaner, Pali, Ganganagar and Nagaur districts of western Rajasthan with the help of aerial photographs, the following photo characteristics of land use are tentatively standardised.

Cultivated land:

In arid zone, cultivated land includes short fallows (current fallow) and long fallows too. Cultivated lands along with short fallows can be distinguished by regular and check board pattern. The photo patterns are very clear. The current cultivated plots have medium to dark tone. In between, lands, having regular and sharp boundaries are noticed in air photographs having light grey to grey tone. These are identified as short fallows. Two or even three tonal variations are marked in these short fallow lands. The slightly heavier tone areas are the lands which have been cultivated in the previous year. The lands that have been cultivated two years back have lighter tone. This has been confirmed from the cultivators and by field investigations. The marginal lands of this check board pattern area often cover large or small areas in a continuous manner. Limit of the area is irregular and they often present diffused boundaries. These are long fallows and practically waste lands. The tone of the image is light grey to

white; it is often bright, the texture of the image is light and structure is often fine. All these are due to the sandy deposits on them. These long fallows are cultivated lands. The cultivation of these lands may lead to the encroachment of sand in the adjacent cultivated land from these areas. This may deteriorate the regular cultivated lands. The irrigated and double cropped areas are marked by dark colour. The presence of wells and extent of distributary channels from the wells help to delineate boundaries of double cropped land and irrigated lands in the photographs.

Waste lands:

Waste lands are surface features of the land and as such they appear clearly in photographs (Moutapa, 1972).

Study of pattern aspects and photo elements enable in the arid zone to distinguish hills, sloping hill sides, gravelly lands, sand dunes and depressional areas in the photographs. These comprise waste lands in Indian desert (Sen, 1972). Uncultivated sandy plains and saline lands can also be identified and mapped by photo-interpretation. In Indian arid zone we have distinguished four types of waste lands-rocky waste, gravelly waste, sandy waste and saline waste. The photographic characteristics of these waste lands are as follows:

a) *Sandy waste:*

Specific photo-pattern is large area covering in a continuous manner often interrupted by hummocks (sand dunes) of varying size. The images are marked by contrasted tones. Sandy plains are best identified by medium grey tones. Sandy hills or dunes are identified by complex or unusual forms. Close examination of stereoscopic pairs are necessary. Dunes are often marked by stippled structure and coarse texture; size and shapes are irregular. Sandy waste lands often indicate diffused boundary. Aerial photographs of desert region will not show vegetative cover on dunes. Dunes are sometimes mantled by grasses which cover darker tones than barren sand. A dune on a sandy plain may appear white against a dark background.

b) *Rocky wastes:*

Image structure is mottled, texture is medium to coarse. Specific photo pattern in large area covering in a continuous manner interrupted by hills and rocky outcrops. Scattered trees and shrubs are identified. Distinct or clear boundary of the unit is often identified. The images presents contrasted colour and tones.

c) *Gravelly waste:*

Specific photo pattern is large or small area in a continuous manner. Tone variation is medium to light. The presence of the gravels are marked by close arrangement of dots—coarse texture in the photo image.

d) *Saline waste:*

It is easier to identify and locate saline wastes on the photographs due to appearance of greyish white or ash-coloured tone of the image as a result of salt formation on the surface of the land. In arid zone the 'playas' or saline depressions often form saline waste lands. These can be easily identified in the photographs.

A survey of waste lands without aerial photographs will be a very costly and tremendous task.

LAND USE OF THE SAND DUNES

In previous surveys, dunes were identified and mapped as sandy wastes, but in actual practice, they are not universally sandy wastes. These are rather often cultivated during rainy season. The active sand dunes are universally waste lands. The stabilised dunes are also often waste lands but the lower and middle flanks of these dunes are cultivated in years of very good rainfall, particularly in rainfall zone of over 200 mm. Long fallows of five years duration in 200 mm - 300 mm rainfall zone and 2-3 years duration in rainfall zone of over 300 mm are evident. Upper flank and crests of the dunes serve as grazing ground of the livestock. Hence, in sand dunes, three land use units viz. cultivated or cultivable (including short and long fallows), sandy

waste and grazing ground can be mapped. But, these details can be mapped only on 1:50,000 scale or above. Such minute details can not also be readily identified by traditional ground survey. This, however, is possible by aerial photo interpretation-particularly 'edge gradient' study. In order to standardise the photo interpretation techniques to analyse the land use pattern of the sand dunes, studies were conducted with aerial photographs in different areas of Jodhpur, south Bikaner and border areas of Nagaur-Bikaner districts. Study areas were selected on stratified sample basis, taking the physiographic regions as the units of sampling. Areas so selected, cover 5 to 10 sq km covering 3 to 5 photographs. This has been evident that systematic photo interpretation enables to analyse and map the different areas of sand dunes according to their present land use. The main findings of the study of poto interpretation has been summarised in Table XV. Another important finding is given below.

Sand dunes in the north western part of Nagaur district; south eastern Bikaner and north eastern Jodhpur are in general cultivated as indicated by the 'check board pattern' of the images in the photographs. Regional and photo pattern clearly indicates the occurrence of dunes at different tiers or elevations. Stereoscopic study indicates the formation of terraces by the dunes. Terraces at 3 elevations in the west and even 4 in the east with narrow interdune lands can be easily identified by direct photo analysis. Terraces are identified by sharp 'break' of slopes with alternate light tones. The check board and grid pattern and rapid tonal variation indicate that these dunes are cultivated since long back. Biotic interference including uncontrolled grazing resulted the wind blown sands to fill up the interdune lands between the initial or original dunes resulting the terrace like formations. The alternate light and dark stipples of the images within the check board pattern along the dunes are noticed. Subsequent field checking reveals cropping of *bajra* by dry farming where the images have light stipple structure in the photographs. The dark stipples having diffused boundary constitute current fallow lands. Sample area analysis or field verification of the findings of the photo interpretation shows only 4 to 5 percent changes of which 90 percent are due to fresh development and only 10 percent due to wrong interpretation.

TABLE XV

PHOTO INTERPRETATION KEY OF THE LAND USE OF SAND DUNES

Land use	Photographs	*Image characteristic of* photographs (aerial)	*Remarks*
Cultivated	Statibilised dunes and sandy plain. Lower and middle flank.	Check board or grid pattern-medium to dark tone-sharp boundaries.	Cultivation is menace to soil erosion.
Short fallow	Stabilised dunes. Lower and middle flank.	Land occurring in isolated patches in discontinuous manner. Limit of the area is regular and presents sharp boundaries—light grey to grey tone.	
Long fallow	Stabilised dunes. Middle and upper flank.	Lands cover small or large areas in continuous manner. Limits of the area are irregular and present diffused boundaries. The tone is light grey to white—often bright-texture of the image is light and structure is fine.	Cultivation should not be practiced which may lead to the encroachment of sands in the adjacent fertile lands and to deteriorate them.
Sandy waste	Unstabilised dunes and marginal lands. Crests, upper flank of stabilised sand dunes.	Land occurring in continuous manner appear white against dark background, limit is irregular and presents diffused boundaries-tone is light grey to white; texture of the image is light and the structure is fine.	Recommended for rangeland.
Grazing land	Unstabilised sand dunes. Crests and upper flank of stabilised and dunes.	Continuous or small areas in isolated patches having sharp boundaries, tone is dark.	Controlled grazing is recommended.

Nomenclature of the Mapping Units for Sand Dunes:

It has now been suggested that the stabilised dunes should not be mapped as sandy wastes. The level on which the land use class of a dune is to be determined should be based on the type of survey and the mapping scale. The detail land use of the dunes should be cartographed only on 1:20,000 and above scale. For detailed reconnaissance survey and mapping following scheme is now being tentatively standardised and followed:

1) The dune areas along with narrow interdune plains, if any, which can hardly be distinguished from dunes, should be demarcated on the base map.
2) The areas demarcated should be traversed systematically along some transects in case of reconnaissance survey and on smaple basis—following a grid—for detailed reconnaissance survey. The gross land use of the dunes are then to be studied. While the study is based merely on eye observation in case of reconnaissance mapping aided by "convergence of evidence" collected by local informations, the semi-details mapping should be based on detail survey of the sample dunes. The type of land use exceeding 50 should determine the land use mapping unit of the dunes. The land use class such determined, should be projected for other dunes of similar occurrence and characteristics.

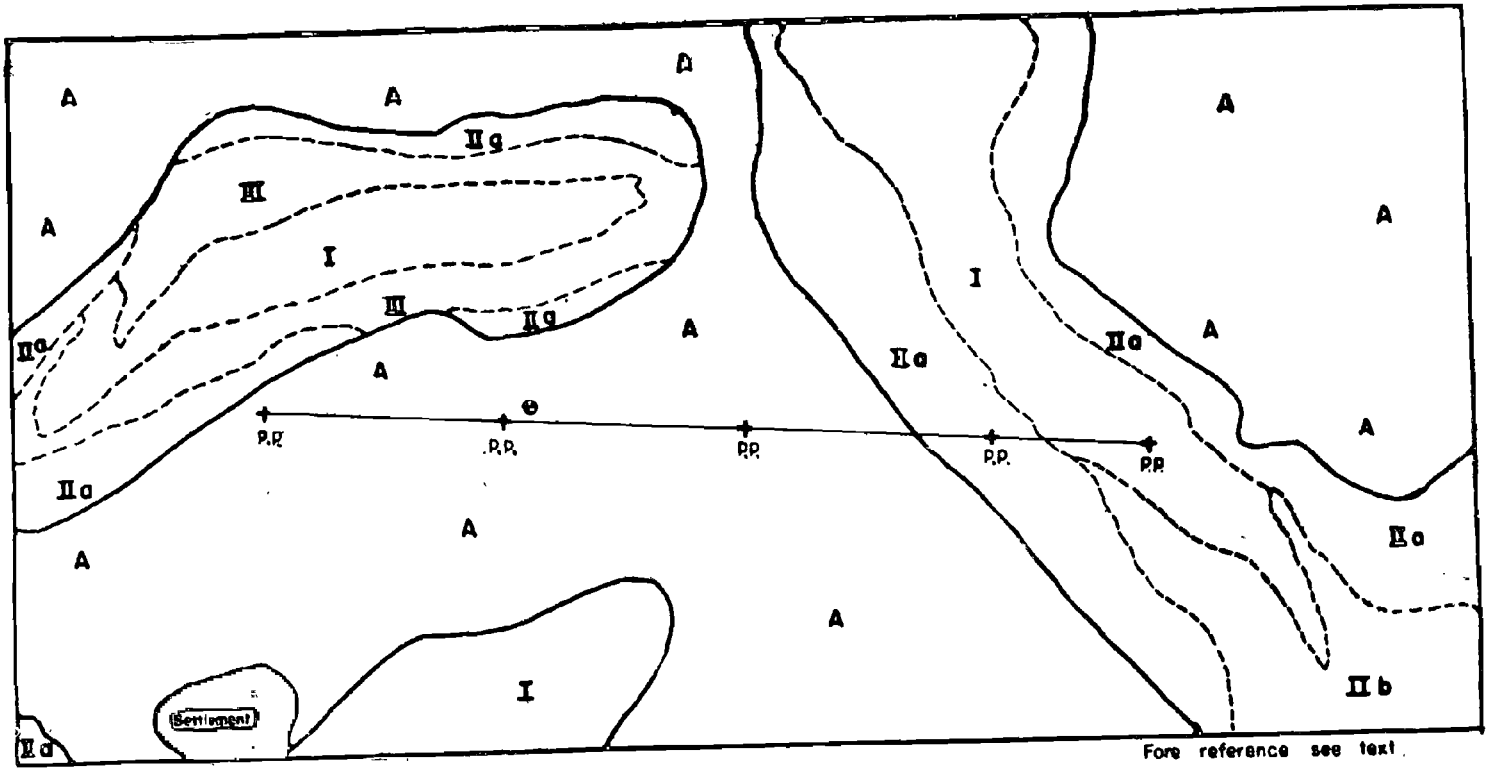
EXAMPLES

A) Figure 3 represents a dune fed tract of the Shergarh area in Jodhpur district. The intensity, degree and extent of the dunes here is very high-being 60 to 80 precent of the area covered by sand dunes. Here, the dunes are all stabilised and located on sandy plains and in the photoraphs appear white against dark background. Specific photo pattern of the region is large area covering in a continuous manner often interrupted by hummocks (sand dunes) of varying size. The images are marked by contrasted tones. Sandy plains are best identified by medium grey tones. Sandy hills or dunes are identified by complex and unusual forms. Images of the dunes are often marked by stippled structure and coarse texture; size and shapes are

irregular. The study and interpretation of the pattern and photo elements of the images indicates the followings:—

1) Areas marked 'I' in Figure 3:—These are continuous areas with diffused boundary. Photo elements do not indicate vegetative cover. The region appears white in the photographs. These are identified as sandy wastes in the field where fresh depositions are still going on.
2) Areas marked as 'II' in Figure 3:—These indicate somewhat check board or grid pattern which however is not very regular. The more regular or clear grids identified are marked as IIa in Figure 3. These are currently cultivated lands. Here, the photo pattern is very clear having medium to dark tone. In between, lands having regular and sharp boundaries, have light grey to grey tone in the photographs. These are identified as short fallows (IIb in Figure 3). The marginal lands of this 'grid' pattern often cover an area in a continuous manner. Limit of the area is irregular and they often present diffused boundaries. These are long fallows (IIc in Figure 3)-cultivated only in the years of very favourable rainfall. The tone of the image is light grey to white.
3) There are also continuous or small areas having sharp boundaries with darker tones than barren sand. This is due to the region being mantled by grasses. Such areas are identified as grazing ground ('III' in Figure 3).

B) Figure 4 represents the land use of the dunes in the border area of N.W. Nagaur and S.E. Bikaner districts. Dunes cover 30 to 50 percent of the total area in this tract. Regional and photo pattern clearly indicates occurrences of dunes at different tiers or elevations. Careful stereoscopic study indicates the formation of terraces by the dunes. There terraces at three elevations with interdune lands are clearly visible in sequence in the photographs (Terraces at different elevations are marked as 'T_1', 'T_2' and 'T_3' and the interdune lands is 't' in Figure 4). The terraces are identified by the sharp break of the slopes in the images of the photographs. Similar terraces are found in adjacent areas also. The appearance of similar morphology indicates that these terraces are of the same origin. The alternate light tones at the breaks of the terraces are observed by stereoscopic examinations and is



(THE BOUNDARIES OF THE DUNES ARE SHOWN BY THICK CONTINUOUS LINES
LAND USE UNITS OF THE DUNES ARE SHOWN BY BROKEN LINES.)

✚ PRINCIPAL POINTS OF THE PHOTOGRAPHS.
PP

A CULTIVATED LAND ON SANDY PLAIN

SCALE 0 3 6 9 12 15 KILOMETRES

Fig. 3

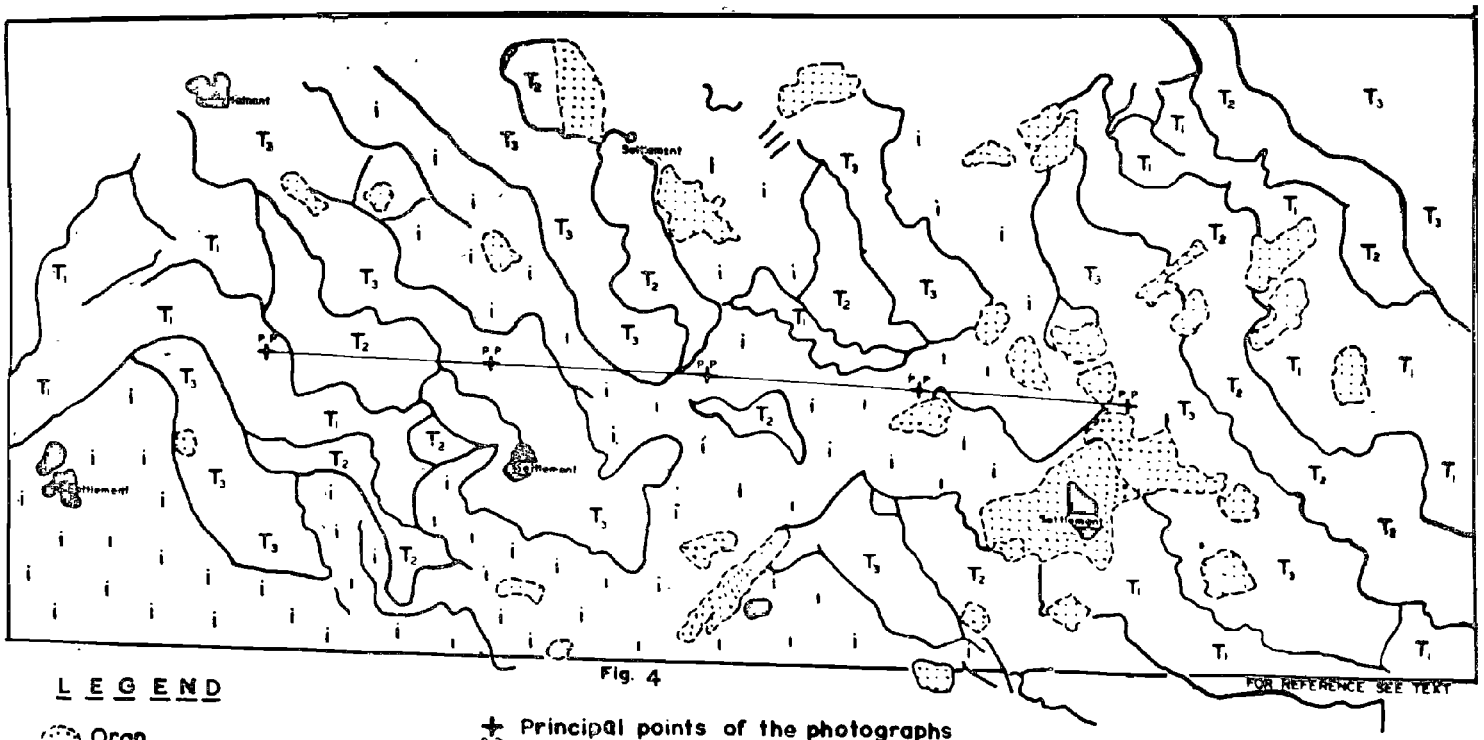


Fig. 4

FOR REFERENCE SEE TEXT

L E G E N D

Oran

Settlement

T_1 Upper Terrace

T_2 Middle Terrace — Sand dunes

T_3 Lower Terrace

I Interdune land (Sandy undulata)

Principal points of the photographs

SCALE 0 3 6 9 12 15 KILOMETRES

due to fresh sand depositions. These dunes are cultivated and this biotic interference resulted the wind blown sands to fill up the interdune lands and to form continuous stretches of sand dunes with the varying elevation resulting terraces.

Photo element studies of the dunes in different terraces indicate the followings (Sen, 1977):

i) Field pattern indicates 'grid' system or check board pattern with alternate light and dark stipples, Subsequent field checking reveals cropping of *bajra* (pearl millet) by dry farming in the areas having light stipples in the photo images. The dark stipples having diffused boundary constitute current fallow lands.
ii) Most of the level land is cultivated land (interdunes).
iii) Marginal lands are continuous with diffused and irregular boundaries and form range lands.
iv) Settlements are clearly seen.

Thus, it is evident that systematic photo interpretation enables to analyse or classify and map the sand dunes according to their present land use. Thus, the dunes in arid zone are often cultivated and not universally waste lands like that of Sahara and Australian desert.

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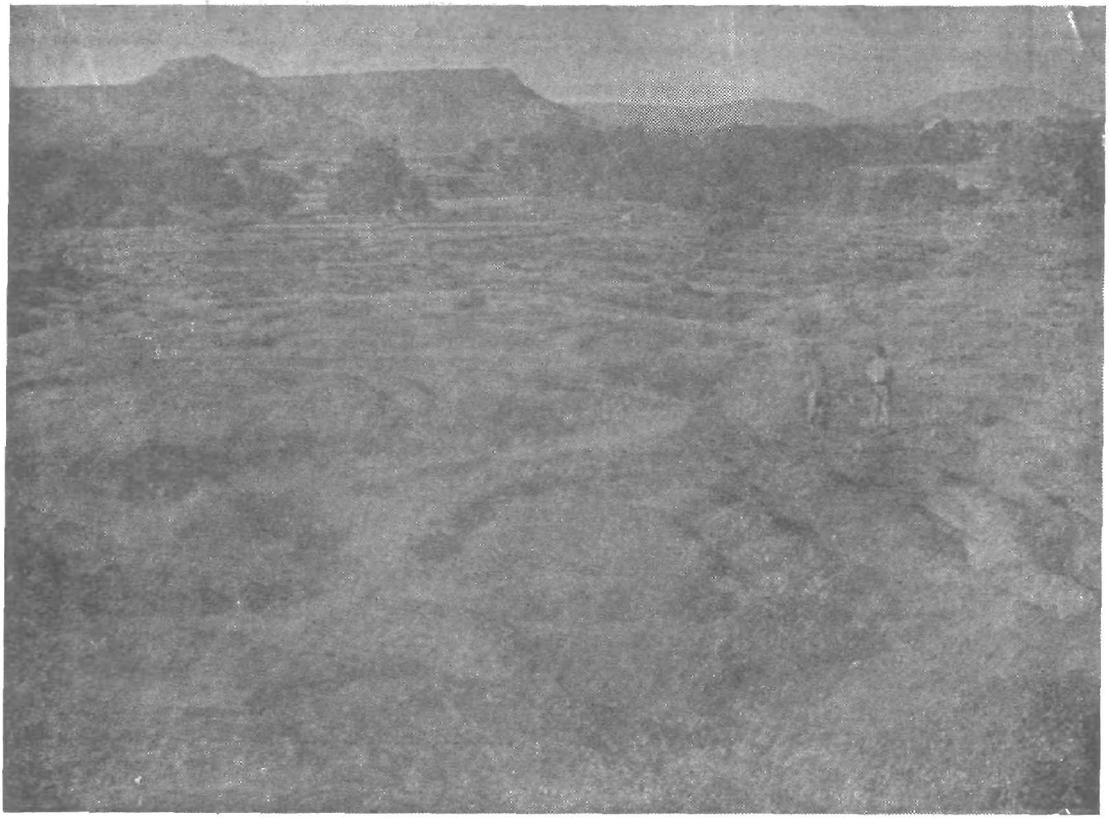
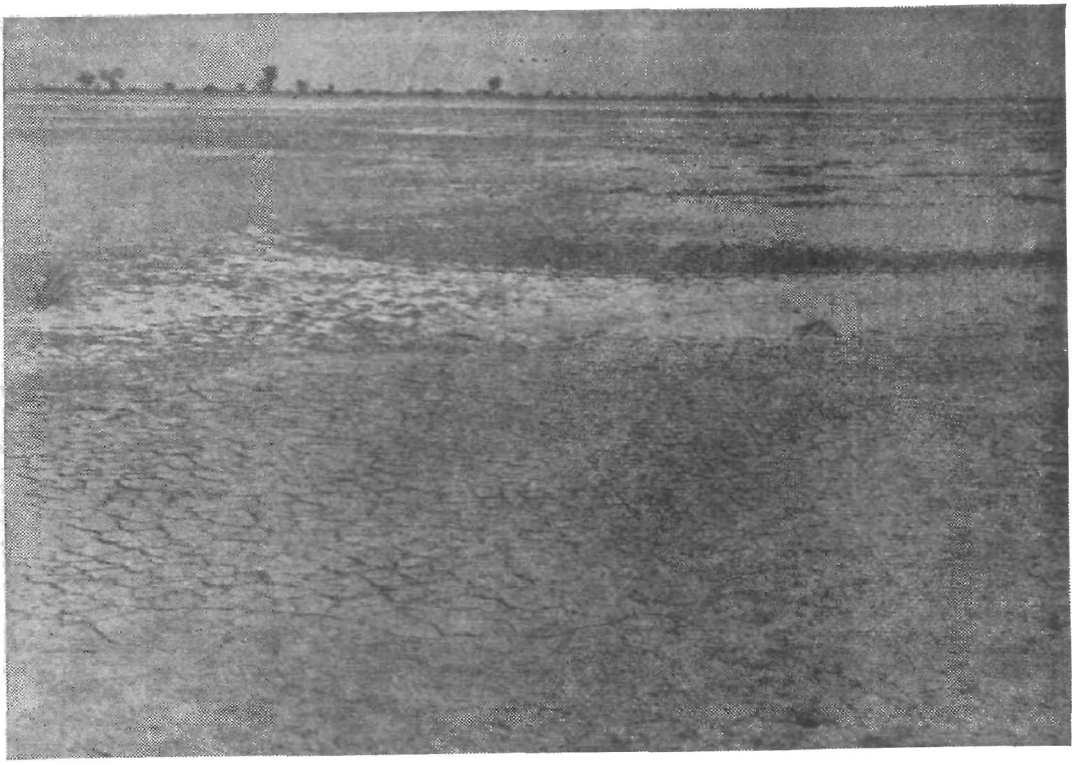
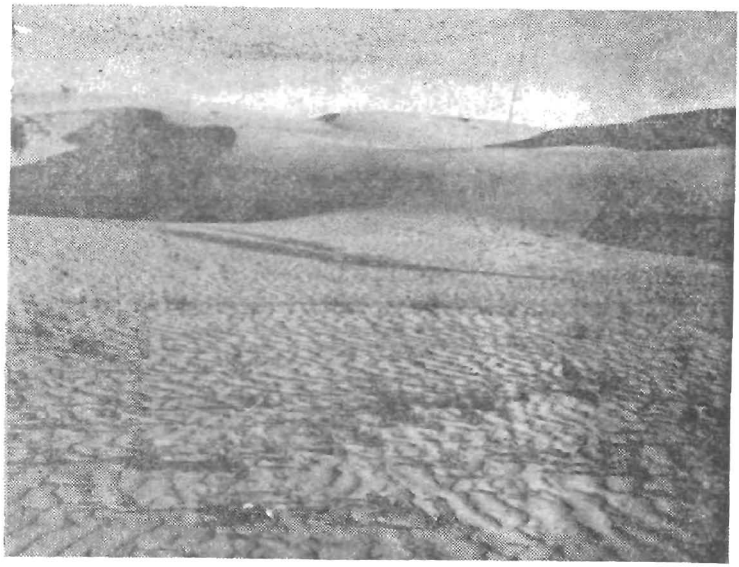


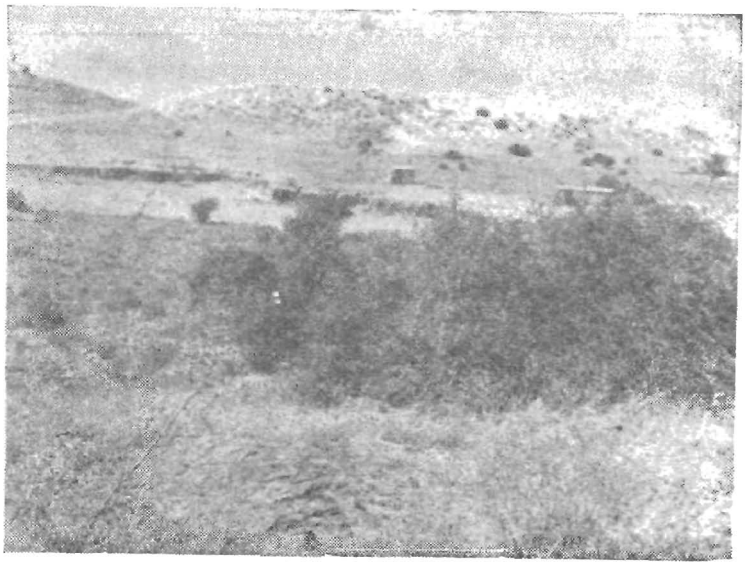
Cultivated lands on piedmont and stony rocky waste on the hills at the back.



Saline waste



Sandy waste

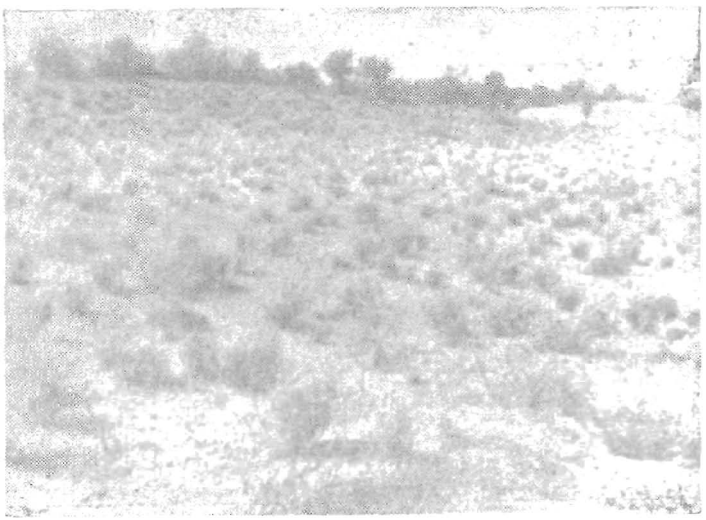


Uneconomic use of marginal lands -a menace of soil degradation and deterioration.

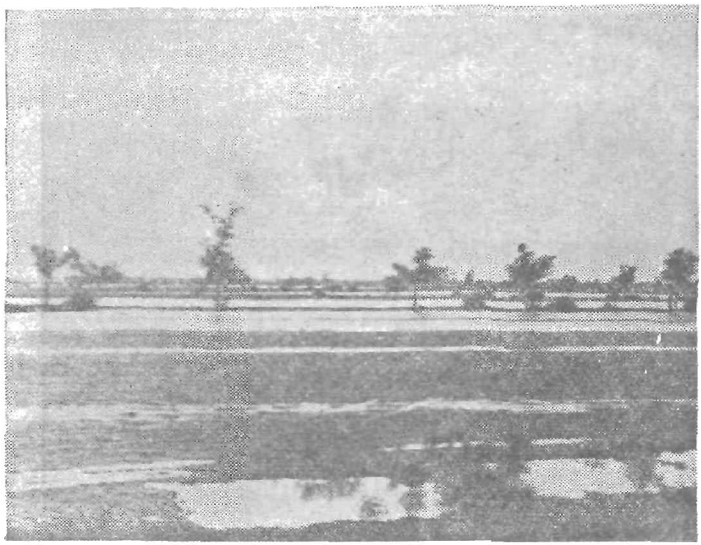
Land use on a stabilised sand dune--grazing and sandy waste.

Rocky waste (hills)-marginal land and long fallows.

Permanent pasture (*Oran*).



Long fallows and pasture land.



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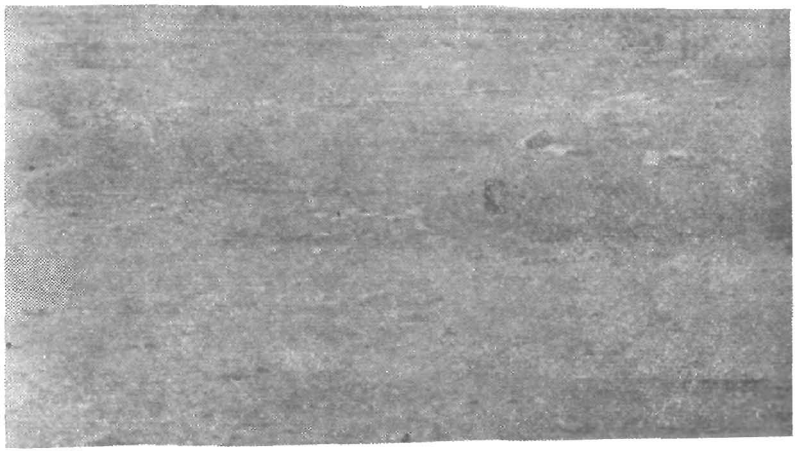

Gravelly waste.