

Durham E-Theses

Soils and agricultural development in the region of Al-Qassim, Saudi Arabia

Mohammed Abdullah Al-Jerash

How to cite:

Al-Jerash, Mohammed Abdullah (1968) Soils and agricultural development in the region of Al-Qassim, Saudi Arabia. Masters thesis, Durham University.

Use policy

The full-text may be used and/or reproduced, and given to third parties in any format or medium, without prior permission or charge, for personal research or study, educational, or not-for-profit purposes provided that:

- a full bibliographic reference is made to the original source
- a <https://etheses.durham.ac.uk/id/eprint/10402/> is made to the metadata record in Durham E-Theses
- the full-text is not changed in any way

The full-text must not be sold in any format or medium without the formal permission of the copyright holders.

Please consult the [full Durham E-Theses policy](#) for further details.

ABSTRACT

The process of agricultural development and its related problems is a serious economic difficulty facing the developing countries throughout the world. In Saudi Arabia such difficulty is greatly amplified by the almost total lack of comprehensive research and studies about the physico-economic elements of agriculture, notably the soil and its related problems and measures of improvement and conservation. The region of al-Qassim is one of the most important agricultural areas in Saudi Arabia. The region is of an area of 17,800 square kilometres with 84,000 hectares of arable lands. The importance of the region as a crop producing area in Central Arabia has been greatly amplified by the discovery of artesian water, in 1953, in quantities estimated to be sufficient to support all the arable lands in the region for many generations to come. The recent completion of al-Qassim highway, in September, 1967, which connected with the great highway of Arabia - from Dammam on the Arabian-Persian Gulf to Jeddah on the Red Sea - has added a significant economic importance, by breaking down the region's geographical isolation, imposed by the surrounding sand-dunes. These favourable physical requirements for promoting agriculture are allied to the ever increasing demand for a more valuable and diversified diet by the expanding urban population as a result of the increasing rise in the standard of living due to the increased national income from oil revenues. As a result a remarkable expansion in cultivated areas and correlated agricultural activities has evolved. The change from an agricultural economy based on a semi-subsistence type of agriculture dictated by a shortage of irrigation water to a water-surplus economy

characterized by market-orientated production was rather sudden, quick, and unprecedented by appropriate studies and plans. Over the years, these random efforts of expansion have produced a complex of intercalated soil and agricultural problems. This research is dedicated to give a preliminary account of the soils and agriculture in the region. A vital conclusion concerning the soils, however, is that the region's soils comprise a sizeable proportion of alluvium soils of highly promising prospects within the wadi and Qaa associations. Agriculture has been approached through two themes: firstly, the pattern of agricultural production and its related land system, method of cultivation, and marketing processes, and, secondly, the problems facing agricultural development at the present time, namely, labour shortage and mechanization, irrigation system, structure and methods, and plant and animal disease control.

SOILS AND AGRICULTURAL DEVELOPMENT
IN THE REGION OF AL-QASSIM, SAUDI ARABIA

BY

MOHAMMED ABDULLAH AL-JERASH

(B.A. UNIVERSITY OF AR RIYADH, SAUDI ARABIA)

The copyright of this thesis rests with the author.
No quotation from it should be published without
his prior written consent and information derived
from it should be acknowledged.

THESIS SUBMITTED FOR THE DEGREE
OF MASTER OF ARTS, DURHAM UNIVERSITY

SEPTEMBER, 1968

PREFACE

The prime aim of this thesis is to study the relations between man and land in the al-Qassim region, Saudi Arabia. The method of approach adopted is to study one of the basic resources of the area, namely the soil, and to analyse the agricultural problems which need to be tackled before a more rational agricultural economy is achieved. Recent changes in the availability of farm inputs, notably the tapping of vast new supplies of artesian water for irrigated agriculture, have altered the traditional agricultural techniques of the region. New agricultural problems have arisen as increased water availability has changed the infrastructure of a traditional and stable agricultural economy.

The work for this thesis commenced in October, 1966 and finished in September, 1968. The period from July to November, 1967 was spent in Saudi Arabia and mostly in al-Qassim, during which time the field work was conducted. The whole of June, 1967 was spent in Rome where the writer had many interviews with various specialists of F.A.O. The writer was able to spend most of the time in the organization's central library and to consult all the available reports and documents on the status of water and agriculture in Saudi Arabia, as well as many neighbouring countries. The outcome of this short visit has had a tremendous effect on the general plan and theme of this study.

Acknowledgments

I am indebted and grateful to King Abdul-aziz University of Jeddah, Saudi Arabia for its moral and financial support during the study period. I also would like to acknowledge the sincere interest, constructive attitude, and unflinching

patience and guidance of my supervisor, Dr. K. Atkinson. My thanks are also due to Professor W. B. Fisher for giving me the chance to conduct this study in his department. I would like to record my grateful thanks to the officials of the Ministry of Water and Agriculture in Saudi Arabia for their helpful co-operation, notably His Excellency the Minister, Mr. Hasan Meshary for his encouragement and generous co-operation which resulted in ready access to all technical files, documents, and reports of the Ministry. Moreover, his help was extended to the field by providing accommodation and transportation facilities. I am grateful to Mr. Taher Ahmed Obaid, the Minister's secretary, for Technical Affairs, for supplying much technical information and data. Also, I would like to extend my thanks to the heads of the Field Extension Services Centres in al-Qassim for their kind co-operation and help in the field. I would like to record my grateful thanks to Dr. D. Burdon, the Director of the Land and Water Resources Branch of F.A.O. and to Dr. R. Budal, the Director in charge of the World Soil Resources Office of F.A.O. and to Dr. V. G. Cervi the Chief of Information Liaison Section of F.A.O.

Finally, I should like to thank my fellow research students, and technical staff in this department for their sympathetic encouragement and many useful comments.

MOHAMMED AL-JERASH

DURHAM, U.K.

SEPTEMBER, 1968.

INTRODUCTION

Studies of soils as related to agricultural development, and vice versa, are of acute necessity in the developing countries throughout the world. This is because of the lack of knowledge and research assessments on such aspects in these countries. This is often a result, in one way or another, of the socio-economic complex of those countries. This certainly applies to Saudi Arabia where socio-economic factors have retarded studies on the soils and the agriculture. Even after solving the economic difficulty to finance such studies, since the early 1950s through the ever increasing oil revenue, Saudi Arabia has failed, so far, to keep pace with the development studies of its agricultural economy. This failure is, undoubtedly, due to a complex of social and political factors, which are beyond the scope of this study.

The severity of such a shortage in agricultural planning studies is well demonstrated by the fact that there is, so far, no comprehensive study or maps of soils nor socio-economic statistical data for the agricultural areas in Saudi Arabia, apart from wadi Jizan area (south-west of Saudi Arabia) where preliminary soil and capability classification studies were conducted by F.A.O. in 1952.

However, a kingdom-wide master plan for water, soil, and agriculture potentiality studies was initiated in 1965. According to this plan the kingdom is divided into eight areas and each was given to international engineering consultants to investigate and report on the natural potentialities of those areas. It is expected that the first results of these studies will be available by the end of 1968 and the latest around early 1971. Such results will constitute a sound and very valuable base of information for any specific further detailed studies.

The region of al-Qassim occupies the northern part of Najd, the central and dominant plateau in the Arabian Peninsula. It extends between Latitudes $25^{\circ} 30'$ N. and $27^{\circ} 00'$ and between Longitudes $43^{\circ} 00'$ and $44^{\circ} 30'$ E. (Fig.1). This part of Najd is of a relatively low relief and forms an extensive basin. The basin is bounded and penetrated from the east, north-east, and south-east by huge sand bodies; and by the relatively high table lands of the Hail Province on the north, the region of al-Hejaz on the west, and the region of Central Najd on the south. With an area of 18,700 square kilometres, al-Qassim consists of many large penetrating sand-dunes which occupy about 20 per cent of the region's total area.

The widespread aridity, and the simplicity of the sedimentary geologic composition of the region have resulted in a rather simple geomorphic setting, and therefore the influence of these major physiographic elements on the soil pattern is readily studied.

Wadi Ar Rma, the largest wadi in Arabia, which crosses the central part of the region, is the most prominent physiographical feature in the area from the economic history standpoint. It has played significant historical and economic roles throughout the known history of Arabia. The economic role was, is, and will remain of great influence and impact to the extent that the following statement: "al-Qassim is the gift of Ar Rma" can never be inaccurate or misleading. The historical role was facilitated by the simplicity of the wadi terrain and the abundance of water wells along its stream bed which extract the shallow subsurface wadi flood water from the alluvial bed of the wadi. These favourable conditions make the wadi the most proper track for the ancient caravan routes which cross Arabia from east to West - north to south communicating pilgrims and trades to and from the holy lands in the region of al-Hejaz. This phenomenon has

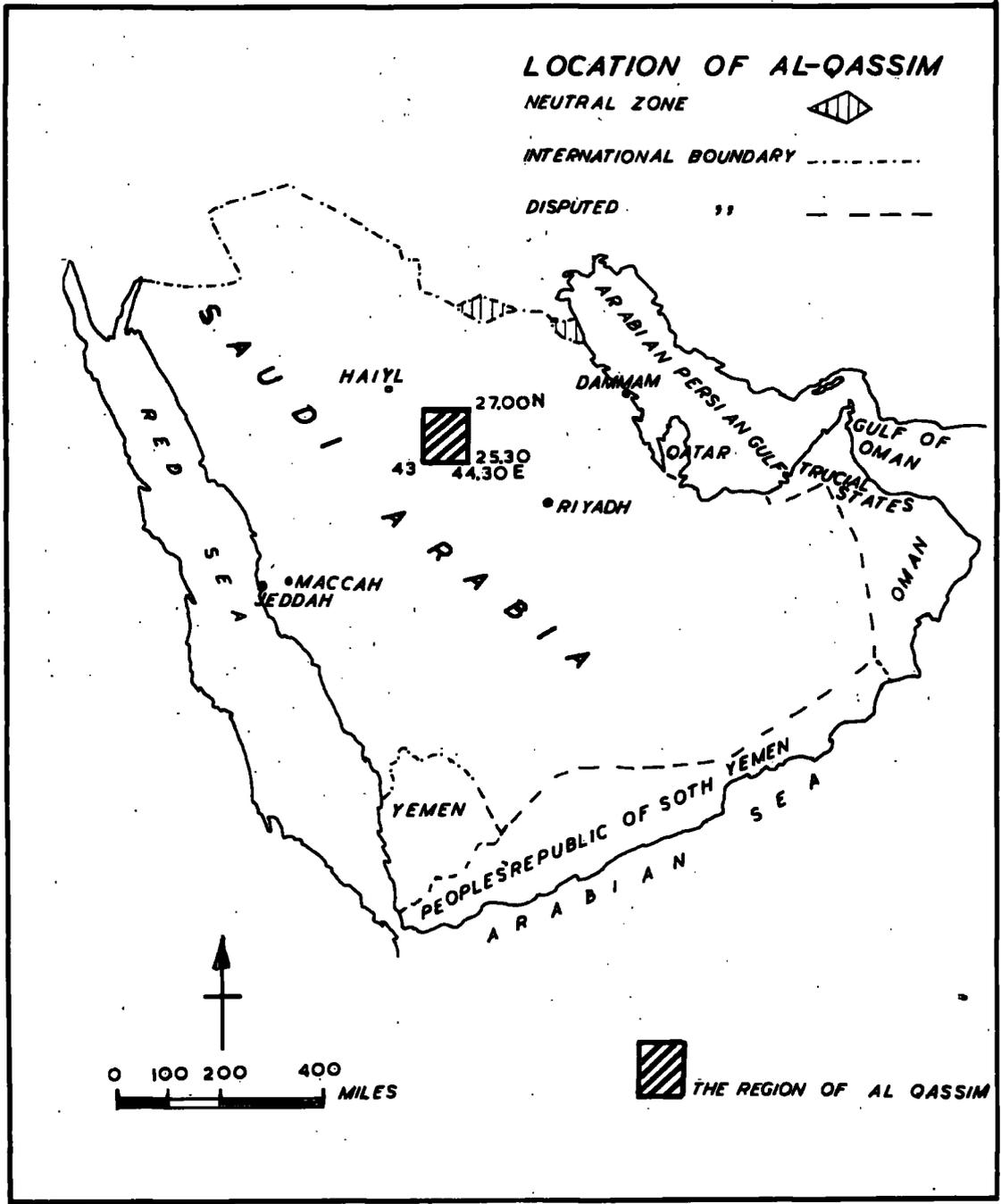


FIGURE 1

has brought about relatively active economic activities and noticeable prosperity to the region's settlements. Consequently, these activities promoted agriculture in the region to a semi-subsistence type of farming at an early date in the history of agriculture in Central Arabia. Therefore, and because of the relatively fertile soil of the wadi alluvium and the abundance of subsurface shallow water, these activities have pronounced effects on the agricultural status in the region, and al-Qassim is considered one of the finest agricultural areas in Saudi Arabia, if not the most advanced. Such a fact has played a significant political role in the history of the region. This significance has been clearly demonstrated throughout the written history of Najd, and the last demonstration was in the recent political conflicts at the time of the establishment of the third and present kingdom of the house of Ibn Saud. The two conflicting parties over the rule of Najd during the 1930s; Ibn Rashid in the province of Hail north of al-Qassim and Ibn Saudi in the region of Central Najd, south to al-Qassim, have realized that the capture and occupation of al-Qassim is the margin between defeat and victory due to its great economic potentiality in terms of food supply capacity for their armies. Therefore, al-Qassim has played a delicate and critical part in the recent political history of Arabia, and the late Ibn Saud succeeded in gaining the confidence of the ruling leaders in the region who accordingly co-operated with him. Then, the resistance of Ibn Rashid failed to delay his final defeat which brought about the end of Aal Rashid rule in Northern Arabia and the start of a new era in the political history of Arabia.

The agricultural prosperity through the years so expanded the population of the region that there resulted an over-population problem, with the limited source of irrigation water in the past inhibiting further expansion in cultivated

areas. Therefore, the Qassim became until recently a depopulation area. In many urban centres in the kingdom, especially Maccah, and Ar Riyadh, complete quarters are occupied almost entirely by the Qassimi immigrants. However, the absolute number of population in the Qassim is uncertain. But, according to the officially unreleased S.P.B.E. (1) census the population number of the Qassim was 222,761 in 1963 which constitutes 6.7 per cent of the kingdom's total population. Taking into account the annual increase of population in Saudi Arabia estimated at an average of 2.5 per cent, the population of the Qassim at the present time is presumed to be about 245,800, a figure which may be taken and considered as a minimum for development planning purposes. The breakdown figures and percentages of the region's population are given in the following table:-

Table 1. The Population of the Qassim

Total population in 1963	222,761
Percentage annual increase	2.5
Estimated total population in 1967	245,886
Density per km.	13
Percentage of male	48.8
Percentage of female	51.2
Percentage of 0-10 years of age	42
" " 10-30 " " "	29
" " 30-50 " " "	19
" " over 50 " " "	10
" " town dwellers	44.3
" " sedentary population	32.3
" " nomadic " "	23.4

(1) Survey of Population, Buildings, and Establishments in Saudi Arabia, 1963. The Central Department of Statistics, Ministry of Finance and National Economy.

MAIN SETTLEMENTS AND ROADS IN THE AL-QASSIM

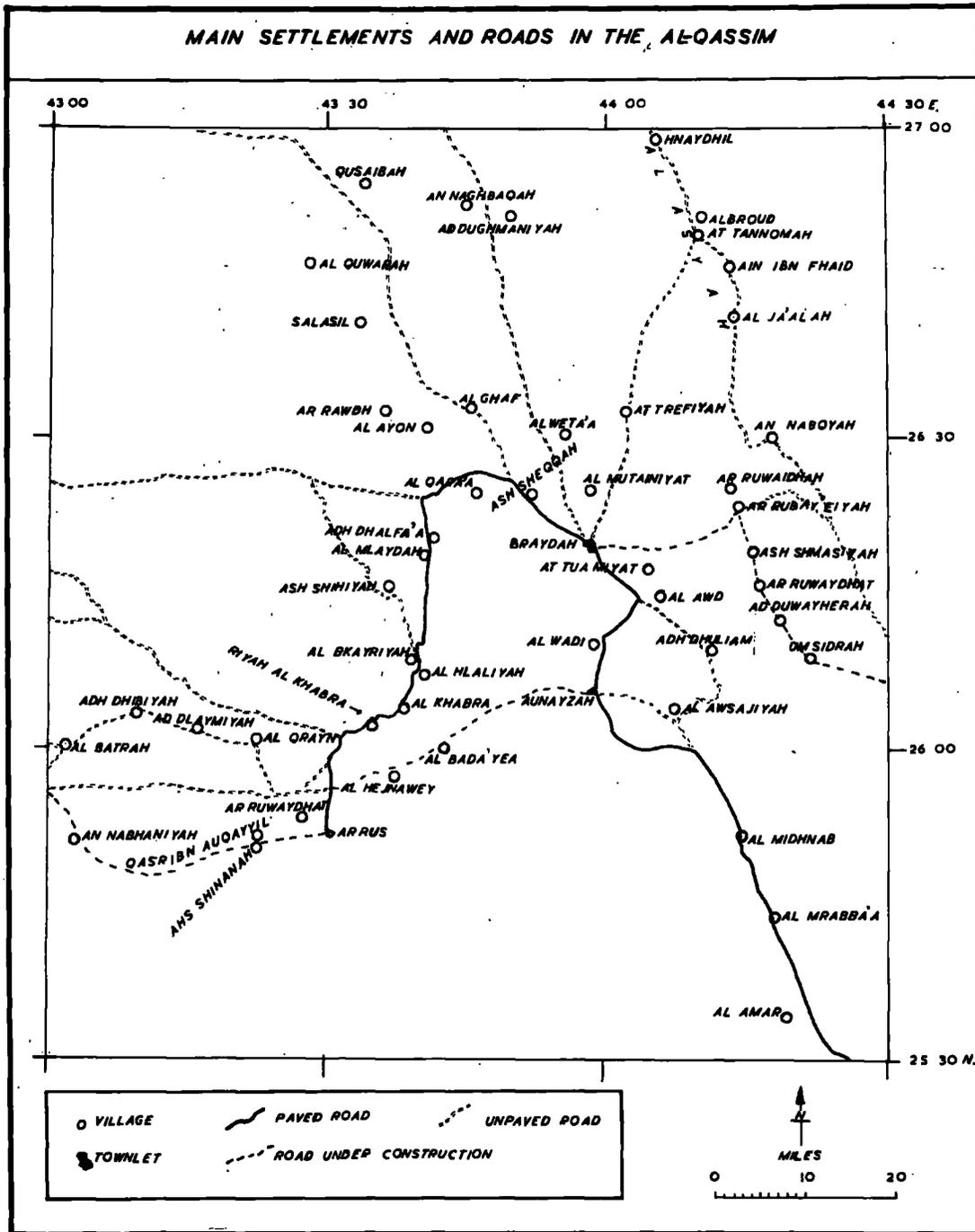


FIGURE 2

Throughout the centuries shortage of water has played a premier role in determining the type of crops, types of farming, location of cultivated areas, and the size of cropped area in the region. Crops were mostly confined to the very staple crops like dates and cereals. Vegetables were grown on a rather small area and confined to limited and unperishable varieties, mainly of the squash group for household consumption. The prevailing type of farming was a semi-subsistence or subsistence in many localities. Water was only abundant along the wadi bed in the shallow hand-dug wells, and thus farms by necessity were established along the banks of the major wadis in the region, notably ar Rma, with a rather small portion of the actual area of holdings being cultivated. These types of farms, producing crops with a very low income, were necessarily of a rather small, simple, and primitive structure. Drainage, soil salinity, and soil water logging were not problems where farms were always under-irrigated. Since the early 1950s. when artesian water was discovered in huge quantities a sudden change has occurred in this simple pattern of farming. More areas were brought under irrigation and agriculture expanded to include other types of soils than the wadi alluvium soil. More water was brought into the old, earthen irrigation system with the grave results of soil water lagging, and soil salinity problems. Farmers who suffered long from the shortage of water to irrigate their lands tend now to over-irrigate their farms. This improper practice is, in fact, a result of the introduction of such abundant flowing water onto the surface without prior research and scientific assessments on the water requirement of the crops and the proper sizes of irrigation channels for the different types of the cultivated soils. Neither has it been preceded by drainage problem studies and plans. These problems have been amplified by the fact that the marketing facilities are those which were

suitable for the very limited market-orientated crop production before the 1950s. These problems have been amplified throughout the years as a result of the rapid but badly planned and organized agricultural expansion by individual enterprises, and by the incompetent services and inadequate development plans provided by the governmental services concerned.

The fact that the Qassim possesses a great soil potentiality with only 38 per cent of the cultivable land being cultivated, the presence of huge quantities of artesian water, and the closeness of the region's location to the vast urban communities of Central Najd with ar Riyadh city, and of al-Hejaz with Maccah and Jeddah, gives the Qassim the most favourable chance to play a major role in the agricultural economy of Saudi Arabia if the present problems can be investigated and cured. Because of this, the writer has chosen to discuss the soils and agricultural problems in the Qassim as the main theme of this work.

The thesis is divided into four parts. Part one includes two chapters. The first (1) is on the geologic setting of the region. The emphases in this chapter are placed on the surface outcrop, and the textural and structural nature of the different geologic formations so as to relate the nature of the soil series composition to them. The second chapter (2) is about the geomorphic features of the area, in which attempts were stressed to show the different settings of the soils which are, in fact, being grouped into associations.

Part two comprises two chapters on climate and water. The first (3) is about the climatic conditions and surface hydrology; the emphases in this chapter are placed upon evapotranspiration, run-off, and recharge capacities in order to correlate them with each other with a view to disclosing the water balance status in the region. This assessment is one of the most vital assessments for soils and agricultural

development practices and plans. The second chapter (4) of this part is about hydrology. As the deep aquifers are the major source of irrigation water and all the future agricultural expansion and activities are entirely dependent on them, the chapter concentrates on the deep aquifers especially on the aspects of their qualities and characteristics.

Part three consists of four chapters discussing the various aspects of the soils of the region. The first chapter (5) of this part is dedicated to the natural vegetation and soil formation factors. Vegetation in the Qassim has an important effect on soil. The second chapter (6) elaborates on soil classification where soils are grouped into four categories, three categories for three identical groups (associations) from the agricultural land use standpoint and the fourth for the agriculturally non-productive soils. The third chapter (7) discusses the soil chemical properties where emphases are placed on the fundamental chemical characteristics of soils, e.g. organic matter content, free carbonate, gypsum, P^H values, and E.C. values, etc., and also the soil fertility and the response of limited various crops to fertilizer application. The fourth chapter (8) is dedicated to land classification aspects; where the discussion is restricted to the arable land classes, deficiencies, and productive capacities.

Part four is allocated to the agriculture in the region. It is divided into two chapters. The first (9) includes a discussion on the pattern of agricultural production in the region supplemented by reviews on land systems, methods of cultivation and types of farming, and marketing conditions and difficulties. The second chapter (10) is confined to discussions on problems of agricultural development, where the following related problems were discussed: problems of labour and mechanization, problems of irrigation, problems

of plant and animal disease control. This final chapter is concluded by a discussion on the future of agricultural development in the region.

Related Previous Studies

Most of the few available studies of geology, soil fertility, drainage and irrigation problems, pattern of crop production and growth, and other related agricultural aspects in the region of al-Qassim are briefly mentioned and discussed in reports concerned with the general agricultural studies of Saudi Arabia as a whole. Most of these studies are, in fact, of a routine administrative descriptive nature with little reference to the real causes of the soil and agricultural problems. Therefore, this research can be regarded as the first comprehensive geographical study of soils and agriculture in the region of al-Qassim as a single geographical unit.

Method of field work

The field work was divided into two stages. Firstly, soils survey and sampling, and secondly, the socio-economic investigation. A preparation for the soil survey was conducted in Ar Riyadh city at the office of the engineering consultants Parson-Basil where the writer was permitted to use the available aerial photographs for the region (stereo scale 1: 60.000 and Mosaic scale 1: 50.000) and use the cartographical facilities available there to delineate the boundaries of the suggested soil associations and to allocate the locations of the proposed sites and the deep pits for soil profile investigations and sampling. 48 pits were located with many intervening auger holes. In the field the 48 pits were dug to an average depth of two metres (plate i), and 12 soil exposures were examined mostly within the wadi and Qaa associations (plate ii). 36 profiles were sampled. The soil samples (totalling 82) were taken to the soil laboratory of the Department of Geography in the University of Durham, and



Plate No.i. One of the examined deep pits



Plate No.ii. One of the examined soil exposures. It represents a dissect phase of the silt loam series of the Wadi association. This exposure is situated approximately 1 km. east of al-Mrabbaa village.

each was given a thorough routine chemical and physical examination. Soil profiles and the surrounding soil morphology were described in standard terms, so that descriptions may be strictly comparable with each other.⁽¹⁾ In general, terms used in the survey follow standard soil profile description designed by the Soil Survey and Fertility Branch of F.A.O., and introduced under the organization's publications series No.29317 titled "Guidelines for Soil Profile Description."

The field investigations concerning farming costs, income, practices, trends of growth, yields per unit for the various crops, etc. were often of a difficult and frustrating nature due to the fact that none of the farmers keep data or information on such matters and farm balance books are not known. Therefore, the use of a systematic socio-economic questionnaire proved fruitless as the majority of farmers failed to answer many queries about the qualities and quantities of their farm production and specific calculations on farm costs and the production balance. Moreover, the existing official information on such aspects is limited in quantity, unreliable in quality, and does not even touch on many important aspects. However, samples of 50 farms for each of the agricultural districts (Fig.28) were adopted for most of the field investigations concerned with the agricultural sector of this study. An even spread of these samples throughout the agricultural settlements was possible due to the availability of transportation facilities provided by the Ministry of Agriculture which enabled the writer to visit almost every single village and settlement in the region.

Finally, although this research has been built basically on raw materials obtained in the field, field information has been supplemented with official statistics. These supplementary data are from various sources, including

(1) Appendix J.

unpublished or confidential material, and personal interviews with top officials of the Ministry of Water and Agriculture. Other sources, particularly those published by the F.A.O., proved of great value in filling many gaps and crystallizing many ideas.

Contents

Preface		i-ii
Introduction		ii-xii
(Part I. The Land. 1-23)		
Chapter 1.	The Geological setting	2-8
1.1	Structural Geology	2-3
1.2	Surface outcrop	3-8
Chapter 2	Geomorphic Features	9-23
2.1	The arid cycle of erosion	9-10
2.2	General land forms in the region	10-11
2.3	West facing escarpment	11-14
2.4	Nufud	14-17
2.5	The gravel plains	17-21
2.6	Wadi Ar Rma	21-23
(Part II. The Climate and Water. 24-44)		
Chapter 3	Climatic conditions and surface hydrology	24-31
3.1	Temperatures	25-25
3.2	Relative Humidity	25-26
3.3	Wind and rainfall	26-27
3.4	Evaporation	27-29
3.5	Run off and recharge	29-31
Chapter 4	Groundwater hydrology	32-44
4.1	Historical background	32-33
4.2	Surface aquifers	33-35
4.3	Deep aquifers	35-36
4.4	Jilh aquifer	36-36
4.5	Khuff aquifer	36-37

4.6	Tabuk aquifer	37-38
4.7	Saq aquifer	38-39
4.8	Aquifers characteristics	39-41
4.9	Water utilization	41-44
(Part III. The Soils. 46-102)		
Chapter 5	Natural vegetation and soil formation	46-52
5.1	Natural vegetation	46-49
5.2	The factors of soil formation	49-52
Chapter 6	Soil classification	53-74
6.1	The Wadi Association	55-63
6.2	The Qa a (Basin) Association	63-69
6.3	The Sahl (Desert Plain) Association	69-74
Chapter 7	Soil chemical properties and soil fertility	75-86
7.1	Chemical properties	75-79
7.2	Soil fertility and fertilizer practice	79-86
Chapter 8	Land classification	87-102
8.1	Introduction	87-90
8.2	Class II lands (CIIL)	90-94
8.3	Class III lands	94-100
8.4	Class VI lands	100-102
(Part IV. The Agriculture. 103-166)		
Chapter 9	The pattern of agricultural production	103-144
9.1	Introduction	103-105
9.2	The land system	105-114
9.3	Methods of cultivation and types of farming	114-124
9.4	Crop production	124-136

9.5	Animal husbandry	136-141
9.6	Agricultural marketing	141-145
Chapter 10	Problems of agricultural development	145-166
10.1	Labour force and farm equipment	145-152
10.2	Problems of irrigation and plant water requirements	152-158
10.3	Problems of plant and animal diseases	158-163
10.4	Future agricultural development	163-166
Conclusion		167-173
	(Appendices 174-220)	
Appendix A:	Glossary of Arabic words	175-176
Appendix B	Climatic data	177-186
Appendix C	Groundwater Hydrology Data	187-192
Appendix D	Vegetation Species Tables	194-199
Appendix E	Soil Chemical Analysis Data	200-204
Appendix F	Summary of arable lands data	205-207
Appendix G	Summary of land holdings in the Qassim	208-210
Appendix H	Agricultural statistics	211-215
Appendix I	Irrigation Water data	216-218
Appendix J	Soil profile descriptions sheet	219-220
Bibliography		221-232

List of Figures

Fig.1	Location of al-Qassim	after page iv.
Fig.2	Main settlements and roads in the al-Qassim	" " vi.
Fig.3	Structural geologic provinces of Saudi Arabia	" " 2
Fig.4	Al-Qassim outcrop sequence	" " 3
Fig.5	Surface outcrop of the geologic formation of the al-Qassim	" " 4
Fig.6	Main geomorphic features of the region of al-Qassim	" " 10
Fig.7	Monthly averages of relative humidity and temperature	" " 25
Fig.8	Temperature averages	" " 25
Fig.9	Relative humidity percentage	" " 26
Fig.10	Monthly averages of evaporation and rainfall	" " 27
Fig.11	Summary of wells inventory in the Qassim	" " 33
Fig.12	Groundwater aquifers in the region of al-Qassim	" " 36
Fig.13	Total dissolved salts in groundwater of the Qassim as related to electrical conductivity	" " 34
Fig.14	Effects of withdrawal of water, Saq-sandstone, Qassim region.	" " 39
Fig.15	Piezometric surface contours of Saq aquifer in the region of al-Qassim	" " 39
Fig.16	Geographical distribution of the soil association, the Qassim	" " 55
Fig.17	Levels of fertilizers applied in the cited experiments	" " 82
Fig.18	Index map of land classification zones, the Qassim	" " 89
Fig.19	Location of arable lands in the region of al-Qassim, Saudi Arabia	" " 90

Fig.20	Arable and non-arable lands percentages	After	page	90
Fig.21	Class II lands	"	"	91
Fig.22	Class III lands	"	"	94
Fig.23	Land classification, the wadi zone, the Qassim	"	"	95
Fig.24	Land classification, Ash Shmaseyyah zone, the Qassim	"	"	95
Fig.25	Land classification, al Asyah zone, the Qassim	"	"	97
Fig.26	Land classification, Qusaiba zone, the Qassim	"	"	98
Fig.27	Land classification, Midhnab zone, the Qassim	"	"	99
Fig.28	Agricultural districts in the region of al-Qassim	"	"	103
Fig.29	Percentages of types of holdings in the agricultural districts, the Qassim	"	"	109
Fig.30	Percentages of cropped areas in the agricultural districts, the Qassim	"	"	125
Fig.31	Percentages of production of main crops in the agricultural districts, the Qassim	"	"	127
Fig.32	Classification of irrigation waters, the Qassim	"	"	153
Fig.33	The water requirements of main crops, the Qassim	"	"	157

List of Plates

Plate i	One of the examined soil deep pits	After page	x
Plate ii	One of the examined soil exposures	" "	x
Plate iii	Hanadir scarp at its point of interaction	" "	5
Plate iv	Fossil wood from Lower Khuff transition zone	" "	6
Plate v	Fossil wood same horizon as above	" "	6
Plate vi	Log of petrified wood, Khuff formation	" "	6
Plate vii	Cross laminated sandstone, upper As Sirr formation	" "	7
Plate viii	Part of Khashm Khurtum	" "	12
Plate ix	Cap rock of Khurtum escarpment	" "	12
Plate x	Another view of Khurtum escarpment	" "	12
Plate xi	Shale bluff capped by hard limestone of Khuff formation	" "	13
Plate xii	A series of shingle-like benches of the back of Khuff escarpment	" "	13
Plate xiii	A remnant of the retreating cliff of Khuff escarpment	" "	13
Plate xiv	Erq al-Madhhur	" "	14
Plate xv	Nufud at Trefiyah	" "	16
Plate xvi	Nufud As Sirr, a view of a radial ridge on sand peak	" "	16
Plate xvii	Nufud Braydah, bordering Wadi Ar Rma	" "	17
Plate xviii	Duricrust, remaining as resistant cap rock	" "	18
Plate xix	Close-up of duricrust, showing spongy, honeycomb structure	" "	18
Plate xx	Al-Mestwey plain, its southern part	" "	19

Plate xxi	Al-Mestwey plain, further north	After page	19
Plate xxii	The complex topography of As Suairah plain	" "	20
Plate xxiii	Same as xxii	" "	20
Plate xxiv	The broad silt belt of the bed of Wadi Ar Rmah	" "	21
Plate xxv	Aunayzah's Meteorological station	" "	24
Plate xxvi	The first flowing artesian bore-hole	" "	32
Plate xxvii	The high-head of the flowing artesian water of the Saq aquifer	" "	38
Plate xxviii	Combination of Ghadha, Nitum, and Rimth shrubs	" "	47
Plate xxix	Art shrubs grown on the sand dunes	" "	47
Plate xxx	Arfaj shrubs on a desert plain	" "	48
Plate xxxi	A load of organic manure	" "	79
Plate xxxii	A storage pit of organic manure	" "	79
Plate xxxiii	Furrow method of irrigation	" "	117
Plate xxxiv	White surface crust of high soil salinity	" "	117
Plate xxxv	The common earthen storage tanks	" "	118
Plate xxxvi	The common wide earthen ditches leading water to the fields	" "	118
Plate xxxvii	The basin method of cultivation	" "	120
Plate xxxviii	Mixed and closely planted fruit trees	" "	120
Plate xxxix	The furrow method of cultivation	" "	122
Plate xl	One of the vegetable growing specialized farms	" "	123
Plate xli	One of the new citrus growing farms, south of Aunayzah	" "	124
Plate xlii	One of the new fruit growing farms, at Ad Dughmaniyat area	" "	124
Plate xliiii	Athl trees as a permanent fence of farms	" "	125
Plate xliv	An example of the unsatisfactory farm service	" "	145

List of Tables

		<u>Page No.</u>
Table 1	The population of the Qassim	vi
Table 2	Soil classification order	45
Table 3	Soil associations' series	55
Table 4	Response values of alfalfa and tomatoes	83
Table 5	Response value of wheat	84
Table 6	Response value of barley	85
Table 7	Barley yield kg/450m ²	85
Table 8	Quantities of organic manure traditionally applied for trees	116
Table 9	Adopted frequency of irrigation water application	119
Table 10	Summary of necessary cultivation practices for female palm-trees	121
Table 11	Estimates of yields, costs, and prices of five major crops and groups in the region	136
Table 12	Rural population of the Qassim	146
Table 13	Peak frequency of irrigation in the Qassim	158
Table 14	Animal diseases in the Qassim	161

PART I

THE LAND

Chapter 1

The Geological Setting

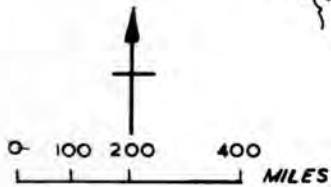
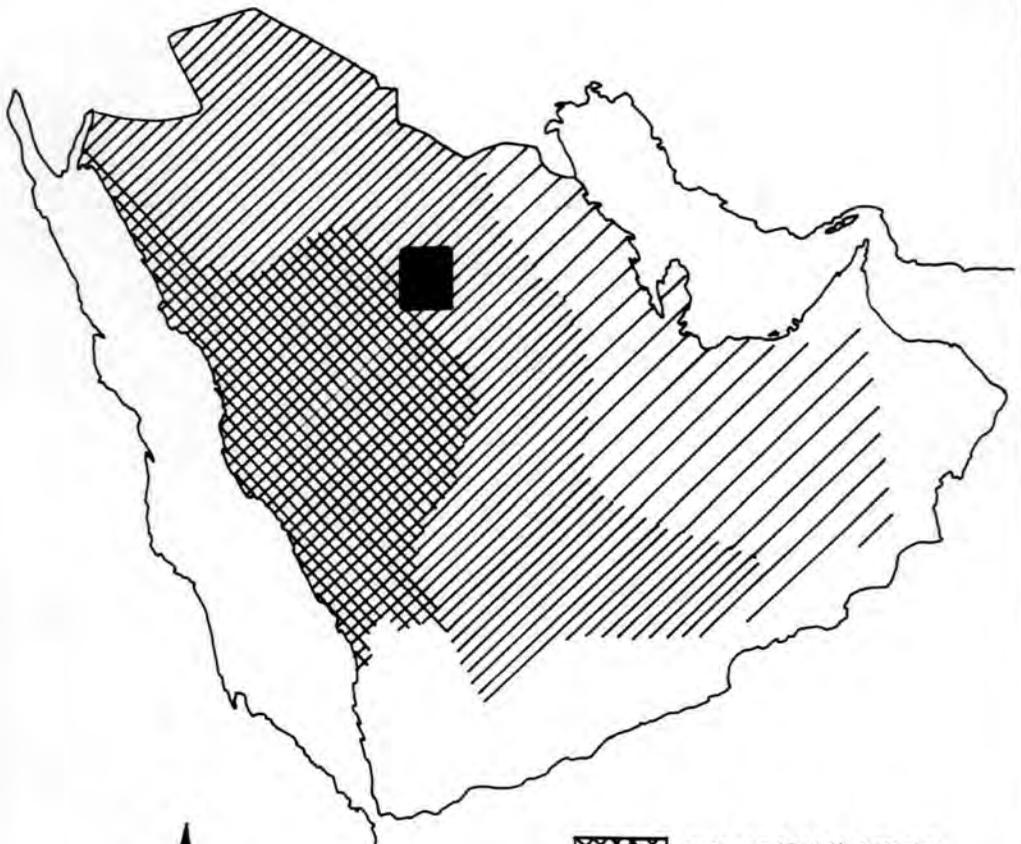
1.1 Structural Geology

Three structural provinces are recognized as the main structural bases of Saudi Arabia (Fig.3). These are the Arabian Shield, the Arabian Shelf, and the Interior Platform. The Arabian Shield occupies the western part of the country, and forms a vast complex of igneous and metamorphic rocks. At the contact point with the next structural unit, the Arabian Shelf, it forms a sharp, sigmoidal-shaped contact zone fringing the south western edge of the Qassim lands. The Arabian Shelf is the second broad division within the stable region of Arabia, and the central, the eastern and most of the western parts of the Qassim lie within it. It is composed of sedimentary rocks ranging in age from the Paleozoic era to the Cenozoic. Limestone is the most striking rock type, but sandstones and shales are present in large amounts and are concentrated largely in the Paleozoic rocks. All units maintain lithologic uniformity over large areas, and where shifts in facies do occur they are usually gradual.

The Interior Platform occupies the eastern part of Saudi Arabia. It forms a broad expanse of relatively low terrain formed chiefly by Miocene-Pliocene rocks. Buried deeply in the Jurassic and Cretaceous strata are the rich oil reserves of Saudi Arabia.

The basic structure of the Qassim is a gently eastward dipping homocline which rests on the stable pre-Cambrian core of the Arabian Shield. Sediments have been deposited along the margin of the Shield in an arcuate pattern concave to the west and roughly concentric to it.

STRUCTURAL GEOLOGIC PROVINCES OF SAUDI ARABIA



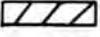
-  *THE ARABIAN SHIELD*
-  *THE ARABIAN SHELF*
-  *THE INTERIOR PLATFORM*
-  *THE REGION OF AL-QASSIM*

FIGURE 3

Gentle epeirongenic movements have been concentrated in an east-west ridge, called the Hufuf Nose, at Latitude 24° N., which roughly bisects the Shield. During early Paleozoic time this zone was a positive ridge in the basement. After its elevation, sediments were removed to permit deposition of Khuff limestone directly on the pre-Cambrian of the Nose during the widespread invasion of Permian seas. The present structurally high position of the Nose is the result of a gradual arching, now evidenced by the slightly steeper dips of the homoclinal beds in the vicinity of the nose.

Further north, the area around Haiyl town (at roughly 27° $30'$ N) has a structural feature superficially similar to the Hufuf Nose. It is known as Haiyl Nose. This Nose was apparently caused by the abrupt south-west curves of the pre-Cambrian contact, which extend roughly north west for 500 km. above the Hufuf Nose, around the precipitous headland of the Ajja mountains, at Haiyl. A broad embayment is known to have extended southward in the region of Haiyl during the Paleozoic era.

The overlying Paleozoic sediments, which have a consistent regional rise of 4° N. 5° W. from Qusaiba (at 26° $50'$ N) north west of Braydah to Baqaa (at 27° $50'$ N.) north east of Haiyl swing gradually west in conformity to the trend of the underlying basement. In the 250 km. between Braydah and Haiyl there is a gradual regional rise in elevation of 200 metres. Structural disturbances in this area are limited to mild tensional adjustment.

1.2 Surface Outcrop

The stratigraphic sequences exposed in the Qassim include formations ranging from the pre-Cambrian basement complex to the Cenozoic sedimentary deposits (Figure 4). The surface outcropping of the geologic formation of the Qassim is of a

AL-QASSIM OUTCROP SEQUENCE

AGE		FORMATION	LITHOLOGY	GENE. LITHO. DESCRIPTION	THICKNESS	MAJOR STRATIGRAPHIC DIVISIONS	
MESOZOIC	QUATER. & TERTIARY	SURF. DEPOS. & BASAL ASSIR FORMATION	[Pattern: Dotted with horizontal dashes]	GRAVEL, SAND, AND SILT	315 m.	PERMO-TRIAS. CLASTICS	
							MINJUR
	TRIASSIC	ASSIR FORMATION	[Pattern: Brickwork]	SANDSTONE, APHAMITIC LIM. ESTONE AND SHALE, SUBO. RDINATE GYPSUM	326 m.	PERMO-TRIAS. CLASTICS	
							JILH
							SUDUIR
	PERMIAN	WESTERN FORM.	[Pattern: Zigzag]	LIMESTONE, SHALE & EVAPOR.	171 m.	PERMO-TRIAS. CLASTICS	
							KHUJF KHURT, SAIDHAB
	PALEOZOIC	AYOUN FORMATION	[Pattern: Dotted with vertical dashes]	SANDSTONE AND SHALE	1072 m.	EARLY PALEOZOIC CLAST.	
							TABUK
							SAQ
		BASIN COMPLEX					
		PRECAMBRIAN					

FIGURE 4

striking gradual horizontal occurrence in a N.W.-S.E. direction. The oldest formation (pre-Cambrian) outcrops in the westernmost part of the region. To the east and gradually, younger formations outcrop, whilst at the easternmost part of the region the youngest formation of the Upper Teriassic is found (Figure 5). The crustal formation of the Qassim is a part of the huge platform of crystalline rocks forming the Afro-Arabian Shield. It is a complex of igneous and metamorphic rocks, dominated by schists and igneous intrusions. There is a major unconformity between the Basement Complex and the Paleozoic Saq sandstone in the Qassim, and low ridges and shallow valleys are preserved along the contact line. An example of these are seen to the north of Jabal ar Raha ($42^{\circ} 50'E. 26^{\circ} 15'N$), east to the Qassim where a narrow ridge of the granite extends eastward into the overlying Saq sandstone. The Saq sandstone is the most persistent and widespread member of the Ayoun Group of the Cambro-Ordovician system. It outcrops in a N.W.-S.E. direction in the western part of the Qassim extending north nearly to the latitude ($28^{\circ} 05'N.$) and south to ($24^{\circ} 20'N$).

From its first appearance underneath the Khuff unconformity the formation widens gradually over the 175 kms. to Aunayzah where it is approximately 45 kms. wide. From Aunayzah the outcrop extends N35W for 325 kms. to the southern edge of the Great Nufud, north of al-Qassim. North of Wadi Ar Rmah it forms a rough, hummocky plain and rises imperceptibly toward the basement. The plain is covered with erratic, wind scraped basins and wind sculptured jebal, usually low and of rugged, irregular pattern. Westward toward the basement the outcrop frequently forms a level surface covered with a talus residue of black, quartzitic slabs.

SURFACE OUTCROP OF THE GEOLOGIC FORMATIONS OF THE AL QASSIM

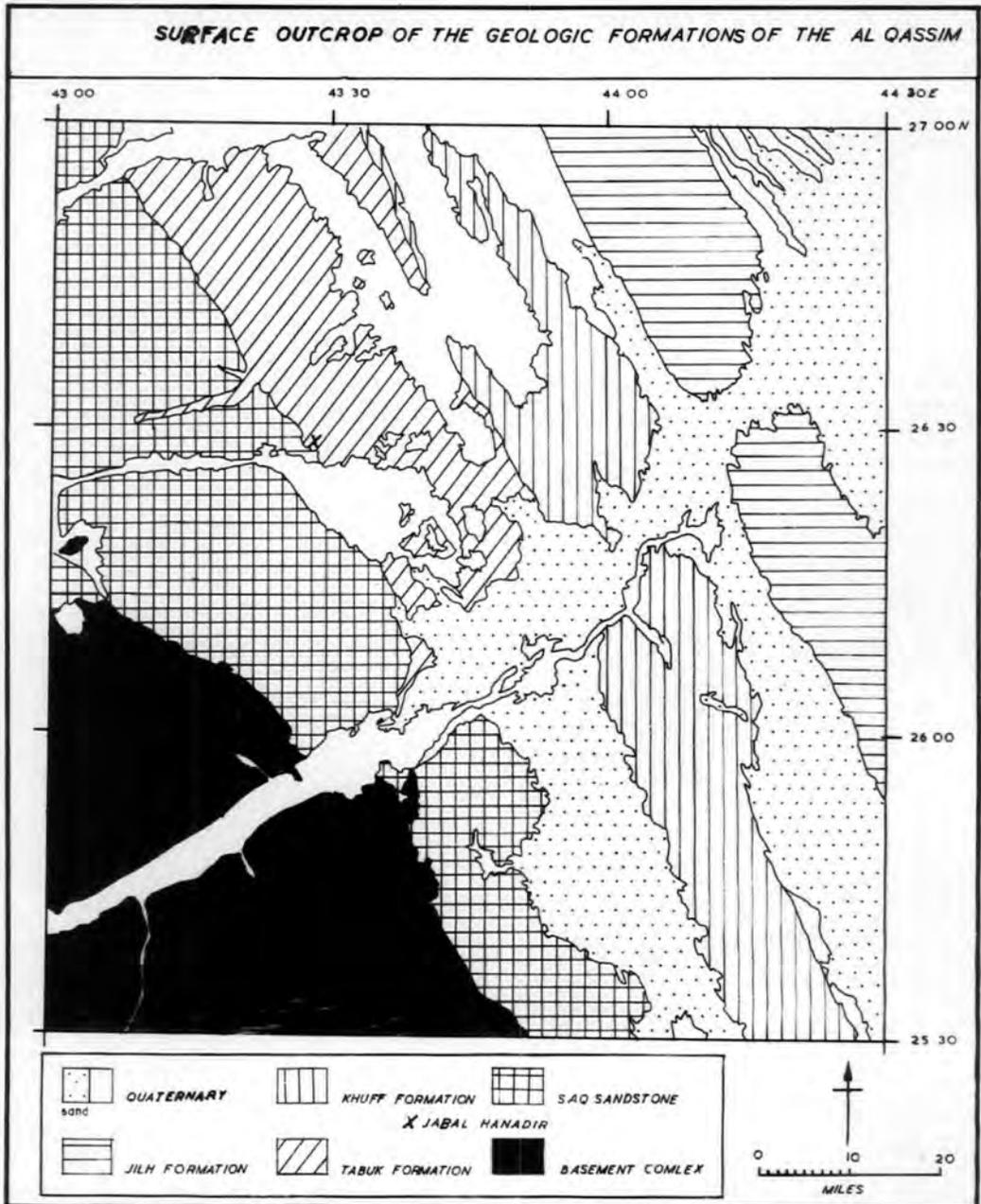


FIGURE 5

Variations in lithology within the Saq formation are largely of colour which may vary locally to mustard yellow or a pale brick red. A few thin partings of purplish seritic siltstone are present. The formation is of a well rounded, coarse to medium grained, white sandstone. Sorting is often poor and thin bands of fine quartz pebbles are common. Sandstone adjacent to granites are pre-eminently quartz with no feldspars or dark minerals.

The Tabuk formation of Ordovician age overlies Saq sandstone and is composed of three prominent shale layers separated by two thick layers of sandstone, and represents the Middle and Upper Ayoun formation. It outcrops intermittently along a 300 km. strip from the Great Nufud (N) to the town of Aunayzah; along the northern two thirds of this band (N. of Jabal Hanadir) it is 35 km. wide. South of this point the western basal contact is covered by gravel and sand dunes. The surface of the outcrop is in part cut by an intricate system of minor drainage channels and no major wadis are present. On the other hand, the duricrust cover which obscures the original topography makes the outcrops appear only in a discontinuous chain of basins where local interior drainage has breached this Tertiary cover.

The Hanadir shale member is at the base of the formation and has a thin zone immediately above the Saq sandstone which is a very pale, blue-grey, slightly marly shale (Plate iii). Above this the shale becomes greenish-grey, with increasing intercalations of extremely thin bedded sercitic sandstone toward the top of the member. The Ar Ra'an shale member lies over the separative layer of sandstone which overlies the Hanadir shale. It is speckled with dark minerals up to 2 cm. in diameter and contains increasing amounts of thin bedded sandstone toward the top of the member. The Qusaiba shale member is a very fine grained well bedded, grey to

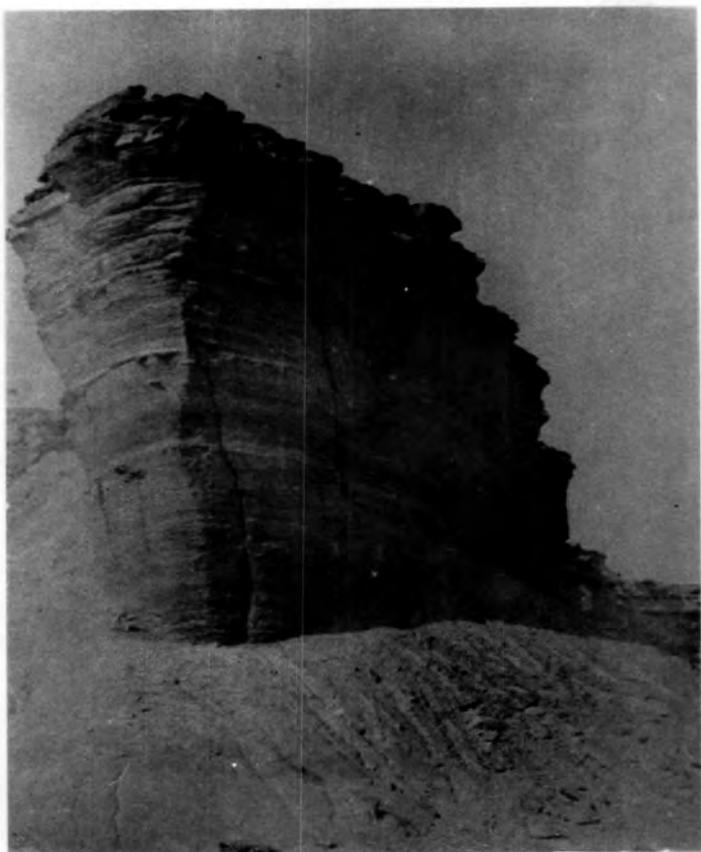


Plate No.iii. Hanadir scarp at its point
of intersection with Jabal Saq. Marl
at the foot of vertical cliff indicates
location of Lower Ordovician Graptolite
horizon.

grey-green shale with small layers of hematitic silicstone. Like the other two shale zones it grades upward into fine grained, well bedded sandstone.

The Khuff formation of the Permian age is known to extend in Najd over a band 900 km. long and roughly 20 km. wide. From the type locality at a point 5.3 km. 8° W. of Ain Khuff at ($24^{\circ} 55'N$. $44^{\circ} 42'E$.) south to al-Qassim, the continuous exposures of the Khuff formation for 200 km. oriented $N2^{\circ} 5^{\circ}$ W., throughout the Qassim region are broken only by the channel of Wadi Ar Rma. Thirty kms. north of Ar Rma channel the outcrop becomes gradually obscured by the duricrust blanket of the Northern Qassim. No complete outcrops of Khuff recur N.W. of this point. In the duricrust area two basins breaching the duricrust expose partial Khuff sections. Apart from these, all exposures of Khuff are small outcrops of extremely weathered limestone which occur in windows through the duricrust.

In water wells that penetrate the Khuff formation in the Qassim, the lithology mainly consists of an upper evaporite and shale section which shows a gradual increase in thickness down dip, and a lower carbonate section intercalated with a shale, dolomite section at the top. This calcaremite section makes an excellent marker for correlation in the Qassim area. In the village of Qusaiba (Fig.2), a deep well at the northern edge of the region, a thin bed of carbonate was encountered at the top of the evaporite. Lenses of sandstone were observed through the main carbonate section. Fossil wood was encountered at the lower Khuff transition zone (Plates iv, v and vi.)

Rocks of Triassic age are represented by the As Sirr formation. This is known to lie immediately beneath the surface throughout the Qassim and outcrops in 53° E. direction on a long strip varying in width from 2 km. to 13 km. wide north of Braidah town.

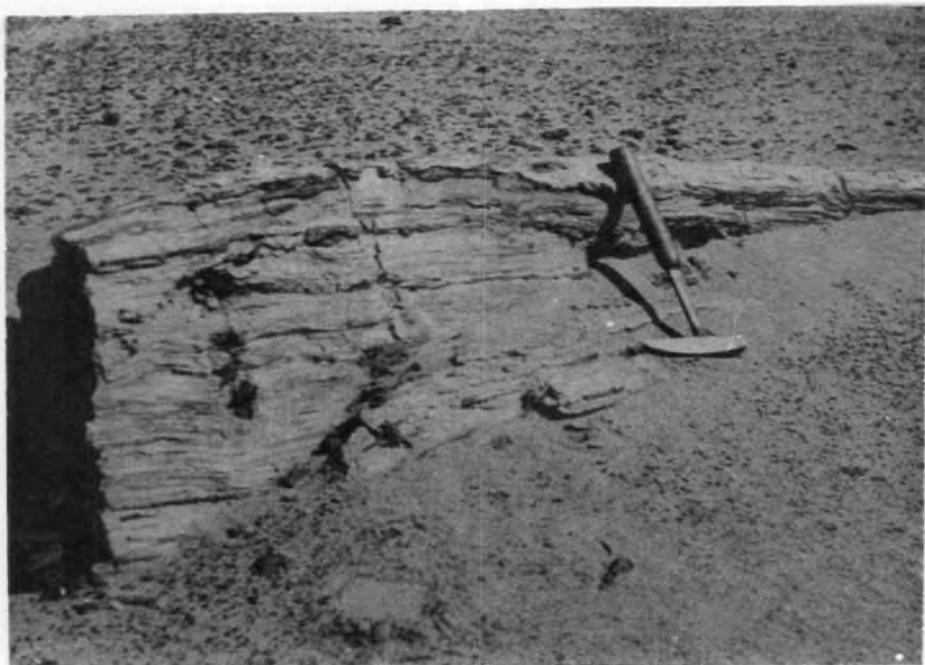


Plate No. iv. Fossil wood from Lower Khuff transition zone. This wood weathers out from soft, red shale at the foot of the Khuff scarp.



Plate No. v. Fossil wood, same horizon as above.



Plate No.vi. Log of petrified wood in
small "Petrified Forest" at the base
of Khuff formation near the northern
part of the village of Ash Sheqqah.

The lower member of the As Sirr (Sudair) is covered by Nufud At Trefiyah and is partially exposed at Abraaj Muddarraaj north to al-Qassim. in a patchy series of benches and erosional remnants. The Sudair member is a dark red massive shale with occasional greenish white layers, many of which are silty. A pale greenish-white unit several metres thick in which calcareous siltstone and silty impure limestone are predominant occurs 50 m. above the base. The lower part includes a number of thin beds of soft fine limestone.

The middle member of As Sirr formation (Jilh) along most of its outcrop forms 10 to 15 km. ledges shingled with parallel benches and banded with interbench khawat. The only prominent interruption of the outcrop band is caused by the channel of Wadi Ar Rma. A characteristic feature of the Jilh is lateral variation along the strike. In the Qassim area the Jilh consists of an interbedded series of hard, grey to tan, microcrystalline limestone, soft mustard to greenish yellow shales and marls and sandstone ranging from sugary cross-bedded medium grained sandstones to fine silty sandstones.

The Upper As Sirr formation member (Minjur Sandstone) is typically exposed in al Mestewy plain (Fig.6) between the Jilh escarpment and Nufud Ath Thuwairat in the latitude of the town of Aunayzah. This member is composed of series of well-bedded conglomerates, sandstone, laminated sandstone and variegated shales (Plate No.vii). The normal colours of the sandstones range from white to variegated or light brown, and in some places the weathering process alters the white-coloured sandstone to jet black quartzitic masses.

The Cenozoic system is represented by the surficial and basal deposits of the Quaternary and the Tertiary ages. Its general lithologic description is summarised as a combination

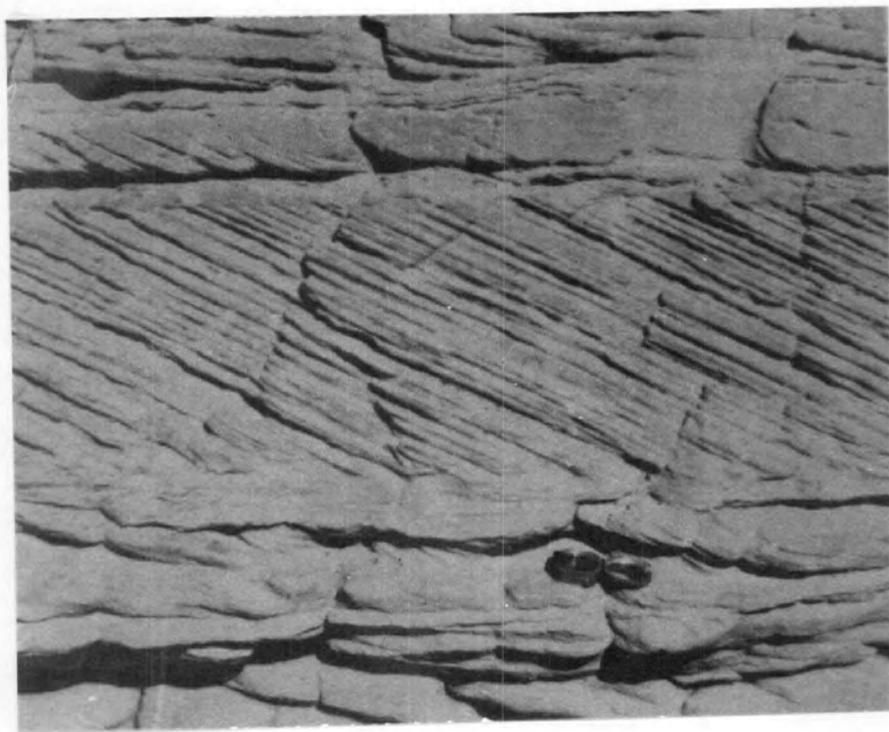


Plate No.vii. Cross laminated sandstone, Upper
As Sirr formation.

of gravel plains, sand dunes, and silt flats, in the extreme western part of the region.

Chapter 2Geomorphic Features2.1 The arid cycle of erosion

Terrain development in the Qassim is controlled by a true arid environment resulting in land forms of a waterless desert nature. In a region such as al-Qassim, of diverse rocks exposed to the action of wind, gravity, wide temperature changes and occasional violent torrential floods prominent morphologic features of the arid cycle are presented. The arid cycle of erosion has been evolved by earlier workers⁽¹⁾ and is summarised as follows:-

1. Rock disintegration predominant over decomposition.
2. The accumulation of sand into dunes and sand sheets by the wind.
3. Basins without surface drainage to the sea may contain playa lakes which exert a base-level control.
4. The local base level rises as the basin fills with debris, resulting in a rock floor convex upward.
5. The centripetal drainage lines into the basins are occupied by intermittent streams shorter than their slopes.
6. Pediments or carved plains are developed which rise on slopes of 0.5 to 7 per cent from the central debris to the base of desert mountains, cutting across different structures and rock types.
7. As the region becomes more mature the spreading basins cojoin, resulting in coalescence of base levels and integration of drainage.

(1) Davis, W. M. 1905, 1933.
Cotton, C. A. 1942

8. In maturity, wind action is more effective as fluvial power decreases, but if the deserts are in a rain shadow and the erosive processes lower the mountain fringe, rainfall may increase and the cycle shift into more humid form.

Davis (1905, 1933) has pointed out that the evolution of the desert cycle is largely controlled by the initial relief, which may be of coarse pattern as in Arabia, or of a fine pattern as in the Basin and Range Province of North America. If the region is of gently dipping sedimentary rocks as the Qassim, the cycle would begin in a manner similar to the ideal humid cycle operating on an uplifted peneplain formed either by former fluvial or marine planation or as a desert peneplain following long period of cliff retreat. Once again the harder beds would form cuestas, of which many are present in the Qassim, representing the most striking and prominent land forms in the region. There would be no substantial period of bahada accumulation but the wind would keep pace with the gullying of promontories and the sediment would extend to near the cliff base by "direct replacement of one already well-planned rock floor by another at the level" (Davis 1933). The desert cycle in such sediments has been elsewhere described in Australia, in the Libyan desert, the Kalahari, and Mongolia.

2.2 General Land Forms in the Qassim

The terrain in the Qassim seems to have been formed under conditions of extreme desertic conditions and possibly for a time in the Pleistocene to have been sculptured under semi-arid conditions. The region may be divided into four major types of terrain which form parallel belts. The only exception to this arcuate monocline structure of the region is the wadi Ar Rma. The major relief units are the west facing escarpments, Nufud, gravel plains, and Wadi Ar Rma (Fig. 6).

2.3 West Facing Escarpments

The escarpments of the Qassim comprise three parallel scarps which strike from north-west to south-east. They are separated from each other by intervening low lying areas of gravel, silt, and sand dunes. Moving from east to west the successive scarps crossed are the Jilh, the Khurtum, and the Khuff escarpment.

The Jilh extends for nearly 550 km., throughout the northern part of Najd, from the southern edge of Irq al-Madhhur 100 km. north of Wadi ar Rma to Wadi Berk, 23°N . 45°E ., south to al-Qassim.

Within the Qassim the scarp has a regional strike of $\text{N}30\text{W}$. It rises from a series of rugged, sand drifted benches in the southernmost part to a bald scarp whose steplike outer profile reaches a relief of 100 metres at Ad Duwaihira, (Fig.2). The lower part of the Jilh is covered by sand dunes of the Nufud As Sirr from Khashm al Jeair, east to al-Amar to Ad Duwaihira (Fig.2). However, along most of its outcrop in the Qassim, the Jilh forms a 10-15 ledge shingled with parallel series of low, rough benches, the upper part being most prominent with 40 metres relief. Between benches occur long narrow silt flats with smooth surfaces, where the agricultural settlements of Ar Rubay'eyah and Ash Shemassiyah area cluster.

At Ar Rubay'eyah village (Fig.2) the scarp is interrupted by the sand choked valley of wadi Ar Rma. North of the wadi it is continuous as a less precipitous, often sand drifted scarp, known locally as Safra'al-Asyah. With an elevation of 40 metres adjacent to Nufud Ath Thuwairat, it becomes lower and more irregular to the north east and finally disappears under Irq al Madhhur. Of particular interest are

the gypsum deposits found south of Ain ibn Fhaid village in al As Syah (Fig.2). Here, on a strong dip slope in the upper Jilh a rockied topography has developed in shales and rubbly marls. Shallow basins, containing small residual mesas and discontinuous benches, have developed in a broad lowland within the upper Jilh. Beds of gypsum, several metres thick, are intercalated with rubbly marls and shales.

The Khurtum escarpment lies to the west of the Jilh scarp and almost parallel to it. The scarp forms a prominent bluff from Khashm Khurtum south of wadi Ar Rma, with a relief of about 30-40 metres for a distance of about 65 km. (Plate viii). South of the Khashm the same limestone beds continue to As SIRR in a low scarp seldom more than 5 metres high.

Northward the cap rock is a series of thin-bedded to massive limestones which are underlain by soft shales, marls, and gypsiferous or saliferous shales (Plate ix). At the base of the scarp for most of its length are low-floored basins or Khabrat, in which are located most of the date garden villages from al-Amaar village at the southernmost edge to the town of Braydah in the middle of the region. The scarp from the town of Aunayzah to wadi Ar Rma is capped by remnants of an old erosion surface with associated gravels and alluvium, which may represent part of a late Tertiary or Pleistocene peneplain. North of wadi Ar Rma channel the scarp appears as Jal wetaa, east to the village of al Wetaa (Fig.2), which is a minor scarp but preserving the same general characteristics.

The Khuff escarpment is a long and persistent limestone-capped scarp 20-30 metres high, extending from Sha'ieb Hadr, south to al-Qassim to wadi Ar Rma at the town of Aunayzah, parallel to the east of the Khurtum with a regional strike of N2 1W. It re-appears north of the wadi, N.W. of the town of Braydah, for a distance of 25-30 kms. before disappearing

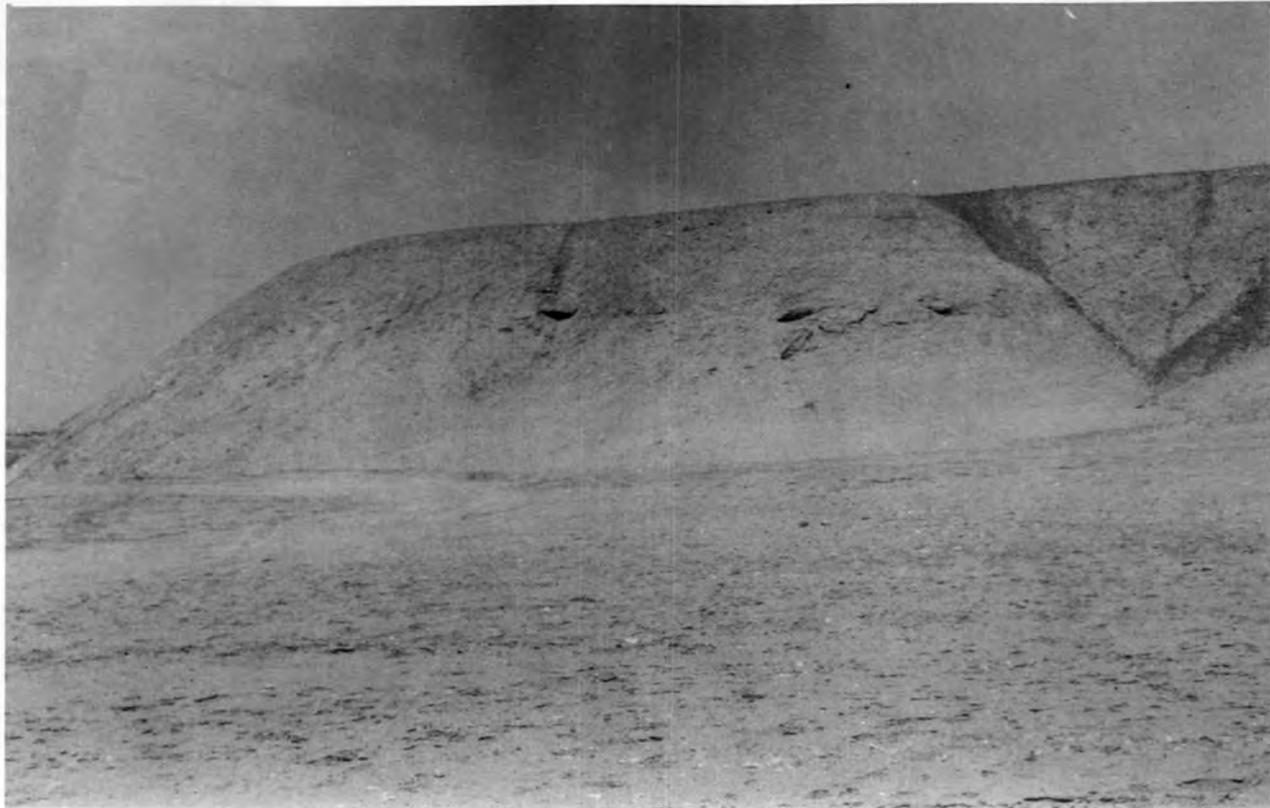


Plate No.viii. Khashm Khurtum looking west to al-Midhuab settlements.

Plate No.ix. Cap rock of Khurtum escarpment north of the Khashm series of thin bedded to massive limestone underlain by soft shales, marls and gypsiferous or saliferous shales.





Plate No.x. Another view of Khurtum escarpment.

under the erosion surface or peneplain associated with the As Sa'irah plain. This gives it a length of some 450 km. For most of its length within the region of al-Qassim, the scarp is a sandstone or shale bluff, capped by hard resistant limestones of the basal Khuff formation (Plate xi). The back slope plunges to the N.E. or E. under the lower As Sirr formation as an upland surface eroded into a series of shingle-like benches (plate xii).

In the northernmost part of al-Qassim three prominent scarps lie parallel in the Hanadir area, forming the basic topographic expression in the area. The scarps appear only in a discontinuous chain of basins where local interior drainage has breached the Tertiary duricrust cover. The three scarps are, from east to west, Al Ayr, Ar Ra'an, Hanadir.

The Al Ayr is a sandstone capped ridge, which extends south-east from the great Nufud for 70 km. Here it is briefly overlapped by duricrust, and reappears at Abraq al Asfar. South-east of Al Asfar it is completely covered for 100 km. by a broad duricrust plain, As Sai'rah, and reappears only briefly as the steep scarp on the west side of Qusaiba basin.

Ar Ra'an Scarp is the central and least continuous of the scarps. At Khashm Ar Ra'an $25^{\circ} 50'N$. $43^{\circ} 20'E$, it forms a vertical bluff 15 km. long with a maximum relief of over 50 metres. Khashm Thalatha, is a southward continuation of the same scarp, and extends as far as the village of Al-Auyoun.

The Hanadir scarp is the most persistent scarp of the group, traceable north-west for 200 km., continuous except for a 50 km. stretch north of Jabal Hanadir, where it is overlapped by Neogene gravel. It varies in height from 40 metres in the southern area to a low, barely traceable bench at its northern end. An almost continuous belt of mud flats marks the sharp lithologic break between the Saq sandstone and Hanadir shale at the foot of this scarp.



Plate No.xi. Shale bluff capped by hard resistant limestone of the basal Khuff formation, a common feature of the Khuff escarpment.

Plate No.xii. A series of shingle-like benches of the back slope of the most part of Khuff escarpment.





Plate No.xiii. A remnant of the retreated cliff of Khuff escarpment, 3 km. approximately northwest of al-Midhaab village.

2.4 Nufud

There are a number of large semi-permanent sand bodies crossing Najd from north-west to south-west which are locally called Nufud. A Nufud is a large continuous body of sand which is formed of sand sheets, dunes, or groups of dunes, deposited by the action of winds. Deposition is generally upon a mature or peneplained surface. The form of a nufud is controlled by the strength and direction of wind, the source and amount of sand, the relief of the surface on which it lies, and the annual rainfall. Dune form is characteristic for each nufud, dependent upon the environmental factors involved.

The nufud in the Qassim are elongated, generally rugged and have high relief. The dominant dune form is the "turtle-back." Usually associated with Nufud are sand bodies, which are smaller than nufud and form local features. These are often long and are known locally as Auruq. However, the sand boundaries are irregular and intricately scalloped with numerous long stringers of sand extending out from the main sand bodies adjacent to each other. Six major areas of Nufud can be distinguished in the Qassim.

The Auruq al-Mudhhur is the easternmost sand body in the Qassim. This body of sand covers an area 40 km. wide and 250 km. long, extending south-east from the Great Nufud north of al-Qassim (28° N. 44° E.) to a point at (25° 50' N. 44° 40' E.), where it intercalates with Nufud Ath Thuwairat which lies west to it. At this point the mass of sand has begun to accumulate in a broad band, bordered on the east by the Auruma escarpment of Sudair region. Al-Madhhur is generally composed of roughly parallel stringers of sand several kms. wide, separated by level interdune areas of gravel, weathered limestone, and flat interdune hollows (plate xiv). Sometimes



Plate No.xiv. Erq al-Madhur, showing extreme development of finger-
like dunes with flat interdune hollows.

these Aurug are gently rolling sand plains which at other times take the form of precipitous dune ridges with steep scarps facing north east. The sand in the northern part of al-Madhhur is relatively low; however, towards the southern end the Aurug coalesce. They form a knot of high, active dunes and sand peaks which choke up the channel of wadi Ar Rma. The nufud is underlain by a peneplained surface partly gravel plain and partly truncated late Paleozoic or Mesozoic beds. The wind direction is predominantly from the north-east and strong and fairly constant, with the result that dune form is generally that of an attenuated ridge.

The Nufud Ath Thuwairat is a long tongue of rugged sand dunes which projects south eastward from the broad sand mass at the southern end of Arug al Madhhur. The total length of this sand body is in excess of 200 km. The south eastern part (65 km. long) is known as nufud Baladin, and the northern two-thirds, 140-150 km. long, is known as nufud Thuwairat.

Nufud Ath Thuwairat has an average width of about 10 km. and nufud Baladin is slightly less, but more variable, ranging from 5-12 km. The lowest pass at Rumhain where the width is about 2 km. represents the separation point between the two nufuds as recognized locally. One of the sand peaks at Rumhain is 60 metres above the silt flat at its base. Elsewhere, the active dunes are estimated to have a relief of 100 metres. Many of these high dunes are composed of active sand, with little or no vegetation cover, and steep slopes are common.

The Nufud At Trefiyah is a small tongue of sand extending north from wadi Ar Rma for 40 km. It is generally only a few km. wide and composed of low, elongated dunes, easily traversable at any point. Towards its northern end the

grades change imperceptibly into a level dikaka plain at the foot of Jilh scarp (plate xv).

The Nufud As Sirr is an elongated body of sand dunes 270 km. long extending N 30° W from Khashm Dalyan 23° 30' N 45° 10' E., to wadi Ar Rma. The northern end is quite narrow and referred to as Nufud As Safiq. This narrow part lies between wadi Ar Rma and Irq al-Mushattit at al Awsajiyah village (Fig.2). The width of As Sirr ranges from 20-25 km. while Nufud As Safiq is less than half this width.

The Jilh escarpment borders the Nufud on its north-east margin. From Khashm al Ju'air to Ad Duwaihira the Nufud encroaches upon the scarp, burying the lower benches under its dunes. Near latitude 25° 30' N., a tongue of sand climbs the escarpment and crosses it to connect with Nufud al Malha. This is known as Irq al Muwasil. The Irq is 8-10 km. long with a total width of 5-6 km., and is split in the middle by outcrops of the Jilh sand passing to either side and forming rows of high active dunes.

The south-west boundary of the Nufud forms an scalloped line. Many Khabrat lie within this indentation, separated by patches of low sand hills, dikaka, and obscure outcrops. Near the village of al Muraba'a (Fig.2), dunes on the margin alternate with large silt or rock-floored basins, some of which are interconnected, making a sinuous valley pattern which can be followed deep into the Nufud, and now the scene of noticeable activity for new agricultural expansion as the deep drilling wells are undertaken.

Nufud As Sirr is made up of large irregular dunes of sand, roughly elliptical in outline, separated by deep marginal hollows. This combination of dome and hollow with a radial ridge on sand peak appears to be a form of dunes of particular character (plate xvi).



Plate No.xv. Comparatively low, traversable
elongated dunes of At Tarafyyah sand dunes.

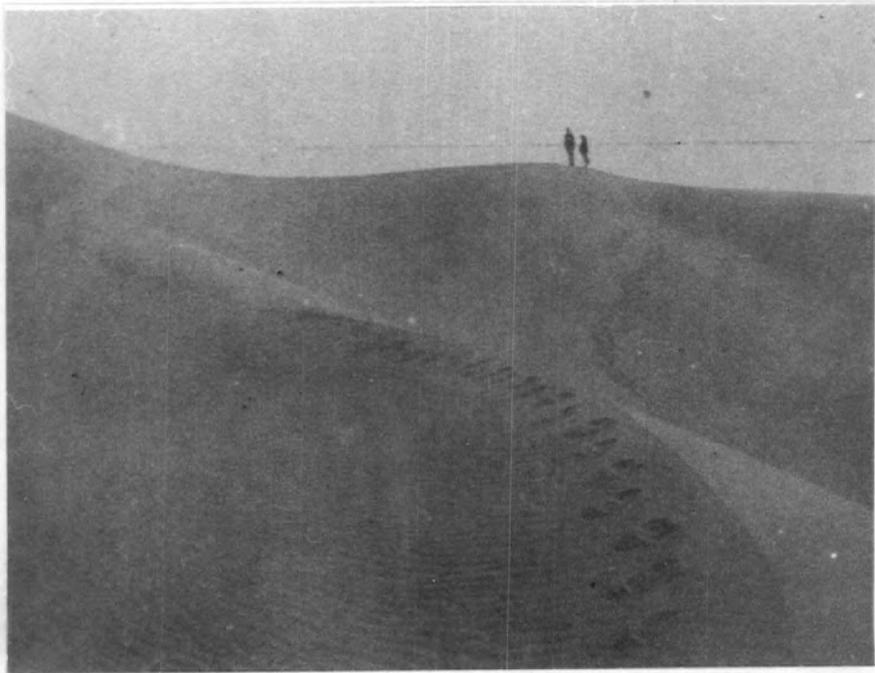


Plate No.xvi. Radial ridges on sand peak, Nufud
As Sirr, near Ruhmain.

The Nufud Ash Shqayqah extends south-eastward from the town of Aunayzah for about 70 kms. and lies parallel to the Khuff escarpment. Its width is estimated at 20 to 30 km. The Nufud narrows sharply at the south-east end and is widest on the southern bank of wadi Ar Rma, therefore its outline is like an acute triangle with the apex pointing south. Relief is comparatively medium and much less pronounced than in Nufud Ath Thuwairat or As SIRR.

The Nufud and Aurug of the Wadi form irregular groups of sand dunes which have accumulated in the low areas of Wadi Ar Rma. The area is known locally as a part of Nufud Ghmays. The Nufud of Braydah is a part of this system and is composed of a number of smooth surfaced, elongated whale-backed ridge dunes, which do, however, have steep slip slopes on the lee side (plate xvii). Migration of these dunes has been retarded during the last several hundred years by the local practice of planting the dune slopes with a variety of tamarisks (Athl), which serve the dual purpose of holding the sand and providing a source of wood for building and fencing. Nufud Ghmays which fills much of the wadi west of the town of Braydah and north-west of the town of Aunayzah, is not clearly distinguished from Nufud Ash Shqayqah which lies south of it, except that the channel through which water flows down the wadi may be referred to as a possible boundary.

2.5 The Gravel Plains

The gravel plains represent an extensive area, which is bounded on the west by the mountains of the basement complex, on the north and north-east by the Great Nufud and Irq al-Madhur, and on the east by Nufud Athuwairat. The southern boundary is an indefinite zone at the southern end of the duricrust 30 km. north-west of the town of Braydah. The term "duricrust," used to describe a widespread, hardened



Plate No. xvii. Nufud Braydah, an elongated whale-backed ridge
dune fringing the northern side of Wadi Ar Rma,
east of the town of Braydah.

surface in Australia, has now become the common terminology for the "Summan" in eastern Arabia along the east side of Nufud Ad Dahna. It applies to a secondary limestone or caliche deposit which varies from a dense grey secondary limestone or caliche to surface detrital material firmly cemented by calcium carbonate. By general usage duricrust has become the accepted term for Arabian occurrences of such secondary calcareous surface, and forms extensive plains in the northern and eastern parts of the Qassim.

The precise chemical conditions which produce this deposit are unknown so far. Where the underlying formations are calcareous, duricrust is particularly hard and resistant and forms a cap rock which protects scarps as high as 50 metres, as it is at the Qusaiba village, N.E. of Braydah. Where the underlying rocks are sandstones, the duricrust is a grey gypsiferous, earthy deposit and much less resistant to erosion, as in al-Mestewey plain east of the Jilh scarp (Fig.6).

The basic fact controlling the topographic expressions over this broad area of gravel plains, in the east and north of the Qassim region, is the extensive post-Eocene peneplanation during which a blanket of duricrust and gravel developed over much of the area (plates xviii and xix). The tops of even the highest Jebal in the area fall beneath the projected surface of these peneplains. They are broad, very gently rolling plains underlain by Palaeozoic sandstone and shales. The topography is altered and obscured by a blanket of duricrust which acts as a cap rock for a series of sinuous, patternless benches and scarps. At intermittent intervals along the north-western trend of shale zones, canoe-shaped basins breach the plains with hollows of interior drainage ranging from 10 to 50 metres in depth.

Plate No.xviii. Duricrust. This Caliche-like secondary deposit preserves a gently rolling, peneplain surface throughout the northern part of the Qassim, N. Wadi Ar Rma. Here it is breached by a shallow basin of interior drainage, the duricrust remaining as a resistant cap rock.

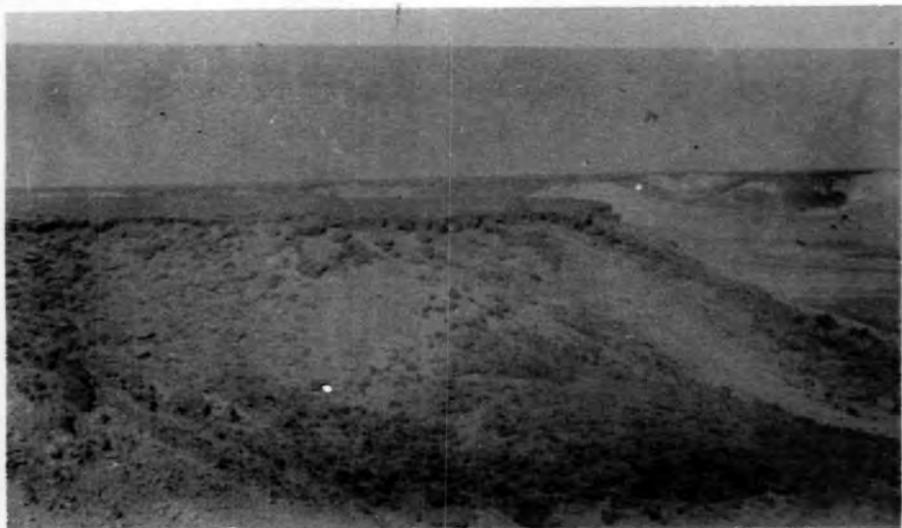
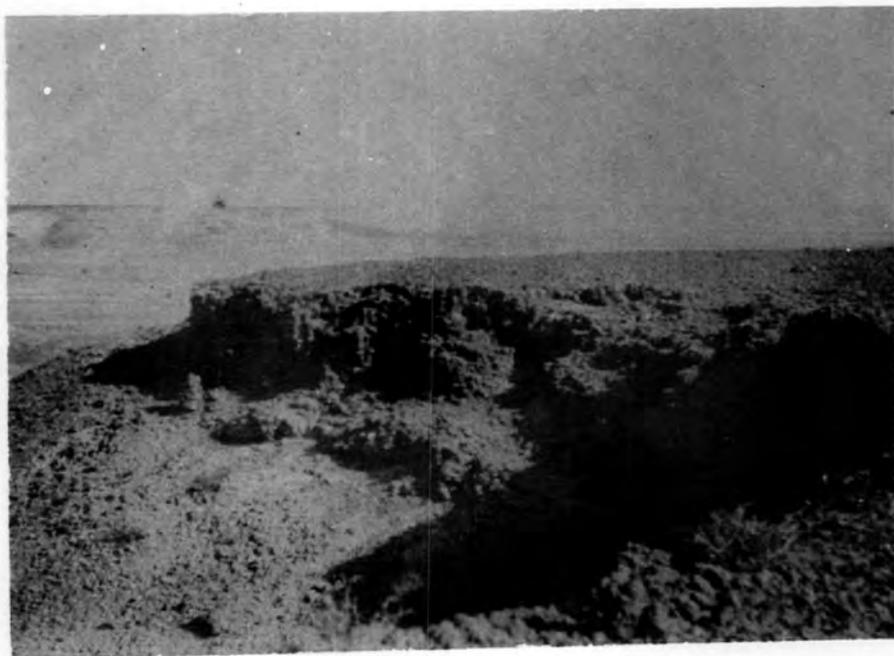


Plate No.xix. Close-up of duricrust showing spongy, honeycomb structure. This ledge is slightly less than 1 metre thick.



Commonly, the west facing scarp of such a breach is capped by limestone or sandstone and the opposing scarp is capped by a heavy ledge of duricrust.

Two especially prominent gravel plains occur within the confines of the Qassin region - the Al-Mestwey Plain and the As-Su'airah Plain.

The Al-Mestwey Plain is 100 km. long by 10 km. wide oriented N30W between Nufud al-Madhhur and Ath Thuwairat on the east and Wadi Ar Rma and the Jilh scarp on the west (plates xx and xxi). The flat, quartzitic gravel plain is broken by low gravel benches and a few gently sloping, black weathered Jebal which commonly have the profiles of low volcanic cover. Toward the northern end relief is more pronounced, Jebal Rakhman and Bruna, at the latitude $26^{\circ} 18'$ N. and longitude $44^{\circ} 25'$ E., reaching a height of 30 metres. At the extreme northern end of the plain, where gravels are removed by runoff into Wadi Ar Rma is the rough area known as Burqa'a al-Khuwaibila.

At the northern end of al-Mestwey plain occurs a narrow neck of sand filling Wadi Ar Rma channel. Beyond this point it outcrops as a broad sabkha-filled trough whose eastern fringe is lined with low Jebal and haphazard benches. This area is known as al-asyah, and from its 8 km. width north of Wadi Ar Rma, al-Asyah is progressively narrowed by encroaching sands of Irq al-Madhhur and finally completely overlapped by the Irq.

The As Su'airah Plain is a gently rolling plain 30 km. wide extending along the south western side of Irq al-Madhhur. The duricrust here, developed from the underlying limestone of the Khuff formation, is extremely resistant and unbreached by drainage channels. Slight undulations in the surface of the plain are sometimes present

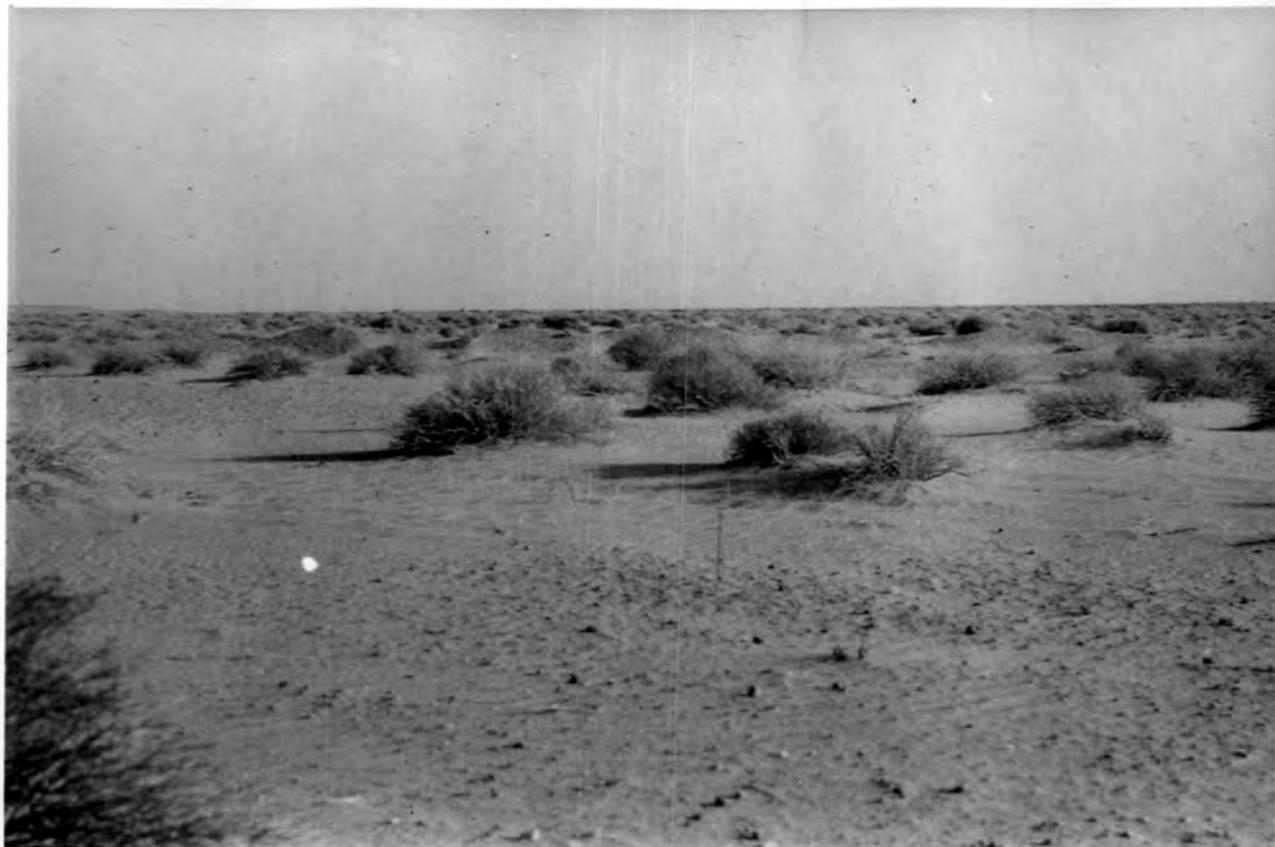


Plate No.xx. A view of the flat gravel plain of the southern part of al-Mestwey plain.

Plate No.xxi. Another view (further north) of the al-Mestwey plain with a more prominent gravelly character.



along its projection, extending toward Jebal Salma, northeast to al Qassim, in the granites. It is floored with a fine gravel outwash from the basement.

The broad band of cross-bedded sandstone at the margin of the basement forms a rough surface of scattered, hummocky Jebal, and wind scooped basins with occasional high, conical Jebal, such as Saq.

Between these two belts, the duricrust on the east and the sandstone on the west, lies a complex topography of basins and intervening plains (plates xxii and xxiii). Within this area the trends of three scarps can be followed from basin to basin but the continuity of these scarps is through lithologic rather than topographic expression. The basins along which they are exposed often appear with striking suddenness while traversing over the smooth surface of the plain. They are usually shale floored hollows with rim rock of duricrust, or less commonly sandstone, and one or two drainage channels leading to a central sabkha or khabra. All the small and scarce plantation villages are examples of these basins, al Aj-far, al Khafa and Qusaiba etc.

The southern edge of the peneplain north of the town of Braydah has an elevation of 556 metres, whereas it is 700 metres at a distance of 150 km. north, so the fall in this component direction (south-east) is about 1 metre per km. The southern edge has been dissected by headward erosion of tributaries to Wadi Ar Rma, forming some minor bad lands. The peneplain also cuts across the truncated edges of scarps from the Lower Paleozoic onto Upper Triassic.

North-west of Wadi Ar Rma and east of the basement complex there is a broad band of rough sandstone, irregular plains and escarpments. The basal Paleozoic sandstone designated the Saq sandstone member of the Auyon formation outcrops in a broad band 50 to 60 km. wide and roughly



Plate No.xxii. The complex topography of basins and intervening plains. An example of the As Su airah plain zone north of Braydah.

Plate No.xxiii. Same area as above.



150 km. long. On the Saq sandstone itself, wind erosion has been dominant. The more friable portions are readily weathered and loose grains removed by wind action. The harder parts remain as outliers and some of them are prominent landmarks, such as Jabal Saq, which is a roughly conical butte made up of hard, almost quartzitic sandstone the surface of which has developed a thick black coat of varnish. It rises 150 metres above the surrounding plain and in times of good visibility can be recognized for a distance of 40 km. There are other smaller outliers and several prominent black sandstone ridges. There are also irregular bands of wind-scooped basins which are indistinguishable one from another. Small sand dunes are associated with those basins, usually on the ridges bordering them.

North-east of As Sheqqah village, there are several prominent sandstone scarps. These are somewhat discontinuous, owing to irregular exposures of the Auyon sandstone and also because of the overlap of duricrust on the north. Between Jal Wetat and Ash Sheqqa village some 20 km. west of Braydah, the surface is mainly a limestone dip slope except for a slight overlap by the duricrust. Several low scarps lie parallel to the main scarps.

2.6 Wadi Ar Rma

Wadi Ar Rma is the dominant drainage channel in the whole of Saudi Arabia. From its headwaters at Harrat Khaibar in the mountains of western Najd its course can be traced 900 km. to its mouth south-west of the town of al Basra in Iraq. Along the lower 400 km. of the wadi channel it is named al-Batin.

Within the Qassim the wadi is a 6 to 10 km. belt of silt whose course is often obscured by sand dunes (plate xxiv). At the town of Braydah, on the northern bank, and Aunayzah, on the southern bank the wadi is confined by low

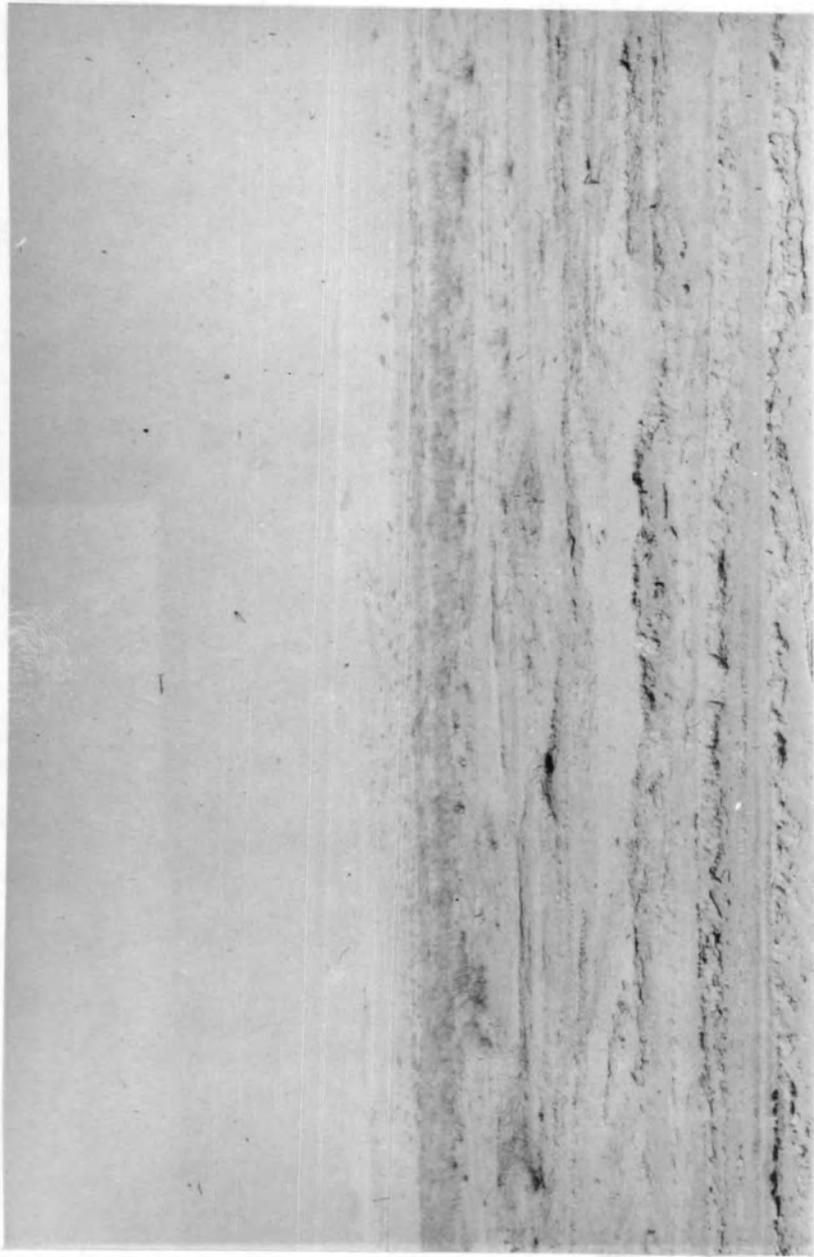


Plate No. xxiv. A view of the belt of silt of Wadi Ar Rma bed at a point of its broadest section between Riyadh al Khabra and al Bada ea settlements east of Aunayzah town.

limestone ridges of the Jilh, Khurtum, and Khuff scarps and its channel can be traced north-east along a series of silt flats and Sabkhat, often scattered with barkham dunes.

Fifty km. north-east of the town of Braydah the channel becomes completely dammed up, partly as a result of a rising base level to the north-east and partly as a result of the encroachment by the Nufud At Trefiyah. Although obviously a major channel during less arid periods of Arabian history, Wadi Ar Rma has not been known to flow through its whole length in recent times. However, within the restricted area of al-Qassim the wadi generally flows once, or rarely twice, during a winter, leaving scatterings of shallow puddles along its course for several days following the flow.

The wadi is the core of al-Qassim indeed and contains the important towns in the region, with Aunayzah on the southern bank at $26^{\circ} 05' 44''$, and Braydah on the northern bank at $26^{\circ} 20' 44''$. Numerous villages are clustered on either side particularly the lowland area west of Aunayzah and Braydah.

Many smaller wadis are scattered throughout the region with much less length and importance particularly along the cuestas of the south and the scarps and basins of the north. All these small wadis have one striking characteristic, they are channels of internal drainage in the scattered basins and Khabrat, whilst a few of them die out in Nufud.

This review of geomorphic features of the region has led to a vital conclusion from the point of view of arable lands. Calculation of the arable land would lead necessarily to the elimination of the huge areas in the region occupied by sand dunes, escarpments, and the vast duricrust cover on the northern part of the region and east of the Jilh. This

leaves the small shale peneplain between Jilh and Khurtum, the tiny strip between Jilh and Nufud Ath Thuwairat where the Ar Bay'iyah and Ash Shmassiyah area, the wadi basin, the north-eastern shallow valley of al Asyah, and the small scattered basins throughout the northern duricrust area. Even these small portions are subject to severe soil, drainage, and topography limitations and deficiencies.

References

1. Abul-Hagag, Y. A recent Karstic phenomenon in the limestone country of North Central Najd, Saudi Arabia
Bulletin de la Societe de Geographie D'Egypte, Cairo Tome XXXVIII, 1965.
2. ARAMCO Geology of Wadi Atj, Buraidah, Hail area, North Central Najd, Saudi Arabia
Geologic reports: No.29
Adh Dhahran.
3. ARAMCO Geologic Map of the Wadi Ar Rmah Quadrangle, Kingdom of Saudi Arabia
Map. No: 1-206A prepared by the U.S. Geologic Survey and the ARAMCO for the Ministry of Petroleum and Mineral Resources, Saudi Arabia, 1960.
4. ARAMCO Geographic Map of the Wadi Ar Rmah Quadrangle, Kingdom of Saudi Arabia
Map No: 1-206B prepared by the U.S. Geologic Survey and the ARAMCO for the Ministry of Petroleum and Mineral Resources, Saudi Arabia, 1960.
5. ARAMCO Geologic Map, Buraidah, Province of Najd, Saudi Arabia
Map No: GF-1389-A Adh Dhahran.
6. ARAMCO Geologic Map, Midhnab, Province of Najd, Saudi Arabia
Map No: GF-1416-A
Adh Dhahran

7. ARAMCO Geologic Map, Saq. Province of Najd, Saudi Arabia
Map No: GF-1437-A
Adh Dhahran

8. Bagnold, R. A. The Movement of desert sand
The Geographical Journal,
Vol.LXXXV, 1935.

9. Bagnold, R. A. The transport of sand by wind
The Geographic Journal,
Vol.LXXXC, (Pages 409-438), 1937.

10. Cotten, C. A. Climatic accidents in landscape-making
(p.p.3-126) New Zealand, 1942.

11. Davis, W. A. The Geographical Cycle in an Arid Climate
Journal of Geology, July-August,
1905 Vol.XIII (pages 381-407).

12. Mytton, J. W. Geological reconnaissance of the western part of the Wadi Ar Rma Quadrangle
(Unpublished mimeo).
Ministry of Petroleum and
Mineral Resources, Saudi Arabia.
Ar Riyadh, 1965.

13. Powers, Ramirez and others Sedimentary Geology of Saudi Arabia
(unpublished mimeo).
Ministry of Petroleum and
Mineral Resources, Saudi Arabia.
Ar Riyadh, 1963.

PART II

THE CLIMATE AND WATER

Chapter 3Climatic Conditions and Surface
Hydrology

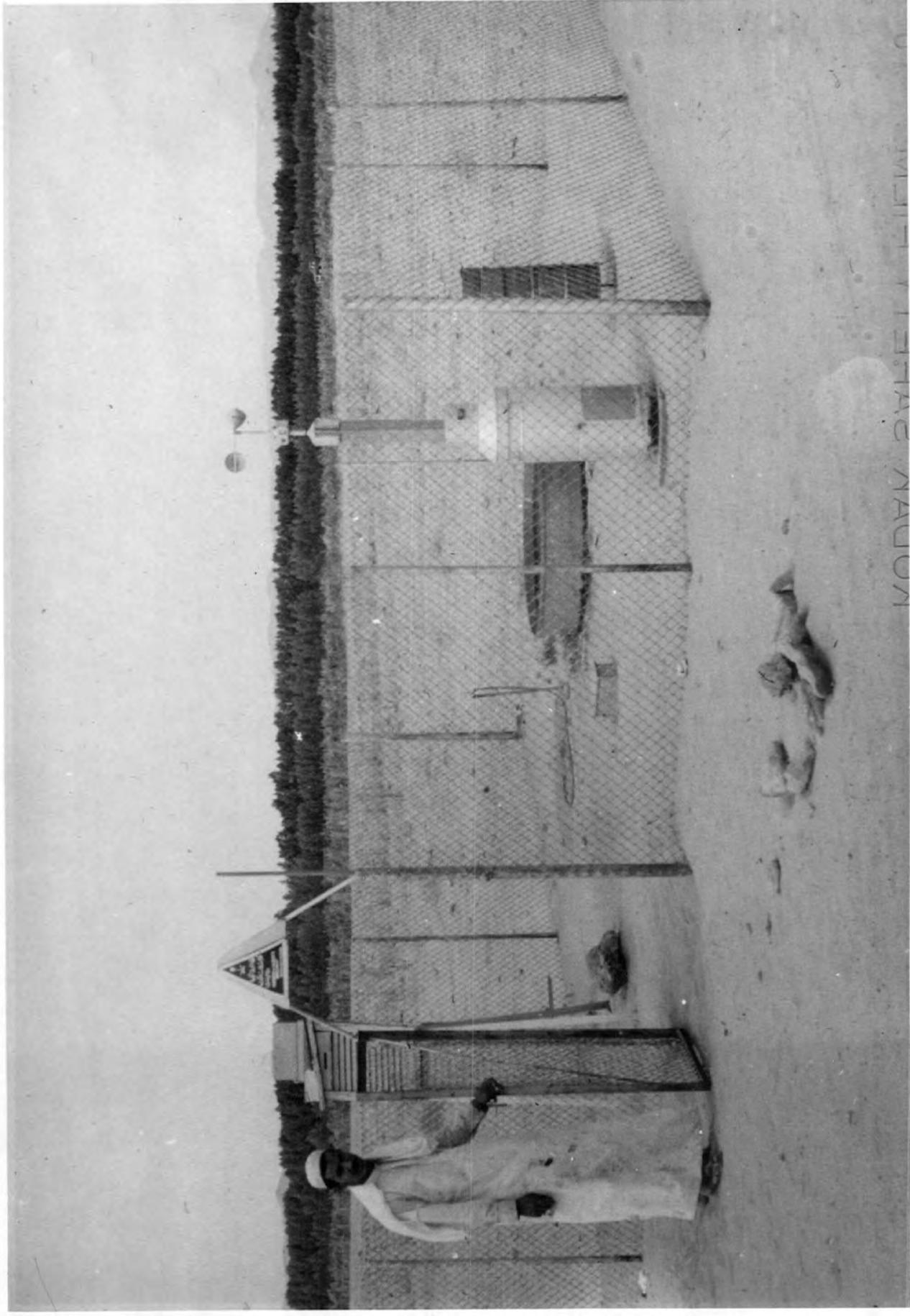
Lying within the dry zone of the tropical climate the Qassim is, generally, a region of intense dryness and heat. According to the Koppen classification⁽¹⁾ the Qassim climate could be classified as BWh type of climate. The control of the intense dryness is the high pressure cell over Central Asia with the co-operation of the low pressure cell over the Equatorial areas. These two different pressure systems have determined the prevailing wind to be of a continental type bearing no water. The sole departure from complete dryness is the cyclonic depression which annually migrates eastward in winter and early spring by its usual path over the Fertile Crescent from the Mediterranean. It creates a wind attraction cell skirting the most northern part of Najd. This cell drags water bearing winds, which reach Najd on their way to the depression path over the Fertile Crescent, just after crossing vast water surfaces in south-east, south and west of the Arabian peninsula.

The available climatic data are of very short period due to the fact that it was only in August, 1964 that the first meteorological station was put in operation in the region at the outskirts of the town of Aunayzah by the Ministry of Agriculture (plate xxv). Another station was installed in 1965 by the Civil Aviation Department at the central airport. However, the data from this station up to the time of writing this thesis was unavailable for analysis.

The available data of the Aunayzah station comprise

(1) Koppen classification as modified by G. T. Trewartha in his book "An introduction to climate" New York, 1954.

Plate No. xxv. The meteorological station of the Ministry of Agriculture, situated at the south-eastern outskirts of the town of Aunayzah. Beyond the station appears the new citrus farm of Aunayzah.



figures on rainfall, temperature, humidity, pan evaporation, radiation, and run-off up to September, 1966. (Appendix B, Tables 1 and 2).

3.1 Temperature

The annual range of temperature in the Qassim is very large. The mean temperature is 13°C . in January and 33°C . in July, resulting in an annual range of 20°C . (Fig.7). During the high-sun period, scorching, dessicating heat prevails. The mean temperatures for the hottest months range between 28°C . and 33°C . However, during this period the comparatively low night temperatures are a distinct relief in contrast to the days. The absolute maximum mean during the summer ranges between 48.9°C . and 44.4°C .

During the period of low-sun the days are still warm with an absolute daily maximum around 30°C . Nights are distinctly chilly in this season with the average of absolute minima ranging between 0.1°C . and 3.3°C ., and the absolute maximum mean ranging between 27.2°C . and 23.9°C . These figures show the immense difference between the diurnal and the nocturnal averages. However, the average monthly temperature during the winter ranges between 11°C . and 15°C . (Fig.8).

3.2 Relative Humidity

Relative humidity is low in the Qassim with 3% to 21% being usual for the mid-day hours. The annual average of humidity is 29.8%, and the maximum yearly average is 52.4% while the minimum annual average is 18.6%. Seasonal averages of humidity percentage indicate that the region enjoys a more humid atmosphere during winter and spring.

Summer has an average of 16.2% whilst winter has an average of 49.6% (Fig.7), the maximum averages being 22.1% during summer and 63.3% in the winter. The average of minimum percentage is 10.3% for summer and 28% for winter.

MONTHLY AVERAGES OF RELATIVE HUMIDITY AND TEMPERATURE

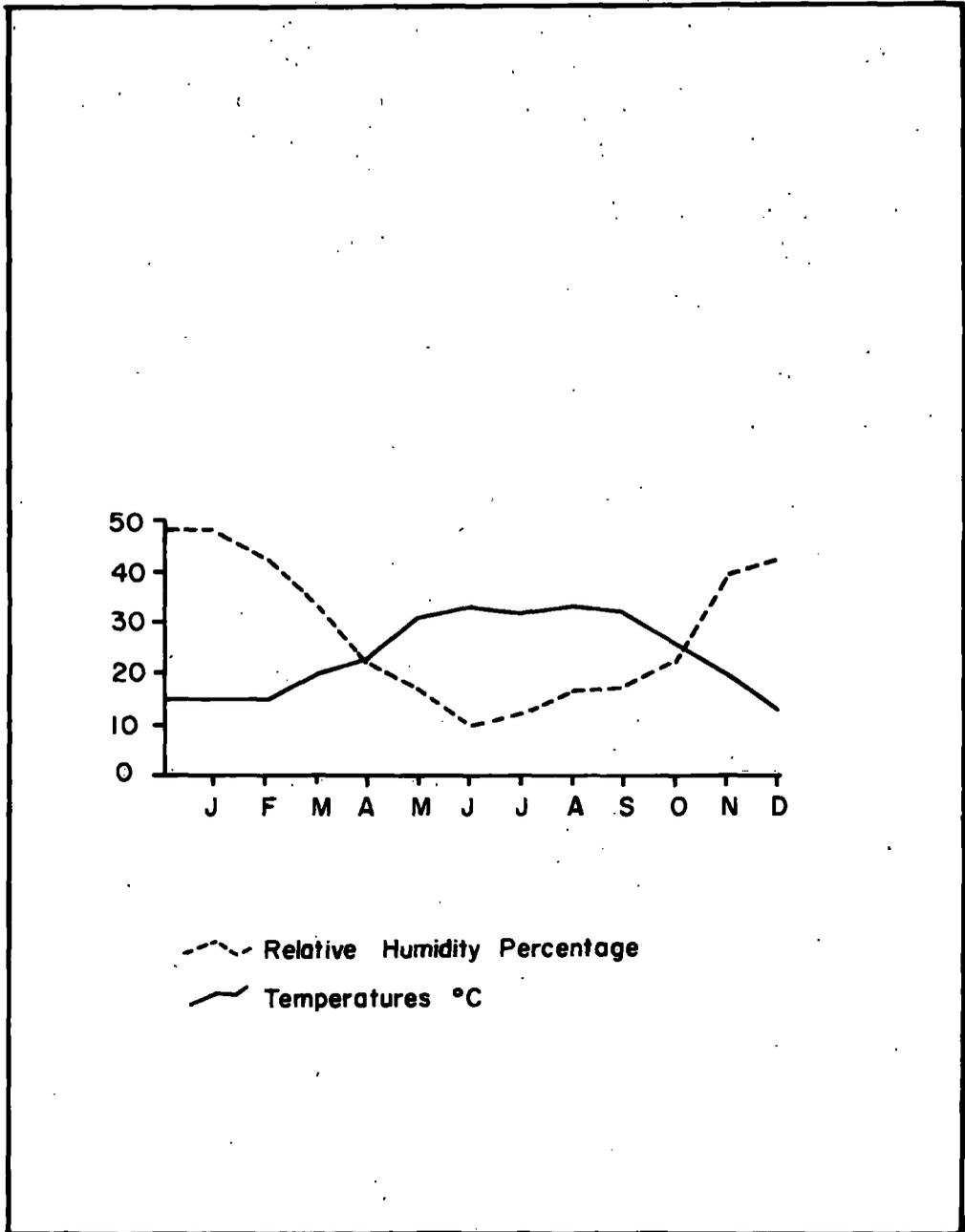
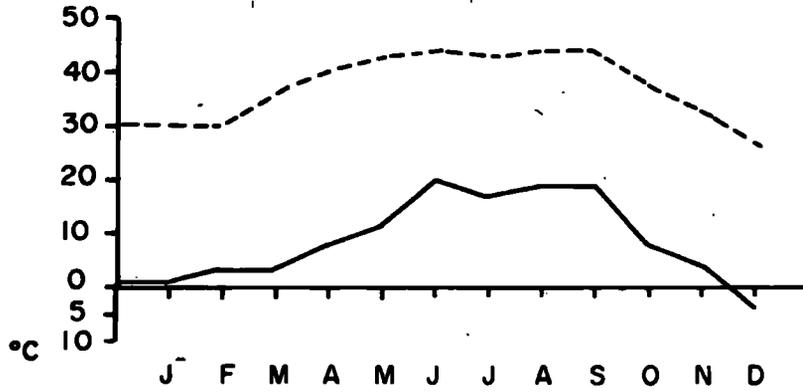
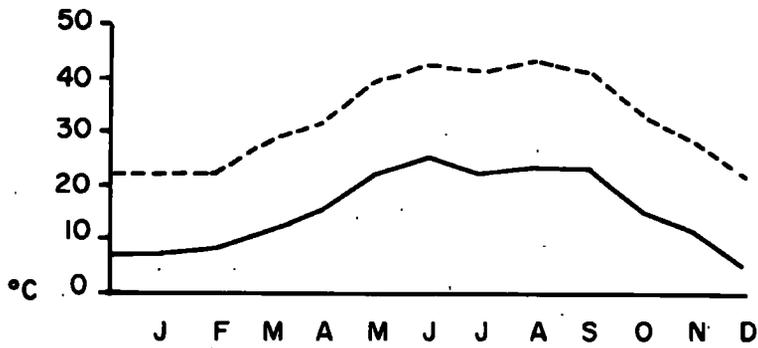


FIGURE 7

TEMPERATURE AVERAGES



A- Absolutes of Maximum and of Minimum



B- Means of Maximum and Minimum

--- Maximum
— Minimum

FIGURE 8

Figures show that humidity percentages during spring and autumn are not far below winter's, but far above summer's (Fig.9). Occasionally the region gains the full humidity percentage as in January and February, 1965, when 100% was recorded as the absolute maximum of humidity during these two months.

3.3 Wind and Rainfall

In winter the high pressure of Central Asia makes al-Qassim, together with the whole of Arabia, subject to north prevailing winds. These northern winds are fairly frequently interrupted by the passage of cyclonic depressions over the Fertile Crescent which bring south-east and west winds which results in cloudy skies and rain, and temperatures are usually above normal. In summer, prevailing winds are still northern, blowing to the low-pressure system over Equatorial areas. Uninterrupted by cyclones they are remarkably constant.

The annual average of extreme knots lies somewhere between 27.3 and ⁽¹⁾ 33.1. Summer averages are 36.9 maximum and 6.0 minimum. The surplus of summer extreme knots is apparently due to the rapid summer daytime heating of lower air over the region and surrounding sand areas, to strong convectional overturning, this interchange of lower and upper air tending to accelerate the horizontal surface current during warm hours. Generally, nights are much calmer, which is a partial explanation of the rapid nocturnal cooling of surface air in the region.

Rainfall in the Qassim is always meagre and it is also extremely variable from year to year. It is a general rule that dependability of precipitation usually decreases with

(1) All wind figures are quoted from the records of the towns of Hail and Ar Riyadh.

RELATIVE HUMIDITY PERCENTAGE

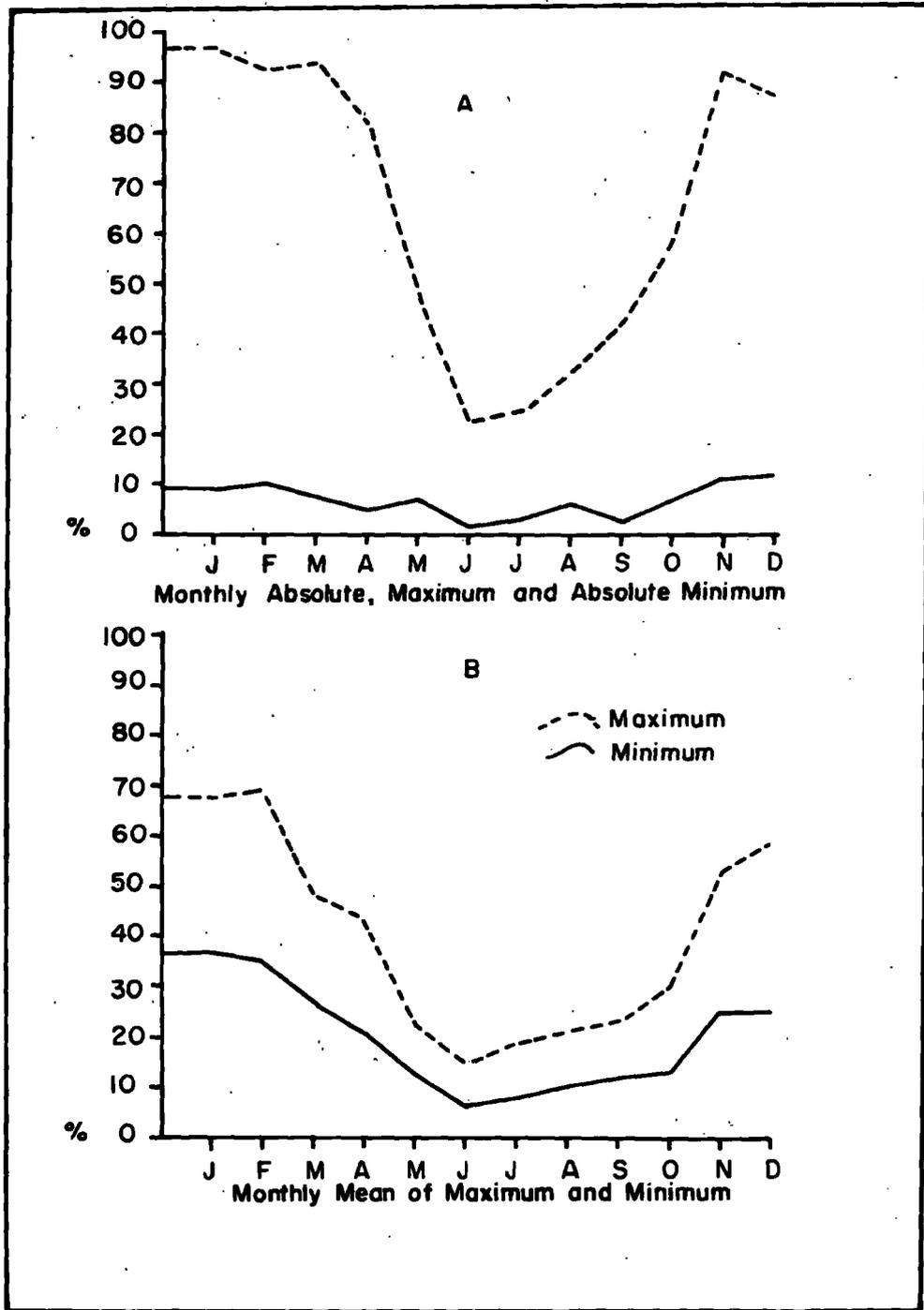


FIGURE 9

the decreasing amount of rain. Although no exact amount of rainfall can be expected as defining the humid margin of the region, the figure usually lies somewhere between 38 and 70 mm. (Appendix B Table 1). Analysis of the longer continuous records at Hail and Ar Riyadh suggest the annual coefficient of variation is over 50%. However, with such a short and broken record it is almost impossible to speak of typical average rainfall curve for the region.

Moreover, downpours in the area are locally concentrated. General widespread rains are almost unknown over the region, most of the precipitation coming in violent convectional showers which do not cover a very extensive area. After one of these occasional flooding rains the wadi may become a torrent of muddy water filled with debris. Settlements suffer, roads may be damaged and irrigation systems are often clogged with debris.

Rainfall in the region is exclusively derived from winter cold fronts that normally move from west to east during early and late winter. These are often preceded by scattered thunderstorms with intensities. No summer rainfall has been recorded in the region which is too far north for the effects of the inter tropical zone to be felt (Fig.10). A fifteen years record at Ar Riyadh proved that May, June, July, and August are rainless months. In August there is, however, a slight increase in relative humidity but insufficient to cause the development of convective type summer rainfall.

3.4 Evaporation

Potential open water evaporation and potential evapotranspiration have been calculated for the Ministry of Agriculture by Raikes and Partners of Rome who adopted a modified form of Penman's approximation of the energy budget and other empirical relationships. Therefore, all the

MONTHLY AVERAGES OF EVAPORATION AND RAINFALL

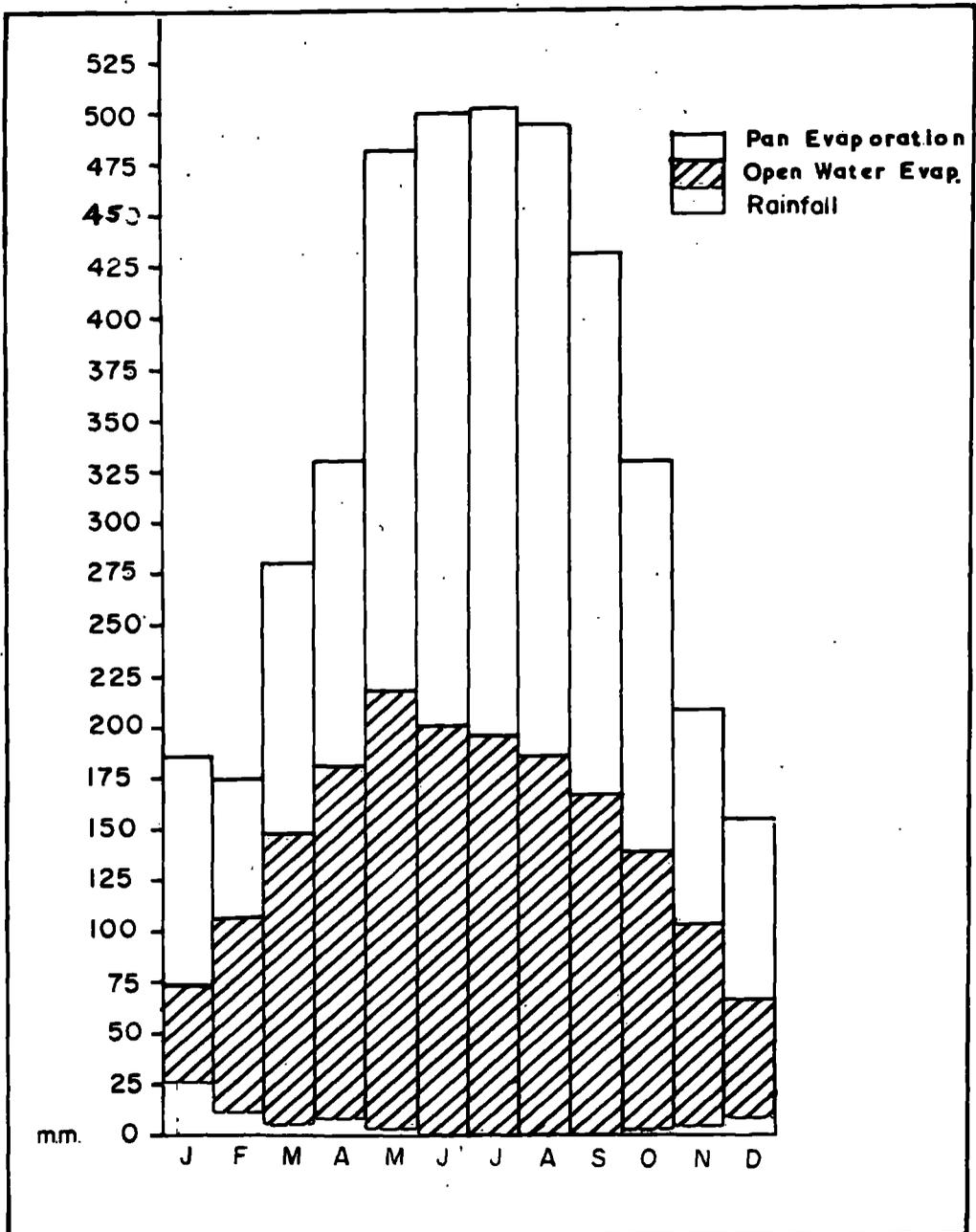


FIGURE 10

figures concerning evapotranspiration, recharge and water balance included here are quoted from the Raikes work of August, 1966.

Raikes have used ten day means of the available data to compute evaporation. They consider that the use of 10 days means instead of monthly means is essential for water budget studies as it provides a statistically acceptable proportion over a year and enables short term weather effects to be distinguished. However, the daily means are shown in Appendix B table 3 and the annual totals for 1964/65 are as follows:-

Open water evaporation	1700 mm.
Pan evaporation	3951 mm.
Potential evapotranspiration	1226 mm.

The indicated evaporation pan factor is therefore 0.45 as computed with the more usual value of 0.7. However, in a very arid environment this is to be expected and similar pan factors have been observed in the eastern desert part of Jordan. The most significant result arising from this analysis is that evaporation appears to be greatest in the spring and tends either to remain at constant level in the summer months in spite of increasing temperature and decreasing humidity. This tentative conclusion is contrary to accepted understanding of evaporation. However, the reasons for this apparent paradox may be explained in considering the effects of humidity on the radiation balance and efficiency of conversion of heat into vapour. In addition, the efficiency at which heat is converted into vapours, expressed in terms of slope of the saturation vapour pressure curve at heat air temperatures, is usually approximately constant up to mean air temperatures of 25-30°C. but sharply decreases at higher temperatures. The net effect of very high mean air temperatures of 30°C. and

over and very low relative humidity of less than 15% appears, therefore, to have the effect of keeping evaporation at a fairly constant level in such conditions.

The corollary to this tentative conclusion is that potential evapotranspiration from soil and vegetation would also remain at a constant level during the hot summer months. Whilst this may be so in the case of an open desert it is not expected that this condition would prevail in irrigated areas in the Qassim. That is due to the fact that the reflection coefficient is smaller, the temperatures of the air near the ground and the ground itself are lower and the humidity is higher. The net effect of these would be to reduce long wave emission from the surface and thus make a greater proportion of the radiation balance available for evaporation. However, the application of normal evaporation computing methods for irrigated areas would be largely invalidated and might be underestimated the water requirements of irrigated crops.

3.5 Run off and recharge

The wadis in the region are liable to flood on rare occasions. The last known time of wadi Ar Rma being flooded was in January, 1965. From water levels pointed out at the gauge site near Aunayzah and a survey of the cross section and slope on site it is estimated that some eight million cubic metres were discharged through the Aunayzah-Braydah Gap over a period of eight days. The channel in this area is small and with a very flat gradient and consequently low velocity flow is released slowly from storage on the wide flood plain between Aunayzah and Ar Rass. Because of the low gradient and velocity and because it is locally comparatively silt free, a large proportion of this discharge is thought to have gone to recharge the wadi alluvium downstream.

Recharges from local run-off to the superficial deposits of the Qassim area is likely to be infrequent, but analysis of rainfall and potential evaporation data indicate that at least recharge to soil moisture would take place. By considering both actual rainfall and the energy available for its removal by evaporation an indication of actual as against potential loss, is obtained. Aunayzah record shows that on three occasions in 16 months there occurred a surplus of water for direct infiltration or for run-off. The 34 mm. surplus occurring in January, 1965 (Appendix B table 3) is made up partly of run-off which is known to have occurred and partly of soil moisture. No figures of the exact proportions of each are available.

Reviewing the climatic condition of the Qassim one may reach a conclusion which asserts that the climate in the Qassim is conducting a major and severe role among the physical phenomena of the Qassim's environment. It is obvious that agriculture cannot be practised on this meagre amount of rain alone, so that dry farming can never exist as a permanent agricultural pattern in the area. This fact severely restricts the area which can be brought under cultivation; agriculture in the area has to be confined to places where the underground water found is sufficient for irrigation. As a contrast temperature values provide no close season for plantation.

The effect of climate on soils in the region is a prominent handicap in weathering solid rocks. It is a fact that weathering of solid rocks is a slower process in a dry climate than wet ones, so that the residual regolith cover must be thin. The high values of evaporation is the reason behind the high salinity nature of the soil classes in the area. As a result of meagre rainfall the process of soil

leaching is slow and because of this soils are rich in mineral contents.

Chapter 4

Ground Water Hydrology

4.1 Historical Background

Throughout the centuries ground water discharge has been confined to the shallow run-off rechargeable unconfined (Phreatic) aquifers. The discharge was from some of 800 hand dug wells scattered throughout the region with an average depth of 20 m., with animal power as the only means of water drafting. A dramatic turning point in this pattern of water utilization emerged in July, 1953 when the artesian water of the deeper aquifers was encountered. This occurred when Mr. S. al-Khriyf was deepening his old hand dug well on his farm at Az Zarqa suburb of the town of Braydah (plate xxvi). When the drilling reached 100 m. depth the artesian water of the Tabuk was encountered and burst its way out to flow onto the surface and marked the first appearance of the flowing artesian water in the history of the region. Soon intense deepening of the adjacent wells was started but mainly by inexperienced drillers using incorrect casing which resulted in an intense seepage of the flowing water through the boreholes. This situation led to a rise of water table in the Braydah area. In a few years the rise of the water level reached a very dangerous point resulting in a collective collapse of many houses in the town, pools of stagnant water in the hollows round and inside the town and crop failures. This critical position urged the Ministry of Agriculture and Water to launch intensive research with a view to terminating the dangerous rise of the water level



Plate No.xxvi. Mr. Sulaiman al-Khriyf the discoverer of artesian water pointing at the blocked neck of his old hand-dug well, which had been killed by the Ministry of Agriculture after investigations had proved that the casing of the bore-hole was incorrect and had caused a serious leakage contributing to the rise of water-table at the time of the crisis.

and eliminating it, and secondly, to appraising the quantity and the quality of the new source of this very vital economic asset to the region.

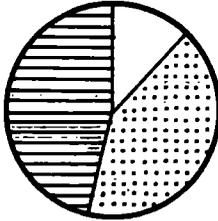
The Wells Inventory and Hydrological Survey was initiated in August, 1965 and continued through to September, 1967. Detailed data were obtained on all wells in the region (1,722 wells)(Appendix] table 1). 46.7% of the total were hand dug type, 31.3% were dug drilled type and 22% were drilled. A summary of the inventory on the source of water, type of wells, use of water, and method of producing water is given in figure 11. A selection of chemical analysis is recorded and tabulated in Appendix C. 11.7% of the total wells in the Qassim are flowing. Generally in the Braydah area, wells tapping or penetrating the Tabuk formation have a moderate flow of water. North of Braydah such wells do not flow except where the land surface is topographically low. Wells penetrating the Saq sandstone flow in the area east of a line running from Aunayzah to Qusaiba village and north from Wadi Ar Rma to the north end of Ad Dughmanyah area. In al-Asyah (N.E.) wells at the village of Hunaidhel, at Tunnumah, and al-Je'a'ala are screened in the Saq sandstone at a depth below 1450 m. The heads in this area extend to 100 m. and more above land surface and with discharge value of 150-240 LPS.

4.2 Surface Aquifers

Recent fill deposits and the upper portions of the older geologic formations are included in this unconfined aquifer. Shallow hand dug wells extract their water from this zone and yield low to moderate quantities adequate only for a limited scale of irrigation which brought about palm gardens practice in most of the topographic depressions of the Qassim. Wells are frequently so closely spaced that

SUMMARY OF WELLS INVENTORY IN THE QASSIM

A - SOURCE OF WATER



FLOWING ARTESIAN

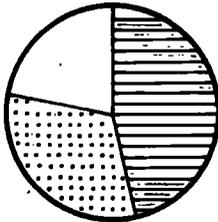


NON-FLOWING ARTESIAN



PHREATIC

B - TYPE OF WELLS



HAND-DUG

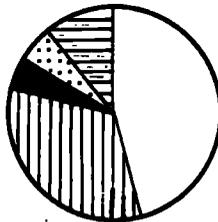


DUG-DRILLED



DRILLED

C - USE OF WATER



IRRIGATION



IRRIGA. & DOMESTIC



DOMESTIC

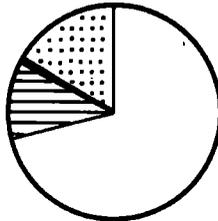


UNUSED



ABANDONED

D - METHOD OF PRODUCING WATER



PUMPING



FLOWING



HANDBUCKET



UNUSED

FIGURE 11

mutual interference is enough to limit daily pumping hours. Permeabilities vary from low for fine-grained cemented sediments to very high for coarse granular materials. Long-term yields from this zone are dependant on replenishment from rainfall, from surface run-off, locally from lower aquifers by leakage where small faults exist or the shale layer is not absolutely impermeable, and from return flow from irrigation.

Water within this zone exhibits great variations in quality. The variations are related to the presence of evaporites in surficial alluvium and phreatic zones of deeper aquifers and the localized concentration of salts that accumulate in topographic depressions.

Water within surficial alluvium and phreatic zones of the Jilh, Khuff, Tabuk and Saq formations commonly contain total dissolved salts (TDS) that range in concentration from 1000 to over 6000 ppm (Fig.13). Waters are dominantly sodium chloride in character although sodium-sulphate waters are not uncommon. Calcium occurs as a secondary cation, usually in concentrations less than 50% of sodium concentrations; magnesium occurs as a minor constituent and rarely exceeds 40 ppm except in the more saline waters. (Table 2 Appendix E).

Bicarbonate occurs as a minor anion in concentrations that range from 100 to 200 ppm but always as a small portion of the total anions. In this respect Phreatic waters are similar to the deeper artesian waters which also contain bicarbonate ion within this range. Nitrate (NO_3) ions are common, but usually in concentration less than 40 ppm.

Some local changes in the chemical characteristics of phreatic waters have undoubtedly occurred since the initial

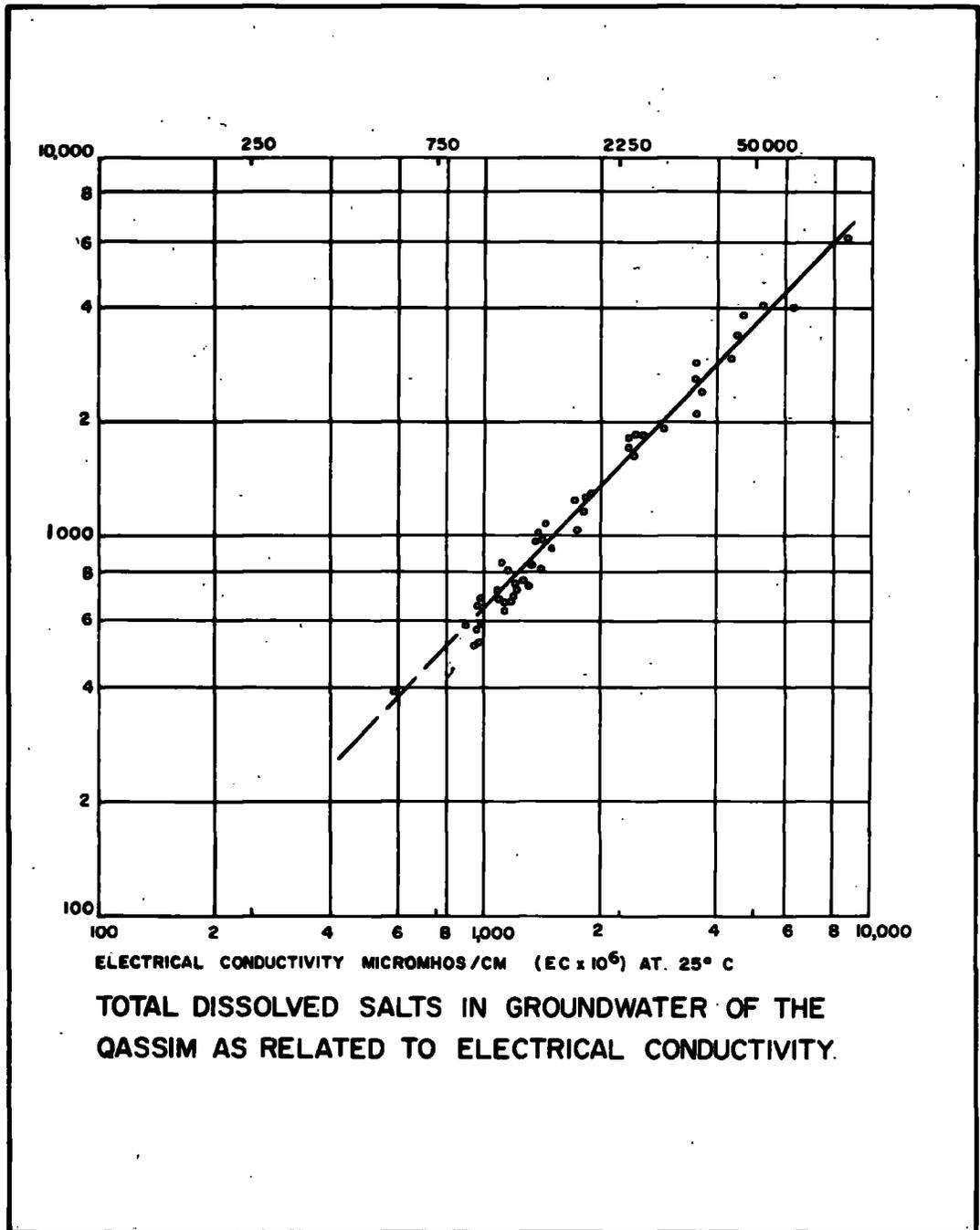


FIGURE 13

construction of deep wells and their use for irrigation began. Unfortunately, the prior chemical character of water is unrecorded. Local residents commonly report that changes, usually salinity increases, have occurred in many of the shallow dug wells, but such reports are largely conjectural. They do not distinguish between natural seasonal changes and those resulting from any constantly increasing concentration of salts from irrigation waters.

However, it is believed that occasional flood flows from Wadi Ar Rma may affect phreatic water quality in the reach of the Wadi between the village of Riyadh al-Khabra on the west and the town of Braydah. Flood flow from other smaller wadis probably could also affect water quality seasonally, but such effects would be localized and of little consequence.

4.3 Deep aquifers

Future development and expansion of agriculture in the Qassim is entirely dependant on these deep water aquifers. This is due to their far larger capacity of better quality water. In fact it is the discovery of these aquifers which makes the Qassim the most promising region for agricultural expansion and development in the whole of Saudi Arabia. A large area of virgin lands could be brought under cultivation on correct and modern bases of irrigation and cultivation practices. Experiences are provided from difficulties which have resulted in a severe soil water logging and salinity, a situation which needs a great effort for soil amelioration practices.

However, drilling tests through the whole of the sedimentary formation to the basement complex have proved that the sedimentary section of the Qassim's geologic formations contain four identical and separate water aquifers.

They are Jilh, Khuff, Tabuk, and Saq aquifers (Fig.12). Within the Tabuk sector three separate sub-aquifers were encountered and classified as Upper Tabuk, Middle Tabuk, and Lower Tabuk.

4.4 Jilh Aquifer

In the Qassim this Triassic formation (Fig.12) is exposed only in the north-east sector and has a few known drilled wells. No aquifer tests were conducted on wells subtracting the Jilh's water.

Electrical conductivity measurements of the aquifer's water indicate that the phreatic zone of the Jilh contains highly mineralized water. This high salinity is related to the occurrence of subordinate evaporites of the limestone components within the thin shale units that characterize the formation, and is probably typical of waters confined within deeper permeable zones of the formation that extend eastward beneath younger sediments. In any case, the Jilh is not considered a productive aquifer because of the low permeability of its formations. Its significance is that it contains poor quality water which could degrade other waters if intercountered with deeper aquifers by improper well construction.

4.5 Khuff aquifer

Shallow drilled wells (less than several hundred metres in depth) and many dug wells in the area north of the town of Braydah derive water from this aquifer. The Khuff aquifer's formation is predominantly a limestone formation with gypsum and gypsiferous beds which would contain a highly mineralized water. Nevertheless two wells tested in Braydah proved the water to be much fresher than it was anticipated, and it is suggested that the Khuff may not contribute any part of the yield of these wells at the time

AL-QASSIM OUTCROP SEQUENCE

AGE	FORMATION		LITHOLOGY	GEN. LITHO. DESCRIPTION	THICKNESS	MAJ. STRATI. DIVISIONS
	QUATER. & TERTIARY	SURF. DEPOS. & BASAL				
MESOZOIC	UPPER	MINJUR	[Dotted pattern]	SANDSTONE; SOME SHALE	315 m.	PERMO-TRIAS. CLASTICS
		MIDDLE	[Brick pattern]	SANDSTONE, APHANITIC LIM. - ESTONE AND SHALE, SUBO. - RDINATE GYPSUM	326 m.	
	LOWER	SUDUIR	[Horizontal lines]	RED AND GREEN SHALE	116 m.	
		UPPER	KHUFF <small>KHUFF, BIGHANAB</small>	[Zigzag pattern]	LIMESTONE, SHALE & EVAPOR.	
PALEOZOIC	ORDOVICIAN AND SILURIAN	AYUN FORMATION		TABUK	[Dotted pattern]	1072 m.
		CAMBRIAN	SAQ	[Dotted pattern]	SANDSTONE	600 m.
PRECAMBRIAN						
BASEMENT COMPLEX						

FIGURE 4

when tests took place. Upward infiltration of the Tabuk or even the Saq by minor fault or by seepage from incorrect carrying of the adjacent wells could present this unusual water freshness for such formation.

Although the Khuff formation in the Qassim area is dominantly dolomite, limestone, and evaporites, physical and chemical characteristics of groundwater from the confined permeable zones are in many respects similar to those of the Jilh. Waters are highly mineralized associated with methane gas, and generally unsuitable for agricultural use. These waters degrade other waters if not isolated during well construction. The chemical analysis and electrical conductivity measurements which are available indicate that the Khuff aquifer's water contains from 2000 to over 5000 ppm TDS. Sodium cations and chloride anions are generally dominant and secondary calcium-sulphate ions. (Table 2 Appendix C).

4.6 Tabuk aquifer

As shown on the geologic illustrations the Tabuk outcrop is areally extensive and the formation is relatively thick. There are three fairly defined water-bearing beds in the Tabuk (Fig.12). Pumping tests conducted on the wells derive the Tabuk water show that the coefficient of transmissibility ranging from about $12 \text{ m}^3/\text{dm}$ to $1350 \text{ m}^3/\text{dm}$. The lower extreme was obtained from the middle aquifer. Thus this aquifer is exceptionally tight, and would not be a satisfactory aquifer except for small domestic and stock use. The higher extreme was obtained from the lower aquifer. However, the average coefficient of transmissibility for eight tests was found to be $185 \text{ m}^3/\text{dm}$. The only value of the coefficient of storage obtained was 2.5×10^{-3} which is believed to be too high for the formation.

Water quality and pressure were similar to what had been expected for the Saq sandstone aquifer. This suggests that during geologic times there has been leakage between the lower Tabuk aquifer and the upper Saq aquifer, thus the two producing zones may act as a single unit.

However, it has not been possible to recognize significant quality variations within any of the three sub-aquifers as indicated from the available chemical analysis data. The Tabuk waters contain primarily sodium-chloride water although some wells penetrating the Tabuk formation occasionally yield sodium or calcium sulphate waters. The mineral content varies from 500 to over 2000 ppm TDS; however, the higher mineralized water samples analyzed are probably indicative of improper well construction which has permitted the mixing of highly mineralized waters from the overlying Khuff aquifer. TDS contained in Tabuk aquifers water east of the outcrop area in the central part of the Qassim probably do not exceed 1200 ppm. (Table 3 Appendix C).

Although water within Tabuk aquifers in the central part of the region may be generally classified for agricultural use, little quantitative water quality information is available on Tabuk's water elsewhere in the region. Water studies on other deep aquifers at Ar Riyadh city generally indicated progressive salinity increases as groundwater migrates toward a discharge area. A similar condition probably exists in the Tabuk's water.

4.7 Saq aquifer

The Saq is the most extensive aquifer underlying the whole of the Qassim. It is probably the most prolific aquifer (plate xxvii) and, in places contains the best quality water. If the high head on this aquifer is not dissipated by excessive waste of water from flowing wells, it should be of importance for generations to come.



Plate No.xxvii. The high-head of the flowing artesian water of Saq aquifer, the deep well of At Tannumah village in al-Asyah.

Most of the wells which penetrate the Saq in the region are also open through at least part of the Tabuk. Four well tests gave an average coefficient of transmissibility of $500 \text{ m}^3/\text{dm}$ with a single value of storage coefficient of 2.5×10^{-4} . One test gave a value of "T" of about 2500, which is exceptional and probably too large. The well has a high specific capacity and may show a high degree of response to barometric change.

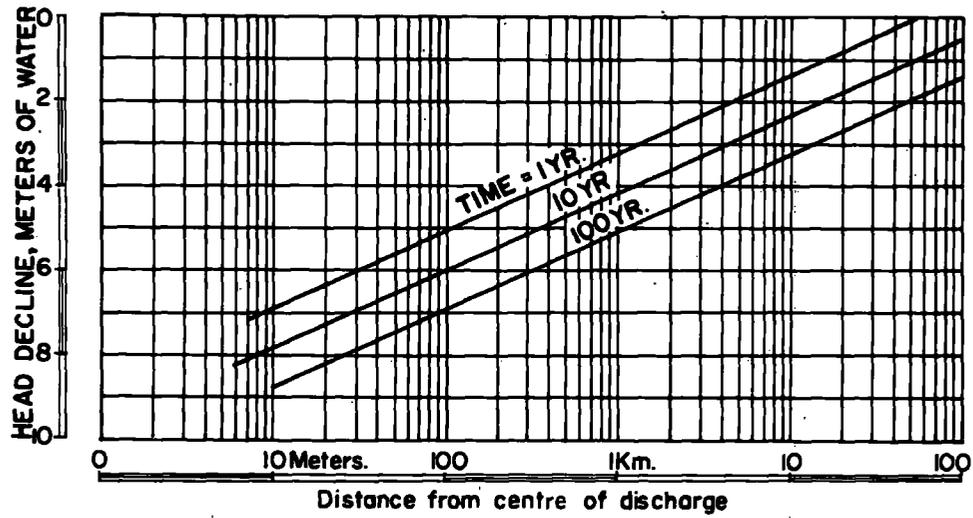
A flow test of the full thickness of the Saq in the Qassim indicates that it is a very good aquifer with "T" $1430 \text{ m}^3/\text{dm}$. However, the wells in the region have an average of about $1000 \text{ m}^3/\text{dm}$. (Fig.14).

Saq's waters contain primarily sodium-chloride water although some wells penetrating the Saq occasionally yield sodium or calcium sulphate waters. Waters appear to be somewhat less mineralized and more uniform in chemical character than those in Tabuk aquifers (Table & Appendix C). TDS generally range from 600 to 900 ppm in the vicinity of the town of Braydah, however, sample concentrations exceeding 1000 ppm are not uncommon.

4.8 Aquifer characteristics

Water in an aquifer moves from the recharge to the discharge area, but at a rate that is very slow compared to surface water velocities. The direction of the water movement in the Saq sandstone in the northern part of the Qassim is normal (perpendicular) to the piezometric surface indicating a discharge area, probably direct discharge of the Saq which directly underlies the wadi on its western part (Fig.15). However, no underground water movement from west to east has been proved due to differences in elevation in the eastern part and the western part as far as the aquifers are concerned.

**EFFECTS OF WITHDRAWAL
OF WATER
SAQ SANDSTONE - QASSIM REGION**



$T = 1,000 \text{ m}^3/\text{d}\cdot\text{m}$
 $S = 2.5 \times 10^{-4}$
 $Q = 63, \text{ ILPS. (1,000 GPM)}$

FIGURE 14

SURFACE OUTCROP OF THE GEOLOGIC FORMATIONS OF THE AL QASSIM

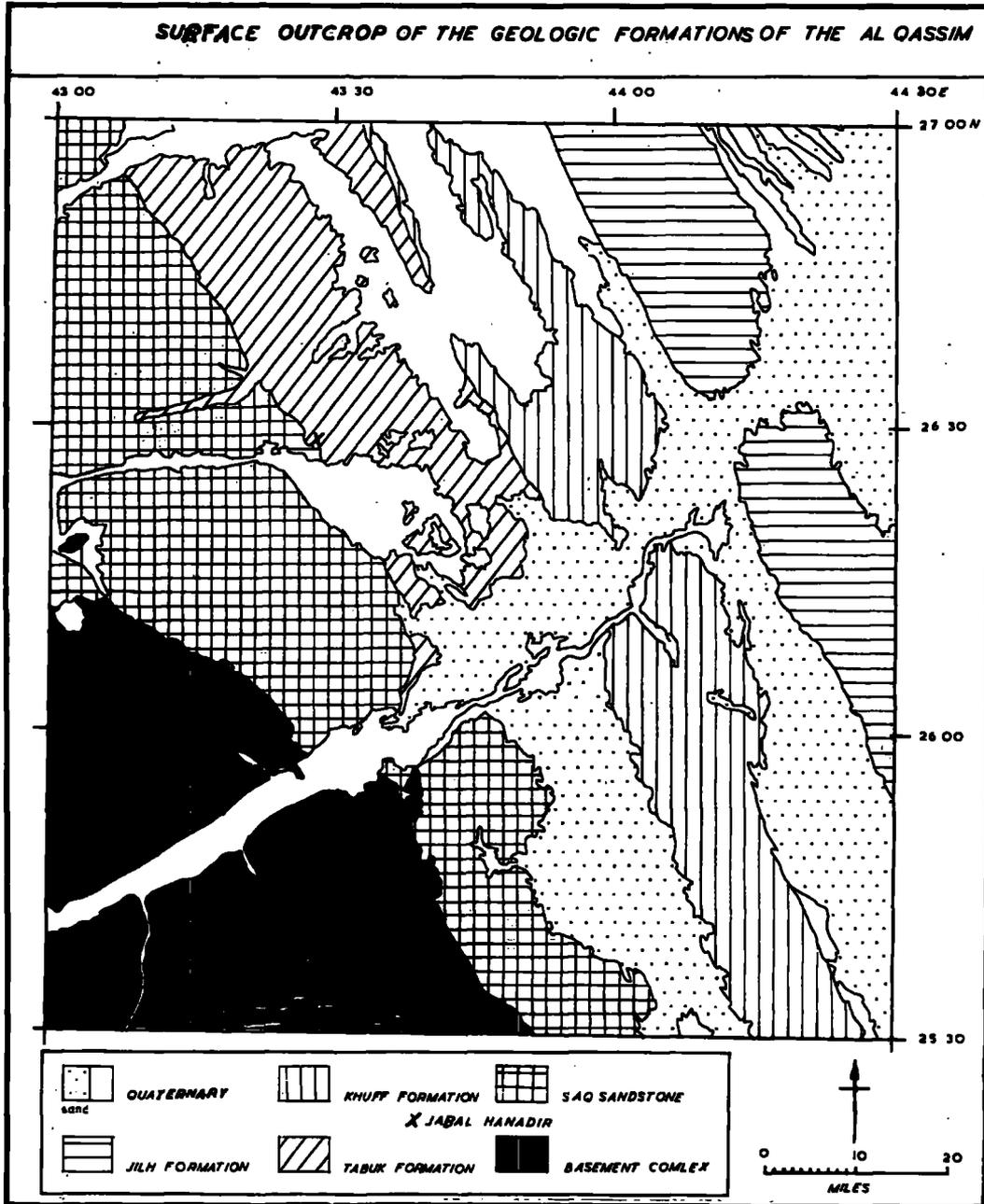


FIGURE 5

Changes in the quantity of water stored in the aquifers of the Qassim are reflected in the changes in piezometric head and seasonal trends are clearly identified. Many well owners in Braydah area told of decreasing yields and declining heads. Most of the drilled wells in Braydah area tap the upper or middle aquifers of the Tabuk; some tap the lowermost sandstone. Some wells in this area produce Saq water.

Analysis of the meagre available data indicates that the Tabuk piezometric surface will continue to decline for some time at a rate of two metres per year, but decreasing slightly in future years. Data for artesian wells penetrating the Khuff and Jilh formations are very sparse, principally because these formations do not generally yield irrigation supplies nor do they occur at an extensive area of the region.

Records of water level changes in the Saq sandstone are not available. Although more than 20 wells have been drilled during the past ten years into the Saq in Ad Dughmaniyat area, and a number of Saq wells drilled in Braydah area, there are no early records of shut in heads. Records of the Ministry of Agriculture and Water's new high-head wells in al-Asyah area are too short to permit extrapolation of pressure into the future, based only on the periodic observations.

The Saq underlies some of 20,000 sq.km. of the Qassim area between the village of Qusaiba on the north and the village of al-Murabba'a on the south, and between the western edge of the outcrop belt to the line of high pressure wells on the east (al-Asyah area).

Preliminary computations show that the quantity of water stored in the Saq aquifer would be sufficient to flood the land above it to an average depth of 50 m. Similar computa-

tions for the Tabuk formation which overlies the Saq show quantities in the same order of magnitude stored in that formation. Most of the Saq sandstone is confined. Thus within this area the amount that may be obtained from storage is the product of the average decline in head, the area over which this average decline takes place, and the coefficient of storage. Assuming then that the average permissible decline in head is about 50 m., the amount that can be developed from the artesian part of the Saq will be about 1.75×10^8 cubic metres. Similar quantities will be available as leakage from the interbedded finer-grained beds and from the less permeable confining beds.

4.9 Water Utilization

The shallow groundwater of the Qassim has been utilized throughout historic times for rural and nomadic purposes, and it was the presence of such shallow groundwater which brought about the ancient Palm Gardens as the typical agricultural pattern in the region for many centuries. Initially there have been scattered springs, e.g. al-Asyah Ash Sehmassiyah, but the simple development was by infiltration galleries (Dubul) and by hand dug wells from which water was lifted by animal power and these sufficed to dry up such weak springs.

With the incoming of diesel motors and centrifugal pumps the picture started to change. The amount of water which could readily be extracted exceeded the capacity of the open wells and the amount stored in the phreatic zone. More groundwater was sought, mainly by drilling in the bottom of existing hand dug wells. These bores tapped confined groundwater in the Tabuk formation. In some areas, it was under sufficient head to flow up the bore and into the dug well from which it was extracted, with the shallow groundwater. In other areas the Tabuk water flowed directly onto the surface; in such cases the original shallow groundwater was

left in the well. In this way, a greatly increased amount of groundwater was brought into the area, but no steps were taken to keep it under control.

Increased pumping made it possible to irrigate more land, but the existing dug wells (sited at low elevation) did not usually command sufficient additional non-saline land. As a consequence excessive infiltration below the root zone increased and led to a rising water table. The size of water level has also been contributed to by more water poured into unlined irrigation canals and pools on porous soils which infiltrated rapidly and by the addition of confined water which filled dug wells and which has let the dug wells act as a recharge point for the shallow groundwater zone. Too often, however, the deep bores were located at or near the sites of the original open dug wells and the intermediate medium depth boreholes. So, into these limited areas with little or no natural drainage or mechanism for salt disposal, additional water was brought to make a bad situation still worse.

The rise of groundwater level also intensified the bad effects on surface run-off. In the past, there was space in the shallow aquifers to store as much surface run-off as could infiltrate, so that the effects of floods became more noticeable at the time of the crisis, and pools of surface water began to accumulate in areas where before they readily infiltrated.

The major factor of creating the rising of water level at the time of crisis was undoubtedly the uncontrolled flowing wells as most of this type of well were without valves to close the bore when water was not needed. Non-flowing artesian boreholes present a much lesser danger in this respect, since the pumping costs restrict pumping to

the range needed. However, extraction from aquifers is certain to decrease the pressure of the water in the aquifers. In the future, all wells in Qassim will probably have to be pumped. At that time the drought of water from the deeper aquifers would be questionable from the standpoint of cost.

However, the Ministry of Agriculture and Water has managed so far with the help of many consultants, to reduce the water level below the danger line. This was achieved particularly in the Braydah area by various methods, the more costly one was killing the wells which had been suspected of having leakages and defects throughout its boreholes. However, it is in the writer's opinion that the Ministry should establish a sound water policy, which would be more successful if the new policy was based on the following steps. Firstly, a complete revision of its water division staffing and management and designation of broad scale plan to meet efficiently its technical and financial requirements and equipment, and, secondly, issuing the proposed national code for water conservation, which necessarily must contain the specific specifications for drilling and well construction. A design which should cover every particular case based on the geologic, hydrological, economic and social findings and considerations, which must be carefully and correctly geared to each other in order to avoid contradictions which might emerge when the code is applied or put into practice in an individual case in a particular area or region throughout the kingdom. If such steps were taken, then the Qassim would be one of the most benefited regions in Saudi Arabia from such a policy and gain the complete reward from this significant source of wealth and prosperity.

It is evident that the deeper aquifers particularly the Tabuk and Saq should maintain their role of reliable water

sources to the maximum agricultural land capacity for generations to come. This might be affected only by pumping cost after flowing ceased, so it is vital for any long-term agricultural development plan that a detailed pumping cost study on the deeper aquifers should be designed and worked out as soon as possible. Another alternative for covering pumping cost could be found in putting up the product price, but this is unreliable and largely governed by marketing conditions.

References

1. Abul-Haggag, Y. Remarks on the Artesian Water of Najd, Saudi Arabia
Bulletin de la Societe de Geographie D'Egypte, Cairo Tome XXXVII, 1964.

2. ARAMCO Water Possibilities at Anayzah and Buraidah
Unpublished mimeograph submitted to the Ministry of Water and Agriculture in May, 1958.

3. ARAMCO Properties and Criteria of Arabian Ground Water
Unpublished mimeograph transmitted to the Ministry of Agriculture in August, 1961 under the number: SAG 41-61.

4. Droulin, G. Future prospects for Hydro-Agricultural Development, Saudi Arabia
Typed publication, EPTA report No. 1638.
F.A.O. Rome, 1963.

5. Burdon, D. J. Water Development in Saudi Arabia
Typed publication.
F.A.O. Rome, 1963.

6. Burdon, D. J. Groundwater Policy for Saudi Arabia: A Suggested Outline
Unpublished mimeograph, Department of Water Resources Development, Ministry of Water and Agriculture, Ar Riyadh, 1960.

7. Burmingham, C. W. Land and Water Resources, Saudi Arabia
Typed publication,
F.A.O. Rome, 1952.
8. F.A.O. Hydro-Agricultural Development Progress, Saudi Arabia
Typed publication,
Rome 1967.
9. Hydrology Staff Bulletin of Hydrological Information, Saudi Arabia
Series No: 1-11, 1966-67,
Ministry of Water and Agriculture
(ARABIC)
10. Khatib, A. Water Resources and Agricultural Development Planning
Typed publication, FT report
No: Sau/FT/2
F.A.O. Rome 1965.
11. Noory, M. A trip to the Qassim (N.W. and W.) of Braydah, and As Sirr area for investigations of Wells Sites and general study of water conditions
Unpublished mimeograph,
Department of Water Resources Development, Ministry of Water and Agriculture, Ar Riyadh,
1963 (ARABIC)
12. Noory, M. A trip to the Qassim (Asyah and vicinity areas) for investigations of wells sites and general study of water conditions
Unpublished mimeograph,
Department of Water Resources Development, Ministry of Water and Agriculture, Ar Riyadh,
1962 (ARABIC)

13. Ozkan, A. and Al-Badori, M. Water problem in Braydah, the Qassim
Unpublished mimeograph, Department of Water Resources Development, Ministry of Water and Agriculture, Ar Riyadh, 1964 (ARABIC).
14. Raiks & Partners Intermediate report on surface hydrology of Qassim, Jawf, Sakakah, and Wadi Sirham, Saudi Arabia
Parsons-Basil Consultants, Ministry of Water and Agriculture, Ar Riyadh, August, 1966.
15. Parsons-Basil An emergency area report for the Qassim, Wadi As Sirham, al Jawf and Sakakah
Water and Agricultural Development Studies, Ministry of Water and Agriculture, Ar Riyadh, September, 1966.
16. Trewartha, G. T. An introduction to climate
Pages 233-6 and 381-3.
New York, 1954.
17. Twitchell, K. S. Water Resources of Saudi Arabia
The American Geographical Review, 1944, Vol. XXXIV.

PART III

THE SOILS

Chapter 5Natural Vegetation and
Soil Formation5.1 Natural Vegetation

In the Qassim, the differences in elevation are not significant, the exposure does not seem to be important, and annual rainfall rarely exceeds 50 mm. This leaves the soil formations as the major primary ecological factor that affects the amount, kind, and vigour of the vegetation cover. The wadis and deep sands provide the best vegetation cover due largely to accumulated moisture allowed by the structural nature of the two. The gravel formations, duricrust, rock areas and saline soils are generally least productive. At the present time there is a general rapid depletion of vegetation cover in this region, due to over grazing, destructive cutting and root collecting by fuel gatherers and attempts at dry farming on those sites with most potential vegetation.

A complete systematic collection of plants has been made by Standing⁽¹⁾ for the Ministry of Agriculture during the period 1st January to early April, 1967 (Appendix D). Fifty-three vegetative species were recognized and identified in the region, five species of grasses and eight shrubs of decreaser types, 7 species of grasses and twenty-five shrub species are of increaser type. There are 10 different species of invading perennials and, of the prominent annuals 8 grass species and 10 forb species. The vegetation in the region can be classified into three categories in terms of

(1) Arnold R. Standing, American range specialist, co-author of "Range plant handbook" and many others.

density and quality; the wadi areas, deep sand dune areas, and the desert plain and limestone outcrop areas.

The wadis are the most favourable vegetative habitats with run-off water bringing silt and nutrients along with the additional moisture. The shrubs and grasses form more vegetative cover than on surrounding uplands. In the wadi Ar Rma, for example, the major forage plants were species of Salazoh, Artemisia, Artiplex and many other decreaseers.

In the wadis, annuals are abundant in the wet season. Some of the wadis are salty (plate xxviii) in which case Haloxylon artieulatum (Nitum), Haloxylon perisum (Ghadha) and Haloxylon salicornicum (Rimth) (Increaseers) are the most common species. They also recur on salty sites in the sandy areas and normally are not extensively grazed.

Concentration of forage supplies in the wadis as a result of run-off water, offer many opportunities for range improvement. The major forage is from shrubs which will maintain forage through the dry season. Soil moisture in the wadis is favourable and re-seeding may be successful if care is taken to seed on wet soil and to give the seedlings a chance of survival by protecting them from grazing for at least a year. However, trials should be taken to determine the feasibility of seeding the best areas in the wadis. Suggested introductory species include Cilaria, Eragrostis, Suporba, and Kochisindica species. Several of the native shrubs like Atriplex and Salsoba species should be tried.

The principal vegetation of areas of deep sand is Panicum turgidum (Thamam) a decreaseer grass. Following the rains, vast green carpets of annual grasses and herbs cover the sands. The common shrubs are Callignum (Ant) (plate xxix), Artemisia (Adhir) (Increaseer types) and others which are all grazed extensively. The sands have an extremely high infiltration capacity and a very low water-holding capacity. As much of the rain comes in high intensity



Plate No.xxviii. A salty side of Wadi al-Midhuab where a combination of Ghadha, Nitum and Rimth are grown constituting the natural vegetation of the site.



Plate No.xxix. A view of the Art shrubs grown on the sand dunes south of the town of Braydah.

storms, these two soil characteristics prevent run-off and promote deep penetration of water. Thus the sand supports more vegetation than is normally expected with such low average rainfall.

Desert plains and outcrops of limestones have plants scattered in the pockets where soil has accumulated. If a sand layer covers the limestone, Rhantherium epapposum (Arfaj) (plate xxx), an increaser species, forms a dominant cover and Stipa tortillis (As Samma), a prominent annual species is a common associate along with many other annuals. This type is found principally in most parts of the region where escarpments and gravel plains are found.

A striking feature of the vegetative cover in the region is the comparative abundance of plants 30 km. distances from the agricultural settlements in the region but the soil is bare near them. This is due apparently to the concentration of livestock round these settlements where water is available for animals during dry periods. This concentration results in far too much overgrazing, a condition which, if continued, would deprive the surrounding villages of vegetation cover. More wells away from the settlements will spread the livestock more evenly and help to relieve local overgrazing.

However, it is evident that a downward trend of plant succession is in rapid progress in the region because increasers are replacing decreasers. This is especially evident in areas of livestock concentration. Unless drastic steps are taken immediately to give vegetation substantial relief from the heavy, unmanaged grazing the present deterioration would accelerate due to the fact that as the amount of plant cover declines, the use of the residual plants correspondingly increases.

The effect of the vegetation scarcity in the region on the soil, is vital in two respects; it determines the organic



Plate No. xxx. A view of Arfaj shrubs on a desert plain 1 km. approximately southeast of al Mrabba a settlement in the southern part of the region.

matter deficiency which is very low indeed lying in the range of 0.01% - 0.08% and it facilitates the transportation of the soil by erosion which results in complete bareness and rocky surfaces in some areas.

The deterioration of the vegetative cover has also made an immense impact on the agricultural patterns as it has necessitated the occupation of comparatively large areas of the under-cultivated lands for alfalfa and other fodder crops specially for those based on the villages and/or near the villages.

Strong management measures and competent staff to carry them out would lead to the improvement of the soil in terms of potential and capability and would diminish the large size of alfalfa practices as a profitable crop for more sound and economic practice in long term agricultural development.

5.2 The factors of soil formation

Soil formation and soil characteristics in any given ecologic zone are the production of the interaction of five genetic factors; climate, parent material, relief, vegetation, and time.

In the Qassim, the climatic factor plays a major role in soil formation. The sharp contrast of the daily and seasonal temperature differences and the scarcity of rainfall have provoked the mechanical weathering process and, on the contrary, rather retarded the chemical decomposition of the parent material and consequently caused a delay in the development of mature soil profiles in the region as a whole. In addition, these two elements of the climatic factor have determined the scarcity of the organic matter content in all soil series in the region as a whole. Moreover, the combination of scarcity, irregularity, and concentration of the rainfall have resulted in a rather

hazardous climatic element from the soil biological point of view. This combination ruled out the fact that the soil remains moist for only a very short part of the year and, hence, its biological evolution each year is consequently very limited and short lived.

The effect of parent material on soil formation is reflected in terms of texture, mineralogical composition and degree of stratification. These properties exercise a strong influence on soil profile development in the region. Where the parent rock is coarse grained with large quartz crystals (sandstone and granite) the weathered material is generally of sandy texture and where the weathered material is derived from a fine grained rock (limestone and shale) a very compact dense soil develops. It is noted that where the weathered materials have been subjected to transportation by wadis floods or wind action the soil develops a more permeable structure. This is apparently due to the fact that a mixing process of different types of weathered material is involved. It is a fact that soil-water correlation is determined by the type of soil texture. Small variations in texture within the range of moderately fine/fine have a sharp effect on farm drainage capability and land surface hydrology.

Relief in the Qassim is of a simple pattern with most of the land in a flat surface dissected by the numerous wadis, low ridges, and cuestas. The significance of the wadis in the Qassim from the soil standpoint is in their role as a transportation agent of the soil cover round their sources and along their flooding limits where water erosion is at its maximum. This process retards the development of the soil profile in both localities. The huge sand dune bodies surrounding and penetrating the region form an active topographic element to soil development in the region.

This is because the aeolian erosion is an active phenomenon and as a result some of the arable soils are being reduced in extent under the creeping sand cover. This cover in few cases develops to dunes where encroachment is on a large scale. Mostly, however, the cover interacts with the soil layers and forms a sandy layer or layers in the profile.

Vegetative cover in the Qassim, on the whole, is not a very reliable guide to soil changes throughout the region. That is determined by the aridity conditions which prevail throughout the region and consequently limit the scope of the vegetation community to small shrubs and some perennial short grasses. However, the sparseness of the vegetative cover has deepened the effect of water and aeolian erosions in the region and enhanced sand dune movement. The effect of the sparse and poor vegetative cover on soil development in the region is reflected in the very thin and rather short root systems within the soil profiles. This case, in fact, does not exert a good and ameliorative influence on the profile development and root systems are considered one of the important elements in soil development. Moreover, this poor vegetative cover does not produce enough material for an effective organic decomposition and consequently the organic content is limited far below the usual requirements for soil maturity development.

Man's activities are the only source of non-genetic influence on soil formation. The influence of man's activities on soil development in the Qassim is demonstrated in two contrasting ways; the first is a constructed way achieved by employing agricultural practices in the lands which have been brought under cultivation. These practices have modified the natural order of the soil profile in a way

which has hastened soil improvement processes, notably on the biological side where organic content and nitrogen fixing process are indicating a sharp improvement within the agricultural soils of the region. The second way is a destructive one of exercising uncontrolled grazing and shrub collecting for fueling by the nomads who roam all over the region. These practices always were and are the most hazardous factors from the soil development standpoint as they deprive such arid land from its most precious and only cover and in most cases limit natural regrowth of the vegetative cover. This leaves the surface soil uncovered and exposed to the erosion agencies which in fact is the most hazardous factor retarding soil development in the Qassim.

Chapter 6Soil Classification

The soil characteristics of the Qassim indicate that, in general, the soils belong to the light coloured soil group (Sierozem) of the arid zone. According to the Kubiena classification, the Qassim soils could be placed and included in the Yarma class of the Terrestrial division (C).

The sierozem in the Qassim is associated with salonchak in the alluvial area, and tends to be parasierozem elsewhere. Generally, the soils are of a varied texture but the silty or sandy profiles are the order throughout the region. This is apparently due to the slow weathering process of the primary minerals, a case which is a characteristic mechanical phenomenon of the soils of some arid areas. Within the alluvial areas the lower horizon tends to be more clayey in profile. This difference, however, has been explained by many pedologists as a result of more prolonged humidity in the deeper horizons and consequently the clay formation would tend to be quicker and more active.

The system of soil classification adopted in this thesis is based on profile characteristics and their genesis. Thus the decisive factors of this classification are the grouping of regional associations and their series definitions, based on the textural nature of the parent material, on depth, and on details of surface morphology.

Following these lines, the classification of the soils of al-Qassim is suggested and outlined as a tentative order in the following table:

Table 2. Soil Classification Order

Category	Soils
Order	Zonal soils } Azonal soils } Sierozem
Sub-order	Light coloured soils
Zonal	(a) - rough broken lands (duricrust cover) and sand dune complex. (b) - Silty sand of aeolian-alluvial origin. (c) - Sandy, gravelly loam, sandy silt, and clayey silt of alluvial-colluvial origin. (Basin and depression association) (Qa'a) (d) - Weakly developed aeolian - In situ formed loamy silt and detrital sandy loam and loamy sand. (Sahl association).
Azonal	(a) - Alluvial soils of the valleys. (Wadi association).

Because of the inadequate available information necessary for a complete discussion of the soil types in the Qassim, the discussion will necessarily be concentrated on the three prominent soil groupings; the Wadi, the Qa a (basins), and the Sahl associations as outlined in the following table:-

Table 3. Soil Associations' Series

Association	Series
I. The Wadi Association	(a) - Wadi sandy loam series (b) - Wadi silt loam series (c) - Wadi silt clay loam series (d) - Wadi loamy sand series (e) - Wadi silt clay series (f) - Wadi sandy clay series (g) - Wadi sand series
II. The Qa'a (basin) Association	(a) - Qa'a sandy loam series (b) - Qa'a sandy clay loam series (c) - Qa'a silty clay loam series (d) - Qa'a loamy sand series (e) - Qa'a silty clay series (f) - Qa'a silt loam series
III. The Sahl (desert plain) Association	(a) - Sahl loamy sand series (b) - Sahl sandy loam series (c) - Sahl silt loam series (d) - Sahl sand series

6.1 I. - The Wadi Association

The wadi association occupies all the valleys of al-Qassim (Fig.16), and largely the huge wadi of Ar Rma, where adequate run-off can cause movement, transportation, and deposition of disintegrated materials from the surrounding highlands. Thus, the soils of this association develop from alluvial parent materials and they tend to be of stratified profiles like most water deposited parent material. This stratification is associated with the outstanding differentiating characteristics of the profiles texture and depth.

The association comprises, for the most part, fine textured soils, where silty loam and silty clay loam are the dominant composition. Sandy loam of a coarser texture

GEOGRAPHICAL DISTRIBUTION OF THE SOIL ASSOCIATIONS, THE QASSIM

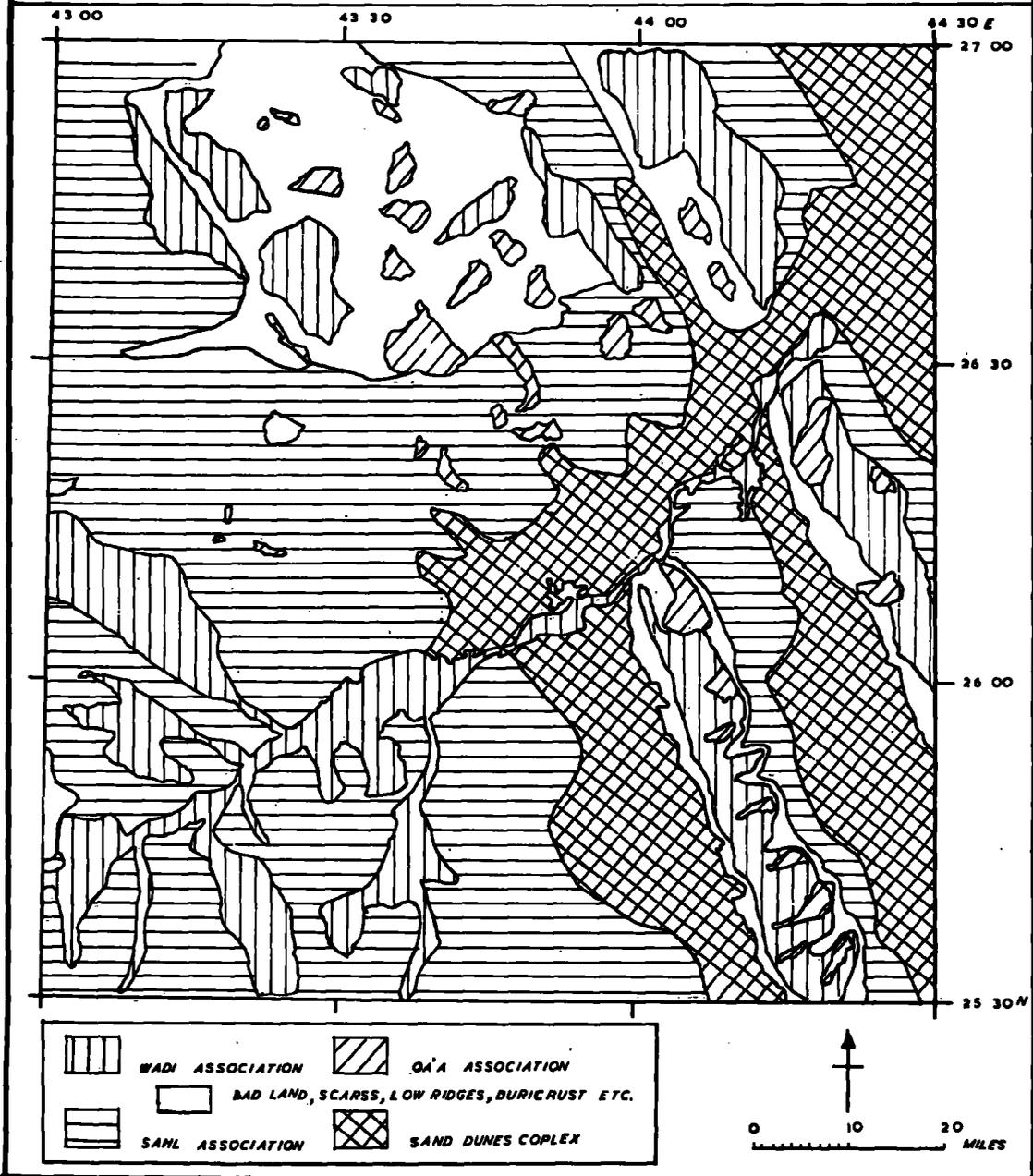


FIGURE 16

is also a widespread feature throughout the association, but the coarser textured soils are confined to channel deposits and consist of coarse sands in the channel streams, with large pebbles and small stones. Small irregular areas of very shallow fine textured soils over bed rock were observed at the upper sections of the wadis and on a few small spots of the duricrust cover in the northern part of the region. A transitional zone between the fine alluvial soils and the sandier soils of the desert plains of the Sahl association was recognized in forms of silt belts deposited largely by water and, to some extent, by wind action and occupying small areas of the plains.

(a) Wadi sandy loam series

The wadi sandy loam series is of a light brown to brown colour and it is, in most parts, closely associated with silty loam. The series has deep profiles composed largely of fine and very fine sandy loam with a small stratification of silt and sand. The profile structure of this series ranges from granular in some profiles to a platy and massive in others. Drainability of the series ranges from good internal drainage in some parts to moderate and moderately poor in others. The general classification of the internal drainage of the series might be described as a moderate internal drainage. This series, like most of the other wadi series, suffers much from wind erosion to a lesser effect from water erosion.

However, variations within the series are demonstrated clearly by the number, depth, and texture of the associated stratifications of sand and silt. Lenses and strata of thin clear fines to very fine sand were observed in many exposures examined within the localities of the series. Nonetheless, it is anticipated that the soils of this series

are capable of producing good yields of a wide variety of climatically adapted crops.

A dune phase of the series was recognized in a rather small area, especially round the extremities of some of the wadis which drain in the sand dunes and round the town of Braydah. The dunes of the phase are made up of fine and very fine sands, and the soil in between composed of the typical smooth-lying fine sandy loam profiles. Cultivation is carried out on this type of soil between the dunes especially around the town of Braydah for many hundreds of years where the dunes are stabilized by the planting of Tamerisks (Athl). Some of these cultivated areas represent the oldest agricultural settlements in the region.

Another phase of this series is represented by the dissected type of surface whose micro-relief has been modified by wind and/or water agencies. However, these dissections were marked enough to require special land levelling and preparation practices. It is expected that by overcoming the levelling problem the soil of this phase should have the same capability of the ordinary fine sandy loam soils of the wadi association of the region.

(b) Wadi silt loam series

Wadi silt loam series occupies level, smooth sides of the association limits. It consists of a deep profile varying in colour from very pale brown, yellow brown, to brown; some profiles were found with reddish yellow colour domination. Most of the series profiles have a minor stratification of fine and very fine sand. Generally, the structure of this type of soil is a platy structure within the upper layer of the profiles. With increasing depth the structure becomes an angular blocky to massive structure with a hard to soft hard character when the soil is dry,

moderately firm to firm character when the soil is moist, and weakly sticky to sticky character when the soil is wet. Some profiles were found to be made up almost entirely of silt loam with no apparent change in colour or structure.

Internal drainage of the series is almost moderate, in some cases it is found to be of a moderately poor and in other few cases it is found with a moderate internal drainability.

Within the limit of Wadi Ar Rma most of this soil is under cultivation where it produces a variety of adapted crops with good and appreciable yield. A phase of this series was recognized as dune phase. The soils of this phase are of a typical smooth-lying silt loam surrounded by low to moderately high sand dunes. Most of the silt loam soils of the dune phase is concentrated in the wadi of Ar Rma, where many small and medium sand dunes penetrate the wadi basin. Most of the soil of this phase has been brought under cultivation, notably in the sector surrounding the town of Braydah. There, it is noted significantly that the agricultural fields are of small sizes and odd shapes, a character which is imposed by the distribution pattern of the surrounding sand dunes. Thus, soil development studies regarding this phase need, in fact, a special consideration to irrigation schemes and systems as it is proved that irrigation practice on this type of soil is of a considerable nuisance to farmers. It is because of this and the need for sand stabilization practices that the soils of this phase are of a limited and marginal capability as far as agricultural development is concerned.

As anywhere within the Qassim soil associations, the active aeolian erosion, associated with slight water erosion, has brought about modifications in the micro-relief which represents dissected phases. The dissected phase of the

wadi silt loam series is marked enough to justify and raise the need for a considerable land preparation scheme. This need is sharpened by the fact that it is only the irrigated farming which can survive in the region and the need is critical for efficient artificial watering systems throughout the farms on the soils of the phase. However, utilization of the soils of the dune phase is, in fact, almost entirely dependant on the degree and extent of soil surface dissection. Nonetheless, all areas concerned could be reclaimed but with varying degrees of levelling and then become of a good farming quality.

(c) Wadi silt clay loam series

In the wadi association in the Qassim, this series stands in the third position after the sandy loam and silt loam series as far as a real extension is concerned. The dominant colour of this series is pale brown with a very few occurrences of pale yellowish white in the lower layers of some profiles. The soils of the series are of a varying structure, but on the whole they tend to be platy at the upper layers, and increasingly massive with depth with a soft-hard character. Internal drainage, on the whole, is moderate in most localities. Due to the fact that this series, as well as the clayey series of the wadi association, lies mostly within the middle and lower portions of the wadis, it has a level slope of silt flats where after one of the occasional wadi floods the water stands for days and percolates slowly through the soil. This process has introduced a much longer moisture duration for the soil layers and consequently accelerated the process of clay formation. Permeability is moderate in almost all localities of the series. The evaluation of the soils of this series from the agricultural standpoint, indicates that this soil is of a promising productive capacity.

In addition to the common dune and dissected phases of the wadi association, a shallow significantly different phase was recognized in a few localities of this series especially near the wadi channel sources with a micro-relief varying from smooth to slightly hummocky. In this phase the profiles are characterized by a top layer of 80-120 cm. of silt clay loam overlying a deep sand layer. The agricultural value of such a phase is largely dependant on the depth of the silty clay loam layer. However, it must be realized that the presence of a sand layer forms a very limiting character as far as watering practice is concerned. Such sand layers accelerate water percolation to an excessive extent which consequently causes great losses of water. The loss of water is too severe to sustain crops under the limited and valuable water supply for irrigation in the Qassim.

(d) Wadi loamy sand series

A representative profile of the series has demonstrated that this series is of a texture which tends to increase in sand particles and decrease in silt and clay particles with increase of depth. In a typical profile the sand particle percentage started at the top layer with 36% and reached 86% at the sector between 120-150 cm. However, this fact has contributed greatly to the existence of a good internal drainage condition, which seems to be the order in most localities of the series.

Lime content is found within the range of 7 to 8 per cent, which is a low content. In fact, this low content of lime seems to be a common feature of most of the soils of the wadi association. Soil structure is platy within the upper layers and with depth it becomes fine granular. The dominant colour for the series is observed to be within the hue range of light brown to brown. Most of the localities

are of a subnormal relief and of a nearly level to gently undulating surface with the water table always under 200 cm. This dry character of all profiles has hardened the normal condition for ordinary organism activities within the root zone of profiles. This hardship has a severe effect on the mechanical and chemical complexes as far as soil improvement and profile development are concerned and it is such factors which limit the productive capacity of the series, notably for its distinct sandy phase which largely occurs adjacent to the wadi channels or tributaries where the flood sheet has been sufficiently dense to cause washout of fine materials. The phase is also found lying adjacent to areas of dune accumulations where sand has crept over the soil surface. However, this phase is most prominent within the limit of Wadi Ar Rma with a land surface of hummocky features and with few areas subjected to dissection of water action.

(e) Wadi silt clay series

The series occupies smaller areas than the previous wadi series, and it is found within the lower limits of the wadis. The series is of a fine to medium platy structure with soft to very soft character throughout. Very pale brown colour is the colour of the series, and in some cases the very pale brown colour tends to change to yellowish brown in the lower layers. The internal drainage is of a poor to medium condition, due to the compact composition of the heavier texture of this soil. An improvement of this aspect is needed in order to bring about the optimum soil productive capacity. However, due to the nearly level to level surface of the lands occupied by this series the drainage problem can be readily overcome in contrast to the dune and dissected phases of the series. The dissected phase of this series is not as dissected as prominently as in the other series due

to the fact that the series occupies mostly the lower portions of the wadis where water run-off velocity is at its minimum.

The agricultural capacity of this series is, in fact, enhanced by the presence of its higher percentage of clay minerals. The heavier texture of the series maintains a higher soil mineral content as a result of scarce rainfall and low leaching rates.

(f) Wadi sandy clay series

The sandy clay series is pale brown to brown in colour; in few cases a pink colour was found at the upper layers and a greyish brown colour at the lower layers of the profiles. The structure tends to be granular with small variations of platy and slightly massive especially in the lower layers. Due to the fact that the water table is deeper than 2m., all profiles examined were found to be dry. In fact, dryness is the common condition of all profiles of all series, especially during summer time. A combination of slight wind and water erosion is the erosion agent which affects the soil of the series. Land reclamation and farm establishment on the soil of this series will, of course, cure such slight erosion.

Most of the soils of the sandy clay series have been under cultivation for many years and a wide range of climatically adapted crops were observed with vigorous quality and quantity.

(g) Wadi sand series

This series represents the coarser textural materials within the Wadi Association and is mostly found in the main channels or aeolian deposits, or adjacent to the main sand bodies which penetrate the soils of the association. In some areas occupied by the series, especially within the wadi channels, a thin strata of silt is found. In such

cases aeolian materials contribute to the basic alluvial-colluvial soil parent material. However, where the alluvial materials dominate, finer soil textures are found. But the dominant material is coarse sand. Small patches of fine textured soils are found in the channels of the larger wadis. However, the main structure of all profiles of the series is of granular, an ill-defined, and ill sorted nature. Consequently internal drainage is excessive to very excessive. In the very few cultivated lands of the series it was observed that the quantity of water needed for normal irrigation practices exceeds the normal average for the soils of other series of the association. However, only a few small areas of the series have been brought under cultivation and the question of the soil evaluation for this series is not of a great consequence as far as soil development is concerned.

6.2 II. The Qa'a (Basin) Association

The Qa'a association occupies the numerous scattered basins and depressions in the Qassim (Fig.16), with soils mostly developed from alluvial materials deposited by the wadis which drain into the basins, and from colluvial materials of the lower outcropping ridges and/or scarps which surround them. An exception to this occurs in some wide and exposed depressions where aeolian action and deposition are relatively active. In addition, the lack of under-surface water within the limit of 20 m. is a serious limiting factor. However, it is significant to note that all agricultural areas within the Qusaiba zone in the north of al Qassim, where most of the association soils lie, are confined to the soils of this association.

Future utility of the association, especially in the Qusaiba and al Ayon areas, faces complex problems notably

in relation to road facilities, water, and manpower.

(a) Qa'a sandy loam series

In most cases, the sandy loam series occupies the smooth flat floors of the basins and depression of the Qassim. The structure of the soils of the series tends to vary from granular to platy with a hard consistency when dry and firm when moist. Gravel layers are common characters of some profiles examined; the gravel layer is of a shallow depth (20 cm.-40 cm.) in the profile with a thickness of about 20 cm. In some profiles the gravel layer was found at deeper depths (140 cm.) and was thick enough to constitute the parent material of the profile. This gravelly characteristic is, in fact, the result of incomplete weathering of the colluvial parent material. However, in cases where no gravel layer is found, stoniness throughout the profile is well preserved. Such a character might indeed interfere with plant root penetration and retard plant vigour and growth. In addition, these gravel layers accelerate internal drainage and water percolation. Surface slope varies from level to nearly level for most localities, but in a few areas it tends to be gently undulating; this undulation is not sharp enough to serve as a basis for a separate phase of the series. Moreover, it has been observed in a few places that the accumulation of sands round the few sparse low shrubs has caused the formation of mounds on the surface of the soil. This undoubtedly would contribute to difficulty of soil reclamation of this series.

Colour is a diverse character of the series, but, in general, the surface and upper layers are of pale brown to brown, and greyish colour, whilst the middle and lower layers are of reddish brown, yellow brown, reddish yellow and greyish white. This variation demonstrates the variety of parent materials involved in the formation of the soil.

(b) Qa'a sandy clay loam

The surface layers of the series are of a varying colour; yellowish brown, greyish brown, very pale brown and reddish pink. In most cases the top layers change in colour with depth to whitish grey, reddish brown, yellowish brown and pale brown. These variations are clearly the result of the interaction of the various origins of the three textural components of the series; sand grains, clay minerals and silt particles. The soil structure of the series is platy to massive blocky with a hard character in localities where the heavier texture is dominant; in others, it ranges from moderately friable to friable where texture is less heavy. Where structure is massive blocky, it is associated with poor internal drainage conditions and there exists a strong tendency for silting up and the formation of a badly aerated soil.

In a few localities, a thin layer of gravelly sand on the surface was encountered. Gravel layers, however, are not common and are only found in a very few shallow profiles. In some localities white gypsum crystals and lime were encountered at depths of approximately 90 cm. or below.

Internal drainage varies according to the nature of the dominant textural element. Where the heavier and compact texture prevails, the internal drainage tends to be imperfect, while it tends to be moderately well to well drained where the proportion of granular and loose texture is high.

The series occupies the flat floors of the basins and depressions with a surface of level to nearly level configuration. Agriculturally, the soil seems to be one of the most extensively exploited sites of the Qa'a association, notably round Qusaiba and al Ayon settlements. The range of crops is confined to dates, cereals, alfalfa, and

a limited variety of vegetables. This is because of the lack of large enough markets nearby to absorb a diverse variety of crops, and the lack of efficient accesses to the larger markets in Braydah or Aunayzah.

(c) Qa'a silty clay loam series

This series has a deep silty clay loam profile with no gravel layers. Stratifications of sandy clay were observed in some profiles at or below the depth of 70 cm. The structure is of an angular blocky nature with a hard, soft hard, and moderately friable character. This structure has resulted in poor soil aeration and imperfect to moderate internal drainage capacity. Moreover, in a few phases the representative profile contains rather thick gypsum traces, but always at a depth of under 110 cm. All examined profiles were dry and the water table is clearly always below 2 m.

Future utility of this soil depends largely on special considerations which should be paid to the complex of problems, of water, drainage improvement, and road facilities. At the present time few sites of the series are under cultivation.

(d) Qa'a loamy sand series

The dominant colour of the series is in the range of brown; very pale brown and yellowish brown colours were often encountered at the top layers, and these colours often tend to change with depth to dark brown colour.

Soil structure varies within the range of platy in the top layers to an angular type of structure with a friable character. Gravel is rather a dominant feature of the profiles; in some places sizeable gravel was found sorted throughout the whole profile, while in others gravel was confined to the lower layers of profiles. Typical profiles of the series have shown its order on the following:-

0-90 cm.	Loamy sand
90-120 cm.	Loamy sand mixed with abundant gravel.
120-125 cm.	Loamy sand mixed with heavy traces and crystals of lime
125 cm.	Shale mixed with gravel.

Heavy gypsum layers were encountered in a few profiles, but always at or below the depth of 110 cm.

A shallow phase of the series was identified by representative profiles of a depth not exceeding 70 cm. where the solid rock marks the lower limit of the profiles examined. Loamy sand layers of this phase were always in the range of 50 cm. and often followed by a thin (20 cm.) sandy clay layer with a blue colour. This shallow phase is confined to the upper parts of the basins and depressions with a gently undulating surface and of a sub-normal micro-relief; hence, the agricultural value of such phase is not of an economic importance.

Although it has been observed that some palm dates gardening and plantation occupy some of the series localities, it is anticipated that for sound agricultural development the series with its sharp immaturity and dominant gravelly character is not of a favourable condition due to its excessive internal drainage and unfavourable condition for root penetration.

(e) Qa'a silty clay series

This series occupies the middle, smooth flat floors of the basins and depressions with deep profiles of mainly clay texture of alluvial origin, with a thin stratification (5-10 cm.) of sandy loam or loam in the upper layers. The structure is mainly platy to massive blocky with a very hard, hard, soft hard, and moderately friable character. The nature of these structural characteristics has consequently resulted in a poor internal drainage condition for

almost all profiles; only a few profiles were observed with moderate internal drainage. Moreover, it is anticipated that a poorly aerated soil structure is a constant character of this type of soil. A thin mantle of sand on the surface appears to be a dominant morphological feature of the series in most localities. Heavy traces, crystals, and thin layers of gypsum were encountered in many localities, but always at or below 110 cm. Nonetheless the presence of such gypsum layers in such compact profiles will aggravate the internal drainage difficulty of the series.

Future utility is largely dependant on the efforts to ameliorate internal aeration and drainage. If such measures are successful this soil is capable of producing good crop yields. This anticipation depends on the other favourable properties and characters of the soils of the series, such as the comparatively high clay mineral content, high water holding capacity, and the comparative richness in the various chemical nutrients necessary for plant growth.

(f) Qa'a silt loam series

The series occupies smaller localities compared to the previous series. It is a series of deep soil mainly composed of silt loam with a very thin stratum of fine sandy loam (0-10 cm.), which often forms the upper portion of the soil profile. This type of soil is always found within the silt flats of the different basins and depressions throughout the Qassim. The light brown colour is the colour of the series, and in most cases this colour tends to change with depth to a more strongly brown colour. The structure of the series, in general, is platy mostly at the top layers and often tends to become more angular blocky to massive compact at the lower portion of the

of the profile, with a soft hard character. No gypsum traces or gravel were reported. Hence, it is estimated that the internal drainage of the series, on the whole, is moderate to good owing to its favourable structural and textural characteristics. Moreover, the association is, as far as the available information indicates, the only association in the Qassim which does not comprise a separate identifiable sand series, a fact which reflects the effect of topographical position, which retards aelion deposition.

Thin stratification of sandy loam or loam of the order of approximately 20 cm., occurs in most profiles. Shallow phases on duricrust or bed rock were encountered on a large scale, a fact which reflects immaturity of the series in general.

Most localities of the association are virgin due to a complex of factors, the most prominent of which is the difficult accessibility to such lands, isolated in the scattered basins and separated by long distances of rough topography.

6.3 III. The Sahl (Desert Plain) Association

The Sahl association occupies the extensive areas of desert peneplains and flat terrains of the Qassim (Fig.16). The topography of this type of land is nearly level to level, with some areas of gently undulating to undulating surface. The micro-relief is, in fact, the consequence of the active wind action and it grades from areas with relatively few and very small sand hummock on the surface to relatively extensive areas of sand dunes. Drainage, on the whole, is largely internal with a moderate rapidity. A complete infiltration in a rather short time by the soil after a moderately intense rainfall has been observed in the region. The Sahl association represents soils developed from

calcareous marls and sands of in-situ or aeolian origin. Profile development in this association, in general, is weak to moderate with a rather weak transition from one horizon to another.

(a) Sahl loamy sand series

The loamy sand series occupies the largest proportion of the Sahl association. It lies within smooth flats of level to nearly level terrain. In some localities these smooth flats are surrounded by huge bodies of sand dunes, whilst in other localities the soil surface is studded with small mounds of sand accumulation round the sparse shrubs. The series is of a light brown to brown colour with a tendency in a few cases to change into grey brown in the lower horizons. The structure of the normal profile of the series is a dominant granular type with thin layers of platy structure where sandy loam layers occur. However, the structure in general is found to be loose when dry, friable when moist and soft sticky when wet.

In some localities gravel seems to be a dominant structural item of the profiles; in such profiles gravel usually is found throughout the profile and with depth the size of gravel increases. In a few cases at 105 cm. the size of gravel was large enough to prevent further investigation of profiles beyond that limit. Another shallow phase of the series was recognized in a few localities where a compact thick layer of limestone halts digging at 135 cm. approximately. In the gravelly soils the drainability is very excessive whilst in the normal profiles the drainability is observed to be moderate to good.

Although the loamy sand soil represents the most extensive series of the Sahl association, its agricultural capacity is inferior to some of the other series, such as

the sandy loam. The presence of the gravelly phase with its excessive drainability is the main reason, a feature which has contributed to inferior immaturity and consequently affected its productive capacity.

(b) Sahl sandy loam series

The sandy loam series occupies smooth to very gentle undulating terrain with a land surface of small hummocks of aeolian sand round sparse shrubs. Minor variations within the series are distinctive. Some localities have a surface cover of 5-10 cm. of light yellow to brown aeolian sand overlying the pale brown "A" horizon. Other localities have a shallow sand-gravel layer at the top overlying the "A" horizon; in other sites white gypsiferous crusts were observed on the surface. However, both surface and sub-surface soils are sandy loam with a prevailing pale brown colour. Soil structure is normally platy to massive with a firm to moderately friable and sticky character. In a few localities it is observed that soil compaction increases rapidly after 15 cm. and at about 60 cm. the continuation of digging was almost impossible. A gypsum pan was encountered in many profiles, but always at or under 100 cm. Thin gravelly layers (5 cm.) do occur but on a very limited scale. Internal drainage of the soil is mostly moderate to poor in very few areas. The hummocky phase of the series is distinctive enough to be considered where the topography is characterized by a micro-relief consisting of numerous sand hummocks of 15-60 cm. in height and 90-150 cm. in diameter around the shrubs. The areas between the hummocks may have the pale-brown surface "A" horizon exposed, or covered by a thin mantle of yellow brown fine and coarse aeolian sand. However, the soil profile characteristics of the phase are those of the normal characteristics of the series.

(c) Sahl silt loam series

Sahl silt loam series represents the lands of the association most comparable to the wadis, where wadi floods reach the edge of the desert plains. This alluvial deposition is very extensive on both sides of the great wadi of Ar Rma. The area occupied by the series is relatively small and is confined to the parts of the plain which a wadi flood usually covers. A distinctive character of the series is that no gravelly layers or gypsum pans were encountered within the examined limits of profiles (1.5 and 2 m.). A thin stratification of sandy loam, loamy sand, and fine sand was found within the deep fine silty loam profiles of the series. The series is of a dominant brown to light brown colour. The soil structure of the series is of a platy nature and tends to massives with depth; thin platy massive structure is associated with soft hard character when the soil is dry, with firm character when the soil is moist, and with a sticky to plastic character when the soil is wet.

Internal drainage ranges in capability between moderate in most cases and poor in a few localities.

From the agricultural productivity point of view, the silty loam series with its favourite characteristics and properties is the most productive soil within the Sahl association. Consequently, it is this section of the association which should receive a special consideration in the future development practices.

(d) Sahl sand series

The sand series is confined to the undulating to rolling parts of the extensive plains of the association, where huge bodies of sand dunes are bordering or penetrating the plains. However, much of the land surface of the series is covered

with sand hummocks up to approximately 1 metre in height. Some of these hummocks have developed and coalesced into low sand dunes. Profile development is very weak or almost indefinite in most cases. Usually the profile consists at the top layers of fine to medium light yellowish brown sand, grading into a yellowish brown loamy fine sand with almost no minor changes in physical characteristics with depth. However, due to the sandy nature of the surface soil and the light texture of lower layers of the profiles, it is anticipated that many problems would be associated with the use of the series. Some of these problems lie in the serious consequences of the active aeolian erosion on such a loose type of soil, the low moisture-holding capacity, low nutrient status and mineral content of the soil, and topographic deficiencies, a combination which would undoubtedly result in a very narrow range of crop adaptability.

6.4 IV. Other types of soils

(a) Sand dune complexes

Sand dune complexes are huge sand bodies penetrating the Qassim: Nufud As Sirr, Nufud Ghmays, Nufud At Trefiyah, Nufud Ath Thwairat E., Ashe Sheqqah W. The bodies vary in height and density but they all fall in the following categories, ridge dunes, turtle dunes, active dunes and loose dunes. It is observed that there are small patches of exposed soil surfaces between the dunes, but because of their very small sizes and very difficult accessibility they do not deserve a special effort for the study of their characteristics.

(b) Badlands

Badlands in the region are represented by gravel and erratic rock outcrops, irregular low outcrops of crossbedded sandstone, gravel plains, low benches, and old erosion surface of cemented limestone and gravel. Because of their

low agricultural productive potentiality, they are excluded from this study.

The fact that the study of the soils of the Qassim and the establishment of their classification is not based on previous studies makes it very difficult to go beyond the scope of establishing the very basic facts and information which are sufficient only for a preliminary study of the soils of the region. Hence, it must be stressed that the need for a further investigation and detailed studies on the soils of the region is very critical and necessary to enable the establishment of vital conclusions. Such conclusions are necessary for presenting an accurate reflection and delineation of specific soil qualities and their distribution in the region.

However, the soils of the Wadi Association seem to be the most promising types of soil, notably those lying within the limit of the great Wadi Ar Rma where a large portion of the association is concentrated. Virtually all agricultural development factors, physical and economic, are present within the Ar Rma limits in the Qassim. In fact, the only need for soil improvement is more investigation to point out where, how, and what necessary practices should be carried out in order to exploit the favourable economic complex in the Ar Rma areas. In the Ar Rma zone, only the lack of soil information would retard any agricultural development project as water is abundant, markets are big and easily approachable, roads excellent, and working power is available. Such fortunate economic conditions do not recur in other sectors of the region, notably within the Sahl association.

Chapter 7

Soil chemical properties and soil fertility

7.1 Chemical properties

The available scarce data on this aspect are given in Table 1 Appendix E. They are essentially for a limited number of selected profiles representing the chemical characteristics of the soils in the region in general, and it must be stressed that they do not in any way reflect a complete picture of the soil chemistry. For instance, the limited time of this research has prevented the writer from investigating the contents of available plant nutrients in the treated samples. Thus, no correlation can be made between fertilizer response and methods of measuring soluble nutrients in the soil, which is in fact a very valuable assessment for soil development measures. The present study is preliminary research aimed at establishing the basic facts and characteristics of the Qassim's soils.

Organic matter content

The plant nutrient content of the soils, the improvement in the physical structure of the soils, and the activity of soil micro-organism are to a great extent dependent on the amount of organic matter of soils. Nitrogen is the most essential element for plant growth and organic matter contains almost all the nitrogen normally present in soils.

As in all parts of Saudi Arabia, the soils of Al-Qassim are of a very low organic matter content. The range of from 0.042 per cent to 0.84 per cent represents the percentage

of the organic carbon in selected profiles of the various soil associations of the region. This very low and limited range indicates the scarcity of organic matter in the soils of al-Qassim, a fact which introduces the need of improving the fertility status of the soils in general. Such improvement can be achieved only by maintaining a higher level of organic matter and consequently increasing the available nitrogen. This is, undoubtedly, especially critical for any future soil development projects in the Qassim; thus it is suggested that the use of legumes and green manure crops would be very helpful in this respect.

Gypsum content

The gypsum content in the soil is a vital element in balancing the need for calcium as a plant nutrient. Its application is practical and appreciable when the need for calcium is desired without any upset of the soil pH status. A high to moderate gypsum content also ameliorates the adverse effects of soil alkalinity. The available data on gypsum content in the soils of al-Qassim reflects the fact that most of the soil profiles of the various associations contain appreciable traces of gypsum, with figures of the gypsum content lying within the range of moderate content (5-30 meq/100 gm. soil). Only few profiles are found with no gypsum traces whatsoever; such profiles frequently occur within the Wadi and Qa'a associations. The Sahl association has a more constant content of gypsum. This steadiness might be due to the small proportion of deposited material in the soil texture within the Sahl association.

Free carbonate content

Data on calcium and magnesium indicate that there is a fairly high concentration of calcium and magnesium carbonates within the soil profiles. This concentration is in fact associated with the insufficient amount of rainfall in the

region and consequently the incomplete and rather weak leaching of the free carbonates from the soil. In fact, in soil classification studies, the presence or absence of Ca and Mg carbonates is a helpful factor in the identification of soil types. Soil development and reclamation are greatly enhanced by the presence of free carbonates. In the Qassim, most of the soils of the various associations are of a moderate-favourable lime content with percentages lying within the range of 2-22 per cent. A few areas, especially within the Wadi association, are of a low content and this apparently is due to two reasons. Firstly, most of the soil parent materials of this association are of an alluvial origin which mostly originated from non-calcareous rocks (e.g. sandstone). Secondly, the comparatively intense soil leaching caused by the Wadi floods. Other areas, notably within the Sahl association, are of a high content of lime, i.e. 36 per cent. This can be attributed to the fact that most of the soils of the Sahl association are developed on weathered in situ materials which have largely disintegrated from limestone rocks. However, for the soils of al-Qassim liming is not a necessary practice as none of the soils in the region suffer from soil acidity.

E.C. values

The concentration of soluble salts is a marked property of arid zone soils, a fact which seriously retards plant growth. Following the U.S. Salinity Laboratory definition (1953), the criterion for evaluating electrical conductivity values is expressed in a numerical values. The value 4 millimhos is the division between saline soils with values over 4 and non-saline soils with values under 4.

The range of E.C. values for the soils of the Qassim is very large and the two extreme values are found to be 0.5 and 165 mmhos. Nevertheless, the majority of soils in the various associations of the region are of a value above

4 and the moderately saline soils are the order, as expressed by the sub-range of 5-20 millimhos. The effect of such moderate salinity on soil development under the prevailing irrigated cultivation is bound to be less harmful on the crop production as a result of the leaching effect of the applied irrigation water. This of course entirely depends on good internal drainage conditions.

pH values

pH value is one of the most fundamental tests of soils, as many important soil properties are correlated with it. The scale of pH is divided into different numerical values. Value 7 indicates neutrality and values above 7 indicate increasing degrees of free carbonates of calcium and magnesium (alkalinity). Soils of pH values above 8.5 have physical and chemical characteristics which are unfavourable for plant growth as a result of increasing concentration of sodium carbonates. In the Qassim, none of the soils is of a pH value below 7, thus acidity is not a soil property in the region. This apparently is a result of the interaction of various ecologic characters favoured by the prevailing aridity condition. The alkalinity values range between 7.2 and 9.4 with the majority laying within the sub range of 7.8 and 8.4, a condition which would furnish very favourable soil properties for the majority of crops. However, another method of alkalinity assessment was suggested in order to check the correctness of the available pH values, and slight differences were discovered which tend to sum up that 20 per cent of the pH values are questionable and are beneath the actual value and reflect less alkalinity than really exists within the soil. The method was as follows:-

$$\frac{\text{No. of exchangeable cations} \times 100}{\text{Cation exchange capacity}}$$

Where the result of this equation is under 15 per cent the soil profile is classified as non alkaline, and over 15 per cent as alkaline.

7.2 Soil fertility and fertilizer practice

The application of organic manure derived from animal waste was and largely is the accepted traditional method of improving soil fertility and productivity in the Qassim, as anywhere in the kingdom of Saudi Arabia. The calculation of the average amount needed per hectare for most of the crops raised in the region, based on field observations, ranges from 35 to 80 tons per year per hectare. The necessity for such large quantities is apparently due to the fact that the local manure usually contains variable proportions of sand and rubbish (plate xxxi), and under the prevailing conditions of high insolation, high temperatures, and severe aridity, its effects are not of full capacity.

The sources of organic manure are twofold; the first is the townlets and village dwellings where most of the households in the region keep one or two cows or a few goats for milking purposes for personal use. The animal waste is collected periodically from the stalls where the animals are kept permanently, and in most cases the rubbish of the household is added to such accumulated manure. That is because the manure's value is, in fact, scaled by its accumulated size rather than by its purity. However, manure merchants and dealers collect the manure from the houses after agreement has been concluded, which is usually based on a truck-load basis. Such collected manure is usually preserved in an open air yard and distributed to farms upon request at an average value of 70 S.Rs⁽¹⁾ per truck-load of 2.5 tons. The second source is the watering points of

(1) One sterling pound equals 10.8 Saudi Riyals.



Plate No. xxxi. A load of organic manure. Note the sizeable proportions of sand and rubbish mixed with the manure.



Plate No. xxxii. A storage pit of organic manure for the purpose of washing out the poisoning elements by irrigating the pit regularly.

livestock, especially during summer time when the animals hang on for a few weeks and thus a great deal of animal waste is accumulated during such concentration periods for thousands of camels, sheep and goats at one time. At the end of summer manure merchants travel to such known points and conclude a verbal contract, of a nominal price for the waste. Many wealthy farmers who practice animal husbandry on a relatively large scale satisfy their farm's requirements from the waste of their own animals or through personal contract with the nomads at some of the livestock concentration points. However, throughout the centuries the application of organic manure was immediately after collection. Such practice has been proved to be, to some extent, harmful for plants as it contains some poisonous elements which need to be leached out. A method for adjusting such practice has been recently demonstrated and taught to farmers by the technical staff of the E.F.S.Cs⁽¹⁾ in the region. The method is simply keeping the manure for a period not less than two months to six months in a large pit and irrigated regularly in order to leach out the poisoning elements (plate xxxii). Such a practice is not a common and widespread practice as most of the farmers, due to their limited financial ability, cannot afford to keep the manure unused for such a long time.

However, the increasing rate of expansion in the cultivated areas in the region through the last and the present decades, as a result of the artesian water discovery, had led correspondingly to increasing demands for organic manure and consequently increasing cost and scarcity of organic manure throughout the region especially in the new development areas. This increasingly deteriorating situation has, in fact, compelled farmers to consider the use of

(1) Extension Field Services Centres

chemical fertilizers as an alternative.

Many types of chemical fertilizer were introduced in the region and the complex 15: 15: 15⁽¹⁾ appears to be the most popular fertilizer mix. This complex was recommended for general use in Saudi Arabia by the agricultural research department of the Arabian American Oil Company (ARAMCO) some fifteen years ago. Unfortunately, since then this department had made no attempt for further investigations on its introduction to discriminate between the individual effects of the component nutrients on the various crops raised in the country. The Ministry of Agriculture has also not carried out sufficient trials.

At the present time, in the Qassim, chemical fertilizers are being applied to the land at unspecified rate per area unit. Such a blind approach to the proper use of nutrient is an inefficient and expensive method of chemical fertilizer use.

It is common knowledge, however, that arid types of soil generally require nitrogen and phosphate fertilizers at a relatively high rate for profitable production. The foliage on many citrus trees in the Qassim exhibit symptoms of micronutrient deficiencies. The symptoms are typical of iron and zinc chlorosis. Due to shortage of thorough and complete investigations on this aspect it is improper to conclude whether these elements are lacking in the soils or not, as they may possibly be in an unavailable condition due to salinity of the cultivated sites. As a temporary correction measure it would be useful to apply small amounts of these elements either to the soil or by spraying them in irrigation water. However, information on crop response to chemical fertilizer application is very sparse. Only a few experiments have been conducted at the Aunayzah's and

(1) 15 nitrogen, 15 phosphate, 15 potash.

Braydah's experimental stations and those experiments were started in November, 1966. The number of fertilizers used was restricted to the three nutrients; urea, triple superphosphate and potassium sulphate. The choice of urea as the nitrogenous source was suggested by the fact that a factory for producing urea is about to be completed in Ad Dammam City and it is anticipated that it will start production by the beginning of 1969.

For purposes of comparison between the obtained results of the two stations and the attempt to establish basic facts and criteria applicable throughout the region the more universal crops in the Qassim, alfalfa, tomatoes, wheat and barley were chosen to be tested.

Alfalfa and tomato experiments were of 3^3 factorial design in which the effect of (N), (P), and (K) at 3 different levels were examined in all combinations to give 27 treatments (Fig.17). Alfalfa was seeded at the rate of 64 kg/hect. and tomatoes were planted along the side of furrows; plants were spaced 50 cm. apart along the rows, and one metre between rows. Each experiment was replicated 3 times so that the experimental comprised total of 81 plots. The application of fertilizers for the alfalfa experiments were as follows:-

- (a) One half of the amount of phosphate and potash were applied before sowing and the other half approximately two months later.
- (b) The urea was split in four equal dosages and was applied at two weeks, two months, four months and eight months respectively.

For the tomatoes applications were carried out in the following manner:-

- (a) One half of the amount of "P" and "K" was applied before planting and the other half one month after planting.

LEVELS OF FERTILIZERS APPLIED IN THE CITED EXPERIMENTS KG/HECT.

A. ALFALFA AND TOMATOES EXPERIMENTS

LEVEL	UREA	TRIPLE SUPERPHOSPHATE	SULPHATE OF POTASium
0	<input type="text"/>	<input type="text"/>	<input type="text"/>
200	<input type="text"/>	<input type="text"/>	<input type="text"/>
400	<input type="text"/>	<input type="text"/>	<input type="text"/>

B. BARLEY AND WHEAT EXPERIMENTS

0	<input type="text"/>	<input type="text"/>	
100	<input type="text"/>	75 <input type="text"/>	<input type="text"/>
200	<input type="text"/>	150 <input type="text"/>	

FIGURE 17

(b) The urea was split into four equal doses and was applied at two weeks, one month, two months and three months respectively.

The result was, in general, that the visual appearance to phosphate application was great, as is indicated in the following scores recorded on 6th February, 1967; urea and sulphate of potash exerted little influence (Table 4).

Table 4. Response values of alfalfa and tomatoes.

Fertilizer	R.V.	Fertilizer	R.V.	Fertilizer	R.V.
N ₀	44	P ₀	28	K ₀	48
N ₁	50	P ₁	54	K ₁	46
N ₂	50	P ₂	61	K ₂	51

R.V. = Response value, each value represents a total of 27 individual plot scores.

Source: Progress report on response to fertilizer application in Saudi Arabia by Dr. E. W. Balle-Jones, FAO soil fertility expert, June, 1967.

It is estimated, however, that some 50 per cent increase in alfalfa yield was the response to phosphate application. In the light of these results, in the case of alfalfa, an early response to nitrogen was then replaced by the predominant effect of phosphate. This had led to the suggestion that a starter dose of nitrogen fertilizer is beneficial. On the other hand, these observations refer mainly to the cooler part of the year and it is possible that nitrogen fixation may diminish greatly in hot summer months.

Cereals were grown in experiments which had a basic 3² design in which the effect of "N" and "P" at three levels

in all combinations were examined. This provided nine treatments per replication but in addition three supplementary treatments at the middle potassium level were included to judge the possibility of response to (K). (Fig.17).

The experiments were laid out in 3 blocks, each containing a full replicate of 12 plots to provide a total of 36 plots for the whole experiment. All fertilizers were applied on one occasion approximately one month after sowing. The cereals were sown at a rate of 139.5 kg./hect. Throughout the experiments wheat showed definite evidence of a response to phosphate but none to urea, as demonstrated in the obtained scores (Table 5).

Table 5. Response values of wheat.

Fertilizer	R.V.	Fertilizer	R.V.	Fertilizer	R.V.
N_0K_0	19	P_0K_0	15	-	-
N_1K_0	20	P_1K_0	20	P_1K_1	24
N_2K_0	20	P_2K_0	24	-	-

Each response value represents total of 9 plot scores.
Results recorded on 6th February, 1967.
Source of figures: The same as Table 4.

The visual effects of "N" on barley were outstanding and of a remarkable uniformity as it is clear from the obtained results Table 6.

Table 6. Response values of barley

Fertilizer	R.V.	Fertilizer	R.V.	Fertilizer	R.V.
N ₀ K ₀	10	P ₀ K ₀	19	-	-
N ₁ K ₀	21	P ₁ K ₀	20	P ₁ K ₁	19
N ₂ K ₀	27	P ₂ K ₀	20	-	-

Each response value represents a total of 3 plots score.
Results recorded on 5th February, 1967.
Source of figures: The same as Table 4.

Values of crop yields are available only for barley (Table 7). Values for wheat were not recorded for the cited experiment, neither for any other so far. Calculation of barley yield values showed that the yields of both grain and straw could be multiplied more than four times by the application of urea. The yield grain given by the central treatment "N.K.P." was of the order of 2.8 tons per hectare.

Table 7. Barley yield kg/450m²

Grain				Straw			
N ₀ K ₀	38	P ₀ K ₀	107	N ₀ K ₀	42	P ₀ K ₀	144
N ₁ K ₀	120	P ₁ K ₀	109	N ₁ K ₀	190	P ₁ K ₀	161
N ₂ K ₀	167	P ₂ K ₀	108	N ₂ K ₀	224	P ₂ K ₀	152

Source: The same as Table 4.

However, the crops showed a visual difference due to fertilizer treatment in the first few months after sowing. Scores were established, on the basis of vigour, colour, and degree of establishment, in the range of one to four, one being weak and poor and four being very vigorous.

It must be pointed out, however, that the findings quoted and represented here are of an interim nature; many other experiments are in progress in the Qassim at the present time and more data are needed for further and more accurate assessments. The available results are, however, encouraging and confirm the belief that chemical fertilizer use will improve soil fertility in the region in general.

All the available data to date suggest that the main requirements of improving soil fertility for the crops examined were for nitrogen and phosphorus containing fertilizers; there was no definite indication of a need for potassium. However, it is important to note that the results were obtained using local methods of cultivation; the only divergence from local practice was the split of doses to make more economic use of fertilizers. This was adopted in view of anticipating that the findings may be almost directly applicable to every farmer's farm as an interim practice to be confirmed or modified later on when more results are available and analysed.

Chapter 8Land classification8.1 Introduction

Land classification is the overall criterion for establishing the boundaries, sizes, extent, position, deficiencies, suitabilities, and locations of arable and non-arable lands within different ecologic areas in a given region. Land classes are established on the basis of similar physical characteristics which determine its economic value in terms of productivity and repayment capacity within the safe marginality of economic production. The classes are divided into sub classes to identify a particular deficiency or combination of deficiencies within one given class. Land classes and sub classes in an ecologic area provide basic criteria for determining proper land use, irrigation systems and requirements, size of farm units, benefits, costs and repayment capacity, land appraisal, and land development problems.

The most important factors of land classification are:-

- (a) Soils - physical, chemical, and biological characteristics.
- (b) Topographical position of the land and the surroundings.
- (c) Farm drainage conditions of the land.

The soil physical characteristics, colour, depth, structure, texture, stoniness, permeability to air and water, consistent infiltration rate, drainability and erodability, available

moisture capacity are often interrelated. Most of these characteristics are of a flexible nature to modifications by the various land reclamation practices and treatments but the case for texture is exceptional as it is proved to be a relatively stable character of the soil. This flexibility varies from place to place according to various ecological factors, such as parent material, climatic condition, vegetative cover, and water quality, which establish the physical order of the different profiles in a given area. The soil chemical and biological characteristics, inherit fertility, amount of organic matter, nitrogen-fixing, salinity, alkalinity, type of clay mineral, total carbonate, lime, gypsum reaction, availability of essential trace elements, etc. control the extent of productive capacity as well as crop adaptability. These characteristics in fact are critical and vital criteria for land suitability from both agronomic and economic standpoints. The significance of the topographical features lies in the degree of slope, relief, and position of the land. These three features must be given considerations in order to correlate the topography factor with the type of land and its degree of suitability. It is evident from a practical point of view that the topography factor reflects to a great extent how easy or difficult it is to construct the irrigation and drainage systems throughout the farm, considering the accessibility and movement of water to and from every single piece of unit of the farm. It also reflects the need, the type and the approximate cost of land reclamation and development and is related to the size, slope, and the cover of the site and the nature of the development project.

Farm drainage is a vital criterion in land classification due to its effect on the productive capacity of the land and consequently on its repayment capacity. Where

natural farm drainage is inadequate to prevent water logging and its consequences within the root zone, an artificial drainage system is necessary and a farmer is compelled to achieve it by channels and underground tile drainage construction. This involves extra costs which might upset the balance of farm input and output.

Maps and information on the land classification of the Qassim presented here have been quoted from the rough information and maps available at the time when the field work was conducted. These were obtained from the Headquarters, in Saudi Arabia, of Parsons Basil, the consultant to the Ministry of Agriculture. Maps were based on aerial photo stereo scale 1: 60,000 and traced on aerial photo mosaic scale 1: 50,000. Field investigation and observation on vegetative cover, slope, drainability, positions, land use, salinity and alkalinity, etc. were included and used for determining the arable and non-arable classes and sub-classes. The survey boundaries did not cover the great sand dune bodies such as Ash Shqayqah on the west and At Thuwairat on the east fringing the great basins, desert plains, valleys and low lands of the region. Land classification maps presented here have been subject to re-arrangement in a different order to suit the nature of this work. The re-arrangement of the map compilation is based on the geologic and geomorphologic sub provinces in the region. This is due to the fact that these two physical items are the primary factors in determining the composition and the nature of the land in the region; neither the climate, nor the vegetation have a comparative effect in this respect. Thus the region is divided into five zones:- Qusaiba zone, Asyah zone, Wadi zone, Shmasiyah zone and Midhnab zone (Fig.18).

The system which was adopted in the land classification of the Qassim is based on the land classification system of the Bureau of Land Reclamation, U.S.D.I., as designated and

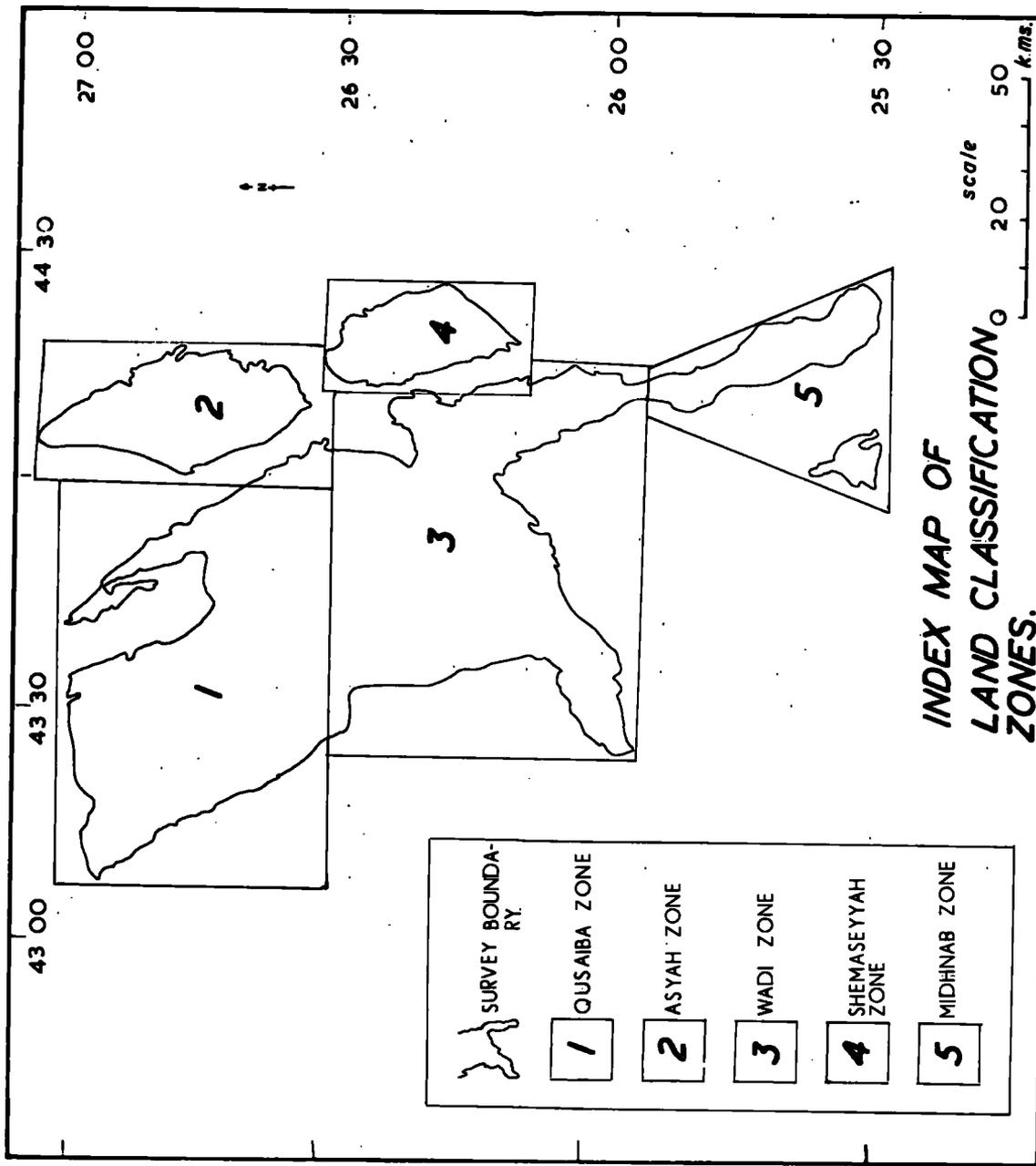


FIGURE 18

described in volume V "Irrigated Land Use," part two "Land classification." The land classes in the Manual are six; four basic classes (I, II, III and IV) were used to identify the arable lands according to their suitability for irrigated farming. One provisional class (V) and one class to identify the non-arable lands (VI). Each class is divided into seven sub-classes to indicate the deficiency, whether in soil, topography, or drainage, or the combination of deficiencies, e.g. IIIs, IIIIt, IIIId, IIIIst, IIIIsd, IIIItā, IIIIstd. To suit the requirements of the present preliminary classification of the lands in al-Qassim, classes IV and V were dropped as they are needed in the case of detailed classification studies only.

10.4% (83142 hect.) of the land in the region represents the arable lands (Fig.19). This portion of land is classified into classes and sub-classes of II and III only (Fig.20) because none of the lands matched the specifications fixed in the Manual for Class I. However, these arable lands if provided with the essential practices of land improvement such as levelling, drainage, irrigation facilities, etc., under sustained irrigation, would have a repayment capacity to meet and cover all production expenses and maintenance plus a reasonable profit.

8.2 Class II lands (CIIL)

The total area occupied by this type of land in the Qassim is (4854 hect.) 5.8% of the total percentage of the arable lands in the region. The general physical characteristics of the CIIL; topographic setting position, drainability, and slope are demonstrated in Fig.21. The compilation of this figure is tentative and based on the available data and information. This figure indicates that 56.2% of the CIIL is found in the closed basins and depressions which are scattered throughout the region. This is apparently due to

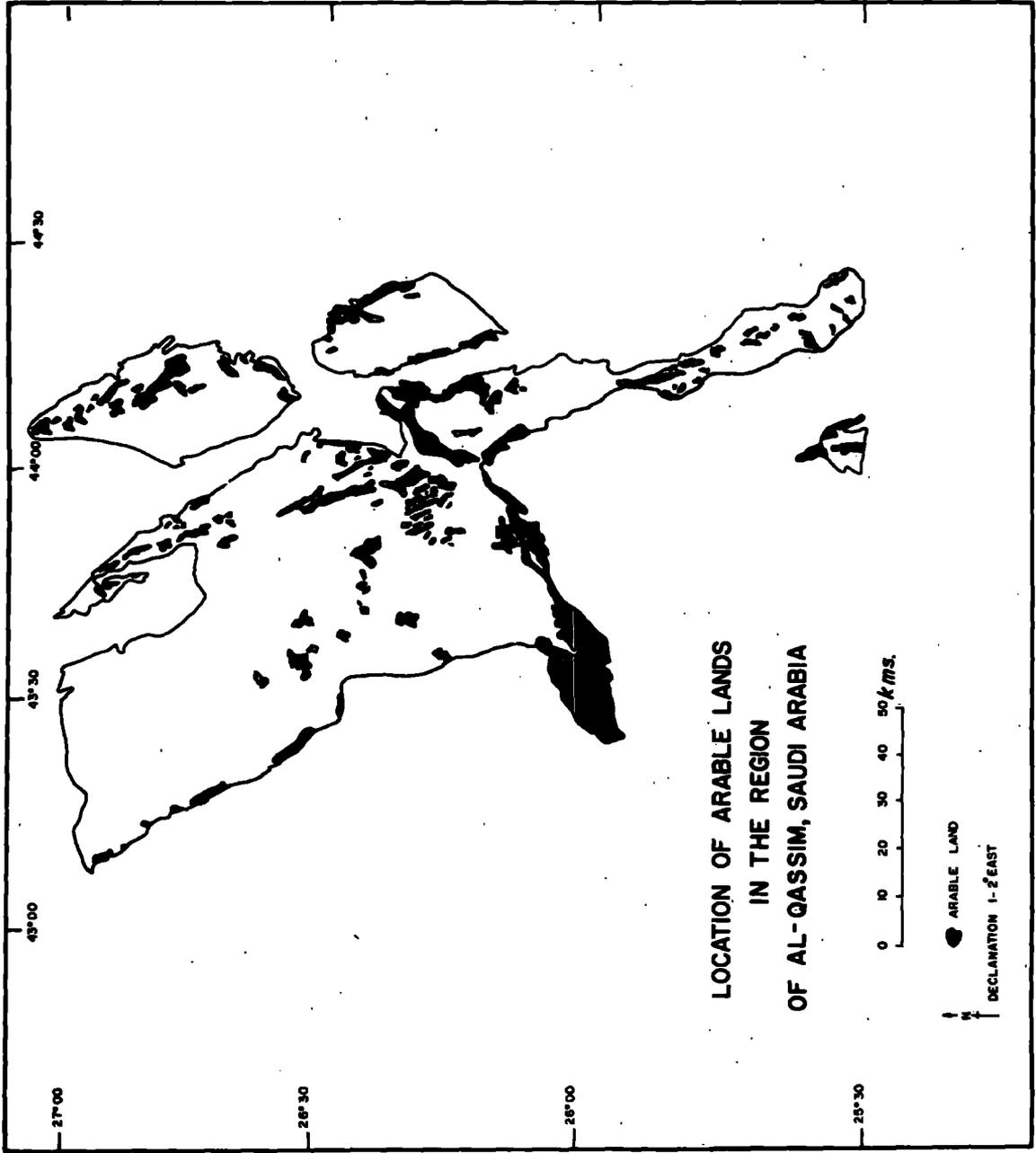
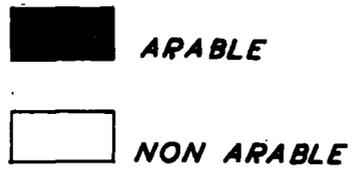
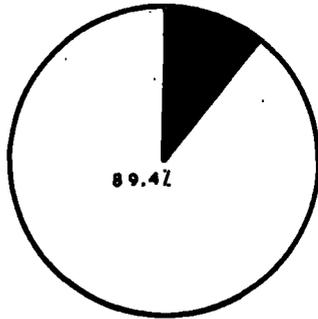


FIGURE 19

ARABLE AND NON ARABLE LANDS



ARABLE LANDS CLASSES

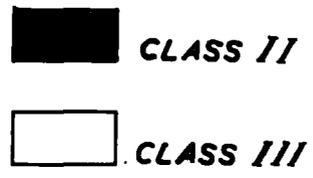
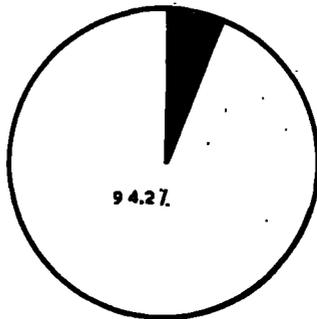


FIGURE 20

the fact that these topographic positions are comparatively protected from wind and water erosion; in addition, they are the terminal points of the numerous small wadis in the region and act as internal drainage basins to them. These wadis, whenever they flood, bring loads of silt, clay, and other fine material from the surrounding small cuestas and low ridges. 18.7% and 12.5% of the CIIL in the region are situated in the wadis and alluvial plains respectively, and the remaining 12.6% are scattered either along the desert plains or silt flats in the region.

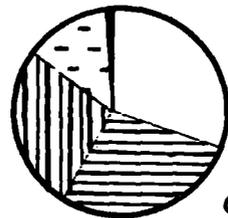
The drainability condition of the CIIL in the region is on the whole satisfactory with 42.8% and 28.7% of this land being well-drained land and moderately-drained respectively. The remaining portion is divided into 21.3% poorly-drained land and 7.2% excessively-drained land. However, the figures reflect that around 30% of the area classified as CIIL needs serious consideration of the drainage problem.

Levelling is not a problem for the CIIL in the region as it is estimated that 42.1% of the land is of a level slope and the remainder is of nearly level slope but none of it is undulating or even gently undulating.

Most of the CIIL in the region is virgin and has never been brought under cultivation. This is apparently due to a complex of political and social factors when the existing settlements were set up. The site of agricultural settlement was judged by those factors rather than by the quality of land. These circumstances have resulted in the fact that most of these lands are remote and involve far too much capital to exploit and operate if the farmers are reluctant and refuse to move from their old households.

It is estimated that 33% of the total is within the Qusaiba zone where it concentrates round Qusaiba and the northern part of al Butain where 16.9% lies and 10.9% is

CLASS II LANDS



A-GEOGRAPHICAL DISTRIBUTION

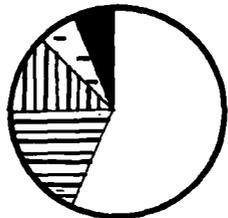


QUSAIBAH AL-WADI

ASYAH

MIDHNAB

SHMASS.



B-DIST. ACCORDING TO TOPOG. SETTING



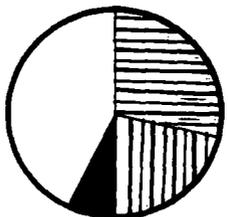
BASINS

WADIS

**ALLUVIAL
PLAINS**

**DESERT
PLAINS**

**SILT
FLATS**



C-DIST. ACCORDING TO DRAINAGE CONDITION

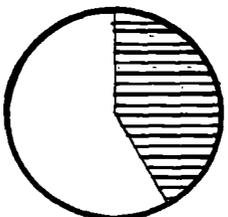


WELL

MODERATE

POOR

EXCESSIVE



D-DIST. ACCORDING TO SURFACE SLOPE



LEVEL



NEARLY LEVEL

FIGURE 21

found round al Weta area. 24.4% of the CIIL total is situated within the wadi zone particularly round the Braydah and Aunayzah areas where Aunayzah area comprises 13.2% of the wadi total and the remaining portion is within Braydah.

Al Asyah zone (N.E.) comprises 24.2% and the Midhnab zone comprises 16.8% of the total percentage of CIIL in the region, the remaining 1.6% is situated in Ash Shmaseyyah zone.

(a) Qusaiba zone

The distribution of the CII lands in the Qusaiba zone (1610 hect.) indicates that all areas of this land in the zone are located in the scattered closed basins and depressions of inland drainage. Consequently as wadi deposition is important, the land in the zone is characterized by a silty loam, sandy loam, and clayey loam textures. Thus it is expected that the clay mineral content and the available moisture capacity is high and favourable. The slope of these lands is very favourable and does not involve any cost for levelling.

Drainability too is not a problem for the CIIL in the zone; it is estimated that 80% of the zone total is of a well-drained condition and 20% of a moderately-drained condition. Moderate salinity is the order in CIIL of the zone and most of the lands need not be leached artificially as it seems that natural leaching by normal practices of irrigation and cultivation is adequate. Few areas reach in salinity the rate of as high as 18 millimhos. The small portion of this type of land which has been brought under cultivation is mainly wheat producing land. The remaining area is still virgin land awaiting development facilities.

(b) The Wadi zone

Half of the CIIL of the Wadi zone is spread out in the alluvial plains of the great Wadi Ar Rma and 25% lies within the scattered small wadis which descend from the surrounding

and relatively high lands particularly in the north. The remaining 25% is found within the surrounding desert plains. The CIIL in the Wadi zone is characterized by a nearly level feature.

Drainage is a real problem in the CIIL of this zone, where it is estimated that 75% is of a poor drainability condition, and the remaining 25% is moderately-drained. This high proportion of poor drainability requires and indeed necessitates particular consideration in any land development project. The E.C. values do not exceed 7.4 millimhos at its utmost extreme and goes down as low as 0.79 millimhos. A striking feature of this type of land is that it is of a uniformly textured composition, mainly sandy loam. This is explained by the great and almost equal portions of aeolian and alluvial deposits which have been deposited throughout the wadi basin and intercalated to produce uniformity in textural composition.

(c) Midhnab zone

In the Midhnab zone where 16.8% of the CIIL lies, the lands are mostly characterized by either basins or wadis as topographical settings, with these two topographical aspects including 33.5% and 33.2% of the zone total respectively. The remaining portion is divided more or less equally between the desert plains and silt flats. The slope is favourable as it is estimated that 57.2% is of a nearly-level feature and the remaining portion is of a level feature. The textural composition varies, with sandy clay loam, silt loam, clayey loam and sandy loam profiles being found. The combination of these factors has favoured a very good drainability condition, and it is estimated that almost 50% is well drained and the other 50% is moderately drained. Salinity is diverse with the maximum 9.4 and the minimum 0.7 E.C. millimhos.

(d) Al Asyah zone

In the al Asyah zone the CIIL are of a uniform topographical setting where they are spread out along the broad shallow valley of al Asyah. Drainability is favourable except for 9% of the total percentage of CIIL of the zone, with 5% excessively drained and 4% poorly drained. The remaining portion is divided into 61% and 30% for well-drained land and moderately-drained respectively. Salinity seems not a critical limiting factor for the CIIL of the zone.

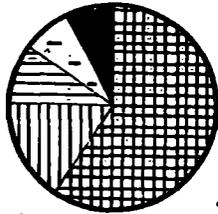
The CIIL of Ash Shmaseyyah (48 hect.) is confined to a basin topographical setting with a nearly level feature with 75% well-drained, 13% moderately-drained and 12% poorly drained.

8.3 Class III Lands

The remaining 94.2% (78,283 hect.) of the arable lands in the Qassim are classified as class and sub-classes III. The distribution of the lands of this class according to their topographical setting indicates that 42.8% is located along the alluvial plains which surround the main and subsidiary channels of the great Wadi of Ar Rma. 27.9% is found in the scattered closed basins and depressions particularly on the northern side of the wadi, and 19.3% is situated in the small wadis which either drain into the wadi or the surrounding depressions and closed basins. The remaining portions, 6.7%, 2.5% and 0.9% are found in the desert plains, silt flats and alluvial fans throughout the zones (Fig.22).

Drainability of this class in the region on the whole is not satisfactory and it is estimated that 54.3% of the total percentage is of a poor-drainage capacity and 0.8% of an excessive drainability, while only 34.3% is well-drained and 10.6% of a moderate-drainage capacity. In fact, this

CLASS III LANDS



A-GEOGRAPHICAL DISTRIBUTION (ZONES)



AL-WADI



SHMASEYY



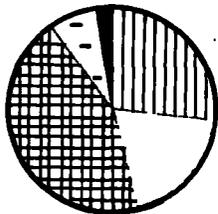
ASYAH



QUSAIBAH



MIDHNAB



B-DIST. ACCORDING TO TOPOG. SETTING



ALLUVIAL PLAINS



BASINS



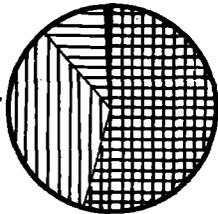
WADIS



DESERT PLAINS



SILT FLATS & ALLU. FANS



C-DIST. ACCORDING TO DRAINAGE CONDITION



POOR



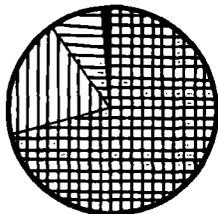
WELL



MODER.



EXCESSIVE



D DIST. ACCORDING TO SURFACE SLOPE



NEARLY LEVEL



LEVEL



GENTLY UNDULATING



UNDULATING

FIGURE 22

deficiency on such a large scale necessitates an intensive investigation for the designation of the lowest cost possible to overcome this problem without any imbalance in the output and input of any agricultural development project on these lands.

In general, levelling is not a serious problem with only 9.8% of the total being in need of levelling. The remaining portion is divided into 70.9% of a nearly-level surface and 19.3% level. Generally, the CIIIL are suitable for irrigated agricultural development but they are rather close to marginality for repayment capacity. This is due to the fact that they are of a relatively restricted suitability because of fairly sharp deficiencies in soil and drainage characteristics. Most of the lands are of a good topographic setting and level but, because of inferior soil characteristics which restrict crop adaptability, they do require larger amounts of water and in some cases special irrigation practices are necessary. In some areas the need for a large amount of fertilization or intensive soil improvement practice is a definite need. Farming Class III lands of the region involves in general greater risks than in farming Class II lands, but, nevertheless, under proper management it is anticipated that they would have an adequate repayment capacity.

The geographical distribution of these lands in the Qassim indicates that 59% of the total percentage lies within the wadi zone where Ar Russ and Ar Rubaeyyah settlements comprise 17.7%, the biggest part of the wadi total. On the opposite sides of the wadi lie Riyadh al Khabra, al Helaliyyah, and al Bukaireyyah settlements with 12.9% of the wadi total. Braydah area comprises 15.9% and Aunayzah 10.7% of the total percentage.

15.4% of the region total is located within Ash Shmaseyyah zone, and 10.6% within al Asyah area. The remain-

ing 15% is divided almost equally between the Qusaiba and Midhnab zones.

(a) The wadi zone (46,489 hect.)

58.6% of the zone's total is located along the alluvial plains of the great Wadi Ar Rma. 24.8% is situated in the numerous small wadis of the zone and 12% lies within the scattered closed basins and depressions where most of the small wadis of the zone drain. 4.6% is found in the desert plains (Fig.23).

Levelling on the whole is not required on a widespread scale, as only 5.5% needs a moderate levelling practice. 78.2% and 16.3% are the percentages which represent the nearly level slope and the level surface lands respectively.

Drainage is a rather serious and widespread problem in this zone where it is estimated that 58.9% is of a poor drainage capacity while 36.5% is of a good drainability condition and 4.6% moderately drained.

Salinity is very diverse in the zone's CIIL. The rate of electric conductivity ranges from 0.9 to 350 mmhos; in the areas of such high extremes considerable work and cost for leaching practices would be involved. Fortunately the majority of lands is far below the high total and in fact the range of 1-20 is the order throughout the zone. The textural composition varies according to the parent material and topographic position of the localities, and the sandy loam, silt loam, and clay profiles are very common almost in every single locality.

(b) Ash Shmasiyyah zone (12,409 hect.)

The Class III lands in Ash Shmasiyyah zone (Fig.24) are scattered throughout the zone on either side of the Jilh escarpment. The western side is a narrow long strip of land bordered by the western edge of the escarpment on the east and by a tongue of the As Sirr sand dunes on the west. All the agricultural settlements within the zone are confined to

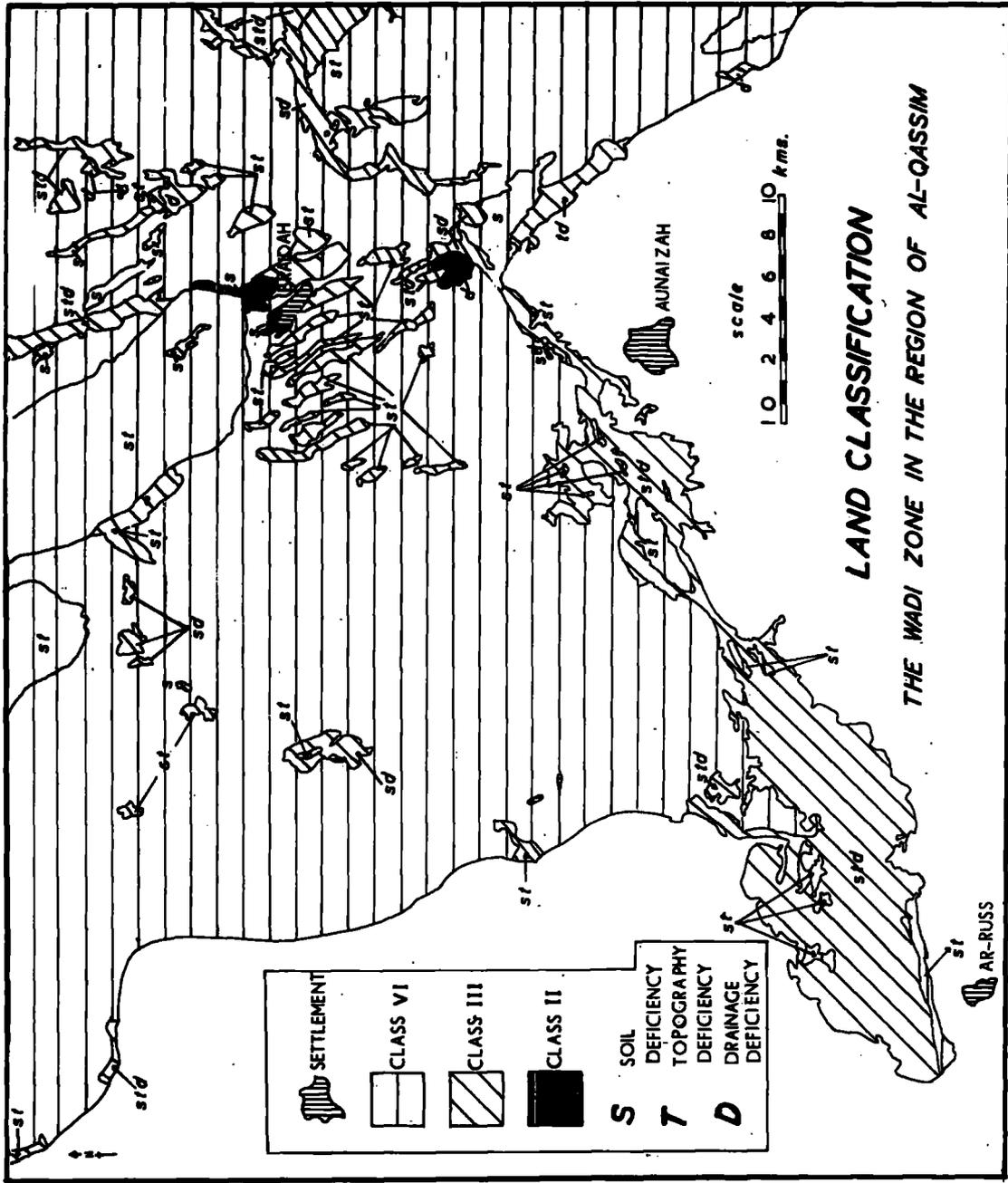


FIGURE 23

and clustered along this strip and it is the only inhabited part of the zone; apart from that all the CIIIL east to the scarp are virgin and have never been brought under cultivation.

55.3% and 26% of this land are located in the closed basins and depressions and in the alluvial plains respectively. Alluvial fans at the front of the escarpment on either side comprise 8.6% of the zone total which is the highest proportion of CIIIL of this type of topographical setting in the region. 5.2% and 4.9% of the zone total are situated in the desert plains and in the wadis throughout the zone.

Drainage is a widespread deficiency of the CIIIL of the zone. It is estimated that 60.8% and 2.1% are of a poor and excessive drainability conditions respectively. The remaining portion is almost of a well-drained type of land where it represents 36.9%, and only 0.2% of the zone total is moderately-drained. Nearly 22.5% of the zone total is in need of slight levelling practices as it has a gently undulating surface, but the remaining proportion does not need such a practice, where 44.8% and 32.7% are respectively lands of a nearly level and level slope. Salinity is a diverse property of the CIIIL where the rate is in the range of 176 and 0.5 mmhos. The higher cases are in fact rare and it is only a few areas which contain above E.C. 50 mmhos. Most of the lands are of a reasonable and moderate salinity in the range of 1-20 mmhos.

(c) Asyah zone (7.714 hect.)

The topographical setting of the Class III lands in this zone (Fig.25) is confined to four topographical positions; the basins and depressions, the alluvial plains, the wadis, and the desert plains within or surrounding the broad shallow valley of al Asyah. The proportion of each is 42.4%, 30.4%, 18.6% and 8.6% respectively. Drainage deficiency is the

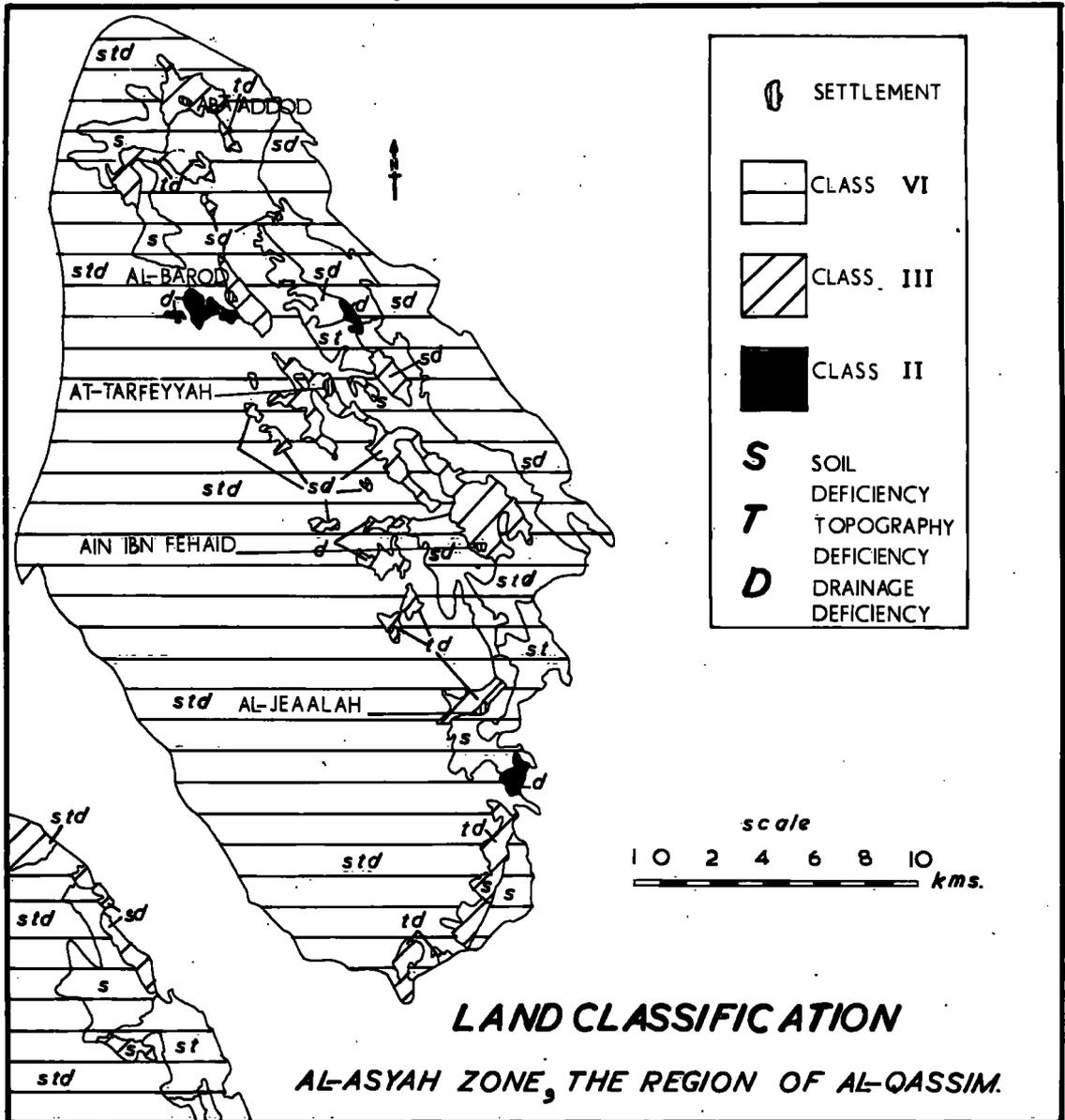


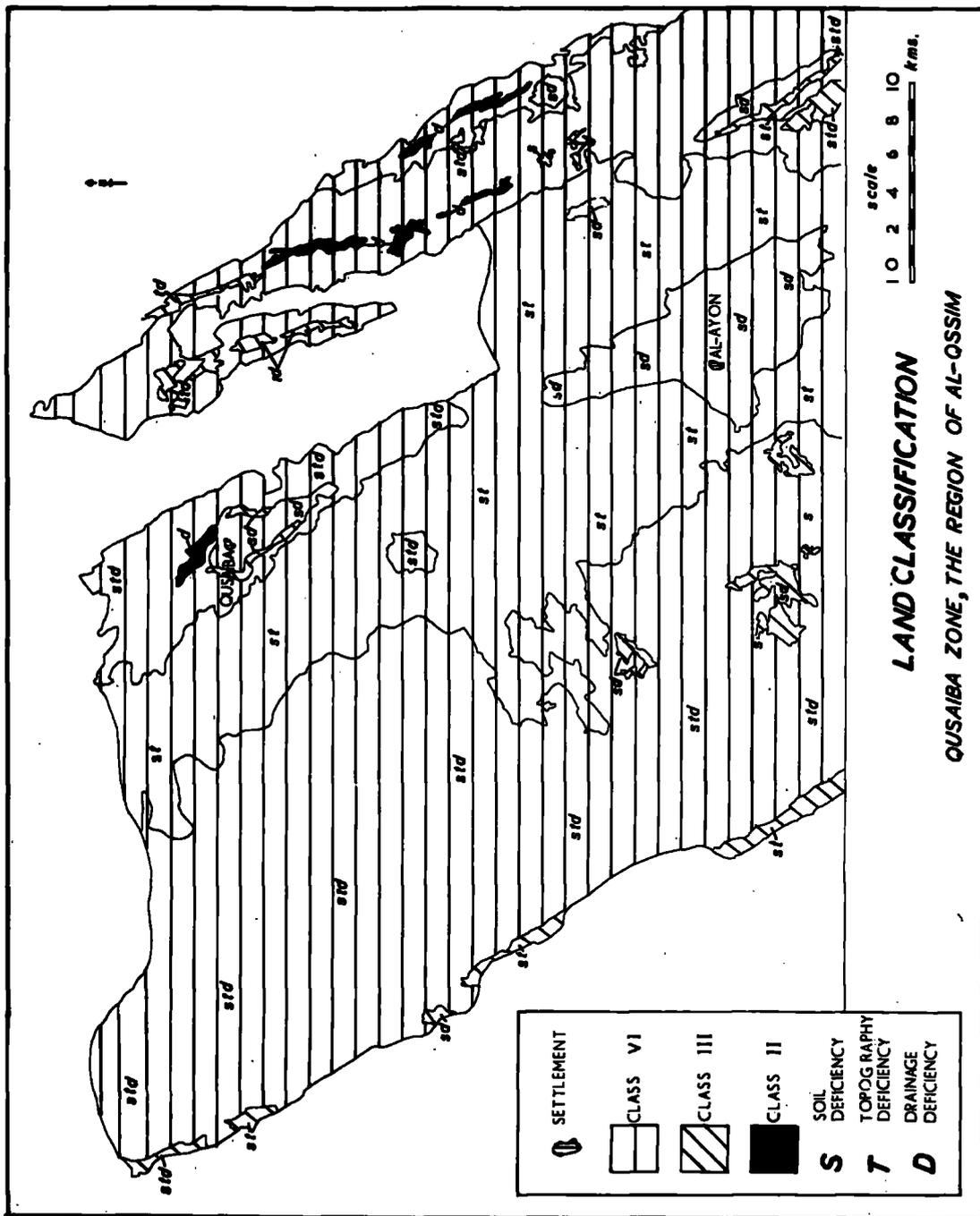
FIGURE 25

character of most of the CIIIL and it is estimated that 64.7% is the percentage of the CIIIL in the zone classified as poorly-drained land, while 17.7% and 17.6% are the percentages for moderately-drained and well-drained respectively. Slope is not a very favourable character of this land as it is estimated that 18.1% and 0.2% represent the gently undulating and undulating lands. 59% and 22.7% are the figures for the nearly level and the lands with a level surface. Salinity of this type of land in this zone seems the most moderate of all in the region where 40 mmhos. is the figure for the upmost extreme case, and most of the lands are of a salinity in the range of 0.5 to 5. This, in fact, is a very favourable character of the CIIIL in the zone and indeed a promising one for a wide range of crop adaptability.

(d) Qusaiba zone (5,890 hect.)

48.9% of the zone total is located (Fig.26) in the closed basins and depressions which are scattered in a series of broken chains throughout the zone separating the low ridges and the cuestas of the zone and breaching the vast duricrust plain. In the alluvial plains lies 25.6% of the CIIIL which usually lies adjacent to the most prominent topographic feature of the zone the low ridges and cuestas. Desert plains of the area comprise 12.8% of the total percentage and the alluvial fans and wadis contain 7.6% and 5.1% of the zone total.

Drainage capacity of the CIIIL seems better than in the previous zones. The moderately-drained lands and the well-drained areas are estimated to be of the order of 34.2% and 26.3% respectively which on the whole surpass the conditions of the wadi zone or Ash Shmasiyyah zone. The slope of these lands is almost nearly level with 72.4% of the zone total and the level lands represent 13.8%.



LAND CLASSIFICATION

QUSAIBA ZONE, THE REGION OF AL-QSSIM

FIGURE 26

No part of these lands has a undulating surface and the gently undulating lands represent 13.8%. If levelling practices should be considered it might be in the case of the latter type of slope where it is anticipated to be of a very moderate cost. Salinity in the zone reaches a maximum as high as 450 and also a minimum as low as 0.2 mmhos. These extreme cases are of a very rare occurrence and the common rate is in the order of 5-20 mmhos. A striking feature of the CIIIL in this zone is that the textural composition is almost confined to loam and/or clay.

(e) Midhuab zone (5,762 hect.)

The Class III lands in the Midhuab zone (Fig.27) have two distinctive and comparatively better characteristics than the other zones in the region. First a very favourable slope confined only to nearly level and level surfaces where 79.2% and 20.8% represent both respectively. The second is the good drainability condition which, with the association of the favourable slope, would promote a good repayment capacity. 41.8% is a moderately-drained land and 33.3% well-drained, while 16.6% is poorly-drained and 8.3% of an excessive drainability. These percentages for unfavourable drainage are the lowest in the region.

The Midhuab zone comprises a completely different topographical setting for 12.5% of the CIII lands which lies within the silt flats the unique topographical position of this zone. 37.7% and 29.1% are located within the wadis and the basins and depressions of the zone respectively. Desert plains in the area comprise 20.7% of this type of land.

As in other parts of the region, salinity is a very variable property ranging from one locality to another with maximum as high as 175 and the minimum as low as 0.8 mmhos.

This extreme variation in the region as a whole indicates the need for extensive and intensive investigations in order to facilitate and enable sharp and accurate lines between the many different salinity rates. This, if accomplished, would lead to the enhancement of land improvement practices as salinity is a very inhibiting and limiting factor to the crop adaptability range.

8.4 Class VI Lands

89.6% (703,925 hect.) is the percentage of the non-arable lands in the Qassim. The geographical distribution of these lands shows that the Qusaiba zone comprises 39.1% of the total percentage. This great percentage is due to the existence of the vast duricrust cover in the area associated with the chain of cuestas and low ridges. The second biggest percentage (30.3%) of this class lies within the wadi zone as a result of the large accumulation of sand dunes in and around the wadi channels and the scarps edges bordering the wadi basin. Al Asyah area comprises 14.2% of the total determined by the gravel plains and Al Trefiyah sand dunes bordering the very shallow and broad valley of al Asyah. Ashemaseyyah area has 9.5% and the Midhuab zone contains 6.9% of the total percentage.

However, generally, class and sub-class VI lands are of a severe, unfavourable combination of topography, drainage, and soil deficiencies. In general they are rough, broken, or badly eroded lands, sand sheets or dunes; land with soil of very coarse or very fine texture, or shallow soils over gravel, shale, sandstone or hardpan. These lands usually have inadequate drainage capacities and high concentrations of soluble salts and/or sodium. Thus, Class VI lands do not have sufficient repayment capacity to cover the costs of production and reclamation practices.

The only capacity of this class is grazing. Further studies on this subject are necessary to determine the actual and the safe margin for grazing capacity of each individual sub-class. Undoubtedly, this, if accomplished in an efficient and accurate way and then handled by sound management measures, would lead to an improvement of land utilization on the range resources. For a considerable time the range husbandry of the region is likely to remain of high economic importance.

This preliminary study of the land classification of the Qassim has outlined the areas that should be given priority in any further detailed studies concerning land and agricultural development in the region. An exception to this simple conclusion is the class II lands of the Qusaiba zone which comprises 33% of the total percentage of the region. Because of the fact that this zone is the least inhabited zone in the region and lacks paved and good roads to the other parts of the region or even to other parts of the kingdom, it is suggested that this zone should not be given the first chance of land developments projects in the region.

The wadi basin zone which comprises the second biggest share of the Class II lands in the region stands firmly for the first project. This is based on the ground of very favourable circumstances; it is the most populated part in the region and enjoys a very modern and efficient highway contacted at its southern end by the central highway which crosses the Arabian peninsula from the west to the east shores (Jeddah-Dammam highway via Riyadh). Moreover, this case is supported strongly by the fact that the wadi basin zone holds 59% of the total percentage of the Class III lands in the Qassim.

Al Asyah zone with the third share of the Class II lands in the region suffers from primitive communication means. Nevertheless, it is in a more favourable position as a whole than the Qusaiba zone due to the fact that the lands in al Asyah are of continuous throughout the shallow broad valley of al Asyah, while those of the Qusaiba zone lie within the scattered basins and depressions which are separated by rugged topography. However, the area which is suggested for the second of any future projects is the Midhnab, one as it is the second most populated part of the region and enjoys a very efficient highway facility across the zone from the south to the north by a sector of the Ar Riyadh - Braydah highway. Moreover, this zone, due to its geographical location, is the nearest part of the region to the big markets of Saudi in Ar Riyadh, Macca and Jeddah. X

References

1. Allerd, B. W. Technical Guide No.1, How to determine range sites and condition classes in Saudi Arabia
Typed publication, Project 117,
F.A.O., Rome, 1965.
2. Allerd, B. W. and others Ecological Evaluation of Plants, Saudi Arabia
Typed publication, Project 117,
F.A.O., Rome, 1965.
3. Balle-Jones, E. W. Progress report on response to fertilizers application in Saudi Arabia
Unpublished mimeograph,
Soil Fertility Branch,
F.A.O., Rome, June, 1967.
4. Clark, J. S. An examination of the P_n of Calcareous soils
Soil Science,
Vol.98 (pages 145-151), 1964
Rugters University,
N.J., U.S.A.
5. Draz, O. Some desert plants and their uses in animal feeding
de l'Institute du Desert d'Egypte,
No.2 (pages 1-95).
Cairo, 1954.
6. F.A.O. Report on the first meeting on soil fertility and fertilizers use in the Near East and North Africa
Rome, January, 1963.
- F.A.O. Soil Map of the Near East: Provisional Examination Note
Typed publication,
Rome, 1963.

7. Fitzgerald, D. F. The vegetation of Central and Eastern Arabia
Journal of Ecology, 45 (pages 779-789), 1957.
8. Healy, H. F. Grazing resources and the problems, Saudi Arabia
Typed publication, EPTA report No.161A
F.A.O., Rome, 1963.
9. Klemme, M. Pasture development and range management, Saudi Arabia
Typed publication, EPTA report No.1993.
F.A.O., Rome, 1965.
10. Kubiena, W. L. The Classification of Soils
Journal of Soil Science, Vol.9, 1958.
11. Parsons-Basil Report and recommendation on range resources of Area 1, the Qassim, Wadi Sirham, Sakakah, al-Jawf, Saudi Arabia
Unpublished mimeograph.
Water and Agricultural Development Studies, Ministry of Water and Agriculture, Ar Riyadh, April, 1967.
12. Schwan, H. C. An appraisal of the wild lands of Saudi Arabia
Unpublished mimeograph.
U.S. operation mission to Saudi Arabia, 1954.
13. Soil Survey Staff Soil Survey Manual
U.S.D.A.,
Washington, D.C., 1953.

14. Survey Staff Guide lines for soil description
Soil survey and fertility branch,
Bulletin No.29317
F.A.O., Rome
15. Survey Staff Land-Capability Classification
Agriculture hand book No.210
Soil Conservation Service,
U.S.D.A.:
16. U.S.D.I. Bureau of Reclamation Manual
Vol.v., Irrigated Land Use,
Part 2, Land classification,
Washington,1953.
17. Zahary, M. On the Ghada trees on Northern
Arabia and Syrian Desert
Palestine Jour. Jer. Series 1
(pages 413-416), 1940.

PART IV

THE AGRICULTURE

Chapter 9The Pattern of Agricultural
Production9.1 Introduction

The Qassim is divided into three main agricultural administrative districts; Braydah, Aunayzah, and Ar Russ (Fig.28). These districts embrace 269,574 hectares of land under a land holding system, which constitutes 58.2% of the total land under a holding system in the kingdom. It is reported in the agricultural survey of the region (1961-62) that this aggregate represents the arable land in the Qassim. A recent study (1967)⁽¹⁾ revealed that the absolute area of arable land in the Qassim is 83,118 hectares. This calculation was based on aerial photograph interpretations supplemented by field inspections. In fact, such a great difference between the two estimates could be easily eliminated by rejecting the assumption of the agricultural survey report on the grounds that the sizes of holding were recorded according to the farmers' statements and were considered as representing the actual arable land. Most of the region's farmers do not know the exact area of their holdings and the ratio of the actual arable land against non-arable land within their holdings and they all have the tendency to exaggerate their positions; in addition, most of the surveyors who conducted the survey were poorly trained and inexperienced, and their estimations of the actual size of the arable land within the absolute size of the holdings is rarely accurate. It was noted during field

(1) Conducted for the Ministry of Water and Agriculture by joint American-Greek Consultants (Parsons-Basil).

AGRICULTURAL DISTRICTS IN THE REGION OF AL-QASSIM

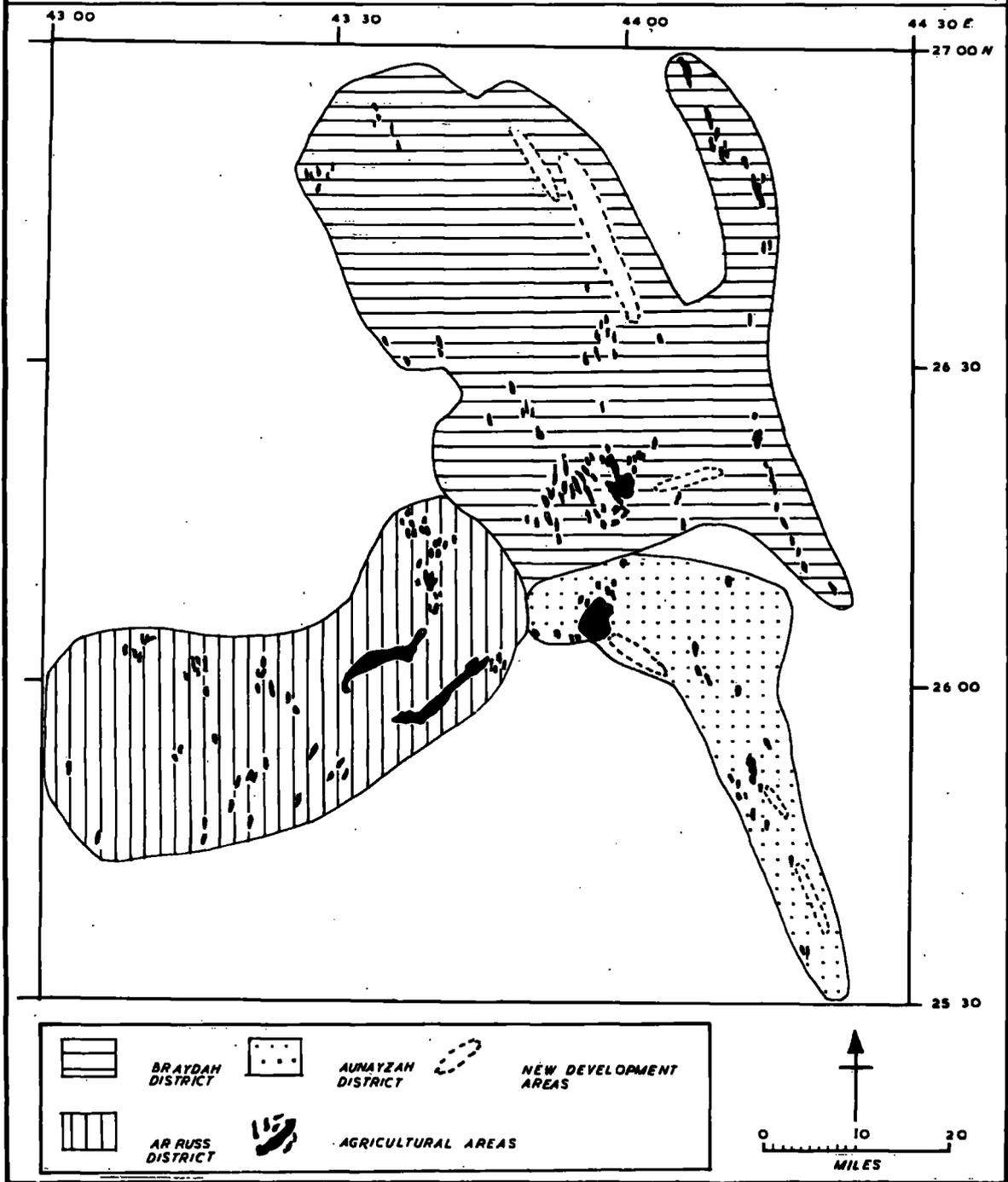


FIGURE 28

work, however, that many holdings comprise a sizeable area of non-arable land.

However, the survey estimates that some 32,000 hectares were under cultivation at the time when the survey was conducted. This magnitude represents 38.4 per cent of the total of actual cultivable land in the region according to the recent estimates. This characteristic, however, reveals the great agricultural potential which, under favourable conditions, could be exploited.

Cultivation in the Qassim depends entirely on irrigation, and it is estimated that only some 0.6 per cent of total cultivated area is rainfed cultivation of cereals.

However, throughout the historical literature on Arabia, several statements occur which refer to the relative prosperity of agriculture in the Qassim in the middle of the barren heart of Arabia. Until the present century, agriculture was confined to the very limited old settlements of the region. Subsistence agriculture was the type of farming. The shift towards a market-orientated type of agricultural economy was retarded until the beginning of the 1950s by a complex of factors. Severe shortage of water was the premier factor, supplemented by regional isolation imposed by an entire lack of paved roads to connect the region with the rest of the kingdom. This isolation was amplified by a physical factor, namely the huge bodies of sand dunes which surround the region. A low standard of living was the economic reason behind the low purchasing power of the inhabitants, and the low prices of valuable crops constituted an economic discouragement to attempts by the farmers to depart from the subsistence type of agricultural economy.

Since the beginning of the 1950s the ever rising

national income from oil has resulted, however, in a steady rise in per capita income and consequently in an increasing purchasing power for more valuable and diversified foodstuffs. This change has resulted in increased farm income and has enabled farmers to intensify their efforts to seek more water in order to irrigate more land to meet the increasing demand. These efforts commenced in a rather desperate way by deepening their original hand-dug wells by hand-drillers to allow more water to seep from the deeper zones and accumulate in the well. One of these hard attempts hit the artesian water of the Tabuk aquifer in May, 1953 to prove the existence of such wealth and mark the start of a new and very promising era in the history of the Qassim. This discovery has urged the government to allocate considerable amounts of funds for detailed investigations on the quantity and quality of this new source of prosperity. These investigations have proved the existence of artesian water in a quantity and quality sufficient to support all arable lands in the middle and eastern parts of the region for generations to come. The increasing national income has also enabled the government to construct a net of paved roads to cover the kingdom, and the Qassim has lost its geographical isolation and is now linked by an efficient highway with excellent access to the big markets in the Central Najd, and Hejaz regions.

9.2 The Land System

There is no land registry map of the cultivated and non-cultivated areas of the lands in the Region. The deeds lodged with the emirs of the region are mere lists of taxpayers (Mezzakkeyn) without any information on the nature of the properties of the taxpayers. The only persons capable of remembering, at least in part, the type of

holding (owned, rented, or income or crop shared), and the limits of each property are the heads of villages who, by tradition, hand down this information. However, even progressing along these lines it was impossible to obtain sufficient, accurate, and reliable data to draw up a complete picture of land tenure for the entire arable territory of the region.

However, the types of land tenure within the region could be classified in the following manner:-

1. Privately owned land (Mulk)
2. Charity land (Waqf)
3. Tribally owned land (Deirah)

Due to the unavailability of data on the areas of each, a proportionate size for each type cannot be drawn; nonetheless, it is expected that the tribally owned land occupies the largest proportion of the arable and non-arable lands in the region as communal ownership is common for most of the population in the Qassim, either settlers or nomads. Privately owned land comes next to the tribal land in size, but it must be noted that it surpasses the tribal land in terms of actual cultivated land size, as most of the tribal lands are exploited merely as a range land.

(1) Mulk system

The breakdown of holdings into small plots and the increase in land fragmentation from one generation to the other does occur, generally, in this type of land tenure. In most cases, heirs often agree to hold the land jointly, and entrust its administration to a senior kinsman, who in return for this service not only retains his share of the crop but also is paid for his labour (Ataab). The remainder of the crop or income is divided among the other owners. This type of arrangement, which is known as Sharakah, was frequent in the past up to the last decade. Marriage between

first cousins further contributed to the consolidation of family holdings by preventing the property of women from being transferred to other families. The current trend, however, particularly in the case of land being brought under cultivation by the newly wealthy sector, who resides in the towns either within the region or elsewhere in the kingdom, is toward partition of property among heirs, with frequent sales to outsiders.

In case the heirs wish to divide the holding among them, the process of division has to be carried out according to Islamic laws. The rules of the law which regulates land inheritance, as well as other types of inheritance, are outlined briefly as follows; One-eighth of the estate is allocated to the surviving spouse; if there is more than one spouse, the portion is divided equally among them. Seven-eighths, the residual estate, is divided according to the number and sex of the direct heirs (Dhurreyah). (Sons and daughters). If there is only one son (or only one daughter) he or she is entitled to the seven-eighths portion; if there are two or more sons or two or more daughters the seven-eighths is divided between them in equal parts. If there is one son and one daughter the former gets two-thirds of the seven-eighths and the latter the remaining one-third. If there are two sons and one daughter four-fifths of the seven-eighths is divided between the sons, the daughter receives one-fifth; the same division also occurs if there happens to be more sons and more daughters; in this case the four-fifths of the seven-eighths portion is distributed in equal parts between the sons and the fifth part is also equally divided between the daughters.

Descendant and collateral kinsmen (brothers, nephews, etc.) only enter the inheritance exceptionally when the dead

householder has had no direct heirs or when it is stated in the will of the dead householder.

(2) Waqf system

Waqf land is land which has been written in a will of a dead householder as charity land. The revenue of such lands must be spent in accordance with the statement of the will; for instance, in cases it should be distributed among his or her relatives or kinsmen, or, if not, among poor people in the village, or to be spent on maintenance of a certain mosque or mosques in the village or towns as a charity from the dead householder. The rent unit always has to be in kind, usually an amount of wheat to be paid yearly. Such an amount is fixed according to the size of the land, its productive capacity, the availability of water and farming facilities. However, it is usually a small amount of wheat in the range of 20 saa⁽¹⁾ per hectare per year. The duration of contract of waqf land is always in the range of 30 to 100 years, in a few cases even up to 200 years. Such a case was reported in Ash Shmasiyyah zone.

(3) Tribal lands

These lands comprise the greatest portion of the land in the region, and are largely used as range lands. Such lands, including their wells, are held in trust for the tribe by the ruling sheikh who may not sell any part of them and who passes them on to his successor. Ultimate jurisdiction over all tribal lands is, however, possessed by the king who retains the right to give them away.

An interesting aspect of communal land tenure attached to dry farming practice in al Asyah area (N.E.) is that the ratio of tribal land is high. When the amount of the occasional winter rainfall or flooding is high enough to permit dry farming (usually cereal), the question of land division of the surrounding communal land is solved by the

(1) Saa is a local unit equal to 2.8 kg.

acceptable traditional way. The first person who starts ploughing the land is the one who is entitled to claim it for the season provided he or she is a settler in the village or a nomad related with the settlement. The size of claimed land is unlimited and the claimers plough from the point he or she starts as far as the ploughing operations set up by other claimers in the area.

Another interesting aspect concerning communal lands is encountered in Wadi Ar Rma area (especially around Badaeya and al Khabra settlements). The wide wadi bed is a common property of the farmers who own farms on either side of its banks where the original palm gardens were established. Every farmer has the right to expand his farm into the wadi bed provided that the extension does not exceed in width the width of the original palm-garden on the wadi bank.

However, the system of land tenure of the cultivated lands in the Qassim is based on private ownership rather than state ownership. This system contains 4,963 holdings which in turn comprise 60,810 separate pieces of land with a total area of 269,574 hect. and only 11.9 per cent of the holdings are under cultivation⁽¹⁾. 90.7 per cent of these holdings are farmed by the owners (Fig.29) who either farm the land themselves with the help of their household members or who run the farm by hired labour with occasional supervision. The remaining 9.3 per cent of the holdings is either rented on the basis of certain amount of cash or kind or on the basis of crop or income sharing basis depending on the individual agreement. Absentee landlordism occurs on a small scale especially in the tribally owned lands, which are cared for by tenants until harvest time when the owner returns to

(1) All these figures are calculated from data given in the agricultural survey of the Qassim in 1961-62.

**PERCENTAGES OF TYPES OF HOLDINGS IN THE AGRICULTURAL DISTRICTS,
THE REGION OF AL-OASSIM**

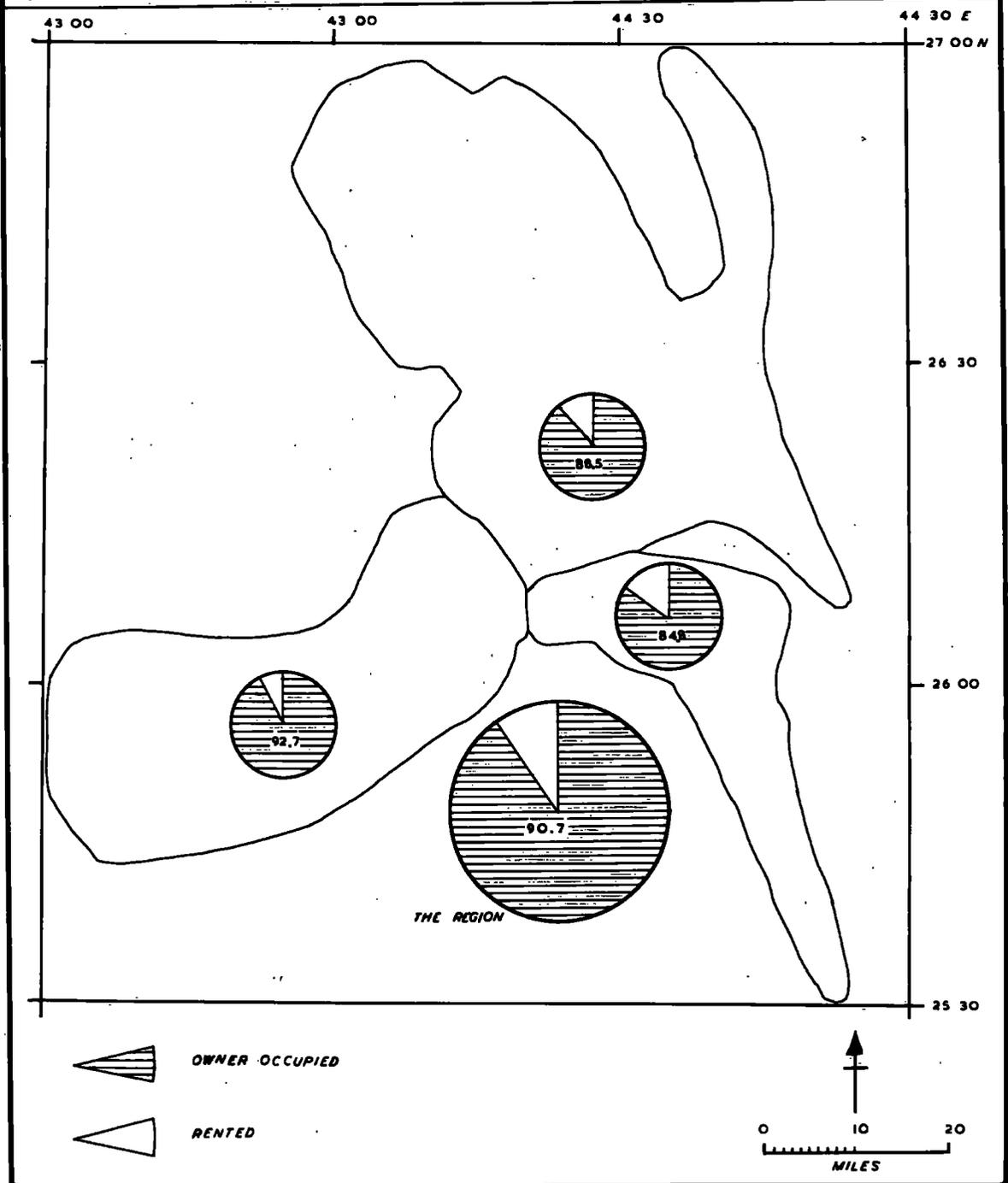


FIGURE 29

collect his share. The rate of rent of agricultural lands is comparatively high in the region. Calculation of the average rate of rent based on the field investigation suggests that the average is in the range of 50 per cent of the production and this percentage is probably the highest in the kingdom. A similar estimate by the Ministry of Agriculture for al-Ahsa region (east) and the northern boundaries province indicate that the average rate lies round 35 per cent of the total cost of production in those areas.

The size of holding throughout the region is relatively large. A calculation based on the agricultural survey data (1961-62) indicates that 48.6⁽¹⁾ per cent of the holdings are of 10 hectares and over, 36.5 per cent 1-5 hectares, and the remainder lies within the range of 5-10 hectares and classified as medium size of holdings.

The most interesting and important aspect of the land holding system in the region is the rent and metayage system.

There are, in fact, many types of rent and metayage contracts evolved and designated according to a complex of intercalated tradition, economic and social implications. Samples of these contract systems were investigated in the field and grouped as far as possible in the following types:-

(a) Tespeer system

The tespeer system is a renting system more commonly found in the isolated cultivated areas. It is always dealt with for abandoned farms or fields. Such farms or fields become abandoned either as a result of the death, illness, or age of the owner whose household members live on another farm in the adjacent village and are unable to continue

(1) See Appendix G.

farming such land. Another cause of such abandonment is because the owner has become bankrupt and is unable to meet the farm's expenses. In this system the rent has to be paid in cash and at the end of the contract period which usually varies between 1-3 years.

(b) Sobra system

The sobra system is a life-long contract, and it is a rather uncommon system at the present time and almost confined to the very isolated settlements. Contract of sobra has to be dealt with through the court of the settlement, or the nearest court in the adjacent village or town. Final registration of the contract in the court has to gain the approval of the judge and the village's mayor. The rent payment is yearly and fixed according to the value of the land. The landlord retains the right to repossess his land only in two circumstances according to the tradition of the system. These are, firstly, the death of the tenant, and, secondly, the failure of the tenant to pay the rent. However, in the few isolated cases which represent this system reasons beyond the adoption of such contract were always reported to be the decision of the original owner to migrate to one of the urban communities to take up a job in trading or governmental services, or the need of the concerned farm or land for considerable reclamation practices and costs, which renders the farm in unacceptable condition for short tenancy.

(c) Income sharing system

The common and prevailing income sharing system is the 50 per cent system. The terms of this system vary from place to place, being affected by the location and potentiality of the farm. The various terms are grouped in the following two types of contracts:-

- (i) The landlord has to participate in the production costs and product transportation to the market at the rate of 50 per cent, plus providing water pumping facilities. In return the landlord will receive at the end of the year half of the farm income.
- (ii) The second type of the fifty per cent income sharing is based on the following terms. Firstly, the landlord has to provide water pumping facilities with or without, depending upon the position of the farm, fuel for pumping. Secondly, the owner has to pay for the ploughing cost of the land and full or, in cases, half the price of the applied chemical fertilizers. Thirdly, the tenant has to bear alone all the other costs of farming including transportation fares of the crops to the market in the nearby town.

However, it is noted that the latter contract is the popular one, but in either case the contract is on a yearly basis renewable automatically if no objection is raised by one of the concerned parties.

Another system of income sharing was encountered in Aunayzah area, but it seems that it is a rather isolated case. It is known as Thulthain system (two-thirds). In this system the landlord has to provide water pumping facilities plus fuel, and to provide or pay for transportation to the market in the nearby town. In return the landlord shares the farm income at the rate of 67 per cent. The tenant has to bear alone all other costs of cultivation, such as labour, seeds, ploughing, etc. The period of the encountered tenancy in the fruits farm case is three years. However, the question of whether this system would become widespread in the future, especially for fruit farms, is

interesting as it is expected to be accepted notably for the new citrus farms around the towns of Braydah and Aunayzah where the income of such farms is high enough to constitute, by one-third of its gross income, a reasonable income for tenants to justify their labour and endeavour in the farm, especially for three guaranteed years.

(d) Metayage system

The metayage system is confined to either old palm gardens or to fallow fields. It includes the following types:-

(i) Aushr sharing (10 per cent)

The Aushr system is usually taken for field crops (cereal), and it is based on ten per cent share of the produce being paid to the landlord. Apart from providing the piece of land or farm, the landlord does not participate in any of the farming costs. Moreover, the metayer has to provide his own pumping facilities, and in cases, he has to dig a well in the field. The period of this type of crop sharing ranges in average between 5-10 years. However, this type of contract is not a widespread and popular land holding among the metayers.

(ii) Ar Rubua sharing (25 per cent)

This sharing is found to be exclusive to palm-tree gardens, but it is a declining system. The landlord has the right to claim 25 per cent of the date crop. All the expenses of palm farming practices are paid by the metayers. According to the tradition of this type of metayage, however, the farmer has the right to cultivate in between the palm trees, usually alfalfa and/or mixed vegetables. In such case, the landlord has no right to share the

product of the grown crops. This system is usually formulated in a one year contract, the contract is automatically renewable unless one of the concerned parties indicates his wish to terminate before harvest time.

(iii) Thulth sharing (33 per cent)

In this type of metayage the owner has to provide water pumping facilities and fuel for pumping. In return he claims 33 per cent of the farm product. Such a contract is usually and exclusively applied to mixed fruit farms, which in some cases includes palm-trees as well. The contract period is one renewable year.

9.3 Methods of cultivation and types of farming

Apart from ploughing and water lifting practices, all methods of cultivation in the Qassim are hand operations with primitive hand-tools and follow traditional procedures of sowing, planting, distribution, fertilization, irrigation, and harvesting. A faint line, however, could be drawn between the methods followed in the cultivated areas. Factors which furnished such differences are recognized as, firstly, physical factors, in terms of the layout of the farms in a larger unit of land size with a well organized irrigation channel system. Secondly, human factors in terms of eagerness shown by the new developers of the new farms who always show considerable anxiety to adopt modern methods, equipment, and techniques in farming. The third set of factors are economic factors in terms of financial ability to spend on adopting modern methods, as most of the new developers derive their financial source from trading in the urban centres throughout the kingdom, where the traditional farmer is dependent entirely on the income of his farm. On the whole, however, standards of farming in the region is considered to be among

the finest and most advanced in Saudi Arabia.

Tillage method

Ploughing, levelling, construction of irrigation water channels, and furrow making are carried out by power machinery on every single farm in the region. Ploughing operations are conducted in two stages; firstly in form of soil disturbance, after which the land is usually left untouched for a period of 4-5 weeks, then a second ploughing takes place. This operation is carried out at an average of 3 hrs./dunum by tractors. Fruit tree plots which have alfalfa planted in-between the trees are ploughed once every three years as alfalfa lasts for two years in the field at least; in the meantime a partial ploughing by hand-tools is carried out twice a year round the trees for the application of fertilizers. The levelling, together with furrow erection operation, usually takes place after the second ploughing at an estimated speed rate of 2 hrs./dunum. Transportation of virgin soil from the wadis beds to exhausted fields and farms is an adopted practice among farmers in the region. The amount of soil needed for such an operation is estimated at 37.5 tons of soil⁽¹⁾ per dunum.

Fertilizer application

Fertilizer application is the dominant cultivation practice reflecting differences between traditional farming, where manure fertilizers are preferable, and the newly established vegetable and fruit-growing farms where modern chemical fertilizers are used. Nonetheless, due to the recent introduction of chemical fertilizers, the application of organic manure is still the dominant addition to the soil. The quantity and frequency of organic fertilizers in all types of farming reflects the financial position of farmers

(1) Fifteen loads of two and half ton truck.

of both types, but, generally, the new developers are increasingly placing more emphasis on frequent application. Timing for the organic manure application is based on traditional experience and knowledge. For all trees the application is carried out once a year in winter, except for vineyards where it is practised in summer. The quantity of application of such annual fertilization is usually designated according to the age and vigour of the trees. A standard quantity has been worked out as an overall average based on the field investigations and tabulated in the following:-

Table 8. Quantities of organic manure traditionally applied for trees

Quantity/in kg.	Object
0.5	For every single fruit tree at planting stage
0.3	For every single vineyard in summer annually
0.5	For every single fruit tree in winter (except vineyard)

Most farmers apply chemical fertilizers (complex of $N_{15} P_{15} K_{15}$) to fruit trees (except palm-trees) once every three/six months with an average quantity of 0.5 kg. per tree. For alfalfa and vegetables, application of organic manure is adopted by all farmers once at the stage of crop establishment only. The quantity of such application varies according to the availability of the manure and the financial position of the farmer and the importance of the crop. An attempt to estimate the quantity applied for vegetables and alfalfa indicates that 100 kg. is the average per dunum of

vegetables or alfalfa, applied at the sowing or planting stage. Chemical fertilizers for vegetables and alfalfa are applied by most of the farmers with almost a standard frequency of an average of three applications per crop. The first application is at the beginning of the growth of crop leaves, the second is at the flowering stage, and the third at the ripening stage. For cereals, fertilization is exclusive to chemical fertilizers and it is carried out once approximately two months after sowing. An interesting method of fertilizing the cereal was reported in the al Asyah and Qusaiba areas. It is known as "Dathouth."⁽¹⁾ Dathouth is used as a fertilizer for cereal; it is carried out and spread by hand throughout the fields, usually after the plant has grown as tall as 20 cm.

Irrigation methods

The method of irrigation commonly used throughout the region is basin (Howdh) flooding irrigation for all fruit trees (except vineyards and palm trees), alfalfa, cereal, onion, and lettuce. For the other crops, vegetables, vineyards and palm trees, the method is furrow irrigation (Mesha'ab). The discussion on the application of water irrigation in terms of quantity and frequency is, inevitably of inaccurate conclusion due to the different sizes of ditches leading water to fields and different sizes of basins and furrows in almost every single farm. However, the fact that irrigation methods are characterized by over-irrigation can be seen by the water logging and white salty crust cover on almost every single farm (plates xxxiii and xxxiv). As an example of over-irrigation a few rough findings based on the field observations⁽²⁾ show that an area of 15 hect. is

(1) Dathouth is the local name for salted clayey sand.

(2) In Ar Rashid farm at Ad Dughmaneyyat (33 km. N.E. of Braydah).



Plate No. xxxiii. A view from a newly established farm in the Braydah area; it represents a section of the farm where the irrigation method is the furrow method; note the water logging of the soil and the traces of white salty crust as a result of over irrigation.



Plate No. xxxiv. Another view from al Qaayer area south of al Midhnab settlement, where uncontrolled water flowing of the artesian hole-bores, and the over irrigation, have resulted in a high soil salinity with white surface crust.

irrigated by 145,000 m³. (1) These hectares are set to wheat in winter and various vegetables in summer. Another example was observed at the farm of the experimental station of Braydah. The artesian deep well flows at an estimated rate of 55 m³/hr. for 24 hours daily (482,000 m³), this amount is used to irrigate 17 hect. under experimental conditions. Clearly, such quantities applied to such areas indicate a great loss of irrigation water in these two examples in one of the finest farming areas in the region. It is assumed, however, that similar or even greater losses occur in every single farm in the region. These losses apparently take place in the earthen tanks where water is collected and stored at the collar of wells (plate xxxv), as well as in the earthen broad ditches leading to the fields (plate xxxvi). Frequency of irrigation application is designated for the various crops varying from area to area according to the traditional knowledge passed down from father to son, which will remain the manner until a real knowledge of water application frequency is established by experimental research and conveyed to farmers. However, the prevailing practice of irrigation frequency observed and studied during the field work is summarized in the following table:-

(1) Water is pumped from deep non-flowing artesian aquifer at an average of 40 m³/hr. for 10 hrs. daily throughout the year.



Plate No. xxxv. A view of the common earthen tanks, where irrigation water is usually stored on most farms.

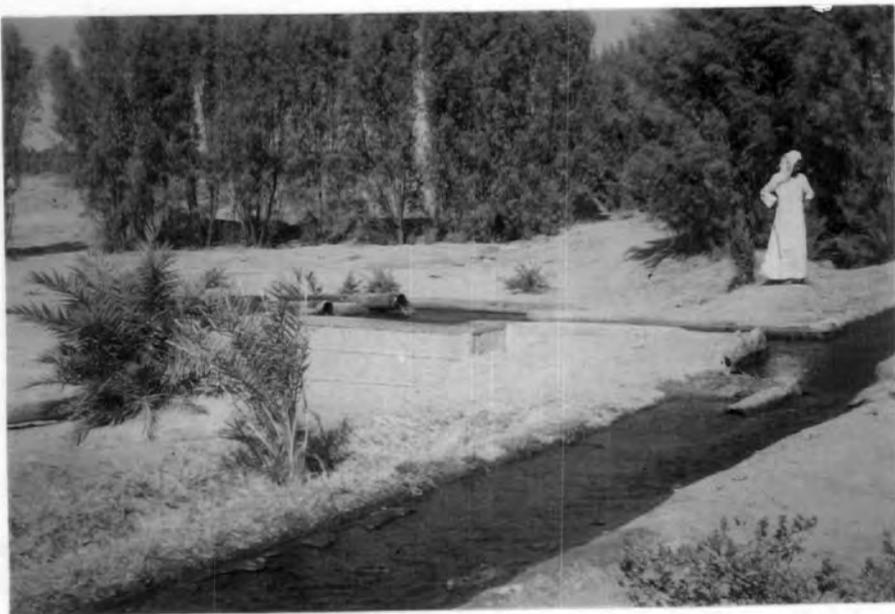


Plate No. xxxvi. This photograph shows an example of the common wide earthen ditches leading water to the fields, a character which contributes to loss of water.

Table 9. Adopted frequency of irrigation water application

Crop	Frequency	
	Summer	Winter
Palm-trees	Once every six days	Once every ten days
Wheat	None	(12-15 applications per crop). Once every two weeks till the crop has grown as tall as 20 cm. then once every ten days till the grains start to ripen, then once every three days till grains complete ripening stage.
Alfalfa	Once every three days	Once a week
Fruit trees	Once every four days	Once every 9-10 days
Vegetables		
(a) Tomatoes	Once every other day till yields start ripening then once a day.	-
(b) Lettuce, onion, carrot	-	Once every other day
(c) Pumpkin	-	Once every other day till yielding stage (two months later) then twice every day till the yields harvested.
(d) Cauget	Once a week	Once every twelve days.

Diversion and control of irrigation water is carried out by hand-tools. Preliminary calculation of manpower needed per one application of water irrigation has suggested that 0.5⁽¹⁾ manpower day is needed to irrigate a dunum irrigated by basin method, and 0.1 manpower per day is needed to irrigate a dunum irrigated by furrow method. Such findings assert the belief that the use of furrows is far more efficient in terms of farming cost in addition to diminishing water loss through seepage of applied water.

Method of cultivation

Cultivation is carried out by two different methods; basin method (Howdh), and furrow method (Mesha' ab). The basin method is used for all fruit trees (except vineyards), palm trees in many cases, alfalfa, onion, carrot, lettuce and cereal (plate xxxvii). There is no standard size for basins, but it is apparent that the size is, in fact, dependent on the type of crops, the size of holding, and the level of land surface. However, the following measured sizes have been observed as the overall average of dominant sizes in most of the farms:-

24 x 15 metres for cereal

30 x 16 metres for onion, lettuce, and carrot

20 x 14 metres for fruits and alfalfa

Vineyards are usually planted on a row along the watering channels in the farm, and such a method subjects the vines to improper continuous watering. Such a technique has been observed in the old palm-tree gardens, where palms are planted in the same manner. Many different types of fruits are planted beside each other in one basin (plate xxxiii). Many farmers import fruit trees for planting long before the land is completely prepared for them; such planning

(1) Based on the field work investigation.



Plate No. xxxvii. A view from a newly established farm in the Wadi Ar Rma area. This section of the farm shows the basin method of cultivation.



Plate No. xxxviii. A view of a fruit farm in the Wadi Ar Rma area. Note the different types of trees planted beside each other, pomegranate in the front, apricot, and plum next to them. Also note the closeness of the trees.

subjects many of these trees to great losses as it is observed during the field work period. Moreover, most farmers do not prune their fruit trees mainly because of the shortage of skilled labour, or, in few cases, as a result of lack of knowledge of the necessity of such practice, as fruit growing is a newly introduced type of farming to the region. However, autumn is the planting season for all fruit trees, except the palm trees. The space in between fruit trees is usually occupied by alfalfa. In a very few cases, farmers sow cereal between palm trees instead of alfalfa in the old farms. For palm-trees, the re-planting operation of off-shoots of an age of 3-5 years, takes place in summer. The basic and necessary practices for every female palm-tree are summarized in the following table:-

Table 10. Summary of necessary cultivation practices for female palm trees

Operation	Manpower days per 1000 trees	Frequency per year	Season of operation
Pruning	25	2	Summer and autumn
Thrones picking	15	1	Indefinite
Grafting	30	2	At the beginning and in the middle of summer
(1) <u>Takhsheep</u>	15	1	Middle of summer
(2) <u>Tarkeeb</u>	15	1	End of summer
Harvest	10	1	Starts in September

Source: Field work investigations.

(1) The operation of separating palm tree branches.

(2) The operation of sustaining the date-bearing branches.

However, the experienced labourer could manage to maintain and carry out the outlined practices for 1000 trees a year. Such a worker needs 90 working days distributed through eight months of each year. The average wage for such skilled labour is 30 SRS per day.

Cultivation of vegetables is always carried out in furrows (Mesha' ab). (plate xxxix). The length of furrow varies according to various factors, but the dominant factor is the slope of the farm surface; hence, on the whole, the flatter the field the longer the furrow. The width of a mesha' ab is standardized for most places; two metres width is adopted for growing tomatoes, cucumbers, caugot, okra, spinach, and peppers. The distance between plants in this type of furrow is 0.5 m. and between rows a metre. Four metres wide furrows are adopted for creeping plants such as melons, marrow, pumpkin, etc. Distance between plants in the four metres mesha' ab is measured at one metre in average and two metres between rows. Mixing various types of vegetables in one furrow has been observed in many areas throughout the region. However, many farmers fail, in most cases, to sow or plant their vegetables at the right time. Correction measures for such practices should be introduced and taught to farmers. The agricultural rotation system is variable in the Qassim; in a few cases the one year fallow system is adopted for fields allocated to cultivate the same crop. In most cases farmers in the region adapt either of the following systems:-

- (a) Two years growing melons, one year growing cereal, and two years fallow.
- (b) One year growing melons, two years growing alfalfa and one year vegetables.

Types of farming

Types of farming in the Qassim are clearly divided into two. Subsistence type of farming is found in the isolated



Plate No. xxxix. A view of a farm in Aunayzah area showing the furrow method of cultivation. Note the closeness of the mixed tomatoes, peppers and other vegetables along the rows. It also demonstrates primitive and impractical irrigation channels, resulting in a soil water logging and salt crusts.

areas of al Asyah (N.E.) and the northern part round Qusaiba and al Ayon areas where human and economic factors are still unfavourable for market-orientated production. The second is the market-orientated type of farming round the region's towns of Braydah, Anuayzah, and Ar Russ, including the Ash Shmasiyyah settlements in the east and al Midhnab area in the south. In those areas, the newly established farms are entirely vegetables and fruit growing farms for marketing, while the old palm-tree gardens have only recently shifted but slowly to cultivate market crops; thus in those farms a balance exists between a combination of the two types of farming. Furthermore, a localized characteristic of farming patterns has been observed throughout the region. In the southern part, between al Midhnab and al-Amar settlements, most of the farms are newly established with a distinct specialization in vegetable growing only. In such farms, there is no real farm establishment in the form of fences, houses, storage facilities, or permanent irrigation structures (plate xl). The farms are in forms of open fields with adjacent deep bore holes tapping water from the deep aquifers, and most of the farmers are metayers or tenants, representing a sort of shifting farmer looking for lands with better terms of contract. A completely similar situation has been observed also in al-Butain area (15 km. N.E. of Braydah). Another localized pattern is observed in the southern fringes of the town of Aunayzah where in the newly established farms the trend of farming is completely towards citrus growing supplemented by alfalfa in the space between the trees (plate xli). A physical factor behind this trend is the favourable nature of the soil texture of this area where loamy and silty sand are the dominant soils. In the old farming sites of the town the traditional pattern of palm-tree plantation is still



Plate No.xl. One of the many vegetable growing farms south of al Amar area in the south of al-Qassim. Note the absence of permanent farm establishment facilities, and the temporary and rather primitive irrigation system. Vegetables are mixed in one furrow on such a farm which is merely an open field and the farmer's household live in a temporary tent or shanty.

dominant but the areas allocated to vegetable growing for marketing are increasing steadily in those farms. The latter pattern is in fact prevailing elsewhere in the region⁽¹⁾ (plate xlii). Braydah, Ar Russ, Bada yea and Riyadh al Khabra areas concentrate on wheat production in winter, where most of the region's commercial production is obtained.

As a common pattern, most farms are divided into small fields, separating the basins and furrow layouts by Athl trees (Tamarisk sp.). The Athl also planted round the whole area of holdings as a permanent fence for the farm as well as sand and wind break (plate xliii).

9.4 Crop production

The size of crop production as related to the area cropped is one of the most important indicators of the level of development of farming in any given region. In fact, an increase in the effective area of arable land together with an increase of the yield per unit of cultivated land are the very necessary measures to raise crop production. Basic decimal censuses supplemented by periodic seasonal data on crop area, yielding capacity per unit, annual variation in output of farm products, and the total crops production are necessary to enable researchers to reveal structural changes, patterns, and trends in the agriculture of any concerned area. Unfortunately, such data are lacking for the Qassim as well as for elsewhere in the Kingdom. However, a good step in the direction of building up agricultural statistics for the Qassim was taken in 1961-62 when the first agricultural survey for the region was conducted. The information given in the survey report could serve as a benchmark inventory on the state of agriculture in the Qassim. The survey's data show aggregate areas of permanent crops, vegetables, and field crops and, in a few cases it provides information on yield and cost of production, in addition to

(1) Especially in the new development area at Ad Dughmaniyat, 30 kms. approximately north of the town of Braydah.



Plate No.xli. A view of one of the citrus growing farms located at the south-eastern outskirts of the town of Aunayzah. Note the alfalfa growing in between the trees.



Plate No.xlii. Another view as above at Ad Dughmaniyat area, north of the town of Braydah.

various related data. The results gained from the survey are believed to be of imperfect reliability, however, due to the poorly trained surveyors, and to the ever expected misleading statements of the farmers, who always deceive the interviewers and exaggerate their farming status, in the view that such statements might lead to financial or material aids from the government. Nonetheless, the availability of such incomplete data is useful because at least they show that certain re-allocations are underway in production, and they give a rough idea of growth state and trend in the region in general. This set of data, however, would serve no purpose unless similar surveys are reported periodically (each 5 or 10 years); therefore, no provision should be claimed for the conclusions drawn from it.

(a) Permanent crops

Permanent crops in the Qassim occupy 27.9 per cent of the total cultivated area (Fig.30). They comprise alfalfa (Berseem) and fruit trees (Appendix H Table 2).

Alfalfa is the principal forage crop in the region. It occupies 21 per cent of the total cultivated area in the region and is grown almost on every single farm. The period of alfalfa productivity ranges between 2-3 years. Harvesting is a hand operation which takes place once every 20 days approximately in summer and 30-35 days in winter. Crop yield per hectare is estimated to range between 100 and 120 tons. Such a size of production could, undoubtedly, be increased considerably through proper fertilization, improved cultivation methods and tools, and proper protection measures against plant disease. In fact, a considerable increase is reported in one of the new and advanced farms in Aunayzah X area where an increase of some 30 per cent of yield per hect. was gained over one crop period (three years). Alfalfa is sold while still green in local markets, and the demand is

**PERCENTAGES OF CROPPED AREAS IN THE AGRICULTURAL DISTRICTS,
THE REGION OF AL-QASSIM**

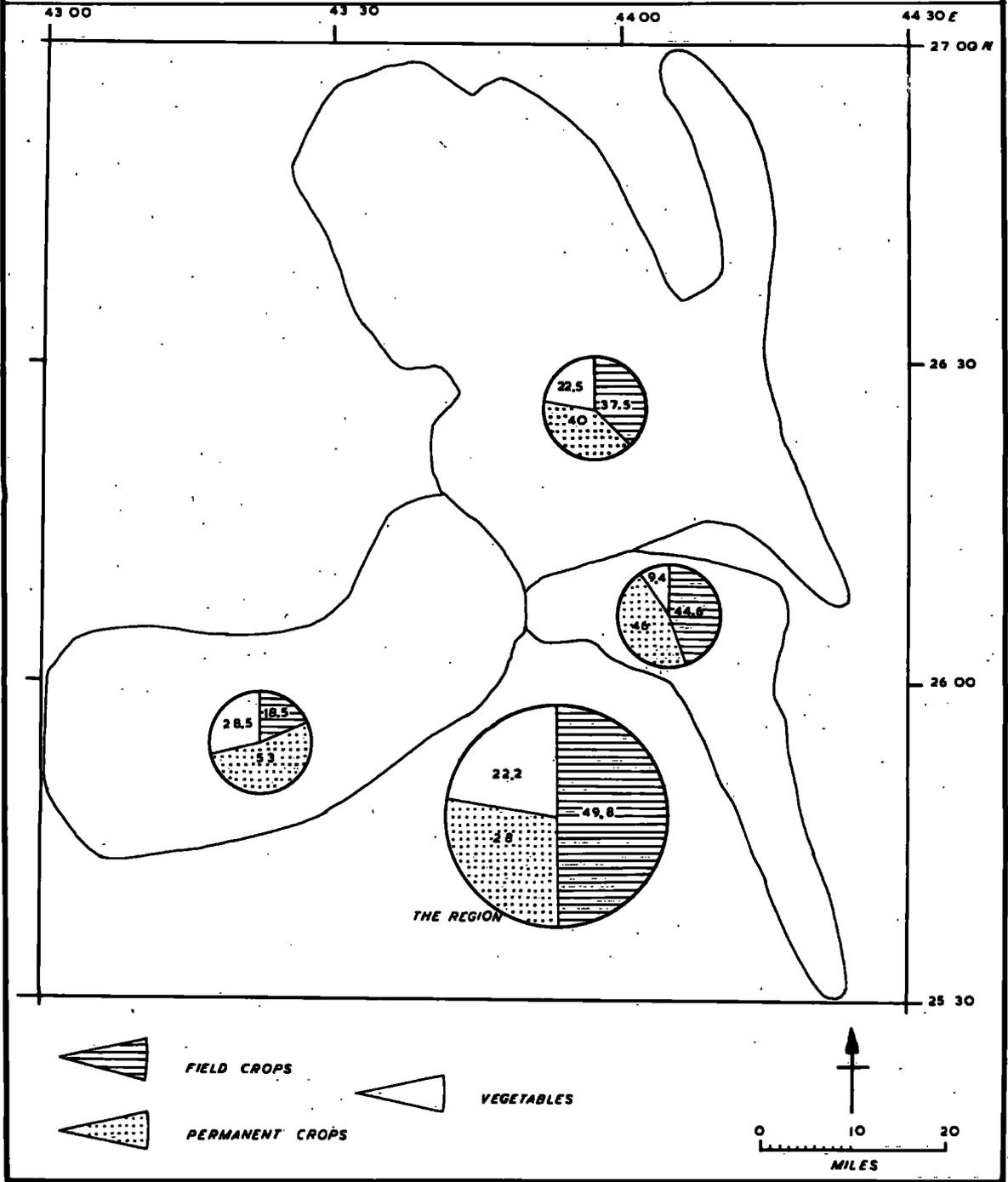


FIGURE 30



Plate No.xliii. Another view of the new fruit growing farm in Aunayzah area; note the lined and well-built irrigation channels, and also the establishment of Athl trees (Tamarisk Sp).

very high as it is used almost entirely by families owning a single cow or a few goats, a situation prevalent in every town and village in the Qassim. Due to the longer period of alfalfa productivity in winter, a shortage of supply in winter season is reported and correspondingly prices oscillate between summer and winter seasons. In order to maintain a level of supply to stabilize prices throughout the year a certain portion of the summer product ought to be stored or dehydrated and sold during winter as a supplement for the main product. It is clear, however, that dehydration processing involves a complex of economic factors which should be appraised before steps towards such a move are taken.

The net income of alfalfa per hectare is estimated to be round 1670 SRs,⁽¹⁾ the second highest net income among crops. Nonetheless, alfalfa net income in the Qassim is the lowest compared with other regions and areas in the kingdom⁽²⁾. This is due to the fact that the rate of rent per hectare of arable lands suitable for alfalfa growing in the Qassim is the highest in the kingdom⁽³⁾.

Fruit trees amounted to 904,900 trees which constitute 8.8 per cent of the kingdom's fruit trees' total. They occupy 7 per cent of the total cultivated land in the region. The fruit trees in the Qassim are palm-trees, vines, pomegranates, plums, apricots, figs, apples, oranges, mandarins and lemons.

The palm-tree is the oldest and traditional fruit tree

(1) One sterling pound equals 10.8 Saudi riyals.

(2) 2970 SRs for Medina area, 2900 SRs for the region of Central Najd and 2310 for the province of the northern boundaries.

(3) In the Qassim 460 SRs per dunum per year, in Jeddah area 325 SRs, in the Central Najd region and in the northern boundaries province 300 SRs.

in the Qassim. Its magnitude in terms of number and production is a very valuable asset to the agricultural economy of the region. According to the agricultural survey, the Qassim's stock of palm trees consists of 735,677 trees (8.6 per cent of the kingdom's total) with 76 per cent bearing date palm-trees (females). The 24 per cent of non-bearing date palm-trees consists of young trees (less than 10 years), male palms, and old and unproductive female palm-trees. The geographical distribution of palm-trees throughout the region reveals that the majority of the productive palm-trees are located in and around the very old agricultural settlement in the region, with 49 per cent planted in Braydah, 22% in Aunayzah and 19 per cent in Ar Russ, while only 10 per cent are scattered throughout the rest of the region.⁽¹⁾ New trees are produced by planting five to eight years old offshoots of older trees. The female blooms and bears fruit four to six years after being transplanted, and one male palm is capable of pollinating fifty female trees. These characteristics mean that the stock of palms can be enlarged only gradually, and thus changing of magnitude of these assets is by nature a long term process. However, average annual yield kg. per productive tree is estimated at 41.3 for the region. This rate is among the lowest averages of date producing areas in the kingdom.⁽²⁾ The total production is estimated at 27,586 tons annually (Fig.31), which constitutes 12 per cent of the total date output of Saudi Arabia. Dates are considered to be the most important staple in the Qassim; not only do dates account for the main local produce but also they

(1) See Table 3 Appendix H.

(2) For Central Najd it is 55.6 kg/productive tree, for Madinah 55 and the province of the Northern Baudria 53.2.

PERCENTAGES OF PRODUCTION OF MAIN CROPS IN THE AGRICULTURAL DISTRICTS, THE REGION OF AL QASSIM

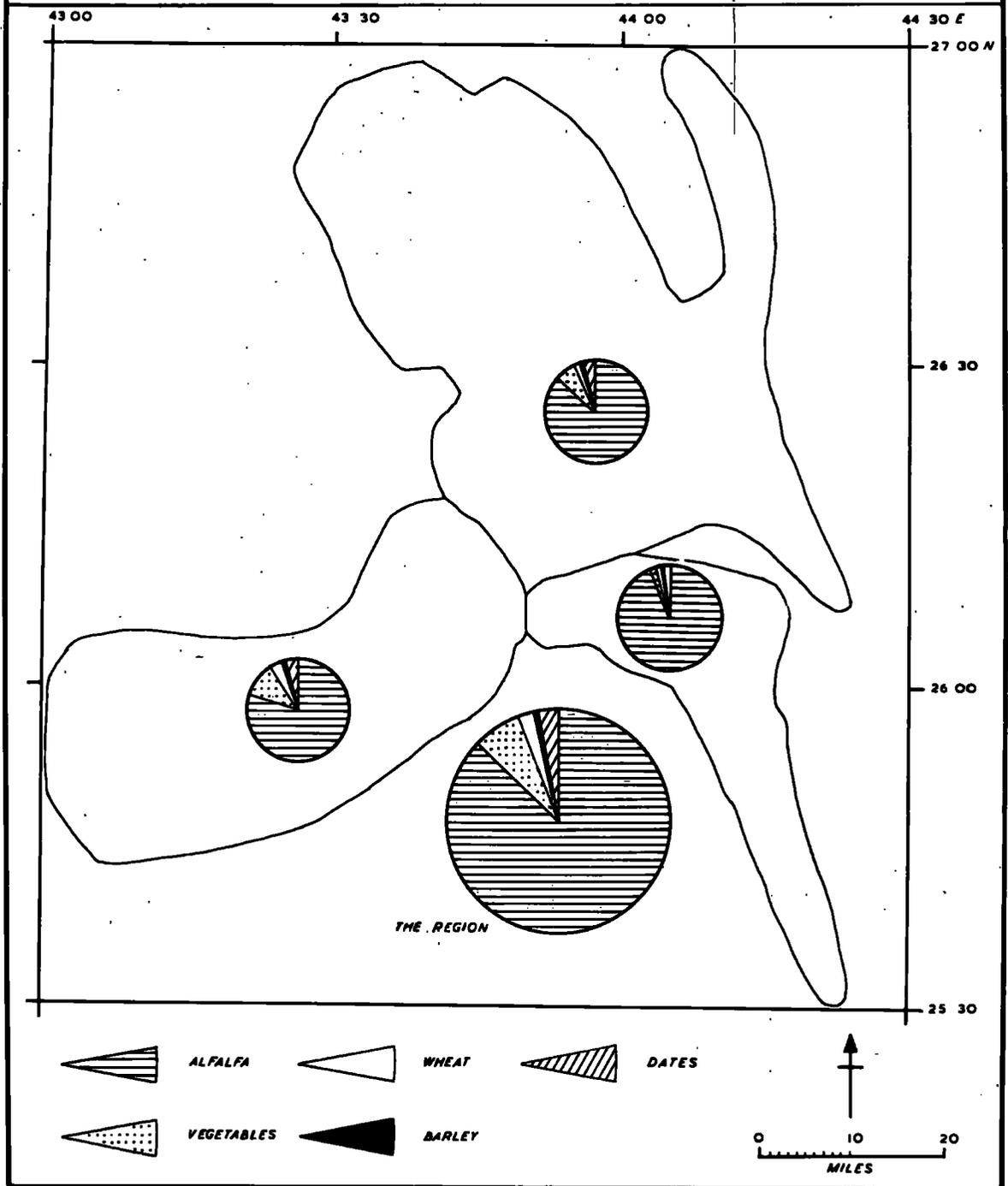


FIGURE 31

constitute the main item of diet of the rural and nomadic section of the region's population.

An interesting aspect of date selling is that most farmers prefer to sell their product on tree in favour of avoiding the operation of harvesting, packing, transporting, and marketing. Many townsmen contact farmers when harvest time is imminent to bargain on 100, 500 or 1000 trees basis or even the whole farm stock if it does consist of more than one thousand trees. As these townsmen are regular customers, sale agreement is always verbal and no cash has to be paid in advance, but the farmer has to wait some three or four months before receiving the money. However, many farmers and dealers have reported that a decline in date value since the middle of the last decade. This narrowing of the profit margin of dates has been severely aggravated in remote and isolated areas where date production is almost unprofitable and is entirely consumed by the householder's families. The decline of date importance as a profitable crop could be ascribed, however, to the following factors:-

- (a) The increase in cost of production, irrigation, fertilization, ploughing, etc.
- (b) The decrease in number, and increase in wages, of the professional skilled labour to maintain properly the palm trees which require special practices.
- (c) The dwindling value of dates as a vital source of staple diet of the population in the Qassim's towns and the urban population of the kingdom. This fall is clearly due to the rise in income per capita which enables people to diversify their diet by more valuable vegetables and fruits.
- (d) The decline in palm-trees' output as a result of the farmer's neglect because of the recent swing towards the production of more profitable and

demanded crops on the one hand, and because of the increasing number of sown palm trees which usually produce lesser product than the transplanted tree, on the other hand.

- (e) The decreasing price of dates as a result of misorganized marketing process and mis-distribution of the dated by marketing all the produce at one time.

Such a deteriorating situation requires an investigation on the economic feasibility of processing the date product in the region.

Other types of fruit trees amount to 196,300 which comprise 11.2 per cent of the kingdom's total. Due to the comparatively recent introduction of such fruit trees in the region an interesting pattern of geographical distribution and concentration were observed and revealed from the available data. 99 per cent⁽¹⁾ of the region's total is concentrated in and around the townlets of the region with 51 per cent planted at Braydah, 37.5 at Ar Russ, and 10.5 at Aunayzah. Pomegranates, vines, apricots and citrus are the most important fruit trees in terms of numbers. Plums, apples, and figs constitute only 9 per cent of the region's fruit tree total. Pomegranate trees count for 75,700 productive trees. Data reveal that Ar Russ town is the major pomegranate area with 61.3 per cent of the region's total, Braydah and Aunayzah have 26.3 per cent and 11.4 per cent respectively. Vines are the major fruit trees and consist of 52,700 productive trees. 68.5 per cent of the vines are planted in Braydah area with the greatest grape production in the Qassim; Ar Russ and Aunayzah have 25 and 5.6 per cent respectively. Apricot trees are estimated to be 21,500 and 72 per cent of this total is planted in Braydah.

(1) All these percentages were computed from figures given in the agricultural survey of the Qassim 1961-62.

Citrus trees (orange, mandarine, and lemon) consist of 21,100 trees; 50.7 per cent, 32.5 per cent, and 15.6 per cent of this total are located in Braydah, Ar Russ, and Aunayzah towns respectively. Plums, apples and figs consist together 9 per cent of the region's non-date fruit trees with Braydah being the major producing area for plums and figs and Aunayzah for apples. However, it must be stressed once again that these figures represent the non-date fruit trees aggregate in 1961-62. It is certain that these trees have undergone considerable increase and expansion.

Aunayzah area has planted far more fruit trees in the last five years with a considerably faster rate than any other area in the region. The technical staff of the E.F.S.C. of Aunayzah have pointed out to the writer during the field work period (Summer, 1967) that some of 70,000 fruit trees, mainly orange, have been introduced to the area during the last five years. However, comparison of such unofficial estimates with the figure given in the survey tables (16,930 trees) indicates a four fold increase in fruit trees in five years.

(b) Vegetables

Melons (water melon and sweet melon), squash group (marrow, caugot, and pumpkin), onions, tomatoes, eggplant, cucumbers, okra, green peppers, carrots, lettuce, leeks, cauliflowers, cabbages, spinach, green beans and peas are the vegetables grown in the Qassim, producing 66,778 metric tons annually approximately and occupying an area of 8,300 hectares (Figs. 30 and 31), which constitute 27 per cent of the total vegetable area in Saudi Arabia. The geographical distribution of the vegetable area indicates that Ar Russ district (especially the eastern area of al Khabra and Bada'ea settlements) is the main vegetable growing area, comprising 62.9 per cent of the total vegetable area in the Qassim. Braydah area comprises the second highest vegetable

* area with 292 per cent of the region's total, while Aunayzah area's share is estimated at 7.9 per cent only. With a concentration of vegetable areas around the towns of the region which is a normal phenomenon in an area of low density of population throughout and a relatively high density in the urban centres where size of markets and access create more favourable profit margins. In addition, of course, the towns are connected with other major urban centres in the kingdom by excellent highways. These favourable factors, in fact, have encouraged the noticeable and rather high increase in perishable crops produced.

Melons are the principal, most profitable, and most widespread vegetable, occupying 42 per cent of the region's total vegetable area (30 per cent for water melons and 12 per cent for sweet melons). The output per hectare for melons is estimated at 6,500 melons, the highest melon yield per hectare in the kingdom.⁽¹⁾ The profit margin of water melon cultivation per hectare is the widest among all the crops grown in the region. It is estimated to be at 37.5 per cent of the total cost. Nonetheless, the melons' profit in the Qassim is narrow compared to other melon producing areas in the kingdom.⁽²⁾ This is due to the higher rate of land rent in the Qassim where it is estimated to be at 66 per cent of the total cost of melon production. This rate goes down in the other regions to 51.2 per cent in the Jeddah-Mecca area, and to 46 per cent in the region of Central Najd. The second major vegetable in the Qassim is the squash group (marrow, cauget, and pumpkin) which occupies 30.8 per cent of the region's total vegetable area. Onions occupy 6.6 per cent and tomatoes 5.6 per cent. The remaining area is

(1) 6,250 melons/hectare for the region of Central Najd, and 6,000 melons/hectare for the province of the Northern Boundaries.

(2) Profitability margins of melon production are estimated at 53.7 per cent and 43.6 per cent of the total production cost in the Jeddah-Mecca area, and the region of Central Najd respectively.

divided in an almost equal ratio among the rest of the vegetables grown in the region. Data of yield, cost, and income per hectare for these types of vegetable are not available, but an estimation for the tomato output is 18 tons/hectare, which is very high compared with estimations for other tomato growing areas.⁽¹⁾ However, on the whole, the conclusion that the vegetable growing is the most profitable cultivation in the region could be safely and accurately drawn on the basis of the farmers' statements. All farmers met and interviewed have expressed a collective statement that vegetable growing is the most profitable provided that it escapes the harmful effects of plant diseases and insects. In cases where plant disease control failed in a vegetable growing farm, a severe or even an almost complete loss occurred. Thus, the sensitivity of vegetables against the numerous diseases and the profitability of their output make the question of the plant disease control of great economic importance. However, the technical staff of the E.S.F.Cs. in the Qassim report a steady and comparatively high rate of increase in the cultivation of vegetables during the last five years and the trend is still moving forward especially in the new development areas. Unfortunately, the lack of seasonally and yearly data on vegetable areas, and magnitude of yield per unit since 1961 makes the tracing and demonstration of the actual trend and growth in vegetable cultivation impossible. Tentative calculations based on sampled farms in different zones in the region show, however, the relative importance of vegetable output, which counts for approximately one fourth of the total value of the agricultural output of these farms.

(1) 15 tons/hectare for the region of Central Najd, and 13 tons/hectare for Taif area in the Hejaz region.

This, undoubtedly, reflects the change in pattern of agricultural production which has tended to shift towards high value vegetables at the expense of the traditional dates and cereals.

(c) Field crops

Field crops in the Qassim consist of wheat, barley, millet, sorghum, hilba, and maize occupying some 49.7 per cent of the total cultivated land in the region (Fig.30). The geographical distribution of the field crop area in the Qassim indicates that Ar Russ district is the main cereal producing area where 57.8 per cent of the region's total layout. 23.7 per cent and 18.5 per cent lie within Braydah and Aunayzah districts respectively. Field crops in the Qassim are grouped in two seasonal groups; winter field crops and summer field crops. Winter field crops (wheat, barley and hilba), in fact, are the principal grain produced in the region, and they occupy 17,289 hectares which constitute 93 per cent of the total field crops in the Qassim. Wheat is the most important single crop and is grown over an area of 15,570 hectares (90 per cent of the winter field crops area). The estimated average output of wheat per hectare was reported in the agricultural survey of 1961-62 to be 1.55 tons/hectare which counts for a gross output of 2,400 metric tons approximately (Fig.31). A few experiments⁽¹⁾ on the date of sowing of wheat have shown that sowing between 15th October and 15th November gives much better results than around 15th December, the traditionally accepted and practised period of wheat sowing throughout the region. These experiments have also indicated that 130 kg.

(1) 1965, 1966 at Braydah experimental station.

seeds per hectare give the highest return among the tested quantities. However, wheat is apparently a dwindling crop and most farmers gradually diminish the size of wheat fields because it is found to be grown at a loss of 0.26⁽¹⁾ Srs/kg. Moreover, it is interesting to note that wheat in many other regions in the kingdom, such as the province of the Northern Boundaries, and the Eastern Province, is grown at a loss of cost return, with the exception of the region of Central Najd where a very slight profit is gained due to the comparatively greater yield per hectare which count for 2 tons/hectare. (The highest in the kingdom). The causes of this loss are, undoubtedly, due to the low yield per unit and to the hard competition with the imported wheat which was introduced into the kingdom's market with subsidies. In fact, although such a measure affects the price of wheat in the markets and consequently brings about loss in cost returns for the home-produced wheat, it is well justified and defended on the nation's welfare ground by providing cheaper bread to the people. The only way out to overcome such a delicate situation is to allocate a similar subsidy for home-grown wheat promotion and the improvement of its capacity of yield per unit. Few farmers apply fertilizers to wheat fields and even the application of those who do is very limited due to the relative vastness of wheat area.

Barley is grown over 9.2 per cent of the winter field crop area with a total output of 338 metric tons. The estimated average yield of barley per hectare was reported in the region's agricultural survey (1961-62) to be some of 2.1 tons per hectare, a yield which ranks among the highest in the Middle East, Asia, and African countries with the

(1) Based on figures on cost and income of wheat given in the agricultural survey of al-Qassim (1961-62).

exception of Japan (2.7 tons/hectare) and U.A.R.⁽¹⁾ (2.6 tons/hectare). No experiments on the proper sowing period for barley were conducted in the Qassim, but an experiment in Braydah experimental station on the proper quantity of seeds per hectare has indicated that 100 kg/hectare is the quantity which has given the highest return among the tested quantities of 60 kg, 140, 180, 230 kg./hectare.

Summer field crops consist of sorghum, millet, and maize. Sorghum is grown over 48.3 per cent of summer field crop total area (1,339 hectare) and millet is cultivated over 46.5 per cent of summer field crop total area, and maize over a very negligible area of 0.1 per cent. Data on the output per unit of these grains are unavailable. The summer field crops together with barley are used as a supplement for alfalfa in fattening the sedentary livestock in both rural and urban households.

However, although a detailed study on the relative costs and returns of the various agricultural crops in the region is impossible to undertake because of the lack of the necessary set of data, nevertheless, the available scattered figures indicate a gap between the profitability of fruits and vegetables on the one hand and dates and cereal on the other. Approximate estimates of yields, costs, and price of five major crops and groups in the Qassim are calculated and tabulated in the following table:-

(1) Agricultural statistical year book, Part I, Production, F.A.O., 1966.

Table 11. Estimates of yields, costs, and prices of five major crops and groups in the region

Crop	Average yield per hect./in kg.	Average cost per hect./in S.R.	Average cost per kg/in S.R.	Average farm price per kg/in S.R.
Dates	5,600	1,400	0.36	0.25
Wheat	1,500	680	0.68	0.42
Tomatoes	13,500	2,310	0.17	0.60
Vegetables	6,000	2,050	0.34	0.54
Fruits	5,000	3,650	0.61	0.96

Figures and percentages have been calculated from data given in the following sources:-

1. Gross national product of Saudi Arabia, E.R.I. of A. University, Beirut, 1961.
2. Agricultural survey of the Qassim, statistics Department, Ministry of Water and Agriculture 1961-62.
3. Economic studies on the agricultural sector of Saudi Arabia. E.R.I. of A. University, Beirut, 1964.

The cost figures presented in the table are for the total of variable and fixed costs including costs of hired labour but excluding land rent. The table reveals that dates and wheat result in net losses to the farmers, while growing of tomatoes and other vegetables are bringing in net returns. It should be noted that neither the cost figures nor the estimates of farm prices are of perfect reliability. Nevertheless, they may serve as a rough indicator of relative directions and trends in this respect not for the Qassim in particular but also for the other agricultural areas in Saudi Arabia.

9.5 Animals husbandry

In the Qassim farm animals consist of sheep, cattle, camels, goats, and a limited variety of poultry (chickens, geese, ducks, pigeons and turkeys). The only available data on the size of farm animals is recorded in the agricultural survey of the region (1961-62). Since then these basic data have not been supplemented by annual series of data on number, and milk and meat yield per unit of the various animals. Moreover, milk and meat yield per unit has not been recorded in the survey, and the number of livestock recorded was not based on a head count but on the numbers of livestock as declared by the householder, who may underestimate the figure to avoid payment of tithe (Zakat al Oshr). The survey's figure for cattle, which are more easily determined due to fixed location, however, can be considered more reliable.

Most of the farm livestock are indigenous to the region, but some imported European cattle, North African camels and a few Iraqi and Syrian sheep, and Egyptian goats are being introduced and absorbed into native flocks.

Farm sheep are the principal animal in the agricultural areas of the Qassim. They number 114,570 which constitutes 13.7 per cent of the kingdom's farm sheep total. The Najdi-bred sheep are the most numerous, and the black Najdi, a large black hardy sheep averaging 60 kg. live weight, is by far the most common. It is an excellent meat producer and its milk yield is superior to others. It has a long stringy hairy fleece with hard black opaque fibres which are difficult to dye. The white Najdi sheep parallels its black cousins for meat and milk production; its white fleece is superior in manufacturing because it is easily modifiable by a variety of dyes. This remarkable breed would be very useful in upgrading and crossbreeding for sheep improvement.

However, improved sheep nutrition at the Hafonf experimental station (Eastern Province) on green alfalfa diet has proved increased quality and lamb growth. Thus, it is obvious that raising sheep on farms where irrigated pasture is produced, is a profitable husbandry practice. During the experimental period most of the mature Najdi ewes have been producing twins and many gave two lamb crops per year. Lambs at five months of age weigh 90 pounds which equals the weight of grain-raised sheep in any country.

Recorded gains of the lambs during the experimental period reveal some interesting facts. During the experimental period when 5.8 months of age, the lambs gained 45.5 kg. (nearly 100 pounds); with an average daily gain per lamb amounting to 0.24 kg. When 9.9 months of age the average gain per lamb was 57.7 kg. (126.5 pounds), with an average daily gain of 0.18 kg. This trend indicates that at 5.8 months of age the lamb gains were 78⁽¹⁾ per cent as much as they were at 9.9 months of age, and thus, lambs made most efficient gains at a younger age, a fact which results in greater returns by selling them when 5 to 5.5 years old. Sheep and goats live mainly on the irrigated pasture produced in the farm supplemented with hay and grains straw, but during winter and spring when natural pastures on the adjacent ranges are relatively abundant they are sent for a few hours daily to these ranges. In such circumstances green alfalfa is provided as a supplement in a relatively smaller rate.

Goats number 39,110 which count for 9.7 per cent of the kingdom's goat total. They are second to sheep in population and are associated with them in herds over much of the region.

(1) The figures were calculated and quoted from data given in the sheets of results of the animal improvement experiments at al Hafuf experimental station during the years 1963-1964-1965.

Hair on most of them is of a medium length and colours vary including black, brown, dun, tan, and white. Most are horned, some have wattles, others do not, and many have long ears. Goat meat is a regular feature of the Qassimi diet but is second choice compared with sheep. Goat's milk is utilized as fresh, and is reputed as the best diet for children on account of its low butter content.

Cattle number 17,870 which constitutes 14.8 per cent of the kingdom's total of farm cattle. Cattle are very scattered, and a household with even five to seven heads is unusual. The majority are found with owners who keep one or two cows for their personal needs for milk. For centuries, however, Qassimi farmers have raised strains of small brown and black hardy native Zebu cattle for water-draft and cereal threshing purposes, milk, and beef. It is estimated that mature cattle weigh from 700 to 1,000 pounds; bulls weigh up to 1,400 pounds. They are horned, small humped animals with dropping rumps and slightly swayed backs. Cattle, generally, suffer from hunger and malnutrition. Forage supplies are far below cattle needs and quality too often is fibrous and low. Cattle in the Qassim are housed next to the families' homes in pest-ridden, poorly ventilated rooms or stalls. Owners give them a short ration of high priced alfalfa to supplement the table scraps. They are also fed on weeds, grass, plant cuttings, paper sacks, and pasteboard boxes. However, experimental research on cattle raising is badly needed, and such experiments would be most useful if directed towards the selection and upgrading of native zebu already adopted and producing well under the Qassim conditions. The question of cattle raising prosperity is dependent entirely on the availability of adequate forage and modern housing facilities. In fact, there is no doubt that it would be wise once such requirements

have been amply provided to introduce superior Zebu dairy blood from neighbouring countries.

Camel herds consist of 17,650 camels, a magnitude which constitutes 22.7 per cent of the kingdom's camel total. The majority of camel herds are concentrated in the wadi Ar Rma area especially in the settlements of al Badaea and Riyadh al Khabra in Ar Russ zone. They are at the present time raised and fattened for meat marketing, with subsidiary milking for farm household consumption. The Arabian camel, or dromedary, Camelue dromedarius, is indigenous in Arabia, India, and all of North Africa. Leggy, lightly built and short haired, the Arabian camel is suited to hot desertic climate. Camel colour varies and includes black, white, gray, brown, tan, and yellow. Farmers buy lean camels from nomads and fatten them, to re-stock their sold stock, by a combination of green alfalfa, weeds, and barley-millet mixture. However, as a result of the recent drought period 1959-1965, many thousands of camels have vanished from ranges throughout the kingdom. In order to re-stock such great losses many thousands of camels were imported mainly from North Africa recently and cross-bred with the remaining native herds. Aged farmers, however, have reported that the original Arabian Peninsula camels were rather smaller but hardy and good workers under the prevailing climatic conditions. As a meat producer, camels seem to be uneconomical on the ground that the females seldom bear young more often than once every two years, and not all she-camels bear young each two years. Hence, the new camel crop is always in the range of 25 per cent per year.

The town of Braydah has by far the largest livestock market in the region, and even in the whole of northern Najd. The number of camels and sheep seen at the market in summer, 1967 (the field work period) suggested a rather active animal

trading centre. Undoubtedly, most of the marketed animals are range-raised stock, and the proportion of the farm-raised herds is not known and impossible to be established as the dealers do not keep such information. However, it is estimated that 11,897 animals are slaughtered yearly to meet the demand for meat. This estimate is based on the report of the slaughter house of Braydah that 25 animals are slaughtered daily. The proportion of the different types of animals daily slaughtered at Braydah is nine camels, twelve sheep, four goats and one cow. By working out the average of per capita gross meat consumption per year for Braydah area, a similar average was applied to Aunayzah, and Ar Russ areas. Consequently the average of the three major areas were calculated as the region's average total of meat consumption per year. The extent to which farmers and town dwellers do their own butchering is, however, not known.

Investigation indicated that little meat is consumed by farmers. Of the 50 farms sampled from the different zones of the region 10 per cent eat meat daily, 32 per cent twice a week, 42 per cent once weekly, and 16 per cent each two weeks. Such a low per capita consumption among farmers in the Qassim presents a very sad situation indeed and reflects the severity of the poor living standards of farmers. Milk yield per day per animal in the Qassim is not precisely known.

9.6 Agricultural Marketing

Almost all agricultural production is marketed in the towns of the region, Braydah and Aunayzah and, to a smaller extent, in Ar Russ. Only a few farmers of the new vegetable growing farms in the southern part of the region market their production directly outside the region. This direct contact of farmers with outside markets has started only lately since the completion of Braydah-Macca and Ar Riyadh highway. Farmers of this area have reported that the return

from selling their product in Ar Riyadh directly justify the extra cost of transportation to such a relatively distant market instead of Braydah. It is anticipated, however, that in a few years time the southern new development area will develop a permanent direct marketing line with Ar Riyadh and other big markets instead of the present system of marketing via Braydah dealers.

At the present time, all the marketing operations are in private hands, commission dealers are acting as a go-between separating the farmers from the market. Commission rate is fixed at five per cent of the total marketed produce price for all the various crops. Farmers have to pay as well for loading, transportation, and unloading the product in the market. No co-operatives operate in the Qassim to organize and handle marketing. The non-existence of such organizations or even cold storage facilities has created an unfavourable situation for valuable and perishable products during peak periods of yields surplus, a case which brings prices down very sharply to the extent that it may not even cover the cost of production and badly affects the farm's balance of payment.

Price stability is a very vital factor in the agricultural economy in terms of organizing appropriate schedules for an effective economic production; such stability cannot be secured in the Qassim under the present marketing methods and facilities. On the contrary, the unstable rate of prices in the region is very high. For instance, an increase of 250 per cent in tomato prices occurs in winter when a shortage of supply occurs, a similar increase occurs in pumpkin and eggplant prices, while onion prices oscillate in the range of 180 per cent of the price of peak period yield.

The complex of marketing difficulties, however, is clearly demonstrated by the prevailing serious lack of

organization in all steps required to get the produce from the fields to the consumers. Factors behind such difficulties are threefold. Firstly, the prevailing techniques of harvesting, handling and packing are primitive. Secondly, there are the relatively expensive and inefficient internal rural transport media through the unpaved roads which link the scattered agricultural areas with the market centres. Thirdly, there are poor, inadequate and unhygienic marketing facilities in the marketing centres. These factors cause considerable damage to the produce and consequently degrade its actual value. Moreover, such factors make marketing process unable to bridge the essential link between increased agricultural production and increased farm income in the region. A failure to improve the present marketing conditions and organization would, undoubtedly, further frustrate all investments and endeavours to increase agricultural production. Great improvement in this respect could be easily secured through the instalment of modern physical marketing facilities, such as cold storage, and the use of hygienic transport means to wholesale and retail shops, as well as the instalment of intake of produce, weighing, and display facilities in the markets. Another aspect of the poor marketing organization in the region is the fact that none of the farmers nor the dealers and commission merchants in the region's markets has ever collected and kept information on the need and the general state of supplies in the other markets either within or outside the region. Such a case often results in mis-distribution of the marketed products and consequently prices vary considerably for the one crop in the different marketing centres within a rather small geographical circle. However, the job of introducing modern marketing facilities is obviously a task beyond the capacity of individual farmers, retailers, and commission merchants. It is, indeed, a task

of organized group or professional body such as co-operatives. Therefore, the evolution of agricultural co-operatives with sufficient financial capacity and organization efficiency is the only way to solve the present marketing difficulties and improve the existing crop returns and farm income.

Chapter 10Problems of Agricultural
Development

The advent of artesian water in the region in the early 1950s. has paved the way for a sudden and considerable expansion in farming without prior planning for the application of such huge quantities of irrigation water, adequate farming facilities and improvement of farming methods and marketing conditions. The following sections discuss the extent of these problems on agriculture at the present time in the Qassim. These problems have, in fact, resulted from the sudden change from an agricultural economy based on a shortage of water to an economy of surplus water, and have arisen by the previous limited capacity of farming and marketing methods and techniques.

10.1 Labour force and farm equipment

The agricultural labour force is one of the most critical and limiting factors which face the agricultural development plans of the Qassim. All interviewed farmers throughout the region have complained about the severe shortage of labour and the comparatively high rate of wages per day per worker. This comparatively high rate of wages has affected farming processes to the extent of discouraging most of the farmers from giving their farms and fields satisfactory care and services (plate xliv) which, owing to the nature of the crop or to the local farm circumstances, can only be achieved with hand tools and light implements. This fact, together with the nature of the overwhelming small farming units



Plate No. xliv. A view from one of the farms in the Wadi Ar Rma; it represents the extent of the unsatisfactory service and severe neglect of the farmer of his farm as a result of combined shortage and high wages of labour to do such hand operations as weeding and pruning the trees. This standard of service is rather common.

makes the full replacement of such labour shortage by power machinery an arguable suggestion. The fraction of the permanent labour force engaged in agriculture in the Qassim is, however, estimated to 16.6 per cent of the sedintery population of the region (Table 12). This small percentage suggests a disguised unemployment among the sedintery population; nevertheless, the percentage of such disguised unemployment is expected to be low due to the following factors. The percentage of the sedintery population who are between 10-50 years of age is 48.8 per cent. The female percentage is estimated to be 51.2 per cent, this large section of the population is not considered as a working sector in the region.

However, the average worker per hectare is 0.3; (the overall average for the kingdom is 0.9). Such an average is very low compared with other countries. For example, the corresponding average in India is 2.2 per hectare, Turkey 2.7, Yugoslavia 1.6, Brazil 1.9, Phillipines 1.2.⁽¹⁾ It is assumed, however, that the low average of labour per hectare in the Qassim and the kingdom as a whole is apparent due to the small absolute area of cultivated lands. Of the total permanent labour force engaged in agriculture in the Qassim, it was observed that only a small percentage consists of hired labour and the rest is drawn from the families of holders.

Table 12. Rural population of the Qassim

Permanent labour in agriculture	11,401
Number of householders	8,947
Population of households	68,668
Average of household size	7.8
Source of figures: <u>The Agricultural Survey of the Qassim</u> , Statistics Department, Ministry of Water and Agriculture 1961-62.	

(1) F.A.O. Agricultural Production Year Book 1950/60.

However, this shortage of labour force in the region had been mostly caused and intensified through the last decade by the discovery of the artesian water which consequently led to the expansion in agricultural areas, and by the increasing present trend of market-orientated production (mainly vegetables and fruits). Such production needs far more working hours throughout the year than the traditional production of cereal and dates. Nevertheless, the use of modern power machinery where the income, size, and structure of the farm units permit, and the use of improved hand-tools and light farm equipment in the small holdings will undoubtedly improve the capacity of the available labour force.

A study of agricultural problems related to the improvement of the farm equipment shows clearly that the quality and quantity of crop production could be considerably increased by more widespread use of modern farm equipment. The first step towards the improvement and replacement of the traditional farm equipment was the change from an animal power water-lifting system to motor pumps. The introduction of the huge quantities of non-flowing artesian water had necessitated such a step. This move was the first sign of farm mechanization in the region. It was greatly encouraged by the Ministry of Water and Agriculture in the early 1950s when the Ministry launched its first specific mechanization scheme. The scheme was a very loose instalment system which helped the farmers to buy power-operated water-pumping sets. The scheme quickly became popular and after a few years the mechanized water-lifting installations had taken over every single farm in the region. Conventional centrifugal pumps are on hand-dug wells, and hand-dug drilled wells. Deep well-pumps are installed on drilled non-flowing wells. The

completion of the scheme had resulted in a sizeable increase in cultivated land. Thus, the need for the use of improved hand-tools, light equipment, and power machinery in performing the various agricultural operations, is critical to compensate the increasing shortage of farm hands and to replace the less economic and slow performance of animal power.

Unfortunately, the swing towards modern and improved farm equipment was and is still concentrated on power farm machinery with almost no consideration for hand-tools and light implements which are, in the opinion of the writer, of equal importance. The full use of the available power farm machinery is limited to large farm units of the new development areas and fields. The farm equipment situation is grave on the small holdings which account for as much as 35 per cent of the region. The small holders (whether owners, tenants, or metayers) still struggle with traditional hand tools and implements in an attempt to improve their production. These farms still bear to a large extent the typical features of subsistence farming. The primary need is for improved hoes, scythes, in addition to simple and small but more effective ploughs, small seeders, and simple spraying, dusting, threshing equipment. The introduction of such improved hand tools and light implements seems to be the only way of improving the existing farm practices and the insufficient capacity of the available labour force.

The farm equipment situation is better on the larger farms whose reasonable income usually permits the use of hire-services of power machinery provided and organized by the Extension Field Centres in the region. The hire-service for power farm machinery is largely controlled by the E.F.S.Cs., which evolved the system in 1955 by demonstrating a small number of crawler tractors with bulldozer blades

for the erection of water-control structures and land levelling operations. As a consequence a few rich farmers and townsmen followed the example to undertake contract works on adjacent farms with their own equipment which is confined to tractors, ploughs, and threshers. It is recognized, however, that the present available power farm machinery is far from being adequate. The number of tractors per 1,000 hectares is 1.8; this represents the second highest average in the kingdom after the eastern province (al Ahsa) which has 2.5 tractors per 1,000 hectares. Most farmers have to wait a long time (4-5 weeks) for the busy tractors and ploughs. Moreover, it has been observed in the field that this low average of tractors per 1,000 hectares is not fully utilized, a situation which aggravates the effects of the shortage. The reason behind this is believed to be the poor standard of maintenance and operation. Indeed, the farm equipment maintenance and repair service is one of the major problems of farm machinery in the region. Spare parts are unavailable in most cases and the supply is very slow and largely jeopardized by the administrative routines in the Ministry headquarters at Ar Riyadh. As a result, often such valuable equipment stands idle for a considerable time. A case was witnessed during the field work period where a tractor of O-8⁽¹⁾ type stood idle for 6 weeks waiting for a small spare part to be delivered. However, the efficiency of the available agricultural machinery in the region, particularly as regards the heavy equipment for earth moving in connection with land levelling and erection of irrigation channels, is extremely low because the present equipment is not fully suitable for such localized practices. In most cases crawler tractors operate with bulldozer blades only,

(1) Worth 35 SRs. an hour (roughly £3).

even in cases where the soil has to be moved over long distances. The recent but limited introduction of buckets to these tractors has brought about a remarkable improvement in the efficiency of such costly equipment. Moreover, the performance of the wheel tractor was also greatly improved recently by using the tiller. This introduction has not only helped to speed up tillage but in addition saved subsequent expensive land smoothing operations which are indispensable in irrigated crop production.

There is a great need for land forming on almost every farm in order to improve the present water control structures, irrigation field condition, and to facilitate the introduction of modern farming techniques. Tillage is one of the agricultural operations which can be successfully carried out by farm machinery provided that the right type of tillage is used. The increased use of the tiller in the region's farms would improve the capacity of the four-wheel tractors. It would help to speed up tillage operations, improve moisture conservation, and reduce tillage costs for farmers. Another advantage of the use of the tiller instead of disc or mouldboard would be the ease of cultivation of even small fields without much damage to irrigation systems and disturbance to land level. Moreover, the operation of the tiller is much easier and the maintenance and repair cost is considerably lower than the prevailing types, disc and mouldboard.

An interesting aspect of tillage in the Qassim associated with soil textural type was observed in many fields which lie on a clayey or silty soil. In the Qassim the land is usually left untouched after harvest until the following sowing season, and under the prevailing arid conditions the land dries out quickly and becomes very compact and hard, and consequently difficult to plough. Thus, the power

machinery requirement for tillage of such lands is extremely high and land is left in a rough condition, unsuitable for efficient cultivation. Tractors and tillers suffer severe strain working over such sunbaked fields and hard irrigation ditches. It is suggested, however, that such lands should be irrigated before ploughing. This practice ought to save power, reduce damage to the equipment, help to speed up tillage operations, and save farmers unnecessary additional working hours. The argument that precious irrigation water is wasted in such a practice is, in fact, only partly correct. Ploughing and planting, as a demonstration in the eastern province (al Ahasa) has proved, can be timed so that a good portion of the soil moisture is still available for the crop.

The threshing process is still in most cases carried out in a very inefficient and primitive manner resulting in production of a poor quality of grain. Farmers were found to be very anxious to use modern dusting and threshing equipment, but their financial situation does not permit them to pay for such expensive equipment. The available threshers, either of the A.E.S.Cs. or of the private contractors, are far below the demand level at the present time.

Grain harvesting is still a hand-operation; an introduction of simple and suitable grain harvesting equipment is necessary to improve the labour force deficiency in the fields of cereal. Alfalfa is another important crop which, due to its vast areas, desperately needs the introduction of mechanized harvesting equipment. An experimental demonstration of such equipment had failed to prove its efficiency when introduced in the region in 1963. Root vegetables, e.g. onions, carrots, are harvested at the present time by hand and the introduction of modern mechanized harvesting equipment for such operations is very urgent.

However, if such equipment is successfully introduced in suitable design for the local conditions it will, undoubtedly, speed up the expansion in cultivated areas.

However, the introduction of new farm equipment and the improvement of equipment in use must embrace hand-tools and light equipment as well as power machinery equipment. The present complete swing towards introducing only heavy machinery in the region must not be allowed to continue any further. Any introduction of new farm equipment is necessary to be based on simplicity in operation, low maintenance and repair costs, and an ability to work in confined areas and fields.

10.2 Problems of irrigation and plant water requirements

The basic cause of all the present irrigation problems in the region is the recent introduction of greatly increased quantities of irrigation water from the deep aquifers into an existing irrigation system based on limited supplies of water drawn by animal power from the poor shallow aquifers of the region. This inefficient and poor structure of irrigation layout prevails in the old palm-tree gardens. It is a combination of ill-organized, randomly distributed, unlined earthen, wide and long channels, and earthen open storage ponds. Unfortunately this bad structure has been extended to the newly cultivated lands annexed to these farms recently after the increase of water production capacity. Moreover, it has been noticed that the same structure has been adopted to a great extent in the newly established fields and farms sponsored by the new developers in the region.

An irrigation water study of all the aquifers indicates that the waters of Phreatic, Jilh, and Khuff aquifers, are less suitable for agricultural use. This is based on the fact that "SAR"⁽¹⁾ values of these aquifers range from 1.0

(1) Sodium Absorption Ratio.

to 4.0 with E.C. values commonly exceeding 3000⁽¹⁾ micromhes/cm. (Fig.32). Boron (B) concentration in these waters is found to be medium to high (0.5-3.0 ppm). It is because of this fact that the use of these waters for irrigation should be limited and carefully applied as, although boron is essential for plant growth, it is highly toxic where its concentration rate is high. However, on the whole, such waters could be suitable for agricultural application where efficient drainage conditions are maintained and salt-tolerant crops are grown. Waters of the Tabuk and Saq aquifers are classified as "C₃-S₁"⁽²⁾ with a boron concentration measured at 0.1 to 0.5 ppm. Thus, these waters are the most suitable irrigation waters in the region.

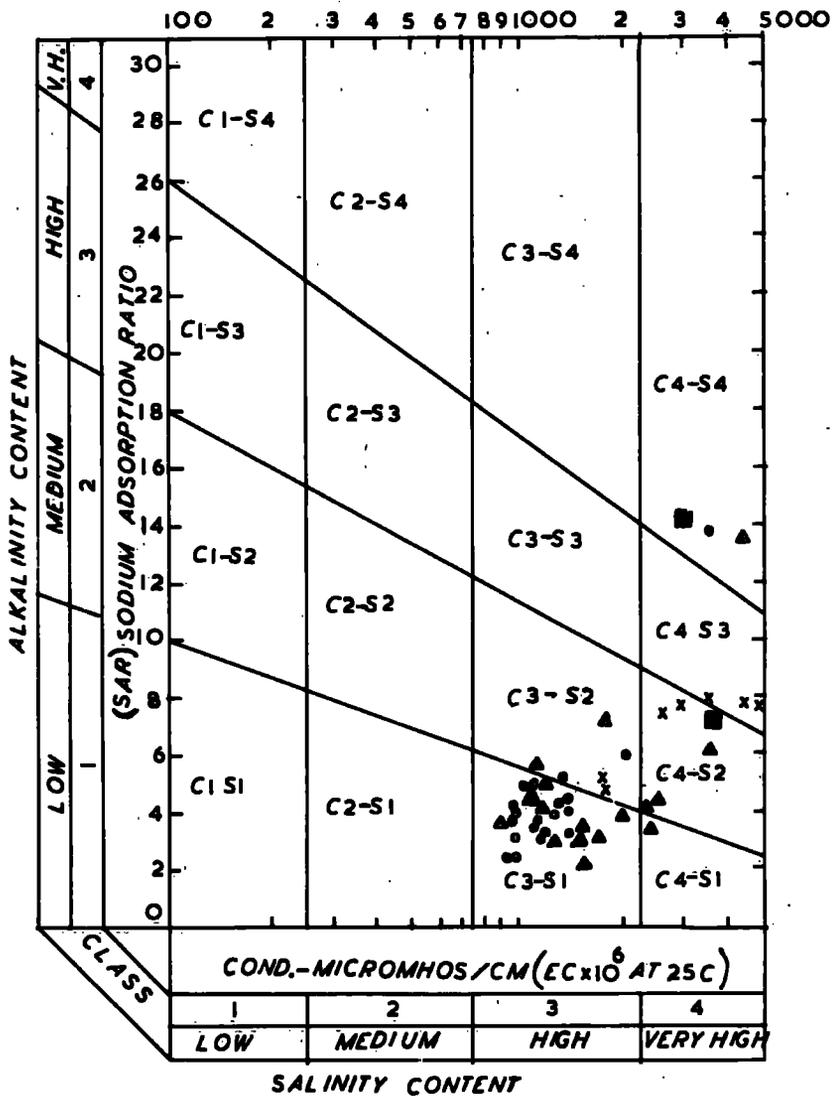
However, the complex of irrigation problems involves three major problems; inefficient pumping systems, over-production of water, and inefficient rate of irrigation with high rate of waste.

The problem of inefficient pumping is clearly demonstrated by the almost universal practice, throughout the region, of pumping water from shallow wells through a pipeline often too small in diameter for the pump stream capacity. Such a structure would exert a bad effect on the pump which consequently involves unnecessary cost of maintenance. In most cases the discharge pipe rises vertically two metres or more above the earthen pond at the collar of the well. Many irrigation engineers have pointed out that such an arrangement is technically unnecessary and costs the farmer considerably more fuel and larger engine capacities than if water is lifted only to the level of the pond and through a larger pipe.

(1) See Table 2, Appendix I.

(2) C₃ for medium to moderately high salinity.
S₁ for low sodium.

CLASSIFICATION OF IRRIGATION WATERS, THE REGION OF AL QASSIM



- x PHREATIC AQUIFER
- KHUFF AQUIFER
- ▲ TABUK AQUIFER
- SAQ AQUIFER

FIGURE 32

104.

The problem of over-production of ground water is, so far, limited to the old and traditional pattern of palm-tree garden areas. It has not been observed on a large scale yet in the new lands which have been brought under irrigation away from the old agricultural sites, nor do they affect the vast areas of non-irrigated pastures. This newly introduced additional supply of deep ground water has led to a great reduction in use of the ground water in the shallow alluvial aquifer, on which the settlements of the Qassim have been originally established, and with whose limited water productive capacity an equilibrium has been maintained. However, such a situation has led to over irrigation practices, plus additional supplies from the Phreatic aquifers from below have led to a rise of the water-table of the shallow zone and consequently reduced drainage capacity. The non-existence of an artificial drainage system forces surplus water to escape through evaporation. Thus, as a result of the prevailing high rate of evaporation, salts are left on the land surface rendering the land unfit for profitable cultivation (plate xxxiv), except for species tolerant to salt from which a diminishing return is expected. With adequate drainage it is feasible to leach the salt out of the soil and reclaim the numerous fields that have become unfit for agriculture and to increase the yields in fields where productive capacity has been reduced by salinity.

The problem of an inefficient net of irrigation and high rate of water waste is the result of the earthen, unlined irrigation canals and unsuitable earthen storage ponds. In the Braydah area, a farmer lifts 19 LPs⁽¹⁾ into the regulating pond near the well. The stream from the pond conveys water

(1) Litre per second.

to the field through a leaky ditch, where only 4 LPs roughly reach the basin boundaries. Such findings suggest that 79 per cent of the pumped water is wasted through the earthen pond and irrigation channels. Certainly, with the use of pipelines or lined canals to eliminate such great losses through seepage, this farmer could have irrigated at least four times as much land and would have saved at least one S.R./day in diesel fuel cost alone. Lining ponds and canals in some of the newly established farms (south Aunayzah) has given immediate and positive results with quick noticeable repayment benefits in terms of water and fuel saving, as well as a reduction in the effect of drainage difficulties. In fact, lining operations for the majority of farmers in the region is very expensive as their farms' income do not permit the cost of such expensive schemes. For these, a temporary improvement could be achieved through levelling the fields and re-locating the irrigation canals far more efficiently. It is also concluded that the present irrigation canals can be improved by removing the obstructions and by regrading, so that the water could be carried at the highest uniform velocity to the fields. However, the random distribution and closeness of trees throughout the fields in most farms constitutes a serious problem in levelling the farm surface in order to develop by grading or lining an efficient irrigation system.

In some places water from the deep boreholes has temperatures in the range of 30°C. to 40°C. e.g. Farm of Prince Met eeb in al Batin east of Braydah (plate xxxv). Farmers consider that it must be allowed to stand in a relatively large pond and cool before it is applied to the field. Such a prolonged stand causes more infiltration in the earthen ponds. Thus, it is necessary to establish through experimental research the fact whether the application

of such hot water affects the plant or not. The expansion in alfalfa growing will undoubtedly participate in diminishing the size of wasted irrigation water especially in summer time, when the absolute cultivated area is smaller than in winter, due to the fact that alfalfa requires the highest ratio of water among the raised crops in the Qassim. In addition, evapotranspiration of alfalfa is estimated at 73 mm/dunum in winter whilst it is in the range of 300 mm/dunum in summer.

The question of the proper size of watering canals which should be adopted in the different farming types and agricultural areas, is highly important for the achievement of efficient irrigation practice. Such a question, in fact, can only be discussed and concluded through adequate information and data on soil intake rate, the depth of water to be applied for the various crops desired to be grown in the farm, and the size of the field. The lack of precise information of these will necessarily make such discussion concerning the two methods of irrigation in the region of a rather general and tentative conclusion.

With Mesha ab (furrow) method individual streams must be larger as the length of furrow increases. Where streams are too small for the soil intake rate, a large amount of irrigation water will be wasted through excessive deep percolation on the upper end of the field. On land of 0.5° slope, the maximum size of furrow stream that does not cause erosion is estimated to be 0.75/LPs. If the slope is less than 0.5° , furrow streams could be of a larger size if desired. Where slopes are more than 0.5° , the stream's size should be reduced to prevent excessive erosion from the furrows. In the case of flooding method of irrigation (basin), if a depth of 7.5 cm. of water were to be applied to a field of medium textured soil (sandy loam) a stream of 31 LPs/dunum

is necessary for efficient irrigation. If 5.0 cm. depth of irrigation is to be applied to fields of soils classed as loamy sand, the stream size should be of 125 LPs/dunum.

For optimum production of the various crops in any given region, definite amounts of water and the number and frequency of applications should be established for every individual plant according to its biological structure and the environmental factors of the area where crops are to be grown. Where such information is available a satisfactory system of irrigation could be easily established. For the Qassim, there is a severe lack, and almost no information of plant water requirements. Therefore, a general discussion on this aspect must suffice. Figure 33 demonstrates the amount of irrigation water generally required by the various crops. For instance, alfalfa requires about 2.8 metres of irrigation water annually whereas beans require about one-fourth as much. However, in an arid region such as al-Qassim, the unit of production and returns should be compared against water required instead of per unit of area cropped. The amount of moisture-holding capacity which the variable soils make available for plant use, the plant root zone, and the level to which the water can be removed by the crops without reducing yields are the most important factors in determining the water irrigation frequency. However, normally irrigation takes place by the time 50 per cent of the usable soil moisture has been removed from the root zone. Thus, if the soil is medium textured and the root zone is one metre, a depth of 170 mm. of water could be stored as usable moisture but only 88 mm. should be removed before replenishment by additional irrigation water. If the soil were a coarse sand, irrigation would have to be much more frequent since not more than about 40 mm. should be removed before replenishment.

Following these lines a tentative calculation of water requirements for seven types of crop were concluded by the Ministry of Agriculture's experts and laid down as a basic guide for use in the region. They are summarized in the following table:-

Table 13. Peak frequency⁽¹⁾ of irrigation in the Qassim

Crop	Soil texture				
	Clay and clayey silt	Silt or loam	Sandy loam or sandy clay	Loamy sand	Sand
Alfalfa	20	14	21	12	10
Dates	16	10	16	10	11
Barley	18	10	14	10	18
Corn	16	9	13	9	16
Lettuce	10	6	07	6	10
Melons	13	7	10	7	13
Tomatoes	16	8	11	8	12

(1) Frequency in days.

Source: Emergency area eighteen months report, Qassim, Wadi Sirhan, and Tabuk.
Ministry of Agriculture and Water, 1965.

10.3 Problems of plant and animal diseases

One of the main agricultural problems facing every individual farmer as well as the agricultural development plans in the Qassim as a whole, is that of crop pests and plant and animal diseases. Control is at present in the hands of the Extension Fields Services Centres (E.F.S.Cs.). These centres, in fact, handle the problem with poor knowledge, inadequate equipment and facilities carried out by a few poorly trained and unqualified staff. This low standard of service is greatly aggravated by the fact that the field

centres provide the service to any farmer upon his request, regardless of the number of dunums or animals, or size of crop to be treated, or the distance the service unit has to travel to reach the infested area. Such flexibility makes it difficult for the present size and capacity of service units to cope with all the demands. These facts are, undoubtedly, the causes of the increasing trend of this problem corresponding to the increases in expansion in agricultural areas through the last few years.

Saudi Arabia is one of the few countries which has not yet imposed plant quarantine restrictions. This situation has, in fact, resulted in many serious consequences because a great variety of agricultural plants are currently being imported to meet the increasing demand for plants for the new development areas as well as the old sites where a swing towards the production of fruits is increasing. Thus, it is expected that such importation will continue for many years to come, and with such a rate many economically important plant diseases have already been introduced into the country. Included among these are citrus leaf cutworm, and citrus leaf minor from Iraq, the melon bores and cucurbit weevil from Jordan and Iraq, spider mites from the Lebanon, and many others.

However, crop pests and plant diseases of major importance and frequent occurrence in the region include "Red spider mites," which were identified on many crops, "Termites," and "Nematodes," which cause serious losses of vegetables especially tomatoes and melons. "Alfalfa Dwarf" (Dabbas) is causing a serious loss in alfalfa fields. It is estimated that over fifty per cent of alfalfa area in the region is suffering from this disease. The disease inhibits plant growth and productivity and as a result the plant dies prematurely. It is caused by a virus organism

and is transmitted from plant to plant by a leaf-hopper type of insect. The same type of virus causes a disease on vineyards known as "Pierces disease." On vineyards it does not cause a dwarfing of growth but seriously impairs fruit development, the control of this disease depends upon the elimination of the leaf-hopper or the destruction of known infected vineyards. Another measure of control can also be achieved by keeping the alfalfa and vineyards well apart.

Most of the pesticides in use in the region are of emulcifiable concentration type. Many experts have pointed out that the use of insecticides containing oil under the prevailing desertic climatic condition is responsible for a great deal of foliage damage. Therefore, it is believed that the shift to wettable powders of pesticides instead is a very necessary change. The method of use, time, and frequency and amount of applications are carried out in all cases, according to the instructions of the company selling the pesticides which usually are printed on the containers. It has been noticed, however, that following such instructions does not, in many cases, result in full efficiency of the pesticides. This problem has raised the suggestion that the application method should be re-considered and modified according to results secured from experimental research carried out under local field conditions. Such investigation would be most useful if carried out immediately on "alfalfa drawf," "Pierces disease" for vineyards, "Aphids" on pomegranates, and "weevil" on cucurbit and on "melon borer." Furthermore, to facilitate such a programme, it is necessary for the field centres to be equipped with insect pest identification facilities in order to establish an insect reference collection. The E.F.S.Cs. at a later stage should concentrate its efforts on research and investigation

rather than protection practices, which, in fact, should be carried out by the farmers themselves when sufficient time permits them to acquire the technique and develop a better rate of net income from their farms. To start with such a policy, farmers owning large farms of a reasonably good net income should be encouraged to buy their own equipment and insecticides and carry out the practice under the supervision and guidance of plant protection officers. Free plant protection services could be made exclusive to the small farms (5-10 dunums).

Animal diseases identified in the region are tabulated in the following table:-

Table 14. Animal diseases in the Qassim

Cattle	Sheep & Goats	Camels	Poultry
Rinderpest	Pleuropneumonia	Mange	Caprine
Foot and mouth	Foot and mouth	Haemonchur	Newcastle disease
Anthrax	Anthrax		Chronic respiratory disease complex
Bovine tuberculosis	Sheep pox		Fowel Cholera
Mastitis	Liver Flukes		Caccidiosis dictry
	Haemonchur		
	External parasites		

Source: Vetinary files, E.S.F.Cs. of Braydah, Aunayzah and Ar Russ (Arabic) 1964-67.

These diseases cause a significant impact on the agricultural economy of the Qassim. The high rate of mortality and the high rate of disease are frequently aggravated by animal weakness due to malnutrition. However, factors contributing to the spread of diseases are the lack of appropriate modern

facilities and measures for feeding, shelters and vaccination on the farms. All farmers re-stock their sold animals from nomadic herds, and a direct cause of disease for the nomad herds in the region is the uncontrolled infiltration of thousands of animals across the northern boundaries of Saudi Arabia, with Jordan, Syria, Iraq, and Kuwait. Such infiltrations penetrate into the country as far south as the extreme southern limits of Najd through al Qassim, and threaten to bring infections capable of paralyzing the livestock community in Najd as a whole. The complete blockade of these infiltrations and nomad movement across the northern boundaries is one measure to block such a source of infection, but regarding a complex of tribal, historical, social, traditional, and political factors, such a step will result in unnecessary and tense inconveniences for the governments and nomads of the four countries concerned. This fact leaves the establishment of points of control at the infiltration points as the most appropriate measure. At such points of control, facilities and staff should be available to inspect the passing herds and to carry out the necessary measures of vaccination. An exchange of information on diseases on each side and collaboration among all concerned would help greatly in the success of such a plan.

In the Qassim, where farmers seek vaccination measures for their animals, the nomads are reluctant to have their animals vaccinated unless disease is imminent. Moreover, the inevitable concentration of such unvaccinated animals round the few and insufficient permanent water holds provides an efficient medium for the spread of diseases. In order to overcome such a problem, temporary units working on seasonal terms are necessary at the watering points for inspection and vaccination measures. Such a step would, undoubtedly, prevent the seasonal and sudden breakout of diseases and infections, which usually end with a great loss in herds.

However, for both farm and range livestock, development plan practices would be more effective if carried out on the basis of seasonal vaccination against seasonal diseases, the introduction of necessary legislations for animal diseases control, and the establishment of a disease reference of the various viruses causing the common diseases.

10.4 Future of agricultural development

The present agricultural development in terms of areal expansion, quality, and diversity of market-orientated production has been evolved in the Qassim since the middle of the last decade when artesian water was discovered and tapped through deep-drilled wells. Insufficient water for irrigation has been, in fact, the main obstacle which held up expansion in agriculture for centuries. Thus, subsistence and/or semi-subsistence types of agriculture were the forms of cultivation in the region prior to the 1950s. These have been based on dates, cereals, and a very limited variety of vegetables produced mainly for household consumption. The agricultural methods, techniques, and practices were very primitive and handed down by tradition from generation to generation. This situation has resulted in the very limited farming knowledge of the Qassim farmers and the productive capacity of farms, the prevalence of improved hand-tools and the existence of rather primitive irrigation system together with odd and clumsy arrangements of the fields and trees in farms.

The sudden active expansion in water resources in the early fifties has led to areal expansion in agriculture with over-irrigation practices. Such a situation has, indeed, imbalanced the agricultural state and strongly shaken the farming process in most of the settlements in the region. However, due to the lack of agricultural statistics on the size of cultivated area, yield per unit, proportion of areas occupied by the various crops, it is almost impossible to

trace the trend and the rate of growth in the percentage of cropped area. An accurate projection of agricultural development into the future cannot be drawn for the region. Thus, an alternative to bridge this serious gap and present at least an approximate status has been sought.

The estimated data are on the size of cropped area, crop output, and value of crop production for a period of 13 years from 1949-50 to 1962-63. (Table 4 Appendix H). The data indicate that the increase of cropped land has been in the range of about 7.5 per cent annually throughout the period. Such a rate of expansion is, in fact, high for an agricultural economy restricted by a shortage of complimentary resources. Nonetheless, the writer inclines to accept that such a rate could be fairly safely taken as the tentative rate of expansion in the Qassim at least since 1961-62 when the first agricultural survey of the region was conducted. This inclination is based on countless statements declared by the Qassim farmers as well as by technical staff of the Extension Field Services Centres in the region. Furthermore, a preliminary calculation based on sampled cropped areas located in the Braydah, Aunayzah and Ar Russ areas has shown a similar rate of increase in the three areas through 1964-65-66 (based on figures on the yearly increases given by the farmers). The rate of increase in these areas averaged 7.2 per annum for Aunayzah, 7.9 for Braydah and 5.8 for Ar Russ area. The relevant data on crop production in the kingdom for the period indicates that the rate of overall crop production increase is in the range of 7.2 per cent.

An interesting feature of the data is the marked increase in vegetable and fruit production. Their yearly growth rate far exceeds the rate of growth in other products, both in terms of cropped area (17.4 per cent for vegetables and 13.7 per cent for fruit) and production (21 per cent for vegetables and 15.3 per cent for fruit) and total value (21.2 per cent

for vegetables and 15.3 per cent for fruit). An explanation of these high rates for vegetables and fruits lies in the fact that the rise in per capita income over the fifties, as a result of increases in the national income through increased oil revenue, has brought with it a demand for a more diversified diet of more valuable crops. Thus price incentives are the most effective means for determining the agricultural pattern and the production trend of individual crops throughout the kingdom. An estimation of the cropped area and crop production growth rates and trends in the Qassim since 1961-62 was attempted and based on the rates of the kingdom. Figures given in the first agricultural survey of the region were used as a benchmark for the assessment, while the period prior to 1961-62 was regarded as a blank period for which little reliable information is available. Following these lines, it is estimated that the size of cultivated area has risen from 31,963 hectares in 1961-62 to 45,886 hectares in 1966-67. Projection of this rate of expansion in cultivated area into the immediate future indicates that the cultivated area in the Qassim will reach 81,834 by 1975, which is almost double the cultivated area at the present time. However, the assumption of the continued expansion in the Qassim, throughout the sixties and seventies, is reflected in a study of the projection of agricultural commodities in the world 1970 made by F.A.O.⁽¹⁾ One of the interesting conclusions of this study was that the increase in agricultural production in the low-income countries during the fifties was due to the expansion of effective cultivable land. Moreover, the study also predicted that the increase in the same trend will continue

(1) Agricultural Commodities - Projection for 1970.
Rome, 1962.

in those countries throughout the sixties and probably the seventies. Therefore, it is conceivable that the Qassim could expand its effective arable land during the next decade. This increase would be some of 35,948 hectares in cultivated land; such an extent should be considered the least to be expected and consequently all future plans of agricultural development up to 1975 should be based on and take account of this factor. Therefore, an increase of some 100 per cent of the available agricultural facilities at the present time should keep pace with the improvement plans of agricultural conditions and facilities. If such a rate of increase of the agricultural facilities failed to be secured the present agricultural problems of irrigation, equipment, training, and marketing will be greatly amplified.

All the conclusions based on results obtained from a study of sampled cases throughout the region have indicated a probable shift in the pattern of crop production in the Qassim in favour of vegetables and fruits against cereal and dates. This shift can only be attributed to the variance in production costs and profit margins. A definite and final conclusion on the nature and extent of this and its projection into the future for agricultural development purposes needs, however, closer investigations of cost and return values for the various crops grown in the region over a number of years. Such data are, unfortunately, unavailable to trace the actual trend in the past and project it into the future. However, the future of the agricultural production growth rates and trends in the Qassim, as elsewhere in Saudi Arabia, will, undoubtedly, depend entirely on various definite factors such as governmental agricultural policy, costs, prices, markets conditions and efficiencies, import policy, agricultural credit scope and terms, extension services efficiency, as well as on other less definable factors which will bear directly or indirectly on the farmer's decision to produce more, or less, of one crop or another.

CONCLUSION

In accordance with the underlying theme of this study, which was to correlate the environmental setting of the Qassim region to its land use pattern and problems, attempts were made throughout to relate the different facets of the natural resources, mainly soil and water, to each other and in turn to the agricultural structure, with the view to evaluating the region's agricultural potentiality.

One of the most vital conclusions of this study is that, within the context of Saudi Arabia, the region possesses a considerable agricultural potentiality. This potentiality, if rationally planned and managed, could result in remarkably beneficial returns to the agricultural economy of the region in particular and Saudi Arabia in general. The extent to which the proper exploitation of the region's agricultural potential will affect the balance of payment of the individual farm, the region, and the country as a whole would need, however, a close investigation of many statistical data and information which are unavailable. Nonetheless, the potentiality could be assessed in two ways; firstly, the increase of production through the areal expansion of the cultivated area where only 38 per cent of the cultivable X land is under cultivation. Secondly, by increases through the improvement of the present low yield and quality per unit. It is clear, however, that the increase of production is, at the present time, and will remain for many years to come, concentrated through the areal expansion of cultivated lands. The present low standard of farming and the deleterious effects of the present agricultural problems, i.e. fertilization, irrigation method and application, plant protection,

etc. give little hope for increases in crop production in the immediate future.

With the discovery of the artesian water in 1953, in huge flowing quantities and reasonably good qualities for irrigation, water ceased to be a limiting factor for the expansion of the cultivated areas in the eastern, the middle, and most of the western parts of the region. The serious limitation has shifted to the soil factor, and all present and future agricultural development plans have to be correlated to soil suitability. It is concluded that the success of all expansion plans will largely depend on the availability of suitable soil to cultivate. Undoubtedly, the abundance of water at the present time has eliminated the most rigid limiting factor which checked the agricultural expansion and activities in the area for centuries. But, nevertheless, and due to local circumstances, the swift shift from an agricultural economy based on water shortage to one based on water surplus has brought a complex of problems relating to the application and utilization of the artesian water, i.e. soil water logging, soil salinity, and drainage problems. In fact, such problems could have been avoided if the farmers were taught and given the proper information and advice. The source of such misuse of water and its consequences lies in the poor standard of Governmental agricultural services, control, and policy. Therefore, at the present time there are two main aspects of water development and use in the region. The first is the prevention of further deterioration in existing areas of water misuse; the second is the improvement of existing areas and the development of new areas on a national and scientific basis.

The main outlines of the region's soils have been set out in this study. Such preliminary findings can never be adequate for a detailed development plan where much specific and

detailed information is required. Therefore, the need for comprehensive research on the soil properties, and suitability is acute and desperate. The proper use of the various soil types and the correct measures for their conservation depends entirely on such detailed findings. Many specific and important farming practice problems, i.e. irrigation, drainage, fertilization, etc. are related and strongly affected by the soil conditions and, unless ample information on the soils of the cultivated areas is available, such problems cannot be solved economically and correctly.

Many agricultural practices in the region at the present time are necessarily carried out with a blind approach based on traditional knowledge passed down from generation to generation. In future, emphasis and more serious considerations should be placed on the role of soil investigation and research as the main theme of agricultural development policy.

This study shows that the wadi soil association - particularly the silt loam, clayey, and sandy loam series - are the most promising types of soil in al-Qassim. Hence, should a sound and rewarding expansion be gained the first investigations and soil research projects should be confined to these soils and consequently the assignment of the agricultural projects to them.

The study of the agricultural structure reveals many intercalated problems which contribute to the existing condition of low net return. It has been impossible, however, to trace the extent, the nature, and the trend of many of these agricultural problems and to reveal any structural changes, patterns, and trends in the agriculture of the region, because of the lack of statistical data concerning the various aspects. It is evident, however, that in order to know precisely the causes and the trend of conditions it is necessary as a first step to evolve a systematic system of decadal censuses supplemented with periodic seasonal data

on land rate, labour wage, prices, cropped area, yield capacity per unit, annual variation in output of farm products and total crops production. It is indispensable, therefore, that the Extension Services Field Centres in the region elaborates on this line of research immediately, so that future development planners can base their judgments and conclusions on reliable statistical materials.

One of the most serious findings relating to the socio-economic structure is the urgent need for agrarian reform in terms of regulating, organizing, and legislating for the tenancy relationships which are necessary to make farming a more attractive occupation for the more advanced section of the community. The mechanization problem in the region has two aspects; the first is the imbalance of heavy machinery at the expense of hand-tools. Such a situation should be reviewed and considered more closely as the improvement of such tools is of equal importance as the many farming practices carried out by them. The second is the severe shortage of skilled farm machinery technicians resulting in a relatively high cost of repair in terms of time and money, a situation which has a bad and frustrating effect on the farm concerned. However, this problem can be solved in the short term as a vocational training centre was established at the town of Braydah in 1966. A study of the list of courses at the centre shows that little attention has been devoted to water pumping motors, and to farm machinery repairing and maintenance practices. Such a situation is totally wrong and closer co-operation between the Ministry of Labour and Social Affairs and the Ministry of Agriculture is urged to remedy such an incorrect policy; the region is more desperate for farm machinery technicians than for electricians or carpenters.

It is in the writer's opinion that the crop and livestock disease policy in the region, at the present time, is more a

matter of control than of scientific research. The principal need is for small laboratories in the Extension Field Services Centres that would assist the agricultural extension officers in the proper identification of diseases and to advise them on the method of control. The ever-increasing market for livestock products makes research on improvement of farm livestock quality a matter of great economic importance. The improvement of animal husbandry in the Qassim hinges, however, on the problem of feeding but the development of the livestock industry is dependent to a large extent on animal health control. Hence, thorough investigations should be carried out on the technical and economic aspects of fattening livestock under the local conditions before marketing.

Marketing difficulties, too, lie at the heart of the agricultural development in the Qassim. Marketing facilities and organization at the present time are inefficient in forming the essential link between increased agricultural production and increased farm income. A failure to improve the present marketing conditions and organization would further frustrate investments to increase agricultural production. The obstacles to improve marketing are many: long distances to the marketing centres, poor and unpaved rural roads and unhygienic transport facilities, lack of physical and financial marketing facilities, slowness in training farmers in the modern techniques of harvesting, handling, and packing, absence of marketing organization, marketing information services, and co-operative societies.

The region has a very desperate need for agricultural co-operative societies to organize the marketing process, the supply of equipment, and supply of seeds and pesticides and related farm maintenance materials. The response of the farmers to the co-operative idea was very discouraging indeed when the writer tested the matter during the field work period,

and many farmers even go further by expressing total rejection and resentment to the idea. This unfortunate attitude is apparently due to two main factors. The first is the common ignorance of the farmers about the real benefits of such organization with a great deal of misconceptions about the function of the co-operative. The second factor in the general attitude of the farmers is that the government is the only responsible body which should provide services for all aspects of development. This concept has been developed and encouraged by the agricultural governmental policy throughout the fifties and even the sixties.

It is vital, however, that every possible effort should be made to encourage or even push the farmers to establish such an organization by denying all the governmental services and aids to individuals and make them exclusive to members of agricultural co-operatives only. At the establishment of the proposed agricultural co-operatives, financial aid from the Ministry of Agriculture would be a very useful incentive. Technical aid is very necessary for regulating and organizing the co-operative procedures and the Ministry of Labour and Social Affairs should be invited to supply such help and advice. When co-operatives are set up and working in a satisfying manner, the Ministry of Agriculture should arrange to transfer the machinery services to these co-operatives on an instalment transaction basis. The Agricultural Bank should add an item to its present code stating that large loans on a long term basis could be provided to co-operatives only. However, this transference would relieve the Extension Field X Service Centres from a very time consuming and tiring service and any spare time can be dedicated to one of research and investigation to deal with the present agricultural development problems.

The Extension Field Services Centres are poorly organized, equipped, and staffed. It is very doubtful whether such

bodies will be capable of handling and carrying out any sound agricultural development programme. All procedures of work and services, of whatever urgency, are dealt with through the normal governmental routine, which was proved, beyond doubt, very slow and inefficient. Moreover, this situation is made worse by the fact that there is, in one way or another, a lack of confidence in the heads of these centres from the senior officials in the Ministry Headquarters. Such a phenomenon has led to very serious frustrations amongst the staff of the centres as their requirements and recommendations are always neglected. Another aspect of this policy is that although the Headquarters' top officials always have the tendency to turn down such approaches from the field centres, they are reluctant to inspect periodically the related problems in the field. Instead, they often ask the centres to apply a theoretical synthesis to the problem concerned disregarding the local circumstances, and thus often giving incorrect remedies. It would be more beneficial if problems were more often discussed in the field rather than in air-conditioned offices.

The recent introduction of television broadcasting services in the region presents a very valuable medium for demonstration and teaching the farmers by conveying illustrated information, guidance, and advice on all aspects of agriculture, water, and soil conservation measures and practices on a region wide basis. It would be useful and even necessary to exploit the T.V. services to the full extent possible for programmes conducted by the various experts in the agricultural field. Such well outlined, planned, and simply presented programmes will undoubtedly speed up the rise of standards of farming in every respect. Therefore, it is necessary for the Ministry of Water and Agriculture to establish a very close co-operation with the Ministry of Information to work on such a plan.

(1) A region-wide television broadcasting service was put into operation in December, 1967.

References

1. Abul-Ezz, S. Report on the projected Agricultural Bank, Saudi Arabia
Ministry of Water and Agriculture
Ar Riyadh, 1962.
- X 2. Abul-Nasr, S. Plant Protection Development, Saudi Arabia
Typed publication, EPTA report
No.2077, F.A.O. Rome, 1965.
3. Asfour, E. Y. Long-term projection of supply and demand for agricultural products, Saudi Arabia
(unpublished mimeograph)
Economic Research Institute,
American University of Beirut,
Beirut, 1965.
4. Asfour, E. Y. Preliminary estimates of gross national products of Saudi Arabia in 1960-61.
(Unpublished mimeograph).
Economic Research Institute,
American University of Beirut,
Beirut, 1961.
5. Crary, D. D. Recent agricultural development in Saudi Arabia
The American Geographical Review,
Vol. XLI, 1951.
6. Dowson, V. W. The dates and the Arab.
The journal of the Royal
Economist, Intelligence Unit, Ltd.
Annual Supplement, Iraq, 1957.

7. F.A.O. Agricultural development planning methods and organization, Near East
Typed publication,
Rome, 1960.
8. F.A.O. Agricultural Commodities, projec-
tion for 1970
Rome, 1962.
9. F.A.O. Date Cultivation in Saudi Arabia
Typed publication, EPTA report
No.1669, Rome, 1963.
10. F.A.O. Agricultural extension in Saudi
Arabia
Typed publication, EPTA report
No.518, Rome, 1958.
- X 11. Hablützel, H. Farm mechanization problems and
services, Saudi Arabia
Typed publication, EPTA report
No.1611, F.A.O., Rome, 1963.
12. Lateef, N. A. Characteristics and problems of
agriculture in Saudi Arabia
(Background country studies).
Prepared in programme
analysis service, F.A.O.
Rome, 1956.
13. Medawar, G. S. Production of dates in Saudi Arabia
(Unpublished mimeograph).
Economic Research Institute,
American University of Beirut,
Beirut, 1963.
14. Medawar, G. S. Agricultural production, Saudi
Arabia
(Unpublished mimeograph).
Economic Research Institute,
American University of Beirut,
Beirut, 1964.

15. Ogata, G. and others Transpiration of alfalfa determined from soil water content changes
Soil Science, Vol.89, 1960.
Rugters University, N.J., U.S.A.
16. Saleh, M. W. Control of Animal Diseases, Saudi Arabia
Typed publication, EPTA report No.1311, F.A.O., Rome, 1961.
17. Statistics Staff Bulletin of Agricultural Statistics and Economics, Saudi Arabia
Quarterly periodical.
Series No.1-12, 1965-66-67.
Department of Statistics and Agricultural Economics,
Ministry of Water and Agriculture, Ar Riyadh.
18. Statistics Staff The agricultural survey of the Qassim, Saudi Arabia 1380-1381H
Department of Statistics and Agricultural Economics,
Ministry of Water and Agriculture, Ar Riyadh, 1963.
19. Statistics Staff Statistical Year Book, Saudi Arabia
Series No.1 - 1965
2 - 1966
3 - 1967
The Central Department of Statistics, Ministry of Finance and National Economy, Ar Riyadh.
- X 20. Tothil, J. D. Agricultural development, Saudi Arabia
Typed publication, report No.76. F.A.O., Rome, 1953.

21. Twitchell, W. H. Report of the U.S. Agricultural Mission to Saudi Arabia
(Unpublished mimeograph).
Ministry of Water and Agriculture,
Ar Riyadh, 1943.
22. U.S.D.A. Notes on the agricultural economy of Saudi Arabia
(Unpublished mimeograph).
Foreign agricultural services,
Washington, Government Printing
Office, 1957.
23. Zerkavish, S. S. Agricultural statistics and Multi-subject Household Surveys
F.A.O., Monthly bulletin of
Agricultural Economics and
Statistics. Vol.II, No.5,
May, 1952.
24. Yasin, S. A. The Control of Animal Diseases, Saudi Arabia
Typed publication, EPTA report
No.1669, F.A.O. Rome, 1963.

APPENDICES

APPENDIX A

GLOSSARY OF ARABIC WORDS

Glossary of Arabic Words

Ain	Spring
bir	Well
Dikaka	Hummocky plain dotted with bushes
eyun	Plural of Ain
Jabal	Mountain or hill. Plural - Jebal
Khaehm	Promontory
Khubra	Saline or silt flat with bushes
Nufud	Sand dunes
Sabkha	Salt flat
Shae'eb	Intermittent stream channel
Wadi	Valley
Demal	Organic manure
Zara	Wheat and barley
Heyalah	Fallow
Jut	Alfalfa
Geh	Water melon
Gero	Sweet melon
Bedaa	Virgin land
Nahl	Cereal irrigation
Qantra	Major channel of irrigation
Teem	Minor channel of irrigation
Khundaq	Drainage channel

APPENDIX B

CLIMATIC DATA

Table 1

Rainfall - Aunayzah Area, October, 1958 - September 1967
figures in mm.

Year	O	N	D	J	F	M	A	M	J	J	A	S
1958/59	-	-	18.0	-	-	20.0	-	-	-	-	-	33.0
1959/60	2.0	6.0	2.5	-	18.0	-	8.2	-	-	-	-	36.7
1960/61	-	4.5	-	2.5	30.0	-	10.0	-	-	-	-	56.0
1961/62	-	-	-	x	x	x	x	x	x	x	x	x
1962/63	x	x	x	x	x	x	x	x	x	x	x	x
1963/64	x	x	x	x	x	x	x	x	-	-	-	x
1964/65	-	0.8	-	0.7	11.0	2.0	-	-	-	-	-	69.9
1965/66	-	5.6	18.1	19.3	19.7	3.9	-	-	-	-	-	66.6
1966/67	2.5	-	10.0	10.4	4.2	10.0	-	-	-	-	-	37.1

Latitude $26^{\circ} 06' N$
Longitude $43^{\circ} 57' E$
Elevation 650 metres
x not recorded period

Source: Meteorological files, Meteorology Office.
Ministry of Water and Agriculture.

Table 2

Monthly Summary of climatic data - Aunayzah Area
August 1964 - December 1966. Temperatures $^{\circ}C$

Average	J	F	M	A	M	J	J	A	S	O	N	D
Abso. Maximum	29.9	30	36.2	40.3	43.2	44	43.2	44	44.1	38.1	33.5	26.9
Mean Maximum	22.3	22.3	28.3	31	39.6	42	41.2	43	41	33.5	28.2	21.1
Abso. Minimum	0.8	3.6	3.3	8	10.8	20	17	19	19	8.4	4.1	-3.6
Mean Minimum	7.3	8	11	14.7	21.6	25.3	22	23.2	23	14.8	10.7	4.7
Max. Average	21.8	22.7	26	30.7	34.7	36	34.7	36	34	28.8	25.3	18.5
Mean Average	14.8	15.2	19.7	22.6	30.6	33	32	33	32.1	24	19.5	12.9

Table 2 (Continued)

Monthly Summary of climatic data - Aunaisah Area
August 1964 - December 1966. Relative Humidity %

Average	J	F	M	A	M	J	J	A	S	O	N	D
Absolute Maxi.	97.5	93	94.1	82	48	23	25	33	42	59	93	88
Mean Maximum	68	59.5	49	44	23	15	19	21.5	23	30	53	59.5
Absolute Min.	9.5	10.5	8	5	6.5	2	3	6.5	3	7	11	12
Mean Minimum	37	35	27.5	21	13.5	6	8	10.5	12	13	25	25
Maximum Average	70	78	58.5	54	31	18	17	25	30	16	67	68
Mean Average	48	43	34	22.2	17	10	12.5	16.2	17	22	39	42

Table 2 (Continued)

Monthly Summary of climatic data - Aunaisah Area
August 1964 - March 1967. Rainfall and Evaporation
from Pan

Figures in mm.

Average	J	F	M	A	M	J	J	A	S	O	N	D
Rainfall	26.2	11.7	4.9	7.4	2.0	-	-	-	-	2.5	3.2	7.6
Evapora- tion	186.8	175	280.6	330	482.2	500.4	502	495.1	433.1	329.3	207.2	161.7

Sources: This table been compiled and computed from
data given in the:
Hydrological Information Monthly Series 1-10
Hydrology Division
Department of Water Resources Development
Ministry of Water and Agriculture

Table 3 (Continued)

October 1964 - March 1965

	January			February			March		
	I	II	III	I	II	III	I	II	III
Mean Daily Temperature °C	12.1	11.6	15.2	12.1	17.9	17.0	21.5	19.4	22.9
Radiation gm cal/cm ² /day	324	294	238	304	368	370	450	480	450
Relative Humidity per cent	54.0	68.7	64.8	54.5	30.7	35.6	35.0	30.8	46.6
Wind, kpd	106	169	142	130	139	154	100	177	139
Open Water Evaporation, mm (Modified Penman)	22.2	27.0	25.0	28.0	41.8	34.6	30.1	56.0	60.5
Potential Evapo- transpiration, mm (desert dwarf shrub)	15.0	18.5	17.1	19.6	23.9	24.0	35.0	38.5	41.0
Rainfall, mm	-	-	50.2	-	-	-	-	-	0.7
Actual evapo- transpiration, mm	-	-	16.2	-	-	-	-	-	0.7
Moisture surplus, mm	-	-	34.0	-	-	-	-	-	Nil

Table 3 (Continued)

Evaporation and Water Balance - Aunaisah

April 1965 - September 1965

	April			May			June		
	I	II	III	I	II	III	I	II	III
Mean Daily Temperature °C	19.1	22.6	25.5	27.0	28.4	32.4	33.3	32.6	33.0
Radiation gm cal/cm ² /day	460	490	520	542	565	586	618	615	590
Relative Humidity per cent	39	43.8	26.8	25.4	18.8	23.5	8.3	8.1	11.2
Wind, kpd	131	130	64	67	62	49	33	31	42
Open Water Evaporation, mm (Modified Penman)	55.2	62.7	64.8	67.4	69.4	80.2	65.7	64.8	70.4
Potential Evapo- transpiration (desert dwarf shrub)	37.5	42.5	44.0	45.6	47.0	55.0	44.5	44.0	47.5
Rainfall, mm	11.0	x	x	2.0	x	x	x	x	x
Actual Evapo- transpiration, mm	9.3	x	x	2.0	x	x	x	x	x
Moisture Surplus, mm	1.7	x	x	Nil	x	x	x	x	x

Table 3 (Continued)

Evaporation and Water Balance - Aunazah

October 1965 - March 1966

	October			November			December		
	I	II	III	I	II	III	I	II	III
Mean Daily Temperature °C	29.2	28.3	24.1	23.6	21.4	18.2	17.7	14.9	11.7
Radiation (gm cal/cm ² /day)	448	460	415	400	364	315	330	329	330
Relative Humidity per cent	18.2	11.8	32.0	36.5	34.4	50.4	31.9	29.3	28.0
Wind, kpd	x	x	x	x	x	x	x	x	x
Open Water Evaporation	44.8	48.4	38.4	35.1	32.7	32.0	37.8	30.2	38.5
Potential Evapo- transpiration (desert dwarf shrub)	31.0	34.5	27.0	24.5	22.0	21.7	26.0	21.5	26.0
Rainfall	-	-	-	-	-	-	5.6	-	-
Actual Evapo- transpiration	-	-	-	-	-	-	5.6	-	-
Moisture surplus	-	-	-	-	-	-	Nil	-	-

Table 3 (Continued)

October 1965 - March 1966

	January			February			March		
	I	II	III	I	II	III	I	II	III
Mean Daily Temperature °C	16.6	13.6	19.3						
Radiation (gh cal/cm ² /day)	325	342	350						
Relative Humidity per cent	24.6	34.4	40.3						
Wind, kpd	x	x	x						
Open Water Evaporation	41.4	34.9	40.5						
Potential Evapo- transpiration (desert dwarf shrub)	28.5	24.0	27.5						
Rainfall	-	13.2	4.9	17.6	1.1	-	8.4	11.2	0.5
Actual Evapo- transpiration	-	12.2	4.9						
Moisture surplus	-	1.0	Nil						

Source: Intermediate Report on Surface Hydrology of Area 1. Qassim, Janof-Sakakah and Wadi Sirham, Saudi Arabia. August 1966.

Raika and Partners: Ministry of Water and Agriculture.

APPENDIX C

GROUND WATER HYDROLOGY DATA

Table 4. Selected Chemical Analysis of Phreatic Zone (Unconfined Aquifers)

Date of Sampling	Depth Meters	pH	Temp. °C	EC ECX 10°	TDS ppm	SAR	B ppm	Ca	Mg	Na	K	Co ₃	HCO ₃	SO ₄	Cl
26.4.66	1.9	8.6	36	4875	3390	27.7	2.04	0.85 96	2.71 55	37.8 470	6.4 45	1.02 7	8.43 91	16.00 730	21.2
24.4.66	4.8	7.7	20	3150	2240	6.1	0.80	9.0 1770	7.4 70	17.4 335	1.26 -	0.11 -	1.15 97	17.4 -	16.65 615
18.4.66	9.7	7.7	19	1057	666	3.6	0.33	2.85 437	2.3 203	5.8 1150	0.361 32	- -	1.61 56	2.72 1640	5.62 1950
15.12.65	14.7	8.2	22	981	-	4.5	-	1.40 214	2.25 135	6.1 590	- 49	0.23 -	1.83 70	- 920	4.36 986
8.12.65	25.5	8.0	24	1642	1082	7.0	0.70	2.85 57	2.87 35	10.8 248	0.45 18	- -	1.84 112	7.40 355	7.66 272
12.12.65	45.0	7.9	24.5	4830	-	3.9	-	8.8 176	11.75 143	32.6 750	- -	0.23 13	1.38 84	- -	34.2 1215
8.12.65	60	7.9	18	4420	2950	14	2.4	9.35 57	12.58 35	45.6 248	1.4 18	0.11 -	1.72 112	35.95 355	29.6 272

Source: Emergency Area, Eighteen Months Report, Area 1, Qassim, Wadi Sirham and Tabuk. Parson's -Basil consultants. Ministry of Agriculture, 1965.

Table 2. Selected Chemical analysis of Khuff aquifer

Date of Sampling	Depth Meters	pH	Temp. °C	ECX 10°	EC	TDS ppm	SAR	B ppm	Ca	Mg	Na K	Co3	HCO ₃	SO ₄	C1
										Milliequivalent per litre					
18.3.66	14.0	7.5	38	3635	2890	7.4	0.4	13.4	7.9	23.5	0.9	-	2.1	16.6	300
								50	20	145	40	-	70	120	
3.11.65	150	7.8	30	8615	6185	14.8	1	17.2	26	68	1	-	1.6	-	108.6
								57	46	600	50	nil	158	nil	1115
6.12.65	324	8	-	2950	2040	-	1.1	2.9	3.8	26.1	-	-	3.1	-	31.4
								61	23	155	50	-	142	150	255
13.3.66	450	7.5	37	6208	4040	15.3	1.1	8	11.5	45.2	1.7	-	2.8	4.1	61.5
								160	141	1040	65	-	16.8	200	2180

Source: This table been compiled and computed from data given in the:

Hydrological Information Monthly Series 1-10

Hydrology Division

Department of Water Resources Development

Ministry of Water and Agriculture

Table 9. Selected Chemical Analyses of Tabuk Aquifers' Water

Date of Sampling	Depth Meters	pH	Temp. °C	EC 10°	TDS ppm	SAR	B ppm	Part per million							SO ₄	Cl
								Ca	Mg	Na	K	Co ₃	HCO ₃	SO ₄		
Milliequivalents per Litre																
6.6.66	32.1	7.8	27	5300	3480	-	0.80	17.05 517	5.76 89	30.4 1200	0.72 38	0.23 6	1.82 194	22 1500	27.5 1758	
24.10.65	50	8.0	-	3480	2880	7.9	1.1	7.2 160	6.8 65	20.09 26.5	0.8 30	- -	2.5 175	9.7 355	216 535	
11.11.65	50	8.0	-	1640	980	3.1	0.9	3.8 190	4.9 90	6.5 240	0.4 25	- -	2.2 120	5.5 700	6.5 355	
17.11.65	66	8.0	27.0	1720	1256	3.2	1.3	5.5 90	6.2 65	7.6 205	0.4 30	- -	3 125	9.6 450	7.3 330	
14.11.65	115	8.0	26.0	1885	1320	4.0	1.2	4.5 65	5.4 60	8.9 150	0.8 15	- -	2.1 135	9.4 265	9.3 230	
19.10.65	120	7.9	30	1492	950	2.3	0.5	6.3 36	2.9 21	4.8 140	0.7 30	- -	1.0 97	9.7 110	5.4 270	
22.11.65	240	8.0	30	2450	1825	4.4	0.8	7.5 115	6.6 20	11.8 155	0.5 15	- -	2.0 130	12.5 250	1.8 240	
3.2.65	300	8.1	30	1775	1175	7.3	0.6	2.2 50	2.5 15	11 80	0.5 10	- -	130 2.1	160 3.3	115 3.2	
18.3.66	500	7.4	40.5	1455	1060	3.2	0.5	5.8 272	2.7 96	6.6 540	0.4 35	- -	2 129	6.2 800	7.2 448	
12.8.66	545	8.0	38.3	1850	1220	11.7	0.30	2.35 141	1.39 43	16.6 320	0.25 45	- -	2.95 173	0.602 190	16.86 645	

Source: This table been compiled and computed from data given in the:-

Hydrological Information Monthly Series 1-10.

Hydrology Division

Department of Water Resources Development

Ministry of Water and Agriculture

Table A. Selected Chemical analysis of Saq aquifer's water

Date of Sampling	Depth Meters	pH	Temp. °C	ECX 10°	TDS ppm	SAR	B ppm	Ca	Mg	Na	K	Co ₃	HCO ₃	SO ₄	C1
Milliequivalent per litre															
part per million															
10.7.66	52.1	7.7	26.0	9500	6630	-	1.62	27.95 192	11.1 17	65.2 410	0.74 1	0.11 6	1.36 164	27.1 350	73.6 670
14.7.66	69.0	7.7	27.0	2750	1850	-	0.65	10.55 245	2.7 32	14.3 360	-	0.11 6	1.36 69	10.4 600	14.5 594
11.7.66	75.3	7.7	27.0	2900	1860	-	0.57	11.6 296	2.8 67	15.2 660	0.11 11	0.11 6	1.51 104	12.5 1060	14 847
11.7.60	87.4	7.5	27.5	4700	3200	-	0.97	14.8 559	5.5 135	28.7 1500	0.28 29	0.11 6	1.7 53	22 1300	23.7 2608
10.7.66	150	7.7	27.0	2860	1840	-	0.3	9.6 80	1.4 65	17.8 135	15	0.11 ml	2.7 90	7.3 390	18.55 210
14.7.66	194.8	7.7	27.0	5450	6600	-	2.08	30.30 232	12.3 35	60 350	0.82 4	0.23 6	1.7 92	36 600	62.8 497
10.7.66	380.0	8.0	-	370	570	-	0.1	2.45 65	1.15 12	2.08 72	0.2 1	0.11 6.1	1.24 104	2.08 140	2 91
4.8.66	530.0	7.4	-	9400	6750	18.6	3.25	355 17.75	125 12.9	1700 73.9	29 0.74	-	83 1.36	2450 51.1	1770 49.86
18.6.66	647.0	7.8	34.5	1050	680	-	0.2	4.4 123	1.23 31	4.87 157	5 0.1	0.11 -	2.04 78	3.34 350	4.57 250
21.3.66	1250.0	7.5	34.0	1400	1020	3.3	0.6	6.2 111	2.6 33	6.8 330	0.1 -	- 6	1.3 83	7.3 500	7.0 514

Source: This table been compiled and computed from data given in the: Hydrological Information Monthly Series 1-10. Hydrology Division. Department of Water Resources Development. Ministry of Water and Agriculture.

Table 6. Selected Aquifer Pumping Tests in the Qassim. (April - August 1966)

Place	Elevat. Mtrs.	Depth Mtrs.	Aquifer	Water Level		Disch. Ltr. P.S.	Temp. °C	I.C.	Aquifer Coefficients	Test hours
				Static	Pumping					
Braydah	603.8	130	Tabuk	+1.31	24.0	11.7	29.0	900	139	24
Ash Sheqqah	643.2	465	Tabuk	13.88	56.07	10.5	-	--	76.5	24
Ar Rashidiyah	633.7	780	Tabuk	8.53	13.80	20.9	37.5	965	2485	24
Al Butain	-	488	Tabuk	22.6	36.5	7.9	32.5	1,175	178	28
Dughmaniyah	641.2	549	Tabuk	+3.16	1.28	11.3	33.3	--	249	24
Dughmaniyah	641.9	762	T. & Saq.	+4.06	0.63	6.9	32.5	--	176	25
Quseibah	656.1	600	T. & Saq.	0.77	29.1	15.8	30.7	--	65	22
N. of Dugmaniyah	654.8	1067	T. & Saq.	+4.95	4.6	20.8	43.0	--	745	22
Qassim Deep W.1.	-	1088	T. & Saq.	+15.0	+1.9	16.3	38.5	2,600	1430	23
Ash Sharqiyah	-	467	Saq	+20.8	44.7	16.5	28.0	--	51	49
Ash Shealanyah	-	427	Saq	9.0	23.1	5.7	-	--	35	2
Tirq	727.4	93	Saq	47.9	66.1	7.6	-	940	330	24
Al Ayun	648.2	540	Saq	+2.68	+1.0	6.7	32.0	960	1230	16
Riyadh al-Khaba	667.1	186	Saq	12.5	29.9	15.8	29.0	2,400	14	24

+ Above reference point.

- Unavailable data.

Source: Emergency Area, Eighteen Months Report, Area 1, Qassim, Wadi Sirhan and Tabuk
Parson's-Basill consultants.
 Ministry of Agriculture, 1965

APPENDIX D

VEGETATION SPECIES TABLES

Ecological evaluation of plants in the
Qassim

TABLE 1. A. Decreasers

<u>Scientific Name</u>		<u>Arabic name</u>
	Grass	
Aristida plumosa		Nassi
Panicum turgidum		Thamam
Cenchrus ciliaris		Subbat
Danthonia foraskahlei		Halfa
Lasiurus hirstus		Dha'ah
	Shrubs	
Artemisia herba-alba		Geysum Orshih
Helianthemum kahiricum		Hashmah
Arnebia hispidissima		Hamat
Scrophularia deserti		Algar
Atriplex leucoclada		Rughi
Convolvulus lanatus		Rakham
Cornulaca monacantha		Hadh
Salsola tetrandra		Dabrrah

Source: Range resources of Area 1.
Qassim, Jwaf-Sakatah, and Wadi Sirham,
Saudi Arabia. April, 1967.
Parson-Basil. Ministry of Water and Agriculture.

TABLE 2. B. INCREASERS

<u>Scientific name</u>		<u>Arabic name</u>
	Grass	
<i>Aeluropia lagopoides</i>		Nigeel Sheitanni
<i>Aeluropis littoralis</i>		Ikrish
<i>Cymbopogon schoenanthus</i>		Hashma
<i>Cynodon dactylon</i>		Rishad
<i>Eleusine compressa</i>		Homra
<i>Phragmites communis</i>		Buz
<i>Poa sinaioa</i>		Ansay'ah
	Shrubs	
<i>Acacia spp</i>		Salam
<i>Achillea fragrantissima</i>		Gaysum-Jabali
<i>Alhagi maurorum</i>		Agul
<i>Anabasis seti fera</i>		Sharan
<i>Anabasis articulatum</i>		Ageram
<i>Artemisia monosperma</i>		Adhir
<i>Astragalus spinosus</i>		Chidad
<i>Atriplex halimus</i>		Qufaf
<i>Calligonum comosum</i>		Arta
<i>Capparis farinosa</i>		Shefellah
<i>Ephedr alata</i>		Alanda
<i>Fagonia bruguieri</i>		Janb
<i>Haloxylon articulatum</i>		Nikum
<i>Haloxylon pericum</i>		Gadha
<i>Haloxylon salicornicum</i>		Rimth

TABLE 2 (CONTD.) B. INCREASES

<u>Scientific name</u>	<u>Arabic name</u>
Leptadenia pyrotechnica	Markh
Lycium arabicum	Ausaj
Ochradenus baccatus	Qurdhi
Rhanterium epapposum	Arfaj
Rhynchosia memmoina	Ragm
Schanginia baccata	Suwwad-Tehamah
Seidlitzia rosmarinus	Shinan
Tamarix spp	Tarta or Athl
Zizyphus nummularia	Sidr
Zygophyllum coccineum	Harm

Source: Same as Table 1.

TABLE 3. C. INVADING PERENNIALS

<u>Scientific name</u>	<u>Arabic name</u>
Anvillea garcini	Iwad
Calotropis procera	Ushar
Centaurea sinaica	Moraar
Daemia cordata	Burrm
Citrullus colocynthis	Ash Shery
Iris sisycrinchium	Ansalan
Orobanche legyptiaca	Uwaithirrah
Pulicaria crispa	Sabat or Jathjath
Salsola baryisma	Ghadharf
Zilla spinosa	Shubram

Source: Same as Table 1.

TABLE 4. D. PROMINENT ANNUALS

<u>Scientific name</u>		<u>Arabic name</u>
	Grass	
<i>Aeigles triuncialis</i>		Abu Sharib
<i>Agropyron orientale</i>		Safir
<i>Aristida</i> spp		Safir
<i>Avena barbata</i>		Sha'irah
<i>Bromus fasciculatus</i>		Sabal Abu Al-Hosain
<i>Bromas tectorum</i>		Az Zaree'ah
<i>Hordeum</i> spp.		Az Zaree'ah
<i>Stipa tortills</i>		As Sammaa
	Forbs ⁽¹⁾	
<i>Allium desertomum</i>		Titah
<i>Anastatifca hierochuntia</i>		Kaff Marian
<i>Asphodelus tenuifolius</i>		Barwaq
<i>Calendula aegyptiaca</i>		Hanuwa
<i>Erodium</i> spp.		Nafal
<i>Malva farviflora</i>		Khubbaiz
<i>Matricaria aurea</i>		Az Ziffera
<i>Medicago ascerseniana</i>		Hasak
<i>Plantago albicans</i>		Ribl
<i>Plantago undulata</i>		Ribl

(1) A Forb is a non-woody plant that dies to the ground each year.

Source: Same as Table 1.

A. Decreasers are species in the potential plant community that decrease in relative abundance under continued moderately heavy to heavy grazing. They generally are perennials that are palatable to livestock and for the most part, are dominant species in the potential plant community.

B. Increasers are species in the potential plant community that normally increase in relative abundance as the decreaseers decline. But Increasers do not always react in this simple fashion. Species that increase at first may decrease later as moderately-heavy grazing continues. Increasers commonly are the less productive, sub dominant species in the potential plant community.

C. Invaders are species that are not members of the potential plant community for the range site, since they cannot withstand the competition for moisture, nutrients, and light in the climax vegetation. They come in and grow along with the increasers after the climax vegetation has been reduced by grazing. They are not restricted to exotic, since they may be members of the climax plant communities on other range sites in the same general locality. Some are annual weeds and herbaceous perennials and some are woody shrubs; many have some grazing value but others have little.

D. Annuals are species of too unpredictable and undependable a nature. They are dependent on a good moisture supply at the right time of the year and they are available only part of the year, even when a reasonable amount of moisture occurs. Although they sometimes supply an important amount of forage for livestock they are not members of the potential plant community for determining the range site.

APPENDIX E

SOIL CHEMICAL ANALYSIS DATA

SELECTED MECHANICAL AND CHEMICAL SOIL ANALYSIS DATA OF THE QASSIM

Depth in c.m.	Field texture	Lab texture	Particle size %			Specific conduc. ECK 10 ³	S.M.P.	Lime % Total	PH 1:1	Gypsum total Meg/100 gm. soil	Soluble na Meg/100 gm. soil
			Sand	Silt	Clay 5 mic						
0-20	SiCL	ClO	34	25	40	5.40	45.5	17.2	8.4	0.5	1.71
50-80	CL	ClO	36	24	40	7.35	46.5	15.7	8.0	14.3	1.31
130-15	CL	ClO	50	22	28	12.30	28.0	17.4	8.4	14.1	2.24
150-19	SL	S	95	5	0	15.30	16.5	2.9	8.5	14.2	1.59
0-30	LS	S	86	14	0	1.48	19.5	4.6	8.4	Nil	0.16
30-40	SL	LS	80	18	2	1.23	21.0	4.2	8.2	-	0.16
50-90	LS	S	98	2	0	0.67	14.0	0.9	8.5	Nil	0.07
100-250	S	S	98	2	0	0.66	14.0	0.5	8.8	Nil	0.07
0-20	SL	SCL	52	23	25	2.35	29.0	8.1	8.4	Nil	0.38
30-50	LS	S	91	9	0	1.08	17.0	8.5	8.9	Nil	0.15
70-100	LS	S	96	4	0	2.07	15.0	2.1	8.5	Nil	0.27
120-15	L	LS	83	15	2	9.26	19.0	7.6	-	-	1.30
0-20	SL	SCL	52	22	28	10.20	31.0	15.4	7.9	6.9	1.13
30-50	SCL	CL	36	26	38	5.66	43.0	16.3	8.0	12.2	0.92
70-100	C	C	32	26	92	9.70	46.0	17.9	8.3	14.6	2.52
0-20	SL	S	87	13	0	50.5	18.0	10.0	8.6	Nil	6.55
40-70	SL	LS	82	15	3	41.8	19.0	14.9	8.3	17.3	
90-120	L	LS	79	19	2	19.9	24.8	10.2	8.1	8.2	
130-160	SL	S	87	13	0	11.22	18.0	5.6	8.2	4.6	
240-270	L	SCL	63	14	23	32.04	30.0	7.5	8.0	Nil	
40-75	SL	SL	70	16	14	0.85	24.0	22.2	8.1	Nil	0.04
75-105	SL	SL	78	12	10	3.02	22.0	13.3	8.7	14.4	0.04
105-130	SL	LS	82	15	3	3.08	18.0	11.9	7.7	14.4	0.05
0-30	LS	S	90	10	0	1.30	16.0	8.0	8.2	Nil	0.32
30-50	LS	SL	74	10	16	1.74	23.2	17.2	8.9	Nil	0.16
60-100	SC	SL SCL	62	18	20	4.56	25.5	8.3	9.1	Nil	0.46

SELECTED MECHANICAL AND CHEMICAL SOIL ANALYSIS DATA OF THE QASSIM

Depth in c.m.	Field texture	Lab texture	Particle size %			Specific conduction ECX 10 ³	S.M.P.	Lime % Total	FH 1:1	Gypsum total Meq/100 gm. soil	Soluble na Meq/100 gm. soil
			Sand	Silt	Clay 5 mic						
0-10	SI CL	CL	38	24	38	151.0	37.4	17.4	8.3	22.7	45.46
30-60	L	L	48	34	18	76.5	26.5	15.5	8.1	19.7	15.4
130-160	CL	SL	54	32	14	46.0	25.0	22.2	8.1	20.2	9.16
0-20	SI CL	L	46	30	24	165.0	31.0	9.3	8.1	24.1	46.5
50-60	SI CL	SL	58	26	18	118.0	26.2	13.6	8.3	22.1	40.5
100-130	CL	CL	36	26	38	78.0	44.0	13.3	8.4	18.6	31.4
150-180	CLC	CL	42	31	28	58.9	31.4	14.3	8.4	18.0	16.0
220-240	CL	SCL	58	21	21	39.7	29.0	12.3	8.3	16.7	10.19
340-470	CL	SCL	58	21	21	21.7	30.6	15.1	8.2	14.9	3.65
0-30	IS	S	94	6	0	0.54	15.0	3.4	8.4	NIL	0.02
30-60	IS	S	92	8	0	0.54	15.5	5.9	8.4	NIL	0.02
90-120	SL	S	87	13	0	0.81	16.0	7.2	8.3	NIL	0.02
0-20	SI L	CL	43	25	34	53.4	38.0	30.9	7.4	10.0	16.2
50-80	SI CL	SCL	50	19	31	25.59	32.0	32.1	7.8	15.7	6.5
120-140	L	CL	41	23	36	20.47	36.5	36.5	7.9	15.6	6.15
0-15	CL	CL	36	32	32	106.51	45.0	15.5	8.0	20.5	47.5
30-70	CL	SCL	50	22	28	87.0	39.0	13.5	8.0	12.3	28.1
110-150	SL IS	IS	80	18	2	165.3	18.0	5.5	8.2	17.1	33.4
30-60	SI L	C	32	26	42	87.8	29.9	39.2	7.9	22.8	30.0
100-140	L	CL SCL	45	22	33	53.4	33.0	38.1	7.9	18.2	31.0
150-200	SL	SCL	47	23	30	8.5	29.0	39.2	7.9	15.6	10
0-10	CL	L	46	33	21	86.0	27.0	17.4	7.7	13.2	14.6
10-20	SI C	CL	36	28	36	123.0	35.0	21.0	8.1	17.5	37.8
30-60	L	SL	57	25	18	123.0	26.1	15.2	8.0	22.2	26.75
120-150	SL	IS	86	10	8	144.0	20.2	5.0	8.0	21.3	25.4
150-350	C	C	30	26	44	40.5	48.0	15.0	8.1	19.5	13.2
0-20	SI CL	SI C	8	32	12	137	39.9	17.3	7.5	11	-
	SI L	SI C	6	32	12	83.0	40.7	19.4	7.15	8.7	-

SELECTED MECHANICAL SOIL ANALYSIS DATA OF THE QASSIM

Exchangeable Cations Mec/100 gm. soil				Cation exchange capacity Mec/100 gm. soil	Soluble Cations meq/l				Soluble Anions meq/l				Boron PPM	
Na	K	Ca	Mg		Na	K	Ca	Mg	Ca	CO ₃	HCO ₃	SO ₄		NO ₃
1.89	2.64	-	-	2.80	38.0	1.9	9.0	3.0	225	Nil	3.0	-	-	1.7
1.29	2.35	-	-	22.7	29.5	2.3	26.0	20.0	14.0	-	2.5	-	-	6.0
7.16	2.18	-	-	18.80	80.0	2.5	29.5	14.0	82.0	-	2.0	-	-	7.7
2.19	0.60	-	-	2.50	96.0	2.8	47.5	11.4	52.0	-	2.0	-	-	6.2
0.88	1.02	-	-	5.40	8.5	1.0	4.0	1.0	7.6	-	2.5	-	-	0.9
0.83	1.12	-	-	-	7.6	1.1	4.0	Nil	8.5	-	2.5	-	-	0.5
0.54	0.59	-	-	1.90	5.0	0.6	2.0	Nil	7.8	-	3.0	-	-	0.4
0.54	0.49	-	-	1.30	4.8	0.6	2.0	Nil	2.6	-	3.3	-	-	0.4
2.60	2.48	-	-	-	17.9	1.7	4.0	Nil	9.6	-	3.0	-	-	1.15
1.06	0.75	-	-	3.10	6.5	0.8	4.0	Nil	4.8	-	4.0	-	-	1.9
1.12	0.61	-	-	2.20	17.4	0.9	3.2	Nil	7.6	-	2.0	-	-	0.4
2.56	1.10	-	-	-	68.0	3.0	15.0	6.0	47.0	-	2.0	-	-	2.1
2.40	3.76	-	-	25.8	35.0	4.8	45.0	15.0	56.0	-	2.0	-	-	7.0
1.68	5.07	-	-	24.5	53.0	5.6	72.0	11.2	8.6	-	2.5	-	-	30.6
5.68	4.45	-	-	26.5	256.0	8.1	23.0	10.2	150.0	-	2.0	-	-	12.2
6.65	6.15	1.07	-	16.0	270.0	23.0	65.0	68.5	388.0	-	3.6	-	-	3.7
0.63	0.55	-	-	6.0	1.5	0.7	4.0	3.0	5.7	-	1.2	-	-	0.3
0.84	0.57	-	-	6.50	2.1	1.0	28.0	3.0	5.7	-	1.2	-	-	0
0.88	0.70	-	-	4.5	2.7	0.9	22.0	4.0	5.3	-	0.7	-	-	0.4
0.40	0.75	-	-	3.9	2.1	0.9	8.0	2.5	10.1	-	1.8	-	-	0.2
1.45	0.52	-	-	3.5	7.2	1.3	4.2	1.0	16.1	-	2.5	-	-	0.6
3.05	0.50	-	-	2.0	18.3	0.5	0.7	0.0	0.7	-	3.0	-	-	2.3

SELECTED MECHANICAL SOIL ANALYSIS DATA OF THE QASSIM

Exchangeable Cations Meg/100 gm. soil				Cation exchange capacity Meg/100 gm. soil	Soluble Cations meg/1				Soluble Anions meg/1					Boron PPM
Na	K	Ca	Mg		Na	K	Ca	Mg	Cl	CO ₃	HCO ₃	SO ₄	NO ₃	
9.23	3.85	-	-	15.4	1217.0	92.0	145.0	484	1247	-	6.2	-	-	0.9
17.2	3.2	-	-	14.1	582.0	46.0	97.0	47.6	541.0	-	4.0	-	-	0
20.34	2.1	-	-	24.1	360.0	33.5	40.0	322.0	-	-	3.0	-	-	0.1
10.35	5.54	-	-	23.9	1443.0	33.8	50.0	105.0	157.0	-	2.0	-	-	4.7
6.85	5.04	-	-	24.1	1173.0	29.6	55.0	42.0	1050	-	3.0	-	-	25.4
16.8	5.6	-	-	25.6	706.0	20.4	50.0	44.0	617.0	-	2.6	-	-	32.9
8.3	6.49	-	-	27.2	497.0	2.1	52.0	44.0	462.0	-	2.0	-	-	28.3
19.70	5.08	-	-	25.3	347.0	10.2	39.0	35.0	285.0	-	1.8	-	-	17.1
11.05	3.85	-	-	24.5	121.0	8.2	60.0	29.0	105.0	-	3.0	-	-	10.0
0.45	0.54	-	-	3.0	1.0	0.6	3.0	1.0	3.9	-	1.1	-	-	0.1
0.55	0.62	-	-	3.2	0.9	0.7	3.0	1.0	4.3	-	2.0	-	-	0.1
0.54	0.74	-	-	3.5	1.7	1.3	3.0	3.0	7.6	-	1.5	-	-	0.04
4.6	-	-	-	23.3	318.0	Nil	195.0	35.0	315.0	-	3.0	-	-	3.0
8.9	1.2	-	-	21.1	208.0	5.4	34.0	28.0	187.0	-	3.0	-	-	4.6
7.15	1.3	-	-	25.6	144.0	6.1	34.0	29.0	115.0	-	3.0	-	-	14.5
10.5	4.5	-	-	27.5	1043.0	51.1	76.0	73.0	1043.0	-	4.0	-	-	4.7
8.0	4.3	-	-	25.8	720.0	40.9	61.0	69.0	752.0	-	5.0	-	-	1.5
11.9	0.58	-	-	-	139.0	77.7	72.4	148.0	1405	-	4.0	-	-	2.8
20.3	1.1	-	-	-	902.0	53.2	81.0	62.8	907.0	-	3.0	-	-	0.7
14.0	1.2	-	-	-	726.0	29.6	74.0	58.2	728.0	-	4.0	-	-	1.8
4.6	0.9	-	-	12.1	428	12.8	64.0	48.0	420.0	-	3.0	-	-	1.6
14.2	4.57	-	-	26.6	539	28.1	234.0	53.0	787.0	-	8.3	-	-	3.3
18.3	5.52	-	-	23.0	1078	67.5	60.0	24.0	998.0	-	4.0	-	-	2.7
14.75	2.4	-	-	18.8	1017	60.8	76.0	37.0	1041.0	-	4.0	-	-	0.7
10.1	0.72	-	-	16.4	1252	59.3	68.0	104.0	1269.0	-	3.0	-	-	0.7
14.0	1.59	-	-	28.0	273	14.0	44.0	77.0	307.0	-	4.0	-	-	1.2
7.37	1.5	-	-	13.8	717.3	15.47	925	249	1614	-	2.45	-	-	0.35
5.26	1.3	-	-	13.8	446.0	6.04	592	168	1047	-	1.63	-	-	0.33
6.98	1.4	-	-	14.7	447.0	6.06	435	131	929	-	3.03	-	-	0.15

APPENDIX F

SUMMARY OF ARABLE LANDS DATA

Summary of arable lands data

Location	Total of arable lands/ hect.	Total of 2nd class lands/ hect.	Percentage of the total arable lands	Total of 3rd class lands/ hect.	Percentage of the total arable lands
<u>The Wadi Basin Zone</u>					
(a) Buraidah 26°15' 25°30' N. 43°45' 44°10' E.	13,120	555	4.3%	12,565	95.7%
(b) Aunayzah 26° 00' 26° 15' 43° 50' 44° 10'	9,026	642	7.1%	8,384	92.9%
(c) Ar Rarr of Bal a eq 25°50' 26°00' 43°25' 43°40' E.	13,926	-	-	13,926	100%
(d) Khabra of Helalyah 25°00' 26° 15' 43°30' 43° 50'	10,165	-	-	10,165	100%
(e) Ash Shayheyya 26°15' 26°30' 43°25' 43°45' E.	1,449	-	-	1,449	100%
Wadi Total	47,686	1,197	2.5%	46,489	97.5%

Summary of arable lands data

Location	Total of arable lands	2nd class total	2nd class percentage of the total	3rd class total	3rd class percentage of the total
<u>The Midhuab zone</u> 25° 30' 26° 00' N. 44° 00' 44° 30' E.	6,586	824	12.5%	5,762	87.5%
<u>Al Asyah zone</u> 26° 30' 27° 00' N. 43° 05' 44° 20' E.	8,892	1,178	13.2%	7,714	86.8%
<u>Ash Shemassyah zone</u> 26° 30' 26° 30' N. 44° 10' 44° 25' E.	12,454	45	0.4%	12,409	99.6%
<u>The Qusaiba zone</u> 26° 30' 27° 00' N. 43° 05' 44° 15' E.	7,500	1,610	21.5%	5,890	78.5%
Region total	83,118	4,854	5.8	78,264	94.2
<p>Source: <u>Land classification study's file, Parson-Basil Headquarters, Ar Ryadh, Saudi Arabia.</u></p>					

APPENDIX G

SUMMARY OF LAND HOLDINGS
IN THE QASSIM

Table 1. Summary of Land Holdings, in the Qassim.

Size of Holding	Owned Holding		Rented Holding		Rent of Owned Holdings		Total	
		%		%		%	No.	%
1-5 D.	341	8	13	2.2	1	1	355	7.2
5-10 D.	190	4.5	25	4.1	4	4.1	219	4.4
10-15	184	4.3	23	3.8	3	3.1	210	4.2
15-20	127	3	30	5	3	3.1	160	3.2
20-25	148	3.5	25	4.1	4	4.1	177	3.6
25-30	114	2.7	28	4.6	5	5.1	147	3.0
30-35	89	2.1	17	2.8	5	5.1	111	2.2
35-40	71	1.7	10	1.7	4	4.1	85	1.7
40-45	201	4.7	27	4.5	5	5.1	233	4.7
45-50	101	2.4	13	2.1	2	2	116	2.3
50-55	80	1.9	20	2.3	3	3	103	2.1
55-60	59	1.4	10	1.7	1	1	70	1.4
60-65	78	1.8	20	3.3	-	-	98	2.0
65-70	51	1.2	10	1.7	3	3	64	1.3
70-75	43	1	10	1.7	2	2	55	1.1
75-80	31	0.7	5	0.8	1	1	37	0.7
80-85	119	2.8	14	2.3	-	-	133	2.7
85-90	54	1.2	14	2.3	1	1	69	1.4
90-95	74	1.7	5	0.8	-	-	79	1.6
95-100	33	0.8	4	0.7	1	1	38	0.8
Over 100	2072	48.6	281	46.5	51	51.2	2404	48.4
Total	4260	100 %	604	100 %	99	100 %	4963	100 %

Source: The Agricultural Survey of the Region of al-Qassim. 1961-62.

Statistics Department, Ministry of Water and Agriculture. (Arabic)

APPENDIX H

AGRICULTURAL STATISTICS

Table # 1

**Area and type of holdings in the agricultural
districts of the Qassim.**

District	Total area of holdings in hect.	Percentage of the region's total area.	Types of holdings			
			Owned		Rented	
			Area in hect.	Percentage of the region's total.	Area in hect.	Percentage of the region's total.
	269,574	100	244,609	100	24,962	100
Ar Russ	158,637	58.8	147,061	60.1	11,576	46.3
Braydah	91,587	34	81,126	33.1	10,460	42
Aunayzah	19,349	7.2	16,422	6.8	2,926	11.7

Source: Data computed from figures given in the

Agricultural Survey of the Region of
al-Qassim, 1961 - 62.

Department of statistics and agricultural economics.
Ministry of Water and Agriculture. (Arabic)

Table 2. Crop's area and production in the agricultural districts in the al-Qassim

1961-62

District	Area in hect.	Percentage of the region's total area	Average yield per unit in/kg.	Total production in/tons	Percentage of the region's production
<u>1. Permanent crops</u>					
(a) Alfalfa	7,846	100	110,000	863,060	100
Ar Russ	2,725	34.7	110,000	299,750	34.7
Aunayzah	2,638	33.6	110,000	290,180	33.6
Braydah	2,483	31.7	110,000	273,130	31.7
(b) Fruit trees	2,645	100			
Braydah	1,551	58.6	X	X	X
Ar Russ	661	25			
Aunayzah	433	16.4	X	X	X
<u>2. Vegetables</u>					
Ar Russ	8,300	100	X	X	X
Braydah	5,225	62.9	X	X	X
Aunayzah	2,428	29.2	X	X	X
	647	7.9	X	X	X
					66,778

Table 2. (Contd.). Crop's area and production in the agricultural districts of al-Qassim

District	Area in hect.	Percentage of the region's total area	Average yield per unit in/kg.	Total production in/tons	Percentage of the region's production
<u>3. Field crops</u>					
(a) Wheat	15,568	100	1,558	24,086	100
Ar Russ	9,009	57.8	1,540	13,875	57.6
Braydah	3,703	23.7	1,345	5,093	21.1
Aunayzah	2,856	18.5	1,790	5,118	21.2
(b) Barley	1,603	100	211	3,380	100
Ar Russ	696	43.5	213	1,482	43.8
Braydah	593	36.9	182	1,149	34
Aunayzah	314	19.6	238	749	22.2

X Unavailable data.

Source: Agricultural survey of the region of al-Qassim, 1961-62. Department of Statistics and Agricultural Economics, Ministry of Water and Agriculture (Arabic.)

Table 3. Number and date production of productive palm-trees in the agricultural districts of al-Qassim

1961-62

District	No. of productive palm-trees	Percentage of the region's total number	Average yield kg/tree	Total production in/tons	Percentage of the region's total production
	556,558	100	41.3	27,568	100
Braydah	329,354	59	45	14,943	54.2
Aunayzah	122,313	22.2	42	7,192	26
Ar Russ	104,891	18.8	37	5,433	19.8

Source: Agricultural survey of the region of al-Qassim, 1961-62
 Department of Statistics and Agricultural Economics, Ministry of Water and Agriculture. (Arabic).

Table 4

TRENDS IN AGRICULTURAL PRODUCTION

(Area in hectares; Output in tons; Value in 1960 S.R. Prices)

<u>Crops</u>	<u>CROPPED AREA</u>				<u>Compound Early Growth Rate (per cent)</u>
	<u>1949/50</u>	<u>Relative Share</u>	<u>1960/63</u>	<u>Relative Share</u>	
Field Crops (excludes alfalfa)	67,838	.71	175,929	.72	7.6
Vegetables	4,128	.04	33,132	.14	17.4
Dates	21,752	.23	22,281	.09	.2
Fruits	2,226	.02	11,487	.05	13.5
All Crops	95,944	1.00	242,829	1.00	7.5
<u>O U T P U T</u>					
Field Crops (excludes alfalfa)	71,300	.20	236,235	.27	9.7
Vegetables	29,226	.08	345,485	.40	21.0
Dates	250,000	.70	257,606	.29	.2
Fruits	5,565	.02	34,461	.04	15.1
All Crops	356,091	1.00	873,787	1.00	7.2
<u>VALUE OF PRODUCTION (SR 000)</u>					
Field Crops (excludes alfalfa)	25,303	.19	94,794	.24	10.7
Vegetables	13,816	.10	168,079	.43	21.2
Dates	90,000	.67	92,738	.24	.2
Fruits	5,342	.04	33,083	.09	15.1
All Crops	134,461	1.00	388,694	1.00	8.5

Source: Agricultural Production in Saudi Arabia
by George S. Medawar. July, 1964.
Economic Research Institute, American University,
of Beirut.

APPENDIX I

IRRIGATION WATER DATA

Table 1.

Summary of Wells' Conditions in the Qassim

Summary	Wells total no.	Part of total percent.
<u>Source of Water:-</u>		
Flowing Artesian	202	12.0%
Non-flowing Artesian	717	42.0%
Unconfined (Phreatic)	803	46.0%
Total	1722	100 %
<u>Type of Wells:-</u>		
Hand Dug	803	46.7%
Dug Drilled	539	31.3%
Drilled	380	22.0%
Total	1722	100 %
<u>Use of Water:-</u>		
Irrigation	787	45.8%
Domestic & Irrigation	566	32.9%
Domestic	081	4.7%
Unused	097	5.6%
Abandoned	191	11.0%
Total	1722	100 %
<u>Method of Producing Water:-</u>		
Pumping	1227	71.3%
Flowing	0202	11.7%
Hand Bucket	0005	0.3%
Unused	288	16.7%
Total	1722	100 %

Source: Wells Inventory Files. Parson-Basil Headquarters, 1967.
Ar Rivadh. Saudi Arabia.

Table 2. Water classification of the Qassim region

Aquifer	TDS PPM	EC ECX10 ⁶	SAR	B PPM	Class
Phreatic	2880	3480	7.9	1.1	C ₄ -S ₃
	3365	4525	7.7	1.4	C ₄ -S ₃
	4385	5955	9.0	3.3	C ₄ -S ₃
	1940	2905	7.8	0.9	C ₄ -S ₂
	3860	4755	7.7	1.1	C ₄ -S ₃
Jilh and Khuff	2890	3635	7.4	0.4	C ₄ -S ₂
	2040	2950	14.5	1.1	C ₄ -S ₄
	4040	6208	15.3	1.1	C ₄ -S ₂
Tabuk	925	1500	3.4	0.8	C ₃ -S ₁
	680	1085	5.7	0.3	C ₃ -S ₂
	720	1220	4.4	0.4	C ₃ -S ₁
	1175	1775	7.3	0.6	C ₃ -S ₂
	1060	1455	3.2	0.5	C ₃ -S ₁
Saq	825	1140	5.0	0.35	C ₃ -S ₁
	755	1070	4.8	0.35	C ₃ -S ₂
	660	1125	3.5	0.5	C ₃ -S ₂
	580	970	3.2	0.5	C ₃ -S ₁
	850	1310	4.1	0.35	C ₃ -S ₁

C. for salinity. S. for sodium.

Source: Emergency area, Eighteen months report Area 1, Qassim, Wadi Sirham, and Tabuk
Ministry of Agriculture and Water, 1965.

APPENDIX J

SOIL PROFILE DESCRIPTION SHEETS

Soil SurveyThe region of al-Qassim, Saudi Arabia, August 1967Descriptions of Individual ProfilesI. Information on the site sampled

- (a) Profile number.
- (b) Soil and home.
- (c) Higher category classification.
- (d) Date of examination.
- (e) Location.
- (f) Elevation
- (g) Land - Form
 - (i) - Physiography position of the site.
 - (ii) - Land - Form of surrounding country.
- (h) Slope of which profile is sited.
- (i) Vegetation or land use.
- (j) Climate

II. General information on the soil

- (a) Parent material
- (b) Drainage.
- (c) Moisture conditions in the soil.
- (d) Depth of ground water table.
- (e) Presence of surface stone or rock outcrops.
- (f) Evidence of erosion.
- (g) Presence of salt or alkali.
- (h) Human influence.

III, Description of individual soil horizons

- (a) Horizon symbol.
- (b) Depth of top and bottom of horizon.
- (c) Colour
 - (i) - Moist
 - (ii) - Dry
- (d) Colour mottling.
- (e) Texture.
- (f) Structure.
- (g) Consistance
 - (i) - Wet
 - (ii) - Moist
 - (iii) - Dry
- (h) Cutans
 - (i) - Pet coating, pressure facere, sliekensider, etc.
- (i) Cementation, if any.
- (j) Pores.
- (k) Content of mineral nodules.
- (m) Pans.
- (n) Content of carbonates, salts, etc.
- (o) Artefacts.
- (p) Features of biological origin.
- (q) Content of roots.
- (r) Nature of boundary with horizon below.
- (s) PH.
- (t) Number of sample taken for analysis.

BibliographyA. BOOKS

- Abul-Ola, T. M. Geography of Saudi Arabia
Dar al-Bayau, Cairo, 1965.
(ARABIC)
- Abul-Ola, T. M. A research on the economic
development possibilities of
Saudi Arabia
Dar al-Bayau, Cairo, 1966.
(ARABIC)
- Armstrong, H. C. Land of Arabia
Ichayat's College Book
Co-operative, Beirut, 1934.
- Daughy, C. M. Travels in Arabia Deserata
London, 1935.
- Hamzah, F. The Heart of Arabia
Cairo, 1933. (ARABIC)
- Intelligence Staff A Handbook of Arabia
Geographical section of the
Naval Intelligence Division,
Naval Staff, Admiralty.
His Majesty's Stationery Office,
London, 1920.
- Kahhala, O. R. Geography of Arabian Peninsula
Damascus, 1944.
(ARABIC)

- Keen, B. A. The agricultural development of
the Middle East
His Majesty's Stationery Office,
London, 1946.
- Libsky, G. A. and others Saudi Arabia
One of survey of World Culture,
Harf Press, New Haven, 1959.
- Palgraved, W. G. Narrative of a year's journey
through Central and Eastern Arabia
London, 1866.
- Philby, St. J. B. The Heart of Arabia
London, 1922.
- Reifenburg, A. The struggle between the desert
and the sown: rise and fall of
agriculture in Levant
Jerusalem, Government Press, 1955.
- Sanger, R. H. The Arabian Peninsula
Ithaca: Cornell University, 1954.
- Shcich, I. Geographical factors in Arabian
life and history
Lahore, India, 1942.
- Shamma, S. The law of income tax and zakat in
Saudi Arabia
Dar al-Ahad, Beirut, 1951.
(ARABIC)
- Thomes, B. Arabia Felix
New York, Scribners, 1932.
- Twitchell, K. S. and
Jurgi, E. Saudi Arabia, with an account of
the development of its natural
resources
N.J. Princeton, 1953.

B. ARTICLES AND OTHERS

- Amer, M. The Oases of Central Arabia, with special reference to trade and pilgrim routes
Unpublished M.A. thesis,
Department of Geography,
University of Liverpool,
May, 1921.
- Albrecht, W. A. Soil fertility and biotic geography
The American Geographical Review,
1957, Vol.XLVII (p.86-105).
- Basinki, J. J. The Russian approach to soil classification and its recent development
The Journal of Soil Science,
1959, Vol.10.
- Beer, F. E. and others A new system of soil classification
Soil Science, 1963, Vol.96
(p.p.1-37)
Rutgers University, N.J., U.S.A.
- Bennet, H. H. The Geographical relation of soil erosion to land productivity
The Ameri.Geogr. Review, 1927,
Vol.XVIII.
- Chisholm, M. Problems in the classification and use of farming - type regions
Transactions and papers, (pp.
91-103).
The Institute of British
Geographers, 1964.
- Cornwell, P. B. Ancient Arabia
The Geogr. Journal, 1946,
Vol.CVII, (pp.28-50).

- Dan, J. and
Koyumedjisky
- The soils of Israel and their
distribution
The Journal of Soil Science, 1963,
Vol.14.
- Dan, J. and others
- The soils and soil association map
of Israel
Typed publication,
The Hebrew University of
Jerusalem, 1962.
- Dan, J. and
Koyumedjisky
- Principles of proposed classification
for the soils of Israel
Special Bulletin, 24, 1959.
Agricultural Research Station
of Rehovot.
- Davis, W. M.
- Geomorphology of mountain deserts
16th Inter.Geol.Congress, 1933.
Vol.II (pp.703-714).
- Dryan, K. and
La Rue, E. C.
- Persistence of feature in arid
landscape
The Amer.Geogr. Review, 1927m
Vol.XVII.
- Glubb, J. B.
- The bedouins of Northern Arabia
(misprinted as Iraq)
Journal of the Royal Central
Asian Society, 1939, Vol.XXII.
- Halm, H. M.
- The agricultural resources of the
Arabian Peninsula
(Unpublished mimeograph).
U.S.D.A.
Washington, 1955.
- Hatcher, J. J. and
Bower, C. A.
- Characterization of salt affected
soils with respect to sodium
Soil Science, 1962, Vol.93.
Rugters, University, N.J., U.S.A.

- Hogarth, D. G. Some recent Arabian explorations
The Amer. Geogr. Review, 1921,
Vol. XI.
- Johnson, D. Rock plains of arid regions
The Amer. Geogr. Review, 1932,
Vol. XXII (pp.656-665).
- Kedar, Y. Water and soil from the desert
The Geogr. Journal, 1957.
Vol. CXXIII.
- McNeal, B. L. and
Stansaterra, T. Mineralogical examination of arid-
land soils
Soil Science, 1964, Vol.97
(pp.367-375).
Rugters University, N.J., U.S.A.
- Papadakis, J. Some consideration on soil
classification
Soil Science, 1962, Vol.94
(pp.115-120).
Rugters University, N.J., U.S.A.
- Peel, R. A. The landscape in aridity
Transactions and papers, 1966
(pp.1-21).
The Institute of British
Geographers.
- Peel, R. A. Denudational landforms of central
Libya desert
Jour. of Geomorphology, 1941,
Vol. IV (pp.3-23).
- Philby, St.J. B. Southern Najd
The Geogr. Journal, 1920,
Vol. IV.
- Philby, St.J. B. Two notes from Central Arabia
The Geogr. Journal, 1949.
Vol. CXIV.

- Popence, P. The distribution of the dates-palm
The Ameri. Geogr. Review, 1926,
Vol.XV. (pp.117-121).
- P.P.S.B. Changing Arabia: Significant factors
in the impact upon Saudi Arabia
Life and Economy of soil develop-
ment
Petroleum Press Services Bulletin
No.XX, New York, 1953.
- Pepelasis, A. A. and
Thompson, K. Agriculture in restrictive environ-
ment
Economic Geography, 1960.
(pp.145-157).
- Raswan, C. R. Tribal areas and migration lines
of the North Arabian Bedouins
The Amer. Geogr. Review, 1930,
Vol.XX.
- Ravikovitch, F. and
others Desert soils of Southern Israel;
the central and southern Negev
Typed publication, 1965.
Agricultural Res. Station of
Rehavat.
- Rutter, E. A journey to Hail
The Geogr. Journal, 1932,
Vol.LXXX.
- Santi, S. P..A. Sajir-Buraidah road, final project
General roads administration,
Ministry of Communication,
Typed report, Ar Riyadh, 1964.
- Santi, S. P. A. Buraidah-Salbukh road
General roads administration,
Ministry of Communication,
Typed report, Ar Riyadh, June,
1965.

Stoddard, P.

An economic survey of Saudi Arabia
Typescript in the Library of
the Central Planning Organization,
Saudi Arabia, Ar Riyadh, 1951.

Tannous, A.

Land reform: Key to the development
and stability of the Arab World
Middle East Journal, No.1, 1951.

U.S.D.A.

Economic development in Saudi
Arabia, 1954
Bureau of Foreign Commerce,
World Trade Information Service,
Economic report, Part 1, No.55-58,
Washington, Government Printing
Office, 1955.

Wilson-Murrow Inc.

Report on:
al-Qurayn-Buraidah road,
Ar Russ-Riyadh al Khabra road,
Qassim airport-Aunayzah road
General ranks administration,
Ministry of Communication,
Jeddah, 1965.

Wright, J. K.

Northern Arabia
The Amer. Geogr. Journal, 1927,
Vol.XVII (pp.177-206).

C. UNITED NATIONS' AGENCIES PUBLICATIONS

- F.A.O. Mediterranean Development Project
Rome, 1959.
- F.A.O. Agriculture in the Middle East:
Development and Outlook
Rome, 1956.
- F.A.O. Classification and rational
utilization of Soils, Syria
by Liere, W. J.
Typed publication, EPTA report
No.2075, Rome, 1965.
- F.A.O. Outline of great soil groups of
Syria
by Liere, W. J.
Typed publication, Report SYR/7,
Rome, 1953.
- F.A.O. The soils of East Jordan
by Moormann, F.
Typed publication, project
JOR/TE/LA, report No.1132,
Rome, 1959.
- F.A.O. Report on Saudi Arabia
(Unpublished mimeograph).
by Oedekoven, K. H.
Rome, 1960.
- F.A.O. Second report on Saudi Arabia
(Unpublished mimeograph)
by Oedekoven, K. H.
Rome, 1961.
- F.A.O. Soil of the arid zone of Chile
Soils Bulletin No.1,
Rome, 1965.

F.A.O.

Soil conservation and agricultural
engineering, IsraelTyped publication, EPTA report
871, Rome, 1958.

I.B.R.D.

Approach to economic development
of Saudi ArabiaInter. Bank for reconstruction
and development, New York, 1960.

UNESCO

A history of land use in arid regionsby Stamp, D.
Paris, 1964.

UNESCO

The problems of the arid zoneArid Zone Research,
Paris, 1962.

Base Materials for Figures

- Figure 1 Arabian Peninsula, map 1-270 B-2
Ministry of Petro. and Miner. Resources,
1963.
- Figure 2 (a) Geographic map of the Wadi Ar Rmah
Quadrangle, Kingdom of Saudi Arabia.
Map No. 1-206B.
Ministry of Petro. and Miner. Resources,
1960.
- (b) Roads Map of Najd, Map No.0-3-7
Research Unit,
Ministry of Communication, 1967.
- Figure 3 Map of Main Geologic Structure of Saudi
Arabia, Map No.GS-R-64, Ministry of
Petro. and Miner. Resources, 1960.
- Figure 4 Modified from a figure showing the outcrop
sequence of Saudi Arabia, included in a
report titled as:
- Sedimentary Section of Geology
of Saudi Arabia.
Aramco, 1958.
- Figure 5 Geologic Map of the Wadi Ar Rmah
Quadrangle, Kingdom of Saudi Arabia.
Map No.1-206A.
Ministry of Petro. and Miner. Resources,
1960.
- Figure 6 Geographic map of the Wadi Ar Rmah
Quadrangle, Kingdom of Saudi Arabia,
Map No.1-206B.
Ministry of Petro. and Miner. Resources,
1960.
- Figures 7, 8, 9 Climatic data of Aunayzah's station.
and 10

Figures 29, 30 and
31

The Agricultural survey of the Qassim,
1960/61.
Statistics Department, Ministry of
Agriculture, 1962.

Figures 32 and 33

An emergency report on Area 1, Saudi
Arabia. Parsons-Basil, 1966.