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SOILS AND SOIL CONDITIONS IN IRAQ

1960

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BY

DR. P. BURINGH

SOIL SURVEY AND CLASSIFICATION SPECIALIST

الجمهورية العراقية

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SOILS AND SOIL CONDITIONS IN IRAQ

REPUBLIC OF IRAQ
MINISTRY OF AGRICULTURE
DIRECTORATE GENERAL OF AGRICULTURAL RESEARCH AND PROJECTS

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BAGHDAD 1960

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FOREWORD

Recent archeological discoveries have revealed that the steppe area that lies in the North Eastern Section of Iraq, adjacent to the caves along the foothills and valleys of the Zagros mountains, had served in ancient time, 150,000 years ago, as dwelling sites for prehistoric man. These same sites, the study further revealed, witnessed the transformation of man the food-gatherer to man the food-producer. On the basis of these historic findings it can be deduced that the earliest practice of land use was first applied in our country.

During the course of history other segments of our country have also been famous for having a flourishing agriculture. Significant in this respect are the Sumerian, Akkadian, Babylonian and Assyrian cultures.

Lateron, during the Abbasid Caliphate, there was another famous period in the agricultural development marked by a wide extension of irrigation and a high level of crop production. It is recorded that the granaries at this time stored enough grain to feed a population more numerous than its present extent.

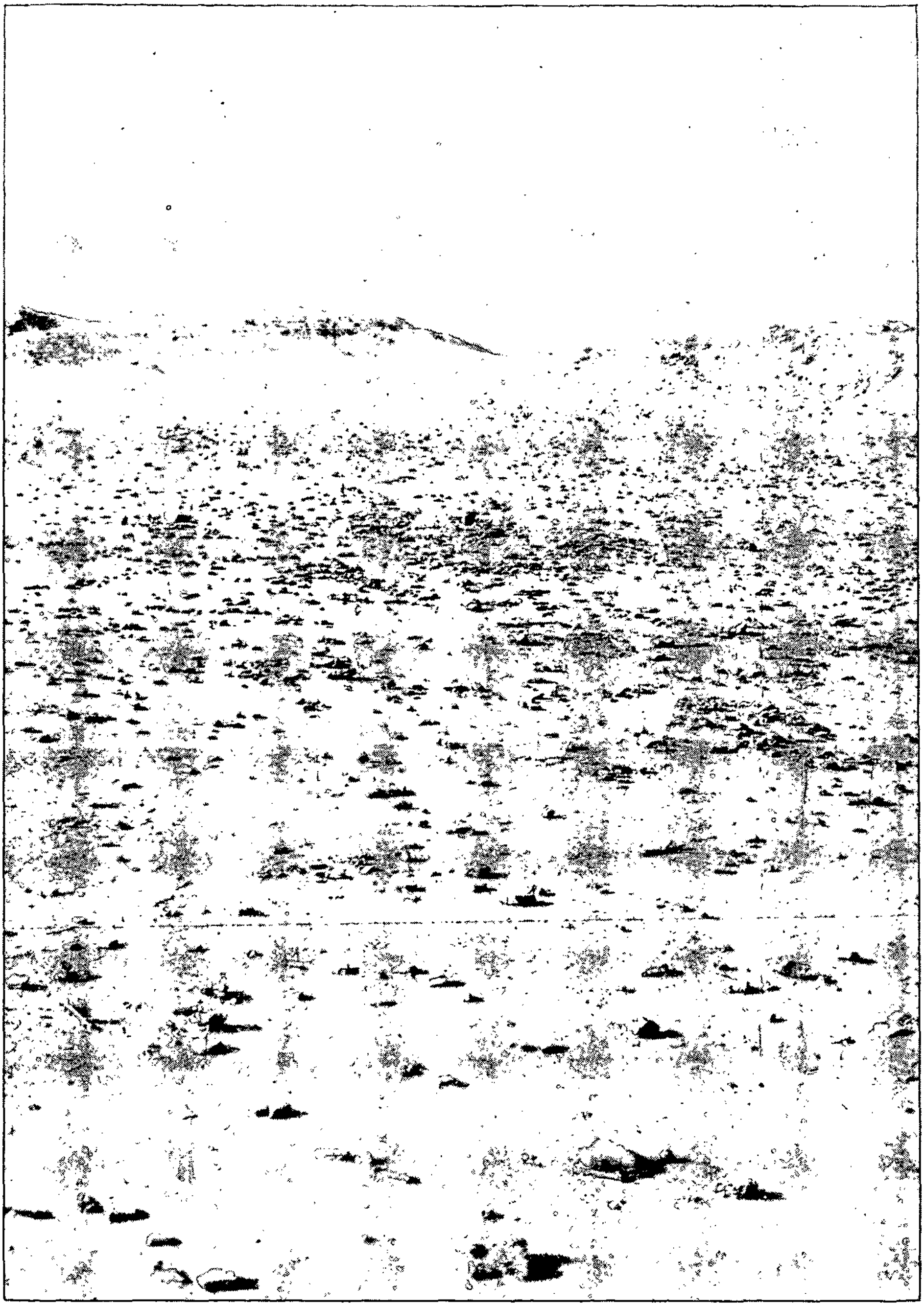
In accordance to the above Iraq could be described as the seat for rich potentials in agricultural land resources. These land resources if soundly managed would materialise a prosperously balanced economy to our nation. It is, therefore, imperative for those who are concerned with the development of the country's agriculture to be guided by a reliable evaluation of the soils.

It is on the basis of collected fundamental physical, chemical and biological data that characterise the inherent features of the different soils and the manner of their distribution in the field that the agricultural technicians would accordingly delineate a judicious course of action. This course of action has for main purpose the promotion of proper methods of land use which are consistent with the aims of a successful economy. It was evidently this latter aspect that the author Dr. Pieter Buringh, specialist in soil science, had set as a criterion to his book.

It is indeed a pleasure for me to express my appreciation to the author for providing this basic reference work to those who have interest in the scientific, technologic, social, economic and educational fields of our country. I am sure that this book shall constitute a positive asset to all who seek the advancement of agricultural sciences and technology of Iraq.

Abdul Wahab Amin
Minister of Agriculture
Republic of Iraq

Baghdad, April, 1960



A gigantic task is being undertaken by the people of Iraq, to rebuild a new country on the ruins and debris of various ancient civilisations.

PREFACE

This book has been written in order to compile the present knowledge on soils and soil conditions of Iraq and to make it available primarily for the Government, its technicians and specialists, who need information on soils for their work in the development of the country, and secondly for the students of the Agricultural College, who are specialising in soils.

The study of soils in Iraq is very new; not all problems on soils could be solved in a period of a few years, during which work often had to be done under rather primitive conditions and with simple tools. This book leaves room for many critical remarks and questions in relation to the information which has not been given, simply because it has not been available so far. A start has been made; the possibilities for carrying out more surveys and also more intensive investigations are rapidly increasing. It is now up the Iraqi soil specialists, probably with foreign help during some more years, to continue the soil investigations, which are one of the fundamentals on which the development of Iraq has to be based.

Baghdad, January, 1958

Since the manuscript of this book was completed the political situation in Iraq has been changed, therefore a few minor corrections have been made in chapter 1 and 2.

Wageningen, the Netherlands, January, 1960

ACKNOWLEDGEMENTS

Numerous people have contributed to this book, as much was learned from talks with Iraqi and foreign specialists and officials, and in particular from local people. It is impossible to mention them all. I first wish to express my warm thanks to all, especially for their kindness, helpfulness, friendship and hospitality. The Director Generals in the Ministry of Agriculture and the Fourth Technical Section of the Development Board, in charge during the time of my stay in Iraq (March 1955–March 1958), have given full support to the development of the soil investigations and in particular to my work. This is highly appreciated and I am glad to have had the opportunity to understand something about the enormous problems that the Government is dealing with during the rapid development of the country.

I am very grateful for the discussions on various soils problems with Professor J. C. Russel, Professor in Soil Physics at the Agricultural College and with Dr. Louya Thasin Kadry, soil chemist and Director of the Division of Soils. These discussions have contributed to my knowledge on the soils of Iraq. I was glad to have had the opportunity to lecture on the soils of Iraq in the Agricultural College too.

I wish to express my warm thanks in particular to Dr. Louya Thasin Kadry, who took over the Directorship of the Division in 1955. There was always a close co-operation, a full understanding and a unity in our work.

Thanks are also due to the assistant specialists and assistants of the Division, in particular to Isa Al Jobury B.Si., Manie Al Athari B.Si., Rhadi Al Obaidi B.Si., and Saad Al Deen Abdulgani B.Si. with whom I worked in the field in various parts of Iraq. Their friendship and help is highly appreciated.

Finally, Mrs. Buringh and I wish to express our warm feelings for the country and its hospitable people. We have tried to understand the social and physical conditions and problems, and we will always feel that the opportunity to work for a few years in Iraq has contributed much to our happiness.

CHAPTER 1

IRAQ, ITS DEVELOPMENT AND SOILS

1.1. Some characteristics of the country

The young Republic of Iraq is one of the few countries in the world having a prosperous future, although the greater part of the country has an arid climate and large areas consist of real deserts. A part of this arid area consists of the fluviatile deposits of the Euphrates and Tigris rivers, forming the extensive Lower Mesopotamian Plain, the birth place of the world's civilization, and the home land of Abraham. Rainfall in this plain is too low to cultivate land without irrigation. The rivers supply water to irrigate the land. Sometimes in spring, disastrous floods occur, destroying villages and crops. In the north-eastern part, which is hilly and mountainous, precipitation is sufficient for winter cultivation.

Natural vegetation is scarce, due to the arid climate. In the northern part of the country extensive grazing lands and forests once occurred, but most of them have been destroyed.

The country is thinly populated with approximately 6 million people, most of them poor and illiterate farmers, until recently living under feudal conditions and having a very low standard of living.

Since the time of the Kalif Haroun Al Rashid, some seven centuries ago, when Iraq was for the last time a world centre of commerce, culture and science, up to some twenty-five years ago the people were living under foreign domination. It was a period of oppression, wars, invasions and internal troubles. In 1932 Iraq became an independent country. Since then the country developed gradually until 1951, when the Government of Iraq was sharing the revenues of the oil, which had already been flowing in this country since April 1927. The Government decided to spend the money on the development of the country, for which purpose a Development Board was set up. The oil revenues are increasing and the development is continuing rapidly. In 1958 Iraq became a Republic.

The country has water, land, money, an increasing population, and an increasing number of technicians and specialists. All these features are very promising for the future.

1.2. Social-economic aspects and soils

The population of Iraq is gradually increasing, especially during the last twenty years. The crude birth rate is high (about 50) and is expected to remain during the next few decades on this high level; the crude death rate (about 30) is still high; however, it is declining as a result of better medical treatment, better drinking water, more education, etc. Therefore it is expected that the total population will increase rather rapidly and within some generations it may become five or even six times the

FIG. 1. Irrigating barley land near Baghdad. As a result of irrigation, the soils in Central and Southern Iraq gradually become saline.

present population (Adams, 1956). According to Valkenburg (1954) Iraq can support 20 to 25 million people. A thin population at the beginning of a promising period will prove to be one of the main advantages for the development of the country.

At the present time the agricultural production in Iraq is low and too low to feed the present population. With an increasing number of people and a rising standard of living, the quantity and the quality of food has to be increased, and consequently the system of farming has to be improved.

It is evident that the success of the development of the country depends on a large number of factors, and that a well-balanced development is possible only if attention is paid to all factors in all stages of executing the programme. The quantity and quality of water and land available for agricultural production are two fundamental factors on which the economy of the country is mainly based. According to experts, the quality of the water of the Twin rivers is good and it is available in sufficient quantities. Many hydrological studies have been made and the first stage of the development, which at present is in progress, is mainly concentrated on flood control and water regulation in order to avoid disastrous floods and to store water for irrigation in the dry summer season.

Up to recently not much attention was paid to the soil and soil conditions in relation to the agricultural productivity, a subject on which a few Iraqi and foreign specialists are working at present. It is generally believed and very often written, that the large Mesopotamian Plain consists of fertile land, suitable to produce food for millions of people, as it did in ancient times. It will be explained later that this statement is wrong. The plain is not fertile at all and even the potentialities are much lower than is expected. Almost all soils are saline, most of them even strongly saline and large areas are out of production. The process of salinization still continues and it will even increase when floods are controlled.

It is well known that soil conditions vary everywhere in the world, in particular in fluviatile plains. The Tigris-Euphrates Plain is no exception at all. Even if all salts could be washed from the upper few meters of the soil, there would be productive and unproductive land. It is estimated that 20% of the land in the Lower Mesopotamian Plain can be made highly productive, 40% medium productive and 40% will still remain marginal land.

If the idea of drainage of soils is generally accepted and reclamation works, with more intensive drainage systems as are planned at present, are carried out, a big change in farm management has to be made. Under the prevailing physical conditions, soils always will tend to become saline again. For the improvement of the areas which at present are cultivated, a new irrigation system should also be made, as it is almost impossible to make an effective drainage system in an area with an existing complicated irrigation system. Within a few years it will be realised that the real improvement of

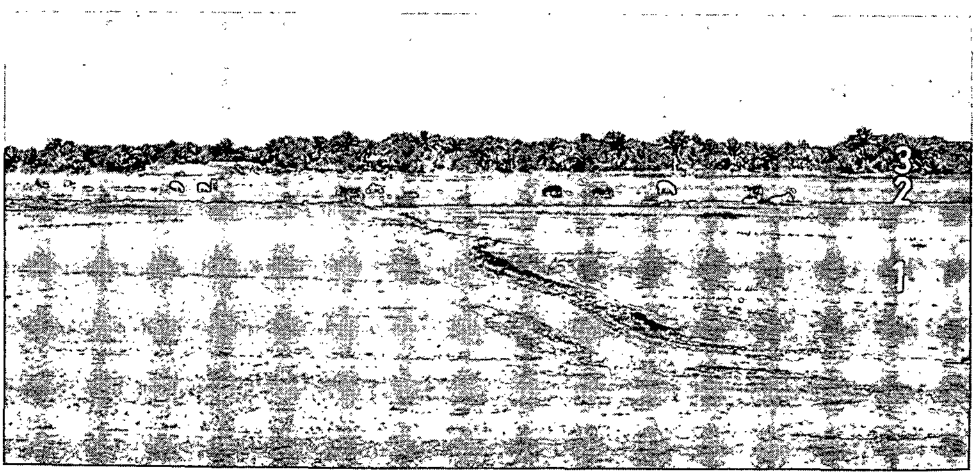


FIG. 2. Strongly saline land north of Hilla. There is a white salt crust on the surface in the basin depression (1) and the land is out of production. In the background there are saline crop and grazing land (2), and date and fruit gardens (3) on the river levee soils near the Euphrates river.

the cultivated areas can be made only if a re-allocation of land is carried out at the same time.

A few problems are indicated to demonstrate that the soil productivity of central and southern Iraq is low, that it is still declining and that it will be difficult but not impossible to improve those conditions.

The situation in northern Iraq seems to be better, as there is almost no salinity problem; however, soil erosion is rather intensive. This destructive process is not going on as fast as it is sometimes stated. In comparison to many other countries the effect of soil erosion in Iraq during one year is not so high. The total effect during a long period is enormous, as may be learned from some recent data published by Gibbs (1954).

TABLE 1. *Soil Erosion in Iraq* (after Gibbs, 1954).

Type and Degree of Erosion	Total Land Area
serious water erosion	12%
serious wind erosion	20%
moderate water erosion	10%
moderate wind erosion	50%
little or no erosion	8%

It is expected that in the near future, soil erosion will become more intensive than it was in the past. A full explanation of the problem is given in Chapter 8. Due to an increasing population, a higher standard of living and better economic conditions, farming will be intensified. The process of shifting cultivation and over-grazing will continue and soil erosion will increase considerably. The acceleration of this process has already started since the time the country started its development. Here, too, the productivity of land is gradually decreasing. There are even more examples of serious mismanagement of land in Iraq.

The overall picture of the soils and of the land use in Iraq is a rather poor one, as destruction continues and is increasing up to now.

The rapid increase of the population (3.5% annually) and the change in economic conditions are facts. The technical and economic development continues. The development of the agriculture in Iraq chiefly depends on water and the productivity of the soils. An increase in production is necessary and the conclusion from the soil studies is that soil productivity is decreasing.

The reclamations undertaken by the Government during recent years are almost all a failure (Ali, 1956). There are several reasons – economic, social and especially technical – causing these failures. Some of the mistakes made could have been avoided; however, the country is young and it is necessary to get some experience, for development planning is really difficult.

Although most farmers of Iraq are poor, illiterate and living under bad conditions, it should be realised that most of them are farming according to systems, which

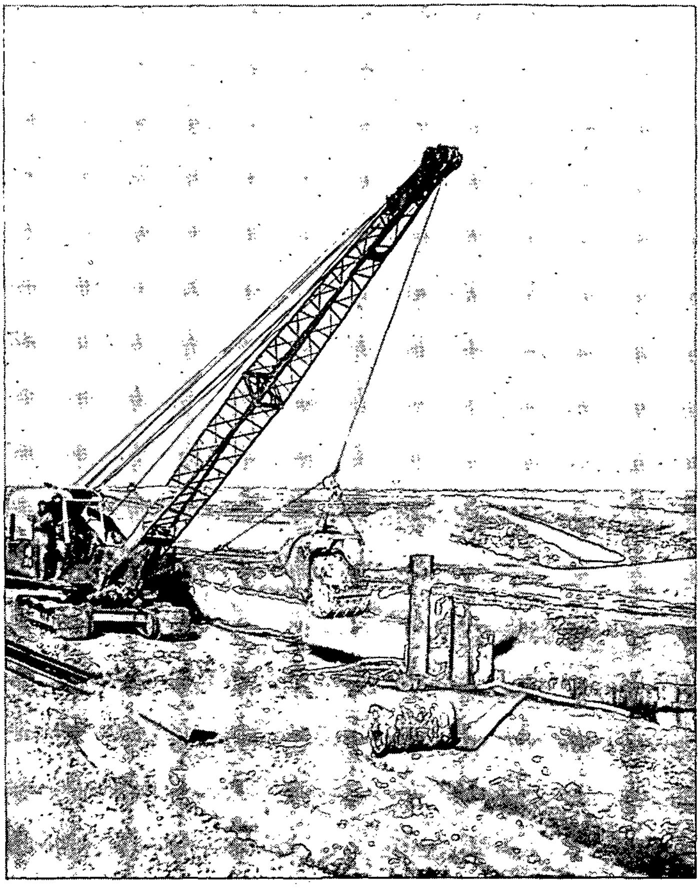


FIG. 3. Dredging a main drain in the Tuwarij drainage project. Drainage is the only way of improving saline soils. 150,000 km. of main drains are required for the development projects in Iraq. The main drain will carry off the saline water.

nearly always are adapted to the environmental conditions. The influence of the feudal system on agriculture in Iraq or in the Middle East in general has often been criticised; some of the facts pointed out will be right. However, it is not easy to change such social conditions, as they are based on imperative and historical facts. Irrigation in ancient and also in present times requires co-operation of farmers, in particular of those living in an area irrigated as one unit. In the past and at present those irrigation units are closely related to soil conditions. As long as there is no strong central government, each unit is more or less independent; it is a unit of fiscal, judicial and military administration, with a chief taking care of the welfare of his people. In Iraq a central government is growing and it has taken over the task and consequently also the responsibilities of the tribal chiefs. This is done to establish a democratic country and to develop it. The feudal system is eliminated recently. From the point of view of flood control, improving the irrigation and in particular for the introduction of drainage systems, a central government is a necessity. Those works only can be carried out if the whole river system, the land in its catchment area and the possibilities to develop them are taken into consideration, and a well-balanced plan is set up.

FIG. 4. Aerial photograph of gullied land west of Tuz. Due to climatological conditions, overgrazing and shifting cultivation, there is no protected grass cover in this semi-arid region. Heavy showers in winter and spring have caused severe soil erosion. The eroded material has been transported to the Tigris river. 1. Deeply gullied land; 2. non-gullied arable land; 3. roads.

The cost of a simple irrigation system to bring water to the land in the irrigated area in Iraq is estimated at approximately ID. 1,500 per donum (one Iraqi Dinar = one English pound; one donum = one meshara = one quarter of a hectare). In newly reclaimed land of the development projects, the cost of bringing the water to the land and of carrying the drainage water through a special drainage system from the farm (not including the field ditches and drains on the farm itself) is ID. 25 to ID. 35 per donum. This investment is rather high. From an economical point of view, much more income should be expected on newly reclaimed land than on land with an old irrigation system. In the older irrigated areas the fallow system of farming and even shifting cultivation is practiced, due to the salinization and silting up of the soils. As long as the cost of technical work is low, this can be done. If, however, large amounts of money are invested in new areas, both in irrigation and drainage, land use has to be intensified and shifting cultivation has to be abandoned. This is possible only if the soil is productive and if it remains in a good condition for a long period.

For northern Iraq, a soil conservation and economic land use plan has to be set up in order to tackle the problem of soil erosion and shifting cultivation. This, too, can be done only by a central government. Although the technical problems are quite different, the social and economic aspects are similar to those of southern Iraq. Shifting cultivation not only has to be eliminated from the point of view of maintaining soil productivity, but also from a human point of view. As soon as people are settled, educational, social, medical and administrative centres can be set up and living conditions can be improved. Settlements however are only possible if the soils can guarantee a permanent production. This depends in northern Iraq on the climate as well.

Another economic problem is that of land evaluation and taxation. The need for the introduction of land taxes will not be discussed. If the Government should decide to introduce a land tax, this tax has to be based on present soil conditions and potential soil productivity.

The whole problem under discussion is a land use problem. If land is used in a wrong way, the results are disastrous, not only for the farmer and landowner, but also for the economy of the whole country; therefore land use planning in general is a task for the Government. In all discussions on economical land use planning, it is necessary to know the present conditions and the possibilities or potentialities for use in order to plan future land use. This is mainly an agricultural and a soils problem. For this reason, governmental institutes for soil investigations have been established in many countries during the last few decades. The economy of all countries, in particular of agricultural countries, chiefly depends on soil productivity, proper soil management and land use.

In the future an important change in the prices of land in Iraq may be expected. On a low level of primitive farming, almost all land is the same; productivity is nearly the same; rent and prices are also similar, except for date and fruit gardens. As soon as some progress has been made, productivity will vary strongly and rent and prices

FIG. 5. Aerial photograph of the Dujaila project area, the first development project in Iraq. The photograph shows the new irrigation system and the regular pattern of the newly reclaimed land. The dark coloured plots are irrigated, the others are fallow. As soils become saline within a few years of reclamation, a drainage system is made. Photographed, October 1954.

of productive land will become relatively much higher than for land with a low productivity. The idea that all land can be made productive by better soil management practices, introduction of chemical fertilizers, etc. has proved to be wrong. In particular, the physical characteristics of the soils are responsible for the important differences in soil productivity. It is hardly possible to influence those characteristics, and if it is sometimes possible, it is mostly not economic.

For a country like Iraq it is of the utmost importance to profit by the knowledge and experience of other countries, to avoid the errors being made elsewhere, and to apply those methods which have proved to be valuable. One of the fundamentals of land development for agricultural purposes is to start with those areas having soils with high potential use capabilities. Therefore no programme can be a success if it is not based on fundamental investigations of water, soil and plant relationships in the areas concerned.

1.3. Technical aspects and soils

Many technical problems have to be solved in executing a development programme. Soils investigations have proved to be valuable or even indispensible, especially for those problems where soils form one of the factors determining the final result of the work. The main technical problems in central and southern Iraq are irrigation and drainage; in northern Iraq, soil and water conservation, and in both sections, proper land use practices.

It will be clear that there is no need for irrigation in those areas where drainage of soils is almost impossible or uneconomical, as land will become strongly saline and unproductive after a few years. The possibilities for sufficient drainage are of primary importance; this is a real soils problem. It can be studied by evaluating soils in the field and in the laboratory. There are always various kinds of soil in each area. Data has to be collected on each soil and a field investigation has to be carried out in order to know the exact location of each soil. Such soil investigations are called soil surveys. The soils and their characteristics, including the results of the various chemical and physical analyses, are described in a report and their geographical distribution is shown on a map, called a soil map. It is wrong to believe that the evaluation of soils can be made on a few soil analyses of samples taken every kilometer or so. More information is needed, in particular on the location and distribution of the various soils. In modern countries no reclamation works are planned before detailed soil studies have been made.

The final purpose of land reclamation is not to carry out engineering works but to establish a permanent agriculture on a more intensive basis. Before making plans, soil and water conditions should be studied and evaluated, and finally the land capabilities or the potential use possibilities for agricultural production under specified conditions of irrigation and drainage should be predicted. When these land capabilities are known, a plan for farming and cropping systems, size of the farms and a regional development plan can be set up. The task of the engineers is to bring the irrigation water to the farms and to carry off the drainage water. This technical plan has to be adapted to the agricultural development plan. The distribution of water to the farms

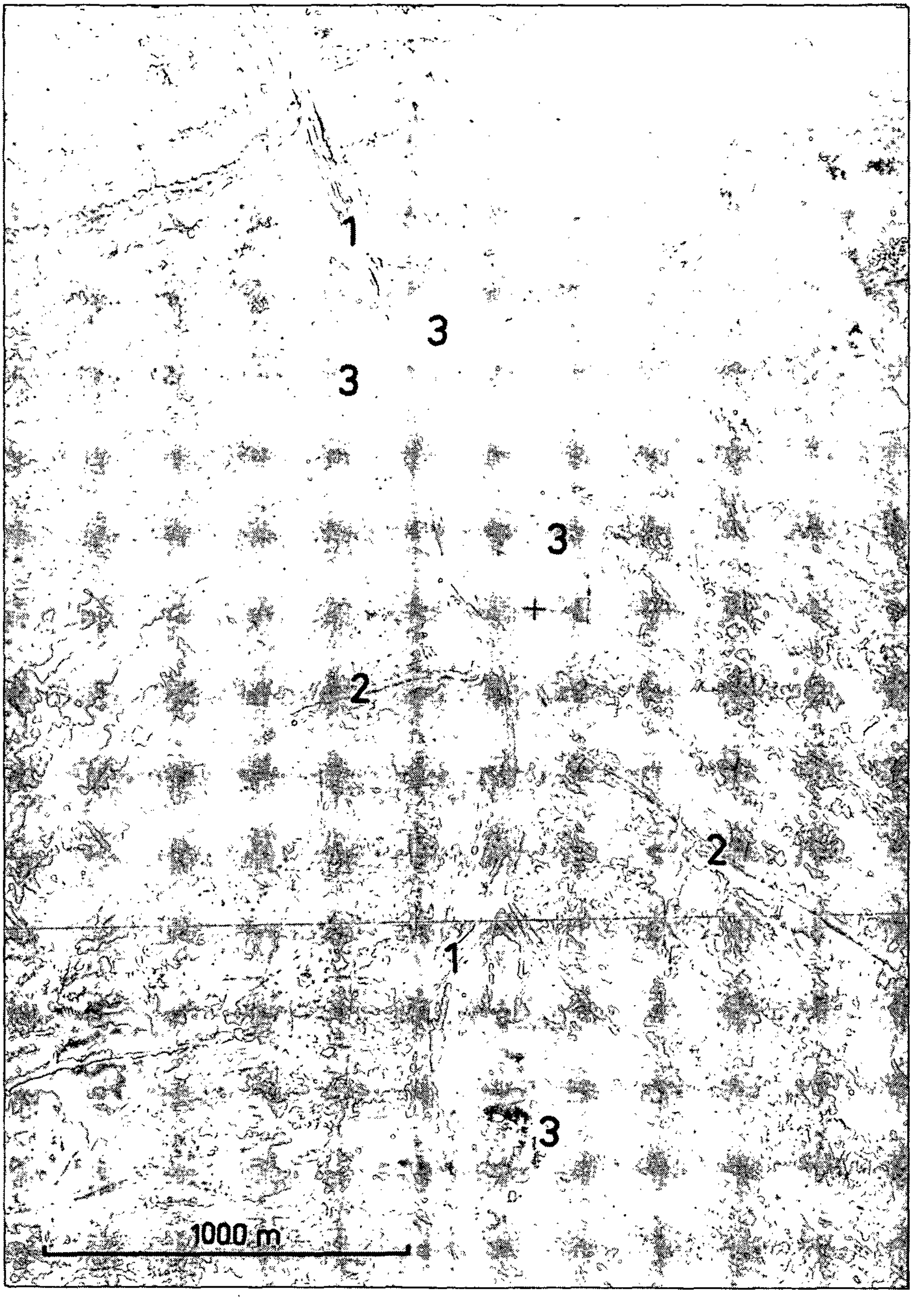


FIG. 6. Aerial photograph of the Mussayib project area, showing land which was cultivated in Babylonian times. Later on land has been abandoned as a consequence of silting up and salinization. The original soils are covered by a few metres of irrigation sediment. All the soils are saline. A new irrigation and drainage system is to be made, salts will be washed out and the land will be levelled and distributed to settlers. 1. Main irrigation canal; 2. branches of the former irrigation system; 3. ruins and tels. Photographed January 1955.

depends on the kind of crops, the crop rotation and the intensity of land use in the various parts of the project area, and consequently on their soils. Therefore soil investigations are primarily made for agricultural purposes, and secondly for planning the engineering works.

The system of agriculture will be changed in the future; it will become much more intensive; shifting cultivation and the fallow system of agriculture have to be abandoned and it is planned to grow more productive crops with a higher economic value in Iraq. The barley area will decrease; more wheat, cotton, sugar-beets, corn, alfalfa and other fodder crops as well as vegetables have to be grown. A permanent and more intensive farm system is possible only on productive soils under a system of mixed farming which is suitable for small holdings. Animal husbandry could be promoted at the same time. It is evident that the good soils only are suitable for such a farm system and that much land which is in production now, or which is planned to reclaim in the near future, will prove to be marginal land under such conditions. An almost similar discussion can be given for northern Iraq.

In studying the soil-water-plant relationships, predictions can be made of the soil productivity under specified farming conditions. The land capabilities can be evaluated for the various soils. The results of the investigations have to be presented in such a way that they can be understood by non-soil specialists who will apply them. It is pointed out that a soil specialist collects, evaluates and presents the data and results of his investigations and in addition he also presents his predictions for the purposes for which the results will be applied, e.g. suitability for crops, or specific crop rotations, special farm systems, drainability, possibilities of improving soil productivity etc. A soil specialist will not interfere in the planning of the project, as this work is not based on soils alone but also on many other important factors in the fields of economy, finance, social conditions and even politics. For these reasons no recommendations are given in this book.

1.4. Soil science aspects

The processes of soil formation are quite different in the various parts of Iraq. This is mainly a consequence of considerable variations in climate and vegetation. Due to these facts, broad fundamental differences among soils occur in this country. The local differences are mostly related to differences in soil parent material, in relief (in flat areas especially micro-relief), and in age. Almost no virgin soils occur in Iraq, because human influence over a period of some thousands of years has directly or indirectly changed soil conditions.

Most soils of central and southern Iraq are arid and semi-arid soils, which have too low a moisture content under natural conditions for the growth of crop plants. Farming is possible only if land is irrigated, which means the introduction of moisture conditions of a 'humid climate' into arid regions. Soil conditions and soil characteristics therefore are changed drastically in comparison to natural conditions, and a wide range of real soil problems is open for study and discussion. The main problem is the maintenance of soil productivity under irrigation practices.

FIG. 7. A highly stratified soil profile near Tuwarij, consisting of layers of different material. Layer 4. represents the land surface in Babylonian times; layers 1., 2. and 3 are flood and irrigation deposits of the last millenia. All soils of the Lower Mesopotamian Plain are stratified and covered by young sediments.

Various types of saline soils are found; they differ widely in chemical and physical conditions, percentage of salt, kind of salt, surface crust formation, etc. The process of soil salinization is intensively studied in countries like the U.S.A., the U.S.S.R. (saline soils in arid regions) and the Netherlands (saline soils in land newly reclaimed from the sea). The only possible way to reclaim land or to prevent land from getting saline is to wash out the salts, to lower the ground water table, and to carry off the water. This can be done by drainage. It should, however, be realised that not all soils can be drained economically and not even technically. The whole problem of saline soils is complicated and for the soil scientist interesting.

The so-called 'Sabakh' soils, a special type of soil salinity characterised by the presence of deliquescent salts in the upper soil layers, are widespread in Iraq and almost unknown in other countries. As these soils are common in the southern half of the country, the study of them should have priority.

It is often believed that saline-alkali and alkali soils, which are related to saline soils, but which are much worse, do not occur in Iraq. Recent investigations however indicate that these soils and even Soloth soils occur in Iraq and unfortunately even in rather extensive areas scattered all over the river plain.

The fertility of the soils in the Tigris-Euphrates Plain is one of the fascinating problems, where land has already been cultivated for at least 6,000 years. The highly prized fertility of the plain in ancient times, however, is gone, and the present status is only a ruin of a glorious past. The ruins of the famous ancient centres of civilization like Ur, Kish, Lagash, Babylon, Borsippa etc. are covered by a thick layer of dust; the old land is covered by a thick layer of silty soil material, transported by the rivers and accumulated on the land during floods and irrigations. The new soil layer, which is at least a few meters thick, lies like a carpet over the ancient plain, making it a new plain with different soil conditions in comparison to those of ancient times. The ancient land surface can be noticed at a depth of a few meters in many soil profile pits (Fig. 7).

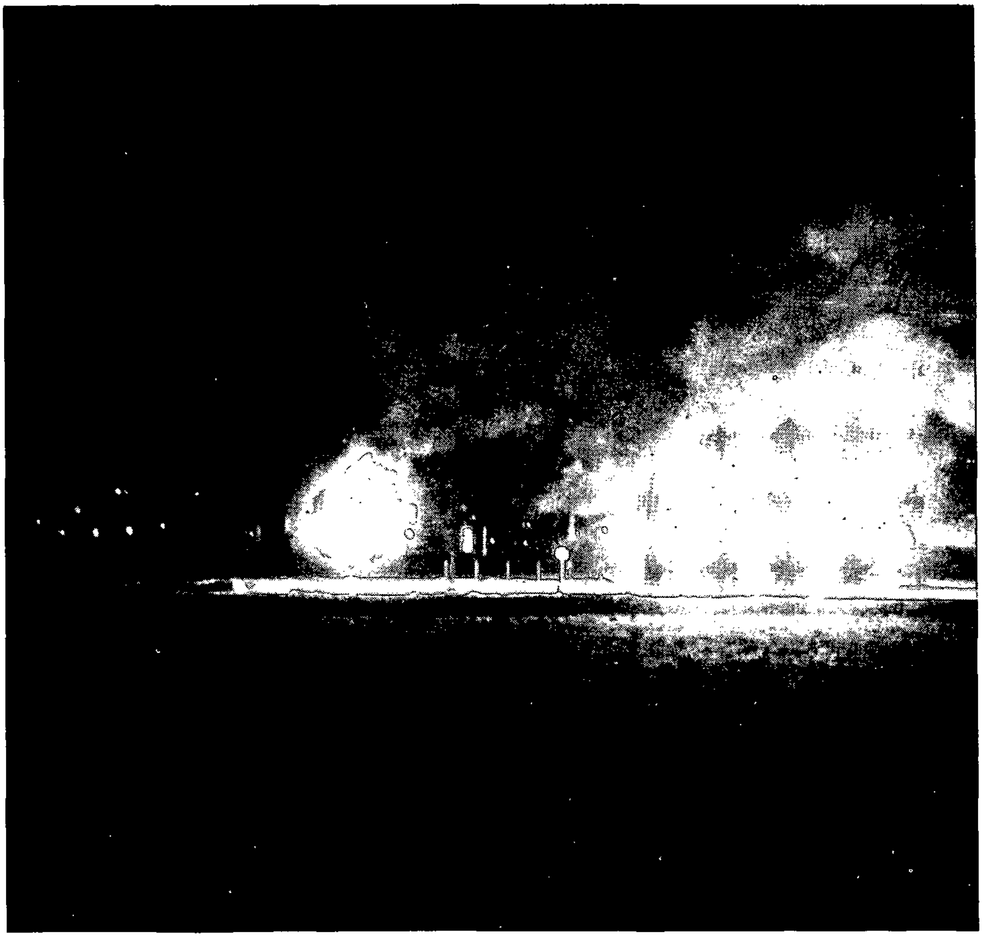


FIG. 8. Oilfields near Kirkuk, the source of money which provides the possibilities for the development of Iraq.

FIG. 9. Aerial photograph of a cultivated and irrigated area north of Hilla. The photograph shows a section of the semidetailed soil map shown in Fig. 142. 1. Argubs along former irrigation canal; 2. roads; 3. tel; 4. cultivated land (without crops); 5. irrigation depression with gilgai gullies; 6. large strongly saline basin depression (waste land). Photographed September 1955.

The sedimentation of silt during irrigations is one of the processes which has to be studied, in particular, in relation to soil erosion processes in the northern half of Iraq. During one flood, millions of tons of new sediment are passing Baghdad in one day! All this material is deposited on irrigated land in the plain. The marshes in southern Iraq are filled up, especially in the regions of rice cultivation.

In northern Iraq, soil problems are different. From the point of view of real classical pedology, this region is quite interesting; however, there are many other and more practical problems which have to be studied, e.g. the soil conditions in the fertile valleys, the weathering of rocks, the soil erosion, the formation of terraces, the self mulching process in many soils, soil depth and soil slope etc.

Many problems on soil fertility have to be solved for the whole country when crop production is intensified and increased. In general, there is a shortage of nitrogen and phosphorus, and in intensified agricultural production potassium will become more important too. In those regions where drainage systems are made, the application of chemical fertilisers will become necessary because most plant nutrients are washed out during the leaching of the salts. It is certain that the natural fertility of most soils in Iraq is too low for intensive farming. In modern farming the natural fertility of soils becomes less important, as chemical fertilisers can be applied. On soils with good physical conditions this mostly is economical.

Another problem is the low organic matter content in the soils of the Lower Mesopotamian Plain. Many times it is stated that the organic matter content of those soils has to be increased, because organic matter improves soil structure, permeability, fertility etc. Although this is true for humid regions, in arid regions it is impossible to increase the humus content of the soils on a permanent basis. A low humus content is normal under arid conditions. If organic material is added to the soils, it disappears in a very short time due to intensive sunshine, low humidity and high temperature. The conclusion of our studies is that burning manure for domestic purposes, as is done by the farmers, is not as bad as it is often indicated and at least it is not an important factor for the explanation of poor soil conditions in Mesopotamia.

There are more problems related to soil management which need study. It should be kept in mind that the farmers are cultivating and irrigating land in a way which mostly is the best under the prevailing conditions. Their methods are based on several thousand years experience. Farm management in saline regions differs from farm management in non-saline regions. Sometimes soil scientists can learn much from the local farmers.

The list of soil problems is far from complete, but it may be learned that there are many aspects of soil science too, and there is a task for a staff of qualified soil specialists.

1.5. Scientific aspects

In studying soils, much can be learned from other sciences like geology, geography, hydrology, agronomy, chemistry, physics and biology. On the other hand the results of the soil investigations often contribute to these and other sciences, which will be to the benefit of the country's economic and cultural progress.

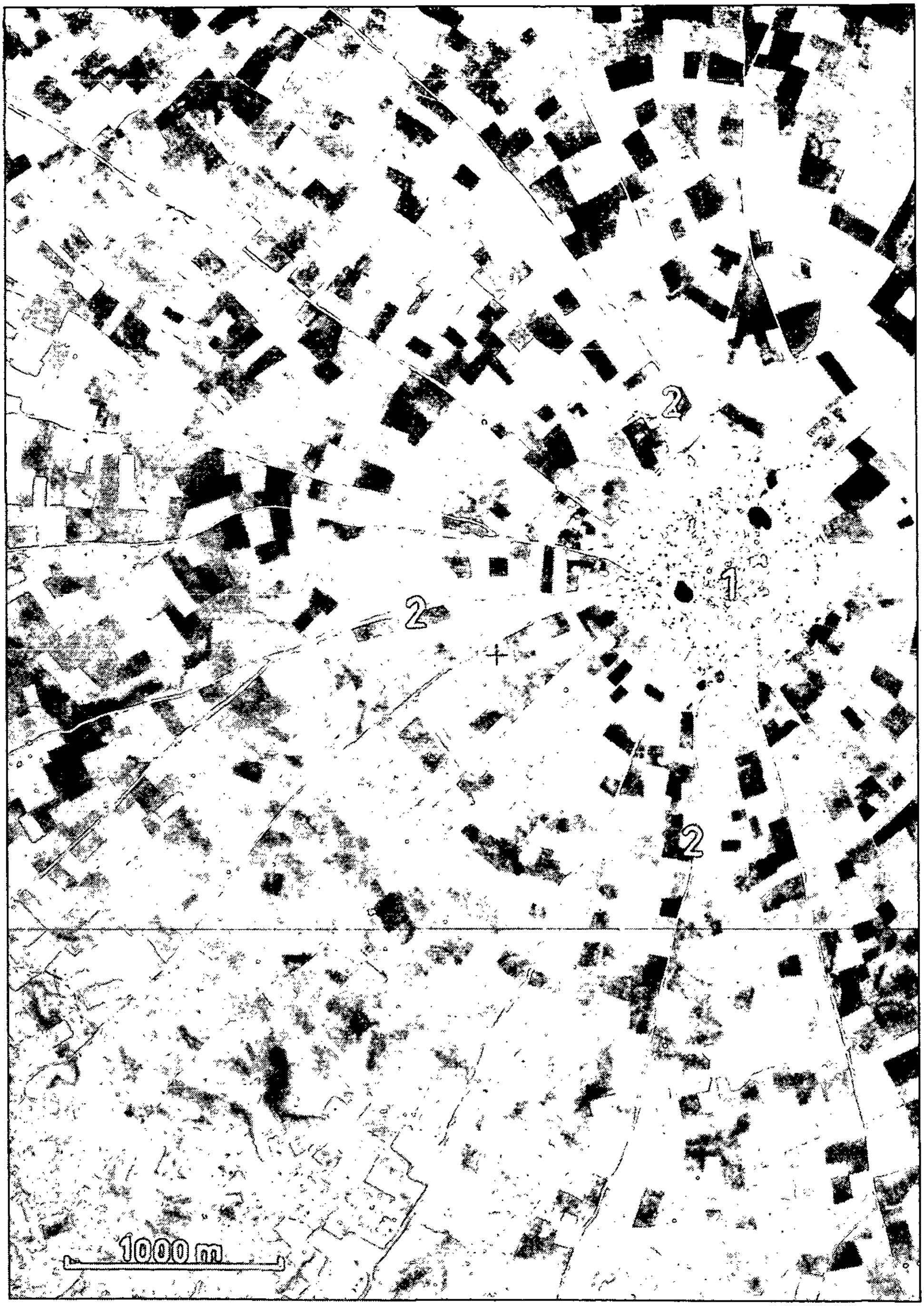


FIG. 10. Aerial photograph of a section of the Erbil plain, showing a radial block pattern of dry farming land on deep Brown soils. In this area rainfall is sufficient to grow wheat and barley as winter crops. The dark coloured fields are cultivated, the light coloured fallow. 1. Qaraqosh village, south-east of Mosul; 2. rural roads. Photographed in May 1954.

It is not necessary to explain the relations of soil science and agriculture. As the soil specialists study the upper layers of the earth's crust, there is a close relation of some of the soil aspects to quaternary geology, geography and geomorphology. In comparison to those sciences, the soil studies are based on many observations scattered regularly over the area concerned, and a new field of common interest with those sciences is opened. Soil specialists interested in the chemical and physical problems often co-operate with chemists and physicists. Those who are interested in archeology and history will be fascinated by the many data presented on a soil map or by the information which can be deduced from it. A few examples are given in the following chapters.

It is not a special task of soil science to furnish information for other sciences; however, the cultural aspects should not be neglected. It is a stimulating factor in soil science, which makes working on the various problems even more interesting.

1.6. Soil investigations

The specific scientific aspects of soils may be interesting for soil specialists, but the practical aspects of the application of soil data in the development programme and in agriculture are of more direct value. First of all it has to be realised that the geographical presentation of soil data on maps is of the utmost importance, as it has to be known in which areas the specific information on various types of soil can be applied. A soil cannot be characterised by some analyses of soil samples or a description of a single soil profile. Soils are three-dimensional bodies with depth (as far as the deeper layers influence plant growth) and with shape over a specific area. There are several ways to present soil data on maps and in reports. Some maps show the main differences in soil conditions in a general way over large areas, e.g. a Liwa or the whole country, and other maps many details over smaller areas. It depends on the purpose for which the soil data will be applied, which kind of soil map and consequently which kind of investigation will be made. In the general soil maps several soils have to be combined in one unit on the map, as it is impossible to show all details on a general map. Such combinations only can be made when soils are studied in detail at least in some typical sections of the area concerned. As soon as it is decided how to combine the various soils in units of the general map, this map can be made for a fairly large area without more detailed studies. The rather poor results of most investigations made in Iraq during recent years are a consequence of neglecting this principle of soil and land classification.

Soil investigations for development projects, which mainly should be detailed studies, have to be carried out as routine work. The results will be applied and the planning cannot wait until all technical and scientific problems are solved. As soils are complicated and crop production depends on many factors, the routine investigations will give the best results when they are based on research work. Therefore soil research has to be done in addition to routine investigations. Without soil research, no progress will be made; however, as long as problems remain unsolved, routine work has to go on, and the results have to be delivered in time. This also implies

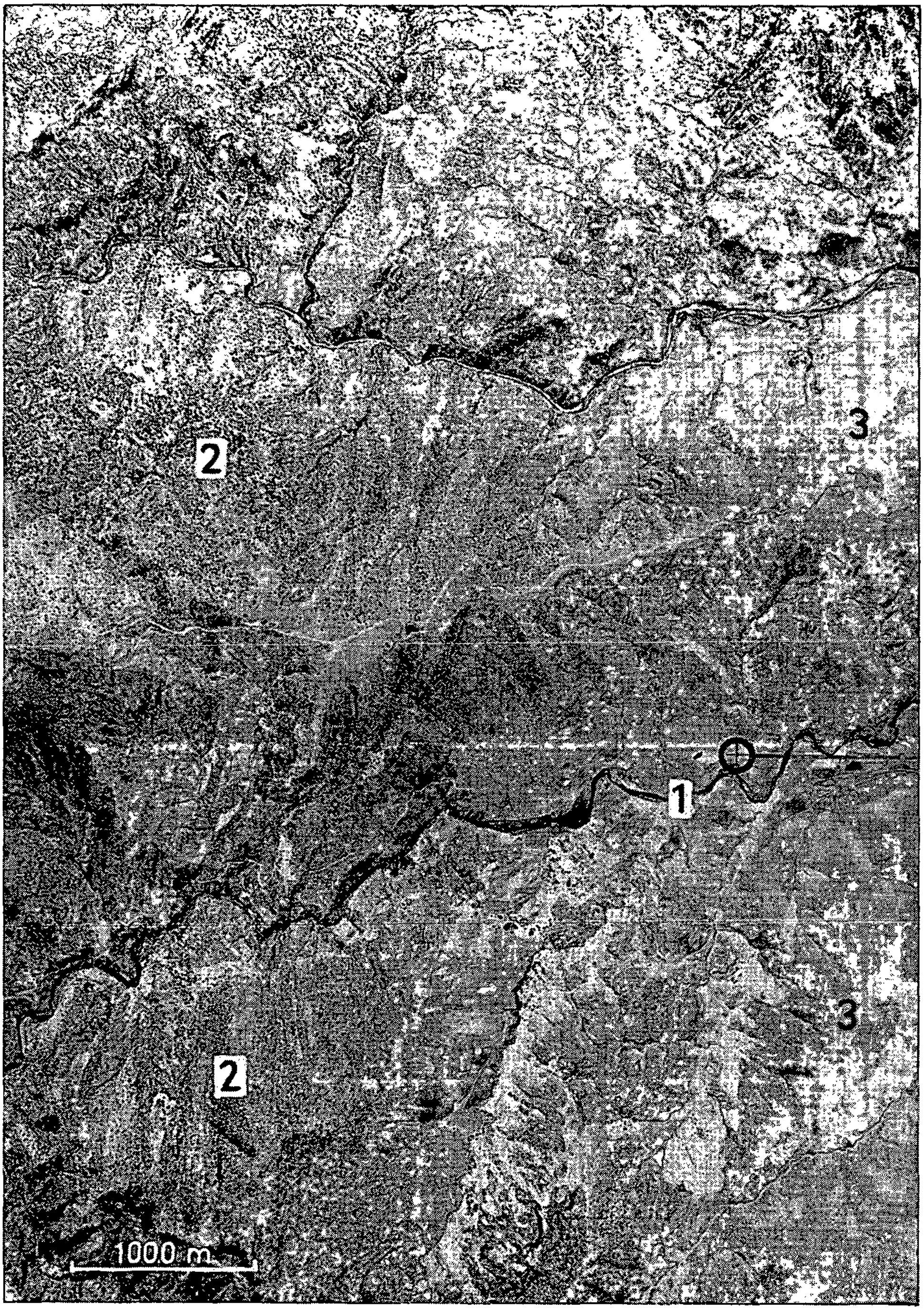


FIG. 11. Aerial photograph of a mountain area in north-eastern Iraq, near Iranian frontier. 1. Tributaries of the Lesser Zab river; 2. mountains covered by oak forest and grass; 3. mountains covered by grass. Photographed in July 1952.

that the order to carry out soil investigations has to be given in time and that a programme for such investigations has to be set up. The need for more soil investigations and especially for more detailed data will increase as soon as the results are applied.

Soil research work has to be carried out in every country, as the influence of the fundamental soil-forming factors (parent material, climate, relief, vegetation and biological activity, time and man) vary everywhere. Although the soils of Iraq may have some characteristics in common with soils from other parts of the world, the knowledge of soils of other countries cannot always be applied to conditions in Iraq. After reading this book, this statement will not need any more explanation. It has already been pointed out that every government needs a central institute for routine soil investigations and for research, as the economic land use planning, being a task of the Government, can only be carried out if the Government itself collects the basic information for it. Another reason is that the knowledge of soils and soil conditions of one area sometimes can also be used in other areas with similar physical conditions. As work progresses and more experience is gained, the investigations gradually can be improved and better predictions can be given. Although it is possible, and for Iraq even necessary, to order soil investigations of some project areas to be carried out by qualified consultants, in particular, during the first decades of the development, the establishment and support of a governmental institute for soil investigations is a necessity. This institute also should co-ordinate, correlate and unify all soils work.

The cost of soil investigations are very low. For Iraq they are less than ID. 0.100 per donum for semidetailed soil surveys, including the soil analyses, transportation, salaries, drawing maps, typing reports, administration etc. In comparison to the cost of making the irrigation and drainage systems (ID. 25 to 35 per donum) this is less than 0.5%! This simply means that there is no financial reason to neglect soil investigations in the project areas or for the whole country, excluding the large desert areas. The shortage of experienced soil specialists in the various fields of soil science is a factor which is normal during the first decade of modern development. Foreigners can be invited to carry out the greater part of the work during the first stage of the development; however, those Iraqis who are interested in soils work should be, and some already are, trained in order to take over the work in due course.

Results on some early soil analyses are published by Willcocks (1911) and a small chapter on the soils of Iraq is published in the books of the Admiralty War Staff (1916) and the Admiralty Naval Staff (1918). Both are of historical interest only. A review of what has been done up to 1953 is published by Guest (1953). The first soil studies in Iraq were made by Webster (1921) and Webster and Viswanath (1921) concerning some saline soils. These studies followed the establishment of the Agricultural Laboratory at Karradah in 1919, where salt problems were studied. The results are quite interesting, especially as they belong to the first studies which were made on arid-saline soils. Regional studies were made in the Diyala region (Webster and Viswanath, 1921) and in the Abu Ghraib region near Baghdad (Tiwary, 1930). In the report on the Diyala region the distribution of soluble salts, clay, nitrogen, potash and phosphorus is shown on small-scale maps. The classification of the soils in Abu Ghraib was based on the chloride content of the soil.

A new start was made in the early nineteen fifties by some Iraqis and a F.A.O. soil technologist. A soils section was established in the Directorate of Agriculture, a soil sample laboratory was set up, and the first field studies were made. Some consultants working with the Development Board made land classifications in various areas; in some areas soil surveys were made as well. Soil analyses for these surveys were carried out in the soil mechanics laboratory of the Engineering College, and later on in that of the Irrigation Department.

In 1955 two Dutch soil specialists were appointed on contract with the Ministry of Agriculture, and some Iraqis finished their soil studies and training abroad. One of them took over the directorship of the section, which later on was transferred to become an independent Division of Soils and Agricultural Chemistry in the Directorate General of Agriculture. A special committee, consisting of various director generals, interested in soil investigations, was set up in order to co-ordinate, correlate and unify all work done in soils and land classification.

In recent years, a number of articles and some reports

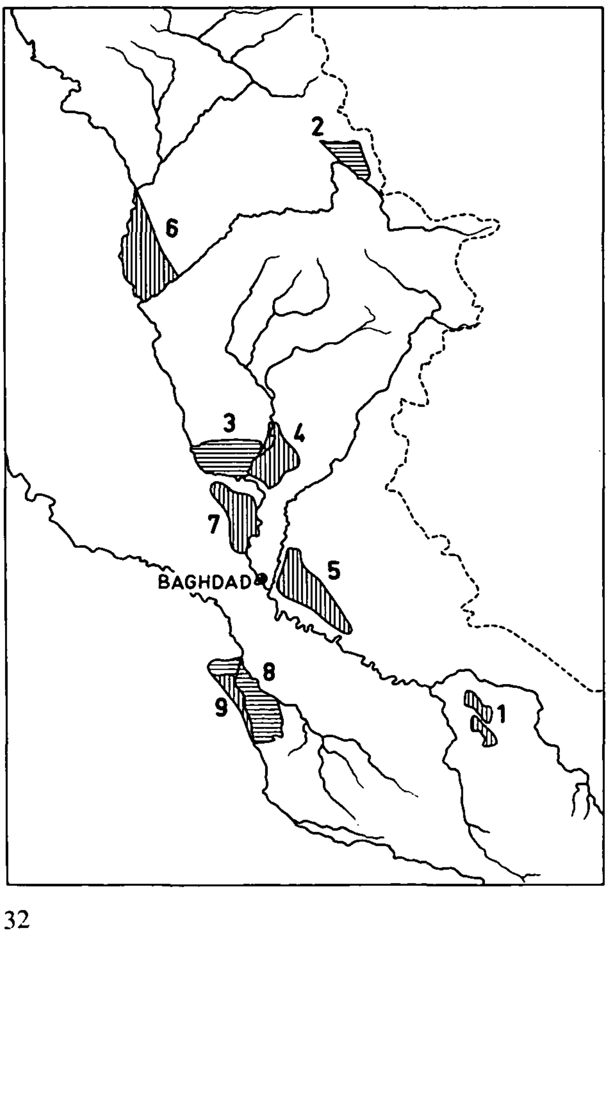


FIG. 12. Map showing the areas where soil surveys have been carried out:

1. Dujaila project, reconnaissance survey, West (1955);
2. Sungassar project, semidetailed survey, Buringh (1955);
3. Naifa project, semidetailed survey, van der Kloes (1956);
4. Adhaim project, reconnaissance survey, Hunting Group (1956);
5. Nahrwan project, reconnaissance survey, Hunting Group (1956);
6. Makhmour project, reconnaissance survey, Hunting Group (1956);
7. Ishaqi project, reconnaissance survey, Hunting Group (1956);
8. Hilla-Kifl project, semidetailed survey, Buringh (1958);
9. Kerbala project, semidetailed survey, Schilstra (in progress).

The present knowledge of soils of Iraq is based mainly on these investigations.

have been published, to which references will be made in the following chapters. Many reports, mainly on land classification in project areas in Iraq, are not published. The soil survey reports of the Division of Soils will be published by the Ministry of Agriculture in co-operation with the Development Board. The first report and maps are published (West, 1955); others are in the press (Fig. 12).

The methods followed in the field and laboratory investigations were not uniform during the first few years. Later on the methods described in the Soil Survey Manual (1951) and Handbook 60 of the U.S. Salinity Laboratory (1954) were followed.

Studying the older unpublished reports and correspondence on the soil investigations in Iraq, there are three striking facts:

a. The results of the early soil investigations (1919–1925) are still important. It is surprising that the soil specialists of those days had a good idea of the soil problems, and of the way in which they could be solved.

b. It is quite astonishing that the recommendations of these experts were not followed, and that even to-day the same can be said as 35 years ago.

c. The list of projects in which soil investigations should be carried out was in 1955 almost the same as in 1921.

It also has to be pointed out that in nearly all reports on the development of Iraq, one of the first recommendations is to carry out soil survey and classification studies before starting a development project (Keen, 1946; Report International Bank for Reconstruction, 1952; Gibbs, 1954; Ali, 1955; Salter, 1955). It is up to the Government of Iraq to put them into effect. For the soil scientists there is a broad field of interesting and important work for a period of many years. This book is only a start.

CHAPTER 2

PHYSIOGRAPHY AND AGRICULTURE

2.1. PHYSIOGRAPHY

The Republic of Iraq lies between latitudes 29° 5′ and 37° 15′, and longitudes 38° 45′ and 48° 45′. The total area is 444,442 square kilometres.

The country may be divided into five broad physiographic regions (see Fig. 13). Each region has its specific geological, hydrological and climatological conditions, and consequently specific soil conditions as well.

It is necessary to understand the geological formations of the country in order to

FIG. 13. Map of physiographic units of Iraq.

understand the soil conditions. In particular, a lithological map would be of great help in studying soils. Unfortunately there is not much information about the geology of Iraq and in particular, the geology of the upper part of the earth's crust, which is important in soil science, is not intensively studied. Many studies have been made in and around the oil fields, for the mineral survey, for underground water investigations and for the construction of dams and barrages in the various rivers (reports of the Development Board of Iraq).

Although there are series of unpublished reports on specific areas in the archives of oil companies and various government departments, hardly anything has been published. The book written by the British Admiralty Staff (1916) is of historical interest only. It was issued by the Intelligence Department for official use, and it was struck off the secret list in 1937. All older geological publications are cited, and a small scale geological sketch map is included. The information given by Blanckenhorn (1914) is also out of date. There is only a provisional geological map, scale 1:2,000,000, of Iraq, compiled from various data and published by Macfayden (1938). In this book some more detailed maps of small areas are published. A schematic small scale geological map is published by Lees (1950). The geological map of the Middle East by Dubertret (1942) also gives some information. The work of Dubertret on geology of similar areas in other Middle East countries is important for Iraq too.

A new geological map of Iraq (1:1,000,000) is now being prepared.

There is a Geological Government Department, which was established a few years ago, mainly dealing with economic geology. Besides oil, sulfur seems to be an important mineral in Iraq. Plans to start with the production of sulfur (annual production is estimated at 500,000 tons) are under consideration.

The most important and up-to-date outlines on the general geology of Iraq are written by Dennis (1953), who studied many unpublished reports of the Iraq Petroleum Company, and Wright, (1955) who studied geology in relation to archaeology. Lees and Falcon (1952) have published an important article on the Lower Mesopotamian plain. The book by Fisher (1950) also contains some general information on the geology of Iraq. Reviews of recent literature dealing with geology and geography are given by Fisher (1947, 1950, 1953) and Dost (1953). Stephens (1954), Longrigg (1954), Lees (1950), and Suleyman (1956) have written on oil.

The information for the following brief outline is taken mainly from the above mentioned reports.

Outline of the historical and stratigraphical geology

Millions of years ago, Iraq was lying in a large depression which is called the Tethys geosyncline. It was submerged by the sea and bordered by plateaux and tablelands, which are known as Gondwanaland (Fig. 14). In the rather shallow sea (or shelf), sediments, mainly limestone, were deposited. The sediments in the inner part were rather stable, whereas those near the outer part were more unstable. Limestone was formed in clear and somewhat deeper water. The streams from the surrounding land surfaces brought mud into this sea; thus shale and marl (limy mudstone) were deposited.

Due to sedimentation, and to a gradual rise of the land, the sea became restricted and some separate inland seas were formed. These inland seas became more and more salty as a result of evaporation. Layers of salt, gypsum and limestone were deposited. Sand, silt and clay was brought in by streams. The northern part of the Mesopotamian plain, mostly called Jezireh, was one of the main inland seas. Therefore it can be understood that in this part of Iraq, much gypsum is formed. Many beds or layers of gypsum can be seen in the bluffs along the Tigris and Euphrates in central and northern Iraq and in the Jabal Hamrin hills. The mud and sand which was eroded from adjacent hills and accumulated in the inland seas now form mudstone and sandstone. The mudstones are red in colour, which, according to Wright (1955) indicates a sub-tropical climate as it is to-day, but perhaps not as dry.

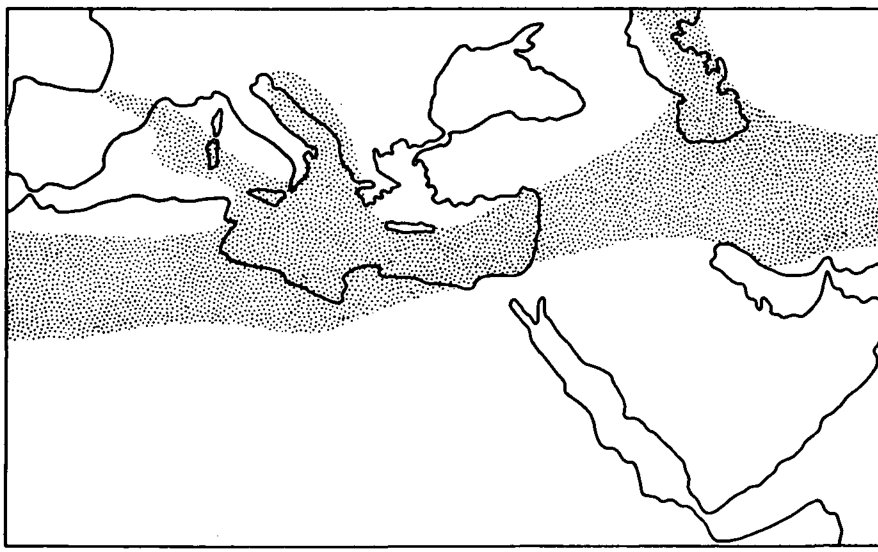


FIG. 14. Sketch map of Gondwanaland and the Sea of Tethys (stippled) in early Permian times (after Schuchert, taken from Fisher, 1956).

Another important fact in the geology of Iraq was the formation of the mountains, in particular, the Zagros mountains near the Iranian frontier and the Taurus mountains in Turkey, about 50 to 30 million years ago, which is quite young in geological history. At that time there was an intensive and strong pressure on the earth's crust from the north-east in the south-west direction. The stable ancient land pressed on the much weaker and therefore unstable layers of the outer part of the shelf. As a result, the earth layers were folded, forming beautiful arches and troughs. Several parallel mountain ranges, separated by lower lying parts were formed. The arches forming the mountains are called geo-anticlines and the troughs forming the valleys are called geo-synclines. The belt of gigantic anticlines formed in front of the compressed central zone, are now the Zagros mountains. The folding intensity decreases in the south-west direction with the approach of the more stable Arabian foreland. The mountain building process still continues, although the maximum intensity is over.

The formation of the mountains was followed by a considerable period of erosional modification of the land surface. The mountains were subjected to erosion by streams, bringing an immense quantity of material down to the valleys, where it was deposited. The erosion products are mainly coarse gravels or pebbles, gravel, sand, silt and clay. These products were accumulated in the synclinal valleys and in the zone south-west of the Zagros mountains which now formed the foothill zone. The rather coarse detrital material forms layers up to 3,000 metres thick, consisting of coarse beds of gravel, conglomerate and sandstone. They form the surface rock over many of the plains and lower hills in northern Iraq (Wright, 1955). The result of this erosion process is the down-cutting of the mountains and the filling up of the valleys. This geological or normal erosion still continues in Iraq. It is a natural process which cannot be stopped. It was not a continuous process of erosion, as it was interrupted by pauses, during which the terraces, which can be found over large areas in northern and central Iraq, were formed in the former valley floors.

The older erosion deposits at the foot of the Zagros mountains became somewhat folded too, thus producing the foothills and valleys in front of the high mountains.

The youngest geological process is the sedimentation of finer material – loamy sand, silt and clay – in the extensive Lower Mesopotamian plain, a process which still continues at the present time.

The geological processes building up the lands of Iraq are characterised by simplicity and regularity. Over the whole area of Iraq five broad physiographic regions can be distinguished (Fig. 13).

1. *The Zagros mountains* consist of high parallel mountain ranges and valleys. The mountains form arches, which for the greater part are eroded, the detrital material being deposited in the valleys and in the area in front of the mountains. The mountains mainly consist of various layers of limestone, which are folded. Consequently the oldest layers are exposed at the top of the mountain ranges. In the north-eastern part of Iraq, near the Iranian border, the situation is somewhat more complicated. During the process of maximum pressure and folding, older and much harder material of the old land has been pushed over the younger limestone formations. The area which has older geological formations resting on top of younger ones, which is quite uncommon, is rather small. It is called the 'Thrust Zone'.

2. *The Foothills,* in front of the Zagros mountains, consist of beds of gravel, conglomerate and sandstone; all these products accumulated during the erosion of the mountains. The area is somewhat folded in a later phase of folding, thus forming a fairly hilly landscape, also with low parallel hill ridges and rather extensive valleys and plains, in which various streams have cut their valleys. As the down-cutting was not a continuous process, some terraces have been formed.

3. *The Jezireh* area is the remains of an old inland sea in which mainly gypsum was deposited (Fig. 15). At the present time it is a large desert and steppe area, which extends over the Syrian frontier in north-eastern Syria up to the Turkish frontier.

4. *The Northern and Southern Deserts* mainly consist of some kinds of limestone, which have been formed on the old shelf. The thickness of these layers is up to 8 kilometres.

FIG. 15. Alternating limestone (1) and gypsum (2) layers in a deep pit east of Mosul. These sedimentary rocks have been formed in the Tethys Sea during the Pliocene. The deep soil on top of the rocks is a Brown soil with stratified substrata.

5. *The Lower Mesopotamian Plain* is the southern part of an extensive geosyncline, which at the bottom (approximately 3 kilometres under the present surface) is filled up with older shelf sediments, on top of which erosional products have been deposited. The upper part consists of very young fine river sediments.

Structurally, Iraq consists of:

a. The foreland, in the northern and southern desert;
b. The geosyncline of the Mesopotamian plain;
c. The minor fold zone in the foothill region;
d. The major fold zone of the Zagros mountains;
e. The thrust zone, or Nappe area in the north-east.

As most geological formations are called after the geological periods in which they were formed, some explanation should be given, as some typical geological names will be used in the following chapters.

The sediments in the sea (shelf) of the Tethys geosyncline were deposited in the

Triassic, Jurassic, Cretaceous and Tertiary periods. The Triassic and Jurassic rocks consist of shale, dark limestone, oolitic limestone and occasional gypsum beds. The Cretaceous is sub-divided into Upper and Lower Cretaceous. The Cretaceous rocks consist of many sediments, mostly limestones and dolomite. The Tertiary period is subdivided into Eocene, Oligocene, Miocene and Pliocene. Here, too, the sediments are mainly various kinds of limestone, such as Eocene, Oligocene and Miocene limestones, which occur over large parts of Iraq.

The folding of these sediments, which were originally deposited horizontally, started in Upper Cretaceous times with a maximum intensity of movements in the Pliocene. In the Tertiary period large-scale faulting occurred, mainly in the mountain and foothill area. Faulting, however, was not followed by vulcanicity as in Syria, Lebanon, Jordan and Arabia, where basaltic lava flows are present over considerable areas. Some basaltic lava flows occur just across the Syrian and Jordanian borders. Some green and black crystalline rocks are found in some small areas in the mountains (Wright, 1955). Some inland seas, mainly with gypsum and salt sediments, were formed in the second half of the Miocene, which has been sub-divided into Upper and Lower Fars. The Lower Fars sediments are mostly gypsum and salt. Shale, grey-green mudstone and marine limestone were formed too. In the Upper Fars, sandstone with interbedded silt and mudstone were deposited; these are reddish and brown in colour.

In the Pliocene, the Upper and Lower Bakhtiari are the most important as at that time the intensive erosion and downcutting of the mountains in combination with the filling up of the valleys were the main factors. This Bakhtiari formation is characterised by gravel and conglomerate interbedded with silt and mudstone, which mostly are yellowish or brownish coloured and poorly sorted.

The erosion and additional accumulation of detrital material still continued, however, with less intensity during the Quaternary period in which we are now living. A summary of the geological periods is given in Table 2 (see page 40).

Quaternary geology

The Quaternary period starting at the end of the Pliocene, is divided into the Pleistocene and Holocene.

The Pleistocene is characterised by glacial and interglacial phases in Northern Europe and North America and by pluvial and interpluvial phases in Africa and the Middle East. During these pluvial periods the climate in Iraq was more humid than at the present time. The higher parts of the Zagros mountain range were at the same time permanently covered by a thick ice sheet. Therefore real glacial phases have to be distinguished in the higher mountain zones and pluvial phases in the lower-lying parts of the country. During the interpluvial periods, the climate was similar to that of the present time. At least three main pluvial periods and probably one or more minor pluvial periods existed in Iraq.

The alternations in climate have greatly changed the physical conditions of the country. During the pluvial periods the vegetation cover was much denser than now. Due to more precipitation (rain and snow) there was much more water, especially in spring, to be transported by the rivers. River and land erosion became important, the

TABLE 2. *Summary of the geology of Iraq.*

Period	Age	Formation	Processes	Occurrence in Iraq
Quaternary	Holocene	Younger river sediments, aeolian deposits	Some erosion in the mountains and hills; deposition in the Lower Mesopotamian Plain.	River and windblown sediments in the Mesopotamian Plain.
	Pleistocene	Older river sediments on terraces	Erosion and deposition in some phases.	Terraces and fans in northern and central Iraq and terraces in upper part of Lower Mesopotamian Plain.
Tertiary	Pliocene	Upper Bakhtiari	Maximum folding of the mountains; erosion and downcutting in the mountains.	Gravel and conglomerates with silt- and mudstone in foothill area and Erbil plain.
		Lower Bakhtiari	Some folding in the mountains.	Gravel and conglomerates with silt- and mudstone in foothill area and Erbil plain.
	Miocene	Upper Fars	Formation of Zagros Mountains; erosion starts.	Sedimentation of sand-, silt- and mudstone in Jezireh, Jabal Hamrin and southern Iraq.
		Lower Fars	Sedimentation in some inland seas.	Formation of gypsum and salts with some shale, mudstone and limestone, mainly in Jezireh, Jabal Hamrin, Mosul area.
		Chama Limestone	Sedimentation in the shelf	In mountain area (folded) and in the deserts of western Iraq (not folded)
		Euphrates Limestone	Sedimentation in the shelf	In mountain area (folded) and in the deserts of western Iraq (not folded)
	Oligocene	–	Sedimentation in the shelf	Partly in the mountain area; partly in western Iraq in desert zone.
	Eocene	–	Sedimentation in the shelf	Partly in the mountain area; partly in western Iraq in desert zone.
Cretaceous	Upper Cretaceous	–	Sedimentation in the shelf and the folding starts.	Coastal sediments, mainly limestone, now on tops of mountains and in desert near Rutba.
	Lower Cretaceous	–	Sedimentation in the shelf	Marine sediments of limestone.
Jurassic	–	–	Marine sedimentation in the shelf.	Shale, dark limestones and oolitic limestone.
Triassic	–	–	Sedimentation.	Mainly Nubian sandstone north of Rutba.

latter especially at the beginning of a pluvial phase. Much material has been eroded in the mountain and upland areas, and afterwards it has been deposited in the valleys and the finer textured material in the broad plain. The land surface was somewhat levelled, but some areas were deeply intersected by erosion gullies and streams which are known now as dry wadis.

During the more arid periods, wind erosion was an important factor, in particular in those areas where the vegetation was scarce.

As a result of alternations in climate terraces have been formed along the rivers and their tributaries in central and northern Iraq. The extensive Lower Mesopotamian Plain has been filled up with fine textured sediments which were and still are brought in by the large rivers.

In some other areas, e.g. Tharthar and Abu Dibbis, large lakes have existed during pluvial phases.

Large desert areas of Iraq are covered by secondary gypsum crusts, locally called 'juz' or 'djoz', which have probably been formed in the beginning of the Pleistocene. In the limestone areas of northern Iraq, limestone crusts have been formed.

The most important phenomena of the Pleistocene are: the formation of the various terraces, deeply intersected desert areas, gypsum and limestone crusts, and the sedimentation in the Lower Mesopotamian Plain.

The Holocene started at the end of the last pluvial period some 8,000–10,000 years ago. It extends up to the present time. It is characterised by an arid climate in central and southern Iraq and a more continental climate in northern Iraq.

Water erosion was still persisted. Wind erosion became an important factor too, especially in the desert areas and in the river plain. Dunes have been formed and layers of aeolian material have been deposited on top of older sediments. Some material has been blown out of extensive areas; only the gravels which formerly occurred in the original material have been left behind forming a thin sheet of gravel on the land surface. This thin gravel layer is called a 'desert pavement' (Fig. 104).

Cultivation of land started during the Holocene on the fertile river terraces in the mountain valleys of Kurdistan some 7,000 years ago. Some 1,000 years later the southernmost part of the Lower Mesopotamian Plain became inhabited. Here cultivation was possible only if land was irrigated. The methods of irrigation have been improved and more land could be used for agriculture. As a result of floods and irrigation, rather thick layers of mud were deposited on top of the original soils. Nearly the whole plain is now covered by this silty material. In the meantime, the courses of the rivers have been changed several times.

Under natural conditions land in arid and semi-arid regions tends to become saline, especially if the groundwater level is near the surface. As a consequence of farming and the introduction of new irrigation systems, nearly all soils in central and southern Iraq became saline.

The influence of tectonic movements has to be mentioned too, although they are of minor importance in comparison with the intensive movements during the Pliocene.

The modelling of the land surface and the development of soils in the whole country are intensively influenced by Quaternary geological processes; therefore the Quaternary geology is of primary importance for agriculture and engineering. In the following chapters these processes will be discussed in more detail.

2.2. Climate and soil climate

The climate of Iraq is a sub-tropical, continental, arid climate with dry hot summers and cooler winters, with some rainfall in central and southern Iraq, and more rainfall in the northern part of the country. The winter is characterised by high pressure, the summer by low pressure. The greater part of the country has a real desert climate. Due to the fact that this area has two big rivers and a large flood plain, living in settlements is possible. The rainfall in northern Iraq is sufficient to support winter crops without irrigation. In all other parts of the country cultivation is possible only by irrigation. In Jezireh and the western and southern desert, no water is available except in a few wells. Rainfall is very low and a large portion of the rainwater evaporates immediately. In reality the amount of water available for plant growth and soil formation is much smaller than is indicated by precipitation data.

The climate of Iraq differs from that of the western parts of Syria, Jordan and Lebanon which have a prevailing Mediterranean climate. The difference from Iran is the occurrence of the twin rivers in Iraq, whereas Iran has no large rivers bringing water to the extensive arid areas. The influence of the Persian Gulf on the Iraq climate is very limited. Near the Gulf the relative humidity is higher than in other parts of the country.

General data on the Iraq climate are given by: Ionides (1937); the Meteorological Service of Iraq (1945); the Government of Iraq (1954), Publication No. 10; Mac-Fayden (1938) gives the data from 1888 until 1936, and Dennis (1953) from 1937–1952.

A map showing climate diagrams of Iraq has been published by Walter (1957), who applied a new method of presenting data concerning rainfall and temperature (Walter 1956/57). Data are published annually in the Statistical Abstracts published by the Ministry of Economics.

Rainfall

A simple rainfall map of Iraq (map of isohyets) is given in Fig. 16, and some general data are mentioned in Table 3. Fisher and Dubertret (1945) prepared a rainfall map of the Middle East. The 200 mm. line on the rainfall map is an important line. In general this isohyet indicates the southern boundary of the rainfed zone. The rainfall in Kurdistan is influenced by the high mountain ranges of the Zagros. From Table 3 it may be learnt that the four summer months are completely dry; during these months there are no clouds at all.

Another important fact is that some winters are dry (for example 1954/55), while others are much wetter. The lowest and highest yearly means are given in Table 3. There are big differences. This means that the isohyets in the rainfall map (Fig. 16) do not have a fixed position. In general they will shift to the north-east in dry years and to the south-west in wet years (Fig. 17). There are also differences in the monthly rainfall data. As an example, the rainfall in Baghdad is given for January 1954, 1955, 1956: 13.8, 54.1, and 7.5 mm. respectively.

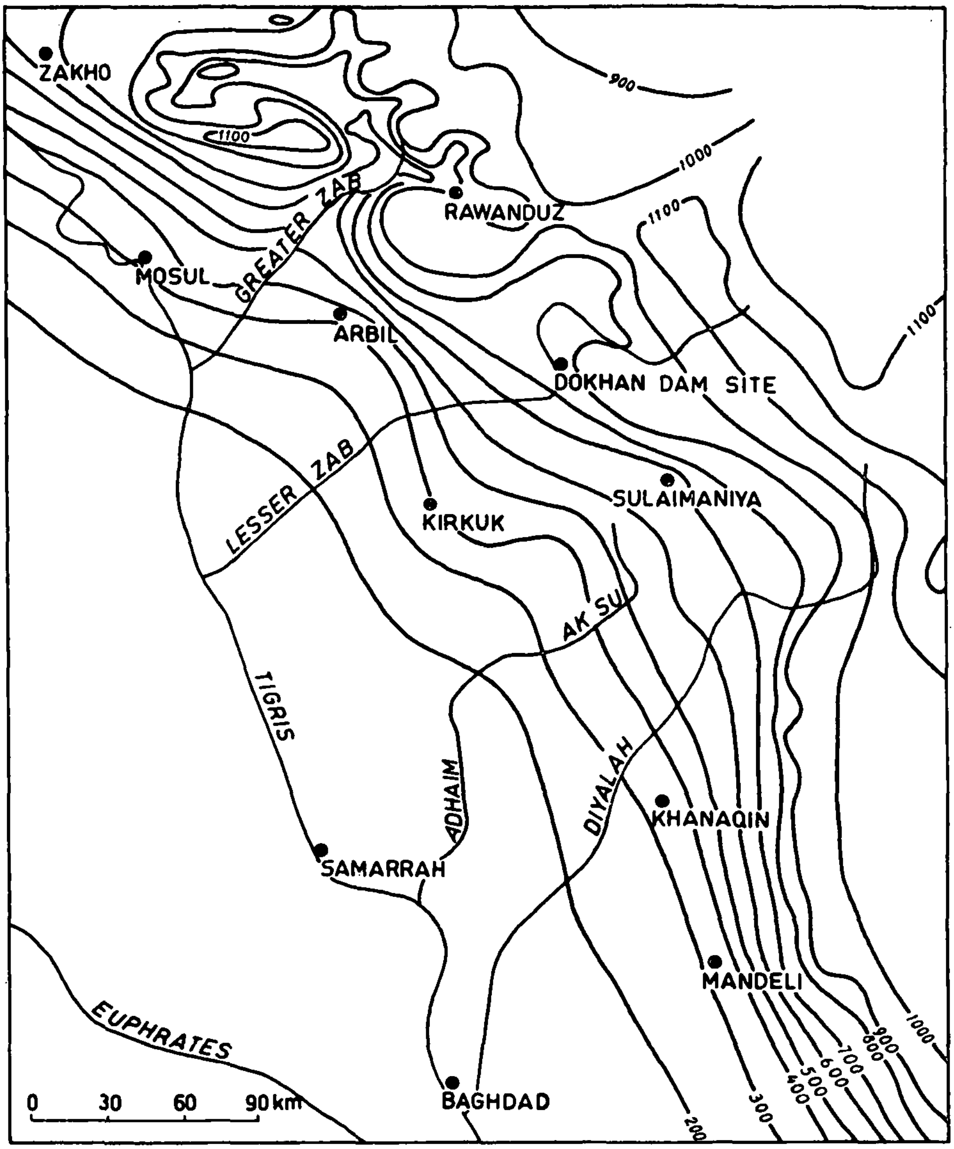


FIG. 16. Rainfall map of Iraq. All precipitation is in winter and spring (see Table 3). The isohyets are based on average data from 1938–1950.

Besides the variations in time, the geographical variations in rainfall are important. Most winter rain falls as showers. For the agriculture in northern Iraq it is highly important which course is followed by such a shower. There are sometimes big differences in rainfall over short distances. Therefore some parts of the semi desert region may be green in early summer, whereas other parts are still dry without any

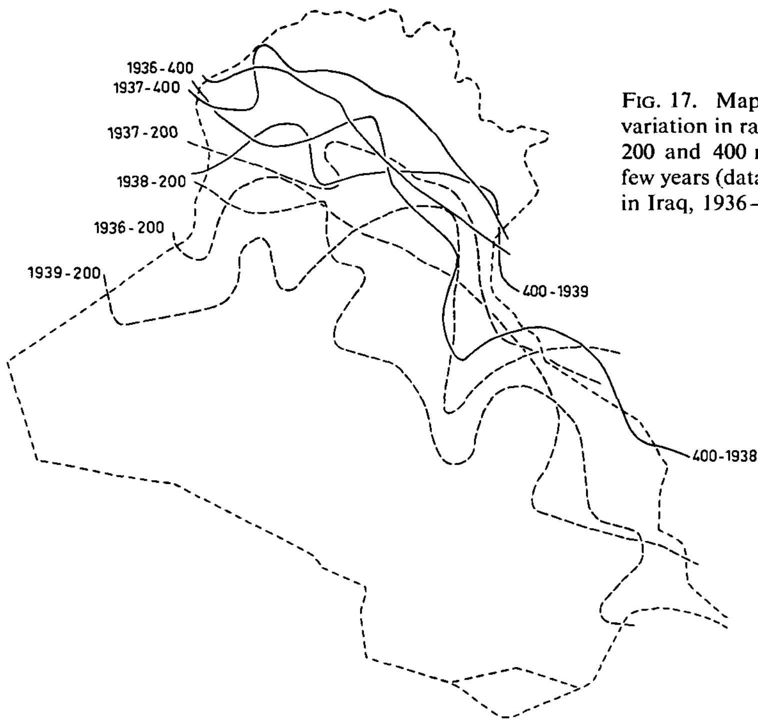


FIG. 17. Map showing the annual variation in rainfall. The isohyets of 200 and 400 mm. are shown for a few years (data taken from: Rainfall in Iraq, 1936–1939, Baghdad).

vegetation as there was no rain at all. The nomadic life of the Bedouins is adapted to these conditions.

For the dry farming agriculture this fact and the amount of rainfall in spring are the main factors for the success of the crops. Some extra rain in March or April can favourably influence the yield of wheat and barley.

The maximum rainfall in one day is 55.6 mm. (16.3.1938) in Baghdad; in Mosul, 86.3 mm. (27.11.1929); in Kirkuk, 97.6 mm. (1.5.1953); in Khanaqin, 93.4 mm. (21.3.1943) and in Rutba, 45.7 mm. (26.12.1935). In Baghdad there are 25 to 30 rainy days per year.

The lesson which may be learnt from these examples is that the statistical data should be carefully interpreted, and that average data sometimes may be rather misleading, particularly for those areas with relatively low rainfall data.

TABLE 3. *Rainfall in Iraq in mm., period 1937–1952.* Taken from Dennis (1953).

Station	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Yearly mean	No. of years	lowest yearly mean	highest yearly mean
Penjuin	311	245	239	105	54	0	0	0	0	51	130	204	1339	11	936	1731
Bakrajo	143	117	117	82	35	1	2	0	0	13	99	117	825	12	147	1036
Erbil	112	92	78	64	33	0	0	0	0	12	51	76	518	15	275	702
Mosul	70	78	53	47	18	0	0	0	1	5	48	62	382	29	253	543
Kirkuk	66	70	81	43	7	0	0	0	0	4	36	63	371	14	263	657
Khanaqin	66	54	68	26	16	0	1	0	0	7	31	59	327	14	172	473
Basra	32	22	34	23	8	0	0	0	0	1	28	23	117	15	70	302
Baghdad	24	26	27	10	3	0	0	0	0	8	19	26	134	16	72	315
Rutba	16	16	14	17	8	0	0	0	0	5	10	23	110	22	68	201

Temperature

This data gives a much better idea, as the variations in time or location are of minor importance. The figures are given in Table 4.

TABLE 4. *Temperature in Iraq.*

Station	Temperature °F.												
	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Year
Baghdad													
Mean	49	53	59	72	83	91	94	93	87	77	64	52	73
Mean Max. . .	60	64	71	84	97	105	110	110	103	92	77	64	86
Mean Min. . .	40	42	48	58	68	73	77	76	68	62	52	42	59
Highest Max. .	74	86	90	104	111	116	121	120	116	107	94	79	121
Lowest Min. . .	18	27	28	38	51	58	62	65	51	39	35	20	18
Basra													
Mean	54	58	65	74	86	91	93	92	87	79	68	57	75
Mean Max. . .	64	68	75	85	96	100	103	106	102	94	80	69	87
Mean Min. . .	46	48	55	63	76	81	81	78	72	64	57	48	64
Highest Max. .	81	87	95	105	112	115	117	120	113	110	98	85	120
Lowest Min. . .	24	36	39	52	63	71	73	68	58	46	38	29	24
Mosul													
Mean	43	47	53	63	76	86	90	90	81	69	58	47	67
Mean Max. . .	54	58	66	75	92	103	109	109	102	92	72	58	82
Mean Min. . .	35	38	42	49	58	65	72	70	61	52	46	38	52
Highest Max. .	66	78	87	104	108	115	124	119	117	104	95	76	124
Lowest Min. . .	12	21	25	31	44	50	59	55	45	32	26	19	12
Rutba													
Mean	43	48	54	64	74	81	86	86	80	69	57	47	66
Mean Max. . .	55	60	68	78	90	97	101	102	97	86	71	59	80
Mean Min. . .	34	37	36	50	59	65	70	70	63	55	46	37	52
Highest Max. .	77	89	95	101	108	111	115	114	113	100	95	76	115
Lowest Min. . .	6	17	21	32	43	54	58	59	48	36	23	16	6

The mean temperature of Baghdad is 73 °F.; the mean January temperature is 49 °F. and the July-August temperature is 93 °F. The highest recorded temperature in Baghdad is 123 °F. and the lowest 18 °F. All temperatures are measured in the shadow in an open field at a height of 2 metres above ground level. In the sun and close to the ground surface they are some degrees higher. Some data are given in Table 5.

The temperature recorded at Baghdad Airport on 4.8.1956. was 46.1 °C. maximum; the normal maximum is 42.8 °C. The wet soil in Table 5 was irrigated and dried during the period of observation. The soil is a silty clay loam. In Baghdad 75% of the day-time hours have sunshine and in Mosul 68%.

The air humidity is rather low. In Baghdad the relative humidity in summer is on an average between 12% and 15%, and in Mosul between 13% and 16%. During some days or weeks in August the relative humidity is much higher with maxima of 40% to 48% (during the nights) and minima of 13% to 19% on the same days.

TABLE 5. *Soil temperatures in °C near Baghdad* (4.8.1956).

4.8.1956 Time	On the surface	Dry soil at a depth of 1 cm.	Wet soil at a depth of 1 cm.
11	50.0	48.3	26.5
12	52.1	49.5	27.2
13	54.2	50.5	29.0
14	54.2	50.8	29.2
15	52.0	50.1	29.4
16	50.6	48.0	30.0
17	46.5	46.0	31.0
18	41.0	43.5	31.2
19	38.3	40.3	31.0

In the period from July 20th until August 10th, very often a heatwave is recorded with temperatures rising up to 46 or 48 °C., sometimes even 49 °C. (in the shadow, in the open field). A characteristic of the arid, hot summer months is that the climate is the same every day. There are a few exceptional days in which the temperature rises above the normal figure.

Due to the high temperature and the dry climate, evaporation, particularly in the summer, is high. On an average the evaporation in summer is 15 mm. per day, sometimes even up to 25 mm., when there is much wind. Without wind the evaporation from an open surface is about 10 mm. The following table (Table 6) gives some data of the Abu Dibbis Lake (K.T.A.M., 1953): other data are mentioned in Chapter 7.3.2.

TABLE 6. *Monthly and annual evaporation* (in mm.) *at Abu Dibbis Lake* (1942–47).

January	103	4.8%	August	304	14.0%
February	92	4.3%	September	272	12.5%
March	165	7.6%	October	93	4.2%
April	130	6.0%	November	177	8.2%
May	142	6.5%	December	125	5.7%
June	249	11.5%			
July	318	14.7%	Annual	2,170 =	100%

The evaporation at Lake Habbanyah is 1900 mm. per year (1.5% of the total loss in January and 20% in July). The daily loss in July is approximately 10 mm. from an open surface and 6 mm. by transpiration from a vegetated surface (Hunting Group, 1955).[1]

As a consequence of the climate, the temperature of the irrigation water is rather high. In summer in the daytime, irrigation water is about 30 °C.; it mostly varies from 28–32 °C.

Frost is rare outside Kurdistan.

Wind

The north-westerly wind (Shamal) is predominant. Figure 18 gives the wind direction

[1] Recently a study for the Wadi Thartar has been made by L. Wartena 'Het klimaat en de verdamping van een meer in Centraal Irak', Wageningen, 1959.

for Mosul, Baghdad and Basra. The prevailing rain-bearing winds blow from the south and south-west.

As a result of rather strong winds in a dry climate, duststorms are quite common, particularly in the deserts and the Mesopotamian plain. The main duststorms are in the early summer months; however, some summer duststorms occur. They are a result of cold air from Northern Europe penetrating into the Syrian desert. The air in the desert becomes very unstable, stirring up strong winds, at some places nearly 100 km. per hour, and dust is brought over hundreds of kilometres. Baghdad has on

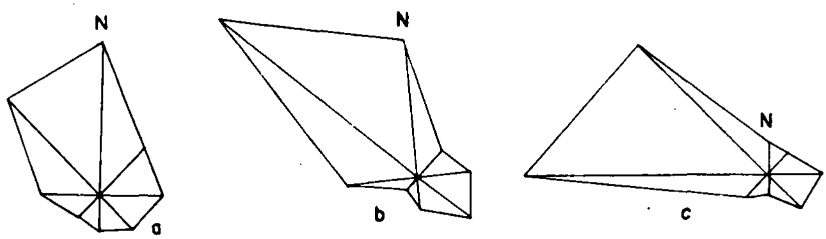


FIG. 18. Wind diagrams of (a) Mosul (1923–23); (b) Baghdad (1937–1941); and (c) Basra (1937–41). (After Vaumas, 1955).

an average 23 major duststorms in the year with a variation from 6–63. The mean number of 'dusty' days in July is five; in many years there are even 15 'dusty' days in that month. According to Lees and Falcon (1953), the duststorms bring (annually) 0.1 inch of material over Iraq; that means 8 feet in 1000 years! On the 15th and 16th of August 1956, nearly the whole country was enveloped in a cloud of very fine dust; there was no wind and the sun could not be seen on either day.

Alternations in Climate

During the Pleistocene the climate changed a few times. It is proved that periods with a much more humid climate alternated with much drier periods; these are called pluvial and interpluvial phases in the Pleistocene, respectively. At the moment there is an interpluvial phase. From a climatological point of view, almost nothing is known about these alternations; however, the old drainage and gully systems, the older Holocene deposits, the occurrence of river terraces and fossil soil profiles prove that the climate has changed at least three times. More details are described in chapter 6.8. According to the present knowledge, the climate has not changed during the last 6,000 years; possibly it is tending to become somewhat drier. A period of desiccation is known from Neolithic times (Fisher, 1950). In the Syrian part of Jezireh, the climate has become somewhat drier since Neolithic times (Van Liere and Lauffray, 1955). According to Wright (1952) there is some evidence of a somewhat more humid climate in the period 750 to 600 B.C.

Soil Climate

Climate is an important factor in soil formation and therefore it should be studied. However the climate as it has been described before is not entirely the same as the climate which influences soil conditions. In a hilly or mountainous area, there are big differences in exposure (and consequently in temperature), and in relief. Due to differences in relief a large part of the rainwater flows over the surface and does not penetrate the soils on hill and mountain slopes. It reaches the valleys which therefore have much wetter conditions, as may be deduced from the rainfall records. On the other hand only a part of the precipitation is effective. In central and southern Iraq most of the rain-water evaporates and not more than approximately 25% of the winter rainfall may be effective. In the uplands and mountains about 75% of the winter rainfall will be effective. Many soils in Iraq have crusts on top. Rainwater does not penetrate the crust; there is a surface runoff and at the foot of hill slopes and in the depressions, much more water collects than may be expected. Several examples are given in the following chapters.

By irrigating land, conditions prevailing in humid regions are artificially introduced into arid regions. Here the climate has been changed by human activity. The effect of irrigation is: wet and moist soils with a high temperature and a large quantity of intensive sunshine.

The summer temperature in most soils is very high because soils are exposed to direct sunshine, except in the fruit gardens on the river banks where the soils are in the shadow and the soil temperature is much lower than the temperature in the open field. A very large part of the rainfall does not reach the soil in the date and fruit gardens, as it evaporates on the leaves. Air humidity in the gardens is much higher than in the open field.

2.3. Hydrology

The hydrological conditions of Iraq are controlled by the Twin rivers, the Euphrates and the Tigris. During the last few decades, several books and many articles have been written on both rivers, which were studied intensively as they are the key to the agricultural development of the country. Therefore I refer to the following authors, and in this book only some general data, which is important for the understanding of the soil conditions, will be mentioned.

Willcocks (1917, 1926); Ionides (1937); Macfayden (1938); Coode, E. A. (1940, 1948); Director General of Irrigation (1944); Soussa and Atkinson (1944/46); Soussa (1945); Haigh (1949); Kholy (1952); K.T.A.M. (1952); Vaumas (1955); Nelson (1956).

The drainage basins of the Tigris and Euphrates rivers cover an area of 704,500 km.^{2}, of which 359,000 km.^{2} is in Iraq. The rest is in Turkey, Iran, Syria and Saudi Arabia (K.T.A.M., 1952). A sub-division is given in Table 7. A map of the drainage area of the Twin rivers is published by Ionides (1957) and by K.T.A.M. (1954).

TABLE 7. *Basin areas of the Tigris and Euphrates* in km.^{2}, according to Vaumas (1955).

River	Mountains	Hills	Plain	Desert	Total
Tigris (S. of Baghdad)	74,385	75,603	15,535	632	166,155
Euphrates (near Hit)	82,330	62,960	–	118,830	264,120
Wadi Tharthar . . .	–	2,980	3,715	17,775	24,470
Wadi Hauran	–	–	–	16,770	16,770

The length of the Tigris is 1,718 km., of the Euphrates 2,333 km. (without the Kara Sou (450 km.) and Murat Sou (650 km.). The Tigris enters the Lower Mesopotamian Plain south of Samarra, the Euphrates near Ramadi. The average flows of both rivers are given in Table 8, a cross-section in Fig. 19.

TABLE 8. *Average river flows* (Nelson, 1956).

Average flow of the Tigris near Baghdad (1906–1952):	38.8 milliards m^3/year
Average flow of the Tigris near Baghdad (1930–1934):	32.4 milliards m^3/year
Lowest flow of the Tigris near Baghdad (1930):	15.7 milliards m^3/year
Average flow of the Euphrates near Hit (1924–1952):	26.4 milliards m^3/year
Average flow of the Euphrates near Hit (1930–1934):	17.2 milliards m^3/year
Lowest flow of the Euphrates near Hit (1930):	12.0 milliards m^3/year

As soon as the rivers enter the flood plain they are meandering rivers, which become more irregular south of Hindiya and Kut. In the upper part of the plain the topographical position of the Euphrates is somewhat higher than the Tigris. Due to this fact the land between both rivers north-west and south-west of Baghdad is irrigated by

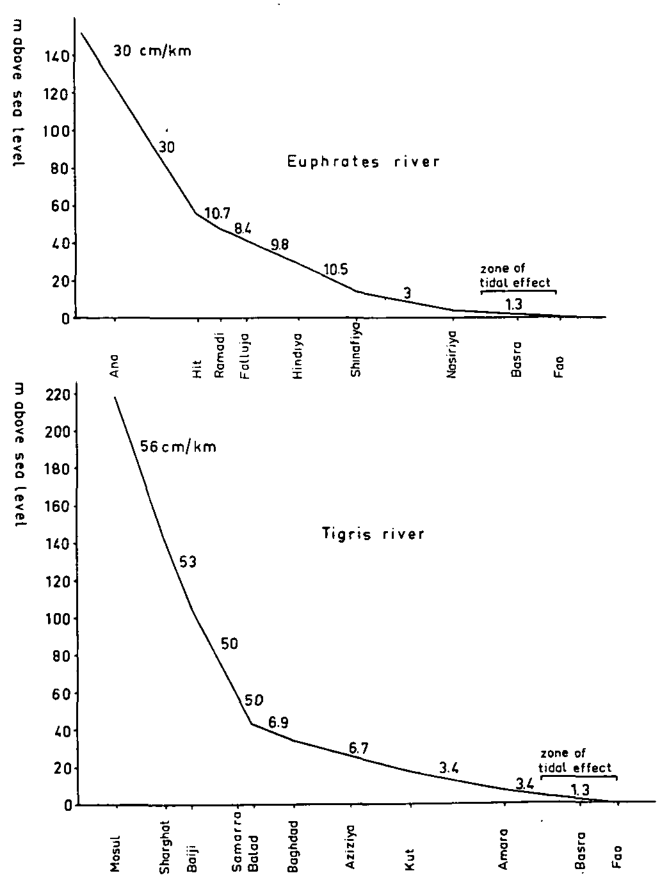


FIG. 19. Two diagrams showing the elevation of the Euphrates and Tigris rivers throughout Iraq.

Euphrates water. In ancient times some canals connected both rivers (Le Strange, 1905).

A fundamental fact is that most of the water from the Twin rivers does not reach the sea. It is partly used for irrigation; a part is evaporated, but a large part just disappears in the marsh region in the southern part of the plain. The Tigris is losing most water between Kut and Amara. Examples are given by Vaumas (1955):

Water passing Kut (17.3.1946):	6,200 m^3/sec.
Water passing Amara (17.3.1946):	560 m^3/sec.
Lost:	5,640 m^3/sec.

The annual loss is 961 $m.^3$/sec. of the 1,179 $m.^3$/sec. which passes the Kut barrage. In the Euphrates between Hit (838 $m.^3$/sec.) and Nasiriya (458 $m.^3$/sec.), 46% of the water is lost over a distance of 680 km. (evaporation and irrigation). The rest is nearly completely lost in the marshes, particularly in the Hammar Lake (Vaumas, 1955). The Tigris level is high in April and May and low in September and October. The Euphrates is high in April and has its maximum in May. Its minimum is in September-October.

Water in both rivers is of a good quality for irrigation and domestic purposes, although it contains some salt (0.2–0.4 g./l.) and a rather high amount of silt (1–4 g./l.). The calcium and magnesium content of the river water is high in relation to sodium; therefore no sodium carbonates are formed. Gypsum is important in the irrigation water. Russel (1957) has made some computations of the published analyses of the Tigris river water. For the nine non-flood months the mean composition is:

Harmful sodium salts, mostly NaCl	55 parts per million
Calcium sulphate, harmless	81 parts per million
Calcium and magnesium carbonates (harmless) . . .	125 parts per million
Total	261 parts per million

of which 206 parts per million are non-harmful, even beneficial. Some chemical analyses are given in Table 9.

TABLE 9. *Chemical analysis of Tigris water* (Hunting, 1956).

Period	E.C. × 10^6	T.S.S. p.p.m.	ion milliequivalents per litre						
			Ca	Mg	Na	HCO_3	SO_4	CL	NO_3
February '55	390	260	2.2	1.0	0.3	2.4	0.6	0.3	Nil
May '55	370	250	2.0	0.7	0.4	2.7	0.6	0.3	Nil
July '54	400	224	2.0	1.7	–	–	0.3	0.3	–

During periods of high discharge, the salt content in the Tigris is 10–15 mg./l., in the Euphrates about 50 mg./l. During periods of low discharge, salt content in the Tigris is 30–40 mg./l. (de Gruyter, 1953). The salt content of the Euphrates is somewhat higher and more variable than in the Tigris river. To the south, salt content in the rivers increases. Near Nasiriyah it was 462 mg./l. in September 1951 (de Gruyter, 1953). The water in the Shatt El Arab is somewhat more salty, as there is an invading salt water wedge from the sea with a fresh water layer on top. Several days a year, when there are strong southerly winds, the salt content near Abadan exceeds 2,000 parts per million.

Salt content in both rivers is relatively low and it is expected to decrease when both rivers are controlled by reservoirs and diversion works (Nelson, 1950).

The silt content, which is highest in periods of high flow, will be lower, too, in the regulated rivers. Desilting of the irrigation canals, especially those near Basra, is a problem. The port of Basra spends ID. 500,000 per year on dredging operations.

The silt content of the Tigris river at periods of high flow (14,000 $m.^3/sec.$) is 25 g./l. or for the whole river, 35,000 kg./sec., or 3,000,000 tons/day (de Gruyter, 1953). Monthly averages for the Tigris will be found in Table 10.

TABLE 10. *Average discharge and silt content of the Tigris river near Baghdad* (K.T.A.M., 1953).

Month	Average Discharge $m^3/sec.$	Average silt content $g./m^3$
January	922	380
February	1,355	650
March	1,985	1,400
April	2,909	2,300
May	2,777	2,100
June	1,661	1,200
July	870	380
August	480	240
September	360	180
October	352	170
November	496	220
December	682	320
Year	1,236	795

The silt content in the Euphrates river near the Hindiya Barrage was, in 1954:

900 parts per million before the flood period, and

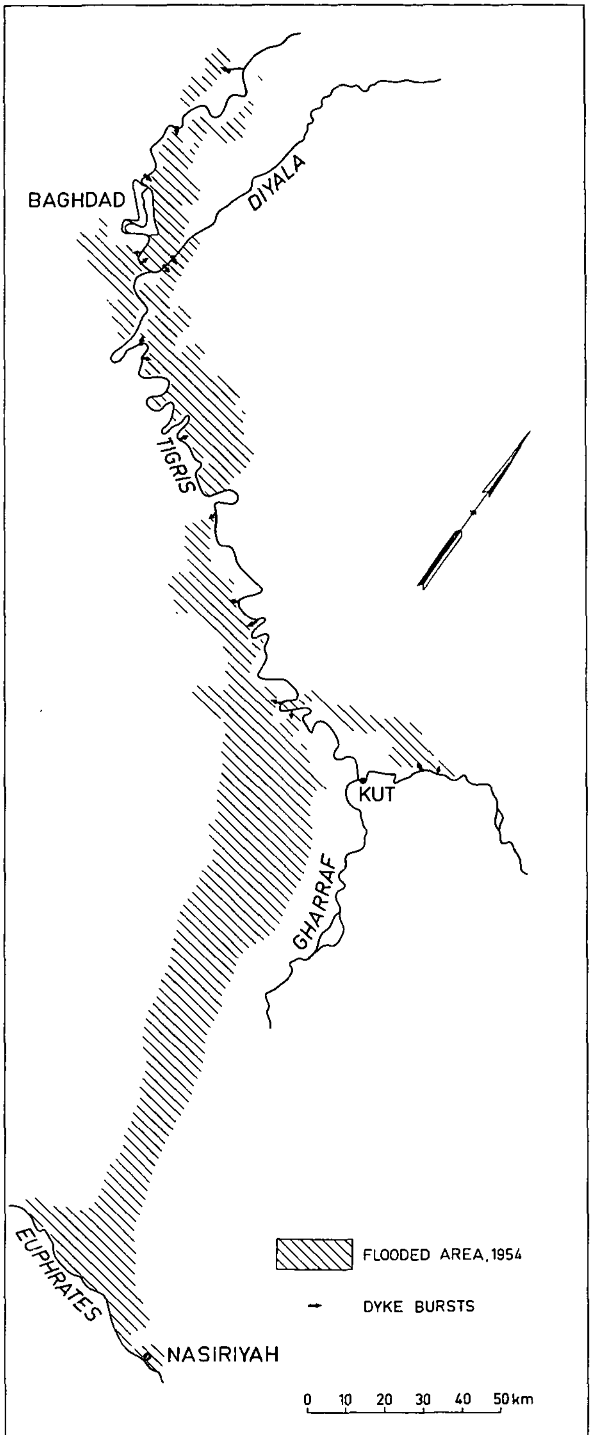
4,100 parts per million during the flood period (Nedeco, 1956).

The silt content of the rivers varies with the flow, the period of the year, the rising and falling of the flood and several other factors.

Recent data on the sediment carried by the Tigris river is published by Kholy (1956). He reported in the data for 1953, when at the peak of the flood of March 3rd, 101 $m.^3$ of sediment were passing Baghdad every second. The following table is given (Table 11).

TABLE 11. *Sediment carried by the Tigris river in 1953.*

Jan. 1. to March 2.	31,284,000 m^3
March 3. to March 7.	23,935,000 m^3
March 8. to March 31.	11,150,000 m^3
April 1. to April 30.	22,940,000 m^3
May 1. to June 30.	10,869,000 m^3
July 1. to Dec. 31.	11,126,000 m^3
Total in 1953	111,304,000 m^3



The Adhaim river was the main contributor of sediment. In 1938 the Tigris river carried 24 million $m.^3$, 10 million $m.^3$ being carried during the peak flood (Gibbs, 1954).

Nearly all salt and silt of the rivers is deposited in the Lower Mesopotamian Plain. Each year the Twin rivers carry 76.2×10^7 cubic feet of silt (Lees and Falcon, 1952) to the plain!

Both rivers have small dykes, the Euphrates from Ramadi to south of Kifl, the Tigris from south of Balad down to Kut and from there on the right side only for a further 68 km. The Shatt El Arab has dykes too.

Almost every 3 or 4 years there used to be a flood in the Lower Mesopotamian plain, mostly in April-May. Factors causing floods are: heavy rainfall in the mountain areas and melting snow. According to Nelson (1956) nearly all great floods in the Tigris have been caused by moderately heavy rainstorms, lasting scarcely more than two days. An example is the rainfall of 94 mm. on 2.2.1946 at Choarta in the Lesser Zab area. The next day there was 45 mm. of rain. Even when all flood control works are finished, there may possibly be some floods near Baghdad and in the south when conditions are unfavourable (Nelson,

FIG. 20. Map of the flooded area in spring 1954.

1956). The mountains in the catchment areas are bare and steep and they have relatively impervious slopes. A list of floods is given by Zeki (1954). The flood of 1954 was the worst in 50 years. It covered an area of 2,105,800 mesharas in the Tigris basin and approximately 400,000 mesharas in the Euphrates basin, with a crop value of about ID. 20,000,000 (Ali, 1955), see Fig. 20.

The highest water flow in Baghdad was 11,600 m.^{3}/sec.

Flood control has the first priority in the development of the country. An outline of the flood control programme is given in a booklet of the Government of Iraq (1956) and in many articles (see 2.9.). In the future the environmental changes may lower the stream beds as a result of normal stream erosion. It is unknown what will be the consequences for irrigation and agriculture.

Some interior basins occur. The most important one is the Wadi Tharthar depression, which is being filled with Tigris flood water since 1956 when it was connected by the Wadi Tharthar canal with the Tigris river. There are some more basins in Jezira and in the desert regions which are all saline. North of Rutba is the Ga'ara depression.

Water from both rivers is used for irrigation and domestic purposes in central and southern Iraq. At the moment 10,400,000 mesharas of land are irrigated. This area will be increased to 22,000,000 mesharas, for which 38.2 milliard m.^{3} of water are needed annually (26.1 milliards m.^{3} in the Tigris and 12.1 milliards m.^{3} in the Euphrates basin). According to this estimation of Nelson (1956) there will be enough water for irrigation all year round. Dennis (1953) expects that there will not be enough water to bring all irrigable land under cultivation. I also doubt whether there will be enough

FIG. 21. An underground irrigation canal or kahrez south of Kirkuk, which is used to collect water from the gravel hills and transports it to lower-lying fields. The photograph shows a pit in a soil with a gravelly substratum. The pit is used to clean the underground canal.

water, as a rather large quantity will be needed for leaching and drainage, and for domestic purposes much more water will be required in the future than is used at the present time.

Besides the normal open irrigation systems, there still are some karezes or foggara's (ganats in Iran, feledjs in Oman), see Fig. 21. Springs occur in the mountain region, depending on the porosity of the limestone and its geological structure. Mostly they are formed in permeable rocks and sediments which are underlain by a less permeable layer. The cultivation of tobacco in Kurdistan mainly depends on irrigation water from springs. Wells are highly important in the desert area. Sub-surface water investigations have been made (Noble, 1926; Dennis, 1953; Macfayden, 1938) and recently by the Parsons Company (1955) which was doing extensive work over almost the whole of Iraq. An important question is whether this sub-surface water in the desert is of Pleistocene age (fossil water) or of Holocene age, and how much water is available.

2.4. VEGETATION

As a consequence of the arid climate, vegetation is scarce in large parts of Iraq. Forest vegetation occurs only in the Kurdish mountains. A forest map of northeastern Iraq, scale 1:800,000, was published in 1954 by the Forest Department of the Ministry of Agriculture. The influence of human activity on the natural vegetation is very important. Nearly everywhere natural vegetation has been destroyed. General studies on the vegetation of Iraq are published by: Guest (1932, 1933, 1953), Zohary (1950), and Springfield (1954). Guest's work is in progress; he is preparing a vegetation map of Iraq and a complete flora. Smith (1944) and Champman (1949) have described the forests in northern Iraq. The books of Hooker (1937) on Iran and of Zohary (1940) on the Syrian desert may be of interest for Iraq too. The following general information is taken from the above mentioned reports, in particular from Zohary (1950) and Springfield (1954).

Due to its geographical position the flora of Iraq is of a heterogeneous phytogeographical character. According to Zohary (1950) three principal plant geographical regions or elements are represented in this country.

a. The Mediterranean element, represented by a number of Mediterranean weeds occurring in cultivated fields. It is believed that these weeds are either the easternmost representatives of the Mediterranean flora or relics of the Tertiary Palaeo-Mediterranean vegetation.

b. The Irano-Turanian element, which is the most important, occuring in the vast areas of the Syrian Desert and Jezira and in the hill and mountain region.

c. The Saharo-Sindian element, occurring in the Southern Desert and nearly the whole Lower Mesopotamian plain.

Some details which are important for the study of soils will be discussed in Chapters 4, 5, and 6.

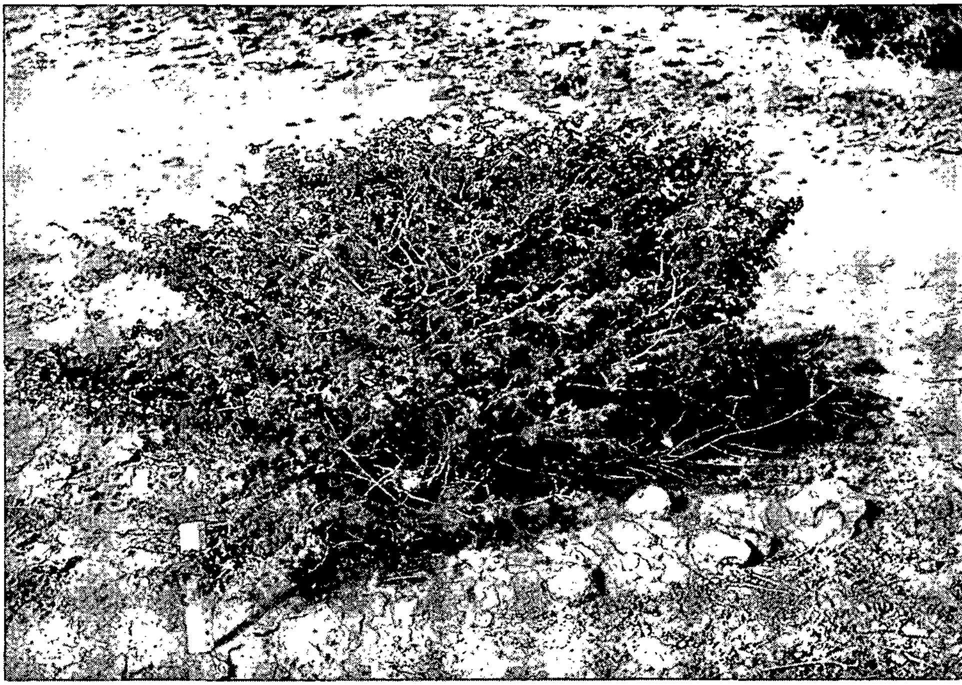


FIG. 22. Shok (Prosopis Stephaniana), a common leguminous weed on saline land in the Lower Mesopotamian Plain (the ruler is 10 cm. long).

The vegetation is adapted to a climate with hot dry summers; it can survive in two ways:

1. when the growth cycle is completed in the cooler, rainy season, the plant dies and the seeds survive, (e.g., cereals, grasses);
2. by structural adaptation (deep roots, bulbs, rhyzomes).

The number of species of plants in Iraq is fairly large. According to Fisher (1950), over 2,000 species occur in the desert and its margins. The vegetation in the river plain has largely been destroyed and the principal vegetation is now hydrophytic, halophytic, segetal and ruderal (Springfield, 1954). Leguminous species are exceptionally abundant as weeds in cultivated land; they are significant from the point of view of maintenance of soil fertility and desalinization (Chapter 7.1. and 7.2.).

Guest (1933) has made the following geographical subdivisions of Iraq, based on variations in vegetation:

1. The Lower River Plain (50–150 m.);
2. The Upper Plain (rolling and undulating plain north of the Jabal Hamrin, 200–500 m.);
3. The Jabal Hamrin belt (separating 1 and 2);

4. The Foothills of Kurdistan (500–1000 m.);
5. The Kurdish mountains.

This subdivision is nearly the same as has been given in chapter 2.1.

Human mismanagement has caused the deterioration of natural conditions; many factors can be mentioned:

a. Cultivation of land for many thousands of years;
b. Shifting cultivation in the steppe region;
c. Grazing and overgrazing, particularly in the semi-arid regions;
d. Using wood for fuel, charcoal burning and house construction;
e. Digging sub-shrubs for fuel;
f. Irrigation with additional salinization and over-silting;
g. and, as a result of mismanagement, wind and water erosion.

If the natural vegetation is destroyed, it is very difficult and often even impossible to restore the natural conditions, particularly in an arid and semi-arid climate and in mountain regions.

Under arid conditions soils are blown and form desert pavements or lime and gypsum crusts, which prevent the growth of grasses. In the mountains the rather thin soil layers under natural forest are eroded as soon as the trees are cut, and bare rocks remain. Erosion control and afforestation are not only important for restoration of

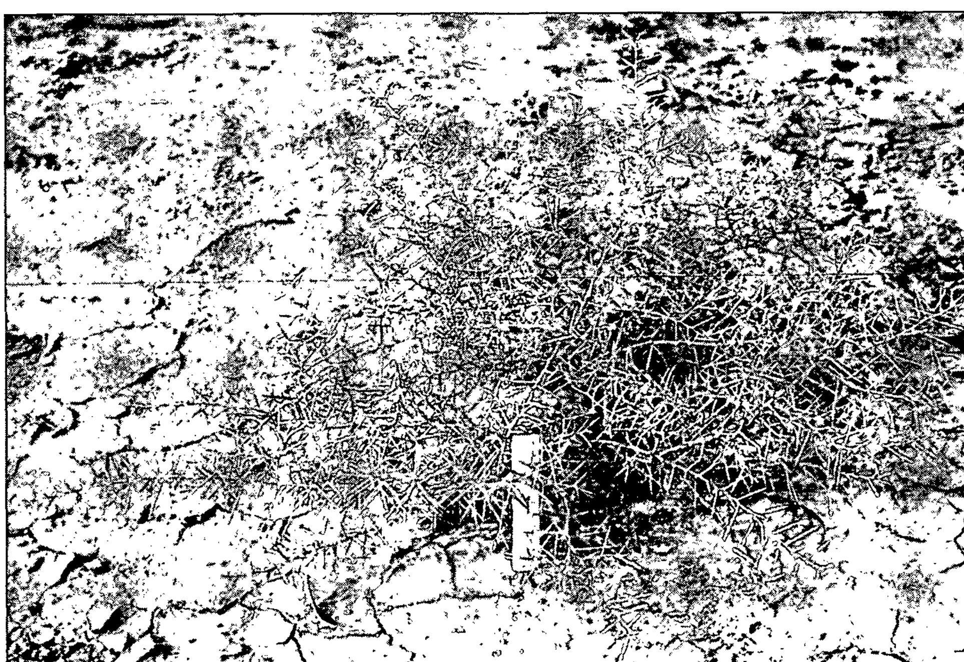


FIG. 23. Agul or Camelthorn (Alhagi maurorum), also a common leguminous weed on saline land in the Lower Mesopotamian Plain (the ruler is 10 cm. long).

natural conditions; they also have to prevent the silting up of the water reservoirs near the dams in the rivers. A plan for the Dokan area has already been made. Afforestation in the mountain area started in a few areas. Bobek (1951) describes the denudation in western Iran which is similar to north-eastern Iraq.

Some plants only occur in special places under specific conditions of climate and soil. Those 'indicator plants' may be helpful in soil investigations. Examples are given in the K.T.A.M. report (1952) and in the soil survey and land classification report of the Adhaim and Nahrwan areas (Hunting Group, 1956). However the influence of man, sheep, goats and camels is strongly evident in all project areas. Using specific plants as indicators in soil surveys can be done only after a careful examination of the situation in the field by professional men. Those readers who are interested in the ecology of the various regions mentioned in the following chapters are referred to an article by Guest (1953).

2.5. Population and communications

The first census was in 1947 and could not be accurate as is clearly explained by Mrs. Adams (1956). The second census took place in October 1957. The data was not available at the time of finishing the work on this book. In 1955 the total population was estimated at 5.9 to 6.1 million. The Statistical Abstracts for 1956 give 4,904,792 people (foreigners and nomadic tribes are excluded). The census of October 1957 has given 6,538,109 people; this is an increase of 38% since 1947. Baghdad has 1,306,604 inhabitants. The rate of natural increase is about 3.5% per annum. In 2,000 the population of Iraq will be nearly 9 million. (Iraq Times, 28.7.1956). 5% of the population are nomadic bedouins. An extraordinarily large percentage consists of children; the age of 18% of the total population is less than 5 years and 34% less than 10 years. These figures are respectively 11% and 20% in the U.S.A. 70% of the population is living in the irrigated zone of the lower Mesopotamian plain. Two-thirds live in villages and camps. The distribution of the population is studied by Lebon (1953).

The majority of the rural population lives in mud-huts. In Baghdad, 13%, and in Basra, 40% of the people are living in mud-huts. In the future much will be done to solve the housing problem; a special housing section was established in the Development Board in 1956. At the present time 453,000 families need houses.

There are three large communities in Iraq:

the Shi'i Arabs	45% of the total population
the Sunni Arabs	30% of the total population
the Kurds	18% of the total population

The Sunni Arabs are living north of Baghdad, whereas most Shi'i Arabs live south of the capital. Furthermore, there are some minorities like Christians (3%), Assyrians and Armenians. The book of Hourani (1947) deals with these minorities. A map showing racial divisions is published by the Admiralty War Staff (1916). The Shi'i and Sunni Arabs both speak Arabic; the Kurds speak Kurdish, and they have the same religion as the Sunni's.

Most people are employed in Agriculture (55%). This figure, however, is too low as many women and children are employed in agriculture too (Mrs. Adams, 1956). As regards the employment, the following table (Table 12) can be given.

TABLE 12. *Employment in Iraq* (F.A.O., 1955).

Agriculture	67%
Trade	8%
Industry	6%
Transportation	3%
Government	9%
Others	7%

For a real understanding of Iraq and its people, attention is drawn to the following authors: Gaudefroy-Demombynes (1950), Warriner (1948 and 1957), Hourani (1947).

Only 8.5% of the people are literate (14% of the males and 3% of the females). During the last few decades, and in particular during recent years, much has been and still is being done to educate the children and adults. In 1953/54 there were 1,451 primary schools, with 258,000 students and 134 secondary schools with 35,000 students. There are several colleges in Baghdad which will soon be combined with the Baghdad University. The Agricultural College, which was founded in 1952, is located in Abu Ghraib, some 20 km. west of Baghdad. Several hundred students receive

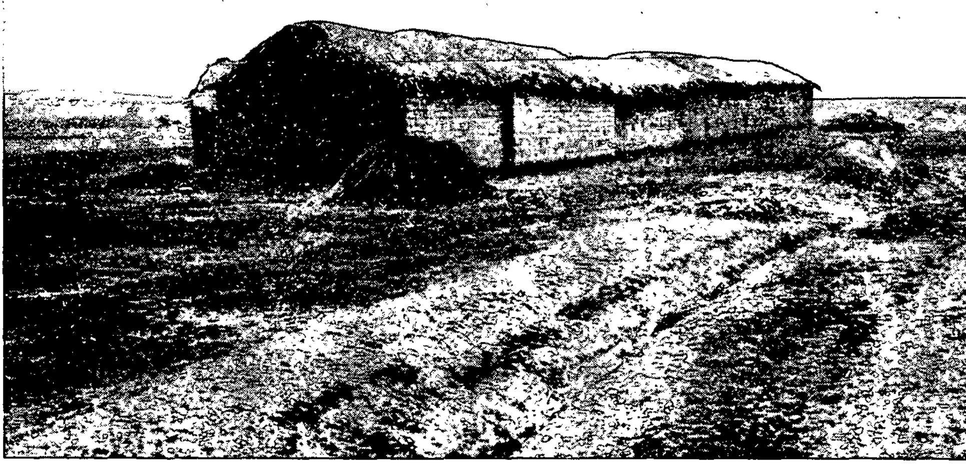


FIG. 24. Most farmers of Iraq live in mud houses, built from mud or sundried bricks. A farm near Mosul.

higher education abroad, mostly in the United States and the United Kingdom, since 1958 also in Moscow. U.N.O. and I.C.A. have granted many scholarships to young Iraqis. Many educational problems have to be solved in the near future (Jamali, 1934).

The birth rate is high (fertility ratio 837); however, infant mortality is very high. The crude death rate is estimated at 30 per 1,000; the crude birth rate at 50 to 55/1,000. (Adams, 1956). In the cities 10% of the babies born alive die in the first year of life; for the rural areas this figure however is 25–40%, and in the malaria areas even 50%. In the irrigated areas 15–70% of the population has bilharzia. Other diseases are: trachoma, hookworm, and dysentery. In Dujaila, near Kut, 80% of the people had trachoma. During recent years much has been done to improve the health of the population. One of the main points is the improvement of drinking water.

Polygamy is disappearing in Iraq; in 1947, 8% of the married men were married polygamously; of these 90% had two wives, 8% three wives and 2% four wives. There are no figures for the nomadic bedouin, but they ar expected to be higher.

The average income in Iraq is low; it was estimated at $ 77 to $ 85 per annum (Van Valkenburg, 1954). According to Time (June 17th, 1957), the income per capita was $ 84 in 1950 and $ 140 in 1956. The average farm income is only ID. 35/- (K.T. A.M., 1952). The national income for 1956 was estimated at ID. 292 million, of which ID. 78 million (25%) came from the oil industry and ID. 70 million or 23% from agriculture (Iraq Times, 15.6.1957).

Malnutrition is probably the main factor undermining the farmers' health. The diet of the Iraqi seems to be sufficient from the point of view of calories; however, the protein consumption is too low. This is probably one of the reasons why human productivity is undermined. The majority of peasants live on the extreme margin of subsistence (Fisher, 1950). In the last 20 years there has been an important migration of peasants to the cities due to adverse social and economic conditions in rural areas and to the unfair treatment of the farmers by the landowners.

The communication system is gradually improving. Basra has an important seaport connecting Iraq with all parts of the world by various ocean routes. Baghdad and Basra have international air ports. A railroad connects Basra with Baghdad, and thence via Mosul, with Syria, Turkey and Europe. A second line runs from Baghdad via Kirkuk to Erbil, the oldest, permanent inhabited city of the world. The road system is very poor and most roads are unmade. During recent years many highways have been constructed. A road map is published by Salter (1955). For the transportation of oil there are pipe lines from the Kirkuk oilfields to Banias (one line) and Tripoli (two lines) on the Mediterranean coast. Another pipe line connects the Mosul oilfields with Baghdad. A short line connects the Zubair fields west of Basra with Fao on the Persian Gulf. The Tigris and Euphrates are not very important in transport.

Readers who are interested in the people of Iraq may refer to the following books and articles: Harrison (1924); Field (1936); Dickson (1949); Douglas (1951); Fernau (1954); Fisher (1955); and the Statistical Abstracts (1956). The political, social and economic history is described by Longrigg (1953); Ireland (1937); Fisher (1954); Frye (1951); International Bank of Reconstruction (1951); and Salter (1955).

2.6. History

Although the history of Iraq as an independant country is very young, the history of the land is very old. There are many books dealing with specific periods which are quite interesting, also from the point of view of soils. Lloyd (1943) has written a brief history of Iraq from the earliest times to the present day. Furthermore, attention is drawn to many books dealing with the archaeology and history of this country, e.g. Hitti (1953); Braidwood (1952, 1953); le Strange (1905); Ghirshman (1954); Lloyd (1947); Conteneau (1954); Ceram (1953); Lloyd (1945); Frankfort (1951); Obermeyer (1929); Parrot (1946, 1953); Huxley (1954); Beck (1950); Longrigg (1925); Speiser (1951); Grant (1937); Hedrin (1917); le Strange (1924); and many articles published in 'Sumer' issued by the Directorate General of Antiquities in Baghdad, the 'Journal of Near Eastern Studies', 'Antiquity', 'Iraq' and several other journals. More literature may be found in the books mentioned and in the annual publications of the Middle East Institute (1955).

Much is known about the archaeology and history of this land. Most studies however do not give a good description of agriculture as almost nothing is known on this subject. History is made in the cities. A golden age in history is not always a golden age in agriculture!

The earliest known agriculture has been discovered by an American archaeological expedition in a mountain valley in Iraq Kurdistan (Breadwood, 1951, 1952, 1953, 1954). The oldest written document on agriculture was found at Nippur in the Lower Mesopotamian valley (Jacobson, 1951). It is well known that irrigation is very old in southern Mesopotamia. It may be learned from the following chapters that human activity greatly influenced soil conditions. There are several reasons why the archaeology and history of this country are important for the soil studies; therefore some of these aspects will be discussed later, when describing soil conditions of specific areas. On the other hand, soil science can contribute to both archaeology and history, especially when the soil scientists are interested in these subjects. A few papers have been published (Wright, 1952 and 1955; Buringh, 1956, 1957; Harris and Adams, 1957).

For those readers who are not familiar with the history of the land which now belongs to the Republic of Iraq, a summary is given below (taken from Lloyd, 1949; the map of ancient sites of Iraq, 1954; and some other authors).

Periods	Years	Periods	Years
Palaeolithic	200 or 100,000 years ago	III Dynasty of Ur	2210–2000 B.C.
Mesolithic	8000–7000 B.C.	Old Babylonian	2000–1600 B.C.
Neolithic	7000–5250 B.C.	Kassite	1600–911 B.C.
Hassuna	5250–5000 B.C.	Assyrian	911–612 B.C.
Samarra	5000–4500 B.C.	Chaldaean	625–539 B.C.
Halaf, Eridu	4500–4000 B.C.	Archaemenian	539–331 B.C.
Al Ubaid	4000–3800 B.C.	Seluicid	312–248 B.C.
Uruk	3800–3200 B.C.	Parthian	248 B.C.–226 A.D.
Jemdit Nasr	3200–3000 B.C.	Sassanian	226–637 A.D.
Early Dynastic	3000–2500 B.C.	Islamic	637–Now.
Akkadian	2500–2210 B.C.		

The more recent history consists of:

Early Caliphate	637–750 A.D.	Turkish occupation . .	1534–1917 A.D.
Abbasid Caliphate . .	750–1258 A.D.	British Mandate . . .	1917–1932
Mongol occupation . .	1258–1508 A.D.	Independant Iraq . . .	1932–Now
Persian occupation . .	1508–1534 A.D.		

Iraq was a kingdom until 1958, when it became a republic. It was created in 1917 by joining together three Ottoman provinces. Many books are available concerning the recent history. They also deal with the present situation and the future development, e.g. Committee of Officials (1946); Government of Iraq (1956); Zeki (1954); and Hourani (1947).

It is quite simple to write down the whole history in a short list, but it is hardly possible to imagine what this means. If we reduce the period from the moment when the first settlers came down from the mountains to the Mesopotamian plain (about 4000 B.C.) until today, to one day, the famous Babylonian period was from 8 a.m.–9 a.m.; the Assyrian period was from 12.15 p.m.–1.30 p.m.; the second Babylonian period and the Hellenistic period both lasted a quarter of an hour. From 3 p.m.–6.30 p.m. the country was occupied by the Persians; up to 9 p.m. the Caliphs were in Samarra and Baghdad; the last three hours of the day are for the Mongols and the Turks, except for the last 10 minutes, of which one minute is for the British, 9 minutes are for the Kingdom of Iraq, and a few seconds for the new Republic.

Nearly 700 years ago the Mongols entered the country, massacred the people and destroyed the cities, villages and irrigation canals. Except for the last few decades the whole country was occupied by foreigners for nearly 700 years. One cannot imagine what influence this has had and still has on the people and on the present situation of Iraq. In studying the problems of this country, this fact must not be overlooked.

2.7. Land use and land tenure

Information on land use is given in many books, e.g. Haider (1942); Soussa (1944); Warriner (1948, 1957); Fisher (1950); Schuller (1951); K.T.A.M. (1952); International Bank of Reconstruction (1951); Ali (1955); F.A.O. (1955); and the Statistical Abstracts (1956). Nearly 80% of the country is uncultivated. There is no accurate information on land use in Iraq; all figures are estimates. The best information is given in the F.A.O. Report (1955) of the Salahudin Conference.

The cropped area is	6% of the total area
The forest area is	4% of the total area
Grazing land is	9% of the total area

The cropped area can be subdivided into:

Rainfed areas	4,000,000 mesharas
Irrigated areas:	
Winter crops, lift irrigation	2,510,000 mesharas
Winter crops, gravity irrigation . .	2,490,000 mesharas
Summer crops	1,470,000 mesharas
Date and fruit orchards	800,000 mesharas
	11,270,000 mesharas

The irrigated areas are generally utilised as follows:

50% irrigated annually (actually cropped area)
35% fallow
20% roads, canals, urban land

De Gruyter (1953) gives the following figures:

Waste land (mountains, desert) . .	312,000 km² = 69%
Irrigable land	80,000 km² = 18%
Cultivable in rainfed zone	41,000 km² = 9%
Grazing land	20,000 km² = 4%
Total area of Iraq	453,000 km² = 100%
Present irrigated area	32,000 km²
Irrigated area in the future	64,000 km²
Actually irrigated in winter	12,500 km² = 2.9% of Iraq
Actually irrigated in summer . . .	2,200 km² = 0.5% of Iraq

Land utilisation in agricultural holdings in Iraq (Statistical Abstracts, 1956):

Cropped area	10,108,118 mesharas
Fallow land	11,178,594 mesharas
Uncultivated	2,577,077 mesharas
Fruit gardens	512,651 mesharas
Pasture	923,565 mesharas
Woodlands	207,230 mesharas
Total land in farm holdings . . .	25,507,135 mesharas

The K.T.A.M. (1952) report gives the following figures for the river plain:

	Euphrates	Tigris	Total	
Total cultivable area	6,100,000	11,500,000	17,600,000	mesharas
Land cultivated at present	3,900,000	6,500,000	10,400,000	mesharas
Potential extension	2,200,000	5,000,000	7,200,000	mesharas

The present-day cultivated land is sub-divided into:

land where water is pumped from streams	3,800,000 mesharas
land where water is obtained by gravity irrigation (Euphrates)	3,300,000 mesharas
land where water is obtained by gravity irrigation (Tigris) . .	3,300,000 mesharas

The cropped area is half the cultivated area, as 50% is cultivated annually (shortage of water).

The area which can be cultivated is 48,000,000 mesharas or 27% of the total area. This includes:

32,000,000 mesharas in the irrigation zone
16,000,000 mesharas in the rainfed zone

The total area which can be irrigated by the Twin rivers is estimated at 22 to 25.5 million mesharas.

Land Tenure

Feudalism was up to 1958 the fundamental feature of the land tenure system in Iraq. The great majority of the peasants were working as share-croppers under severe conditions of employment and exploitation. The large landowner or sheikh exercised absolute authority over his peasants in almost every phase of their life, and their fate was entirely in his hands (Ali, 1955). In Iraq there were 107 sheikhs with holdings exceeding 20,000 mesharas (5,000 ha). In Kut there were even several holdings of well over 300,000 mesharas. The average size of a holding was 147 donums in northern Iraq and 282 donums in central and southern Iraq (Walter, 1956). Small-holdings mainly occurred in the rainfed zone in the north; most large holdings occur in southern Iraq. With the increasing pump irrigation in the Lower Mesopotamian plain, the influence of the land owners and pump owners was increasing. The Bedouins do not consider land as private property; it is the property of the tribe ('dirah').

All together, there were 125,045 farm holdings, of which 24,270 were smaller than 4 mesharas, and 25,040 have 4–20 mesharas (Ali, 1955). The size distribution of private land holdings (1951) is given in the F.A.O. Salahudin report (1955), see Table 13.

The figures quoted here are no longer applicable as from July 1958.

TABLE 13. *Size distribution of private land holdings (1951).*

1–100	mesharas	15.7%
101–500	mesharas	11.0%
501–1,000	mesharas	6.2%
1,001–10,000	mesharas	42.8%
10,000–100,000	mesharas	23.2%
100,000–200,000	mesharas	1.1%

The holdings mentioned in Table 13 are units of management, not units of property. Often several holdings were owned by one landowner. The figures therefore do not show the distribution of land ownership in Iraq; (this has never been published).

The newly introduced Land Reform Law (September 1958) however, has fulfilled a radical change in the Land Tenure System that had previously been existent as represented by table 13 above. Under this new Law the creation of Co-operative societies are to be encouraged and all farm labourers that are of mature age are entitled to acquire small-holdings.

The extent of the areas of these small-holdings that are to be allocated is to be determined in relation to the soil characteristics and the provision of subsistence for an adequate living standard for the families of the small-holders of the future.

There are several types of land tenure in Iraq (Table 14). Short outlines are given

TABLE 14. *Type of land tenure in Iraq in 1954.*

	Cultivable land	Uncultivated land
Mulk	0.4%	0.3%
Matrukah	0.2%	19.6%
Waqf	1.4%	0.3%
Miri Tapu	22 %	4.5%
Miri Lazma	21 %	3.6%
Miri Sirf	55 %	72.0%
Total %	100 %	100 %
Total mesharas	49,171,000	18,460,000

by Warriner (1948 and 1957); Schuller (1951); F.A.O. (1955); and Ali (1955) a book on this subject has been written by Dowson (1932). The historical background on land-tenure in Iraq is described by Ali (1955) and Warriner (1957); land tenure studies have been published by Binns (1953).

Mulk or Mamloukah is land held in absolute private ownership; Matrukah is land left for public benefits (roads, gardens, etc.); Waqf or Mauquofah, and in Kurdistan communal grazing land, are lands dedicated for religious and philanthropic purposes. Miri or Amiriyah is state land of which there are three sub-categories: Miri Tapu, – land in permanent tenure by private persons; Miri Lazma, – land held by private persons in almost permanent usefruct and occupation; Miri Sirf, – pure or de facto and de jure government lands.

At the end of 1954, the land rights in Iraq were registered in about 72% of the land area, excluding the three deserts.

When the mandatory powers took over the Government, there was complete chaos in regard to the ownership of land (Warriner, 1948). However, during the period of British occupation (1917–1932), the feudal system was upheld and encouraged (Ali, 1955). The Ottoman Law was not a success; it never succeeded in enforcing general registration. The individual title was unsuited to the type of collective or semi-collective village and tribe organisation which always prevailed. The difficulties arising from the bad land tenure system have already been known for several thousands of years. It is not a new problem.

The peasant share of the crop was in general (Ali, 1955):

In flow irrigated areas	1/2–2/5
and when the sheikh provides the seeds	1/3,
The areas with pump irrigation	2/7–3/7,
and in the rainfed zones	90% of the winter crop and 2/3–1/2 of the summer crop,
In date and fruit orchards	1/5–1/8 of the crop.

Another example is given by Warriner (1948, 1957) about the share-cropping system in southern Iraq: taxes 10%, landowner 40%, sub-tenant 7.5%, overseer 2.5%, farmer (fellahin) 40%. Out of this 40% the farmer must pay ½ or 1/5 for the upkeep of the irrigation canals. According to Fisher (1950), sometimes only 1/6 of the crop is for the farmer, who has an extremely low standard of living. Interest rates of 50% or more occurred.

The Iraq Government is organising credits for the farmers at normal rents. The need for a fairer land tenure system is obvious.

The share cropping system does not work well on grassland; therefore most land is arable land. Mixed farming is almost unknown. Introducing new farming methods, crop rotation systems, ley-farming, etc. is extremely difficult.

In studying the land use problems of Iraq it should be kept in mind that the greater part of the agriculture depends completely on irrigation. Irrigation agriculture is possible only when there is:

1. A strong central government or a co-operative society to construct and maintain extensive irrigation and drainage systems;

FIG. 25. A farmer of Central Iraq.

2. A careful control of the irrigation practices.

In areas like the Lower Mesopotamian plain it is impossible to have completely independent farmers.

The Government of the Republic is quite aware of the urgent need for improving agriculture. Up to 1952 there was a Department of Agriculture in the Ministry of Economics. From 1952 there has been a Ministry of Agriculture with several departments. Its position, however, is rather weak, mainly due to the fact that the Department was run for the first 10 years by British and Indian officers and no Iraqis were trained. In other fields of science, Iraqi students were sent abroad, but this was not done in agriculture. Those few students who graduated at their own expense, were later on so disappointed that most of them found a job outside agriculture (Radi, 1944). This lack of policy in the first two decades is still influencing the position of the present Ministry of Agriculture. A Miri Sirf Land Development Committee was established in 1945. Since 1951 there has been a special 'Miri Sirf Land Development Law', which can be studied in the book by Ali (1955). In the Development Board (see 2.9.), there is a special Agricultural Section which is promoting investigations, experiments, etc.

Land reclamation projects are carried out in various parts of the country, mainly on Miri Sirf land. The newly reclaimed land is given to farmers free of charge. In the period from 1945 until 1955, 2,221,271 mesharas were distributed to 15,492 landless Iraqi persons (Ali, 1955). At the present time there is a tendency to charge the farmers for the land which is given to them; it is supposed that they will then more appreciate it.

Interesting details on the various land settlement projects in Iraq are published by Ali (1955).

In the Miri Sirf projects the maximum size of the holdings is:

20	mesharas	in mountain areas;
100	„	in flow irrigated areas;
200	„	in high land pumping irrigation areas;
400	„	in areas depending on rainfall.

The actual size is to be determined by the Committee according to the productivity of the soil, the environment, the quantity of irrigation water available, the market conditions and the location.

The Miri Sirf Land Development Committee has recently been merged with the Ministry of Land Reform. The latter ministry will be entrusted with the duty of supervising the execution of the extensive land reform programs that are actively taking place throughout the country. The Ministry of Irrigation and Agriculture will back the requirements of the Law of Land Reform in the technical and research fields with a view to establishing a more effective agriculture in the country.

Prior to the currently existent Republican regime the land reclamation projects were carried out on Miri Sirf Land. Immediately after the establishment of the Republic of Iraq the first fundamental step towards contributing to the improvement of the standard of living of the common farm labourers was initiated by the government. This step has for basis to retrieve the large landowners of their land property beyond the one thousand donum limit at the irrigated areas, and the two thousand donum limit at the rainfed areas, in return for adequated compensation to the previous title holders. The retrieved areas were divided into small landholding farm units and distributed to the farm labourers that had inhabited those same areas. This step was taken in conjunction with fostering the expansion of extension service activities, the creation of pilote farm enterprises, the promotion of soil survey and land classification work and the encouragement of co-operative societies to handle the necessary action phases of agricultural production and marketing.

Land use in ancient times was nearly unknown, although Ghirsham (1954) points out that the feudal system was introduced in Parthenian times. It may even be much older, as it belongs to primitive irrigation farming. The remants of ancient irrigation canals and the irrigation deposits over the ancient land surface indicate which areas have been cultivated in the past. It is often said that once 40 million people were living on the Mesopotamian plain. It is certain that nearly all parts of this plain once were cultivated. This, however, does not imply that all land has been cultivated at the same time.

The land use practised by the nomadic tribes is quite different. These tribes have their own territory in the three deserts. During the dry season they move to the grazing lands in the mountains and the Mesopotamian plain. In the plain the herds graze on the cropped land after the crop is cut, and in the extensive uncultivated depressions and lower parts of the basins.

In the transitional region between the deserts and the rainfed zone some areas are cultivated. The cultivation is mainly in slight depressions where the soil layer is somewhat deeper and where extra rainwater collects as a result of runoff from surrounding land.

2.8. AGRICULTURE

The agriculture of Iraq has been described by: Bonné (1934); Eaton (1949); F.A.O. (1955); and in books on the Middle East by: Keen (1946); Weulersse (1946); Warriner (1948 and 1957); Schweng (1953); and Walter (1956). The book by Walter (1956) contains a series of maps of Iraq showing statistical data. Data is published annually in the Statistical Abstracts of the Ministry of Economics.

From all these books and articles one could get a pessimistic view about the agriculture in this young country. Agriculture and livestock management are still very

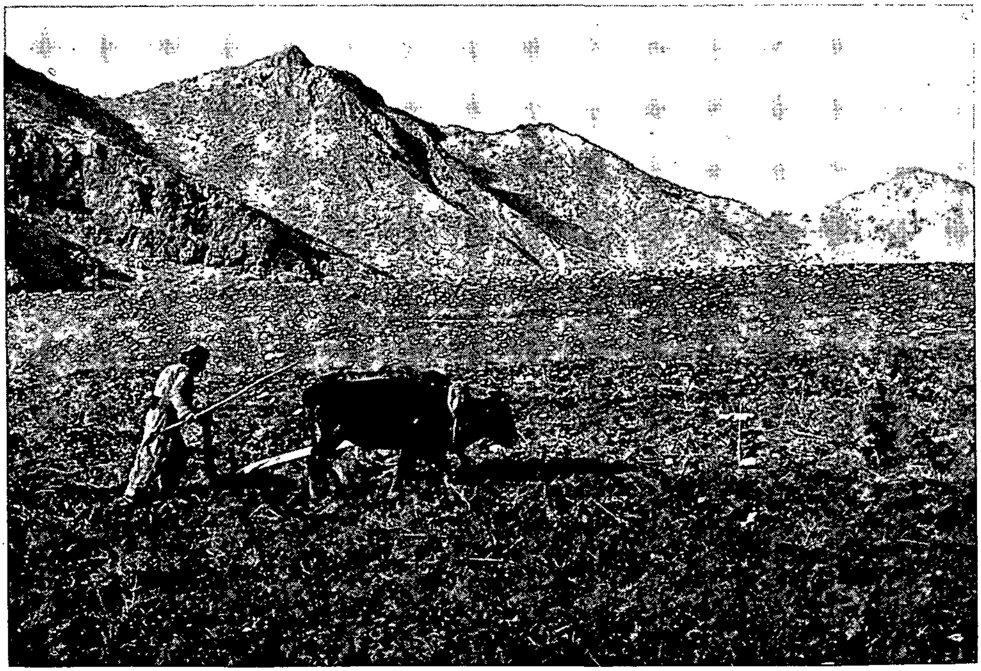


FIG. 26. A Kurdish farmer in Northern Iraq, ploughing land in a mountain valley.

primitive and the standard is low. Proper farm management is unknown; the implements often are the same as they were thousands of years ago; the methods are mostly ancient and traditional, and the farmers are leading a miserable life (Ali, 1955).

On the other hand, Iraq is one of the most fortunate young countries in the world as it has:

1. Extensive land resources of a high potential value;
2. Significant water resources in the Tigris and Euphrates rivers;
3. A large source of foreign exchange from the oil revenues;
4. A relatively small population;
5. The chance to profit from the experience of other countries;
6. A small group of well trained Iraqi specialists who are anxious to serve their country.

Although the present situation is still poor, the future is promising.

A well known American soil expert, (Kellog, 1952), even points out that irrigated agriculture in an arid and hot climate may have some advantages. If land is productive and if enough water of a good quality is available, good crops with high yields can be grown as there is abundant sunshine; these are all very favourable conditions which do not prevail in humid areas.

In order to have some idea about the present agriculture in Iraq, some figures are given below. As most figures are estimates, efforts have been made to find the best sources of information. Tables 15, 16 and 17 give data on field crops, fruit crops and vegetables respectively. See also Walter (1956).

TABLE 15. *Field crops.*

Crop	1954 area in donums[1]	Yield per donum in kg.[2]	Growing Period	Main Regions
Barley	4,842,130	290	Winter	Lower Mesopotamian Plain and Uplands
Wheat	4,182,585	209	Winter	Uplands and Lower Mesopotamian Plain
Rice	514,822	376	Summer	Diwaniya and Amara
Sorghum, corn .	216,266	206	Summer	Diwaniya and Basra
Cotton	96,492	200	Summer	Around Baghdad
Millet	87,224	260	Summer	Marsh region
Sesame	87,024	134	Summer	Baghdad and Diwaniya
Green Gram . .	84,176	157	Summer	Baghdad and Diwaniya
Tobacco	40,731	200	Summer	Mountain plains
Lentils	22,639	177	Winter	Mountain plains
Chick peas . . .	19,552	–	Winter	Mountain plains
Beans	17,313	–	Summer	Baghdad
Vetch	8,868	122	Winter	
Linseed	3,343	66	Winter	
Alfalfa	8,000	–	Summer	
Potatoes	3,200	–	Summer	

[1] From Bakir (1955), Statistical Abstracts (1956).
[2] From F.A.O. (1955).

TABLE 16. *Fruit crops.*

Crop	Estimated area in donums	Main region
Date palms	364,000	Basra, Hilla
Pomegranate	10,000	Along Diyala River
Oranges	16,200	Along Diyala and near Baghdad
Apricots	8,000	Along Diyala and near Baghdad
Apples	8,540	Near Baghdad
Sweet Lemons	4,160	Near Baghdad
Lemons	2,270	Near Baghdad
Peaches	1,780	
Pears	1,290	
Walnuts	2,080	
Almonds	340	
Olives	500	
Pistacchio nuts	130	
Other fruits	92,560	

TABLE 17. *Vegetable crops.*

Crop	Area in donums
Water melons	51,081
Tomatoes	45,328
Melons	21,449
Cucumbers	20,338
Egg Plants	16,654
Miscellaneous	15,000

Wheat and barley make up 89% of the total acreage of field crops. Considerably more than half of the wheat and barley was grown on non-irrigated land. The production is given in Tables 18, 19 and 20. Alfalfa is not included; it now occupies a very few thousand donums in the neighbourhood of the cities. The rice yield (Table 20) is mostly 300–400 kg./donum, but in the north it is higher (Kirkuk Liwa, 910 kg./donum).

TABLE 18. *Wheat production in Iraq* (tons).

	1955	1956	1957
Wheat: N. Iraq	213,000	520,000	780,000
C. Iraq	197,000	242,000	320,000 (C. and S. Iraq)
S. Iraq	64,000	71,000	
Whole country	474,000	830,000	1,100,000
Barley: Whole country	756,000	1,061,000	

TABLE 19. *Total wheat and barley production in Iraq.*

Year	Wheat tons	Barley tons	In the period 1938/39–1955/56
1938/39	482,000	825,000	
1946/47	235,500	500,000	lowest
1953/54	1,160,000	1,239,000	highest

TABLE 20. *Production in kg/donum of some crops.* (Data: Statistical Abstracts, 1953, 1956, Baghdad).

Year:	Wheat	Barley	Year:	Rice
1949/50	137	200	1950	277
1950/51	132	229	1951	344
1951/52	124	185	1952	420
1952/53	159	253	1953	432
1953/54	209	290	1954	376
1954/55	83	157	1955	386
1955/56	148	217	1956	395

In 1952 there were 400,000 donums planted with cotton, which were seriously affected by the spring bollworm *(Earias Insulan)*; the yield was only 57 kg./donum. The next year cotton was planted in the northern liwas only. In 1955 approximately 200 tons of endrin were used. In 1950 cotton was planted in:

Erbil, Kirkuk and Sulaimaniyah Liwas	56,200	donums
Baghdad, Diyala and Kut Liwas	114,000	,,
Dulaim, Hilla and Kerbala Liwas	26,600	,,
Mutafig and Diwaniyah Liwas	1,500	,,
Total	198,300	donums

The wheat and barley production in the north depends on rainfall; this is demonstrated in Table 18. There was some extra rain in the spring of 1956.

The estimates on the number of date trees vary from 18 (Ali, 1955) to 56 (Springfield, 1954) million trees, yielding annually 350,000 to 400,000 tons of dates which, for the greater part, are exported. The date production of Iraq is about 80% of the world's total output. In the period 1938/39–1952/53, the lowest production was 150,000 tons (1943/44) and the highest 450,000 tons (1950/51). In a date orchard there are about 50 trees per meshara, yielding about 875 kg./meshara.

Dates and barley are the main export products. In the period 1951–1953 the agricultural, livestock and livestock products (wool) values amounted to 99% of the total exports! (Ali, 1955). A book on the Iraqi dates, which are mainly grown along the Shatt-Al-Arab, has been written by Dowson (1921).

Rice is mainly grown in the marsh region in southern Iraq (Diwaniyah and Amara). Tobacco comes from the mountain valleys in Kurdistan. Wheat is the main crop in the north, whereas barley is most important in southern Iraq, as it is salt-tolerant.

About 98% of the total area of field crops contributes some fodder for animals (Ferguson and Kadry, 1956), e.g., straw from wheat, barley, millet and rice, residues from beans, green gram, peas, lentils and vetch.

The traditional cropping scheme on farms growing winter grains is: one year wheat or barley followed by one year of idle ('idle' means not planted and not ploughed, but will be planted next year; 'fallow' means ploughed or tilled once or more but not planted during the uncropped years, (Ferguson and Kadry, 1956).

The fallow or idle period permits some natural amelioration of fertility and tilth. Nitrogen has been accumulated by leguminous weeds, some soil micro-organisms and the mineralisation of organic matter. In the dry farming regions, water has been stored. The idle system provides pasture land. During the winter there is a significant growth of annual grasses and legumes, depending on rainfall. In a dry winter a considerable part of the land sown with barley provides green feed for sheep and cattle. It is true that much can be done to improve crop production, particularly the improvement of the fodder crop production will be important. Ferguson and Kadry (1956) made proposals for the improvement of fodder crops like alfalfa, berseem clover, (Melilotus indica), and irrigated pastures, etc.

Much can and still has to be done in weed control, insect control, disease control, soil drainage, application of fertilisers, irrigation practices, farm management, etc. Work has been started during the last few years. There are some important results from various kinds of experiments which show that the situation can be improved.

If we try to understand the primitive farming in Iraq under the present economic and social conditions and the low level of farm technology, we are led to believe that the farmers follow methods which are the best suited under the present conditions. (See also Chapter 7.1.). The level of agriculture and farming is low. Improving the situation is difficult as the whole problem is most complex. As far as soils and related technical problems are concerned, they will be discussed in the following chapters.

Barley is exported, but there is a general shortage of wheat. It is therefore planned to grow more wheat. The acreage of cotton will also be increased considerably. It is expected that 1,000,000 donums will be planted in 1958. This depends on the mechanisation, the quantity of water which will be available and on the international market. About 70% of the wheat comes from northern Iraq. In the future more wheat will be grown near Baghdad. The production of both barley and wheat are expected to be increased by 50%.

Sugar beets have been introduced into northern Iraq with good results. Some sugar factories have been built and are planned. The Government also pays attention to agricultural industries (sugar, cotton, wool, fertilisers, dairying, breweries, date syrup, cigarettes).

The rivers and marshes of Iraq contain a plentiful supply of fish, which is mainly consumed locally.

Some horticulture is found around the cities.

The number of cattle is estimated at 712,000; the Jenubi breed is the most important. Water buffalos are found in the Mesopotamian plain; there are about 50,000.

The improvement of the milking capacity of the local breed has been attempted by introducing Ayrshire and Friesian breeds.

About 4.5 million sheep of the fat-tailed variety are utilised for meat, wool and milk production. There are 1.6 million goats, 78% of which are in northern Iraq. Donkeys and mules are important; there are two types of donkeys, the Hassawi and the Cyprian. 92% of the 57,000 mules are in the four northern liwas; there are about 400,000 donkeys. Approximately 38,000 camels are used for long distance transportation in the desert. The last agriculture census reported 137,446 horses. Only Arab horses are bred in Iraq.

The forest area in north-eastern Iraq is approximately 1.8 million ha., but the density is very variable; real forest is scarce. About half the area is regarded as productive. Oak and pine forests are the most important types. Afforestation is on the development programme. More data on the forests of Iraq have been published by Chapman (1949, 1957).

The agricultural investigational and research activities are centralised in the experimental station at Abu Ghraib (Agriculture) and Zafaraniyah (Horticulture); both are near Baghdad. There are five sub-stations at: Bakrajo (near Sulaimaniyah), Hawiyah, Mosul, Basra and Eski-Kelek. Similar stations are due to be established in each Liwa.

2.9. The development of the country

April 18th, 1927 was an important day in the history of modern Iraq. On that day the oil began to flow in the first well of the country at Baba Gugur, north of Kirkuk. The stream of oil became important in 1934 and it was always increasing; more wells and more oilfields have been developed, and particularly since 1952; the annual oil production is nearly 34,000,000 tons (1955). This is six times the production of 1945 Iraq is now the fifth oil producing country in the world. In the course of time it will be the second or third. In 1958 the production is expected to be 44,000,000 tons. Due to the political difficulties in the Middle East at the end of 1956, the oil production in that year was only 29,000,000 tons. After the Ghawar fields in Saudi Arabia, and the Burgan fields in Kuwait, the Kirkuk fields are the most important in the Middle East. At the moment only 7% of the oil found in the Middle Eastern countries is used, and half of the oil is perhaps still to be found. The Iraq oil contains 4% of sulphur, which is high; therefore the oil has to be stabilised. During the first 24 years Iraq did not reap much benefit from this oil, which has been exploited by the Iraq Petroleum, The Mosul Petroleum and the Basra Petroleum Companies.

Since 1951 Iraq has received 50% of the profits from the oil. Each year 70% of these oil revenues are used for the development of the country, and the rest (30%) goes to the Treasury for the normal budget, and it is approximately 40% of this budget.

In order to have some idea about the money which is available, some figures are given:

The normal Government budget was in 1939: ID. 9,040,000, in 1950/51: ID.

27,978,000, and in 1956/57 ID. 74, 509,655. The total oil revenues for 1955 were about ID. 74,000,000, and for 1956 they were estimated at ID. 78,000,000. For the first nine months of 1956, Iraq received ID. 58,874,133, for the last three months, just over ID. 9,000,000, making a total of ID. 69,000,000. For the five-year period 1956/60 there is an estimate of ID. 464,000,000.

In May 1950 a Development Board was established, with three purposes:

a. To conduct studies on resources development;
b. To determine the priority of jobs;
c. To supervise the execution of the work.

The 70% of the oil revenues, which is used for the development of the country, is used for these purposes by the Board. As an example, the budget of the Development Board for 1955 consisted of the following general items:

Board, administration, studies	ID.	650,000
Irrigation, drainage and storage schemes	,,	21,700,000
Roads and bridges	,,	10,970,000
Airfields	,,	500,000
Railways	,,	5,500,000
Building	,,	4,300,000
Industry	,,	8,211,900
Agricultural Development	,,	1,665,000
Institutes	,,	6,750,000
Miscellaneous	,,	1,525,000
Total for 1955	ID.	66,771,900

The new five-year programme (1955–1959) of the Development Board, which since 1953 has belonged to the Ministry of Development, has a budget of ID. 340,000,000. More details can be found in: 'Government of Iraq' (1956), the 'Annual reports of the Development Board' and in the report by Lord Salter (1955).

General data on the Development of Iraq can be found in: 'The Report of the Mission of the International Bank for Reconstruction' (1952); 'The Report of the Haigh Commission' (Haigh, 1949); Salter (1955); and Ali (1955). The last book deals with the land reclamation and settlement programmes in Iraq. From the latter book it may be learned how difficult it is to make some progress.

Point one of the development programme of Iraq is flood control, because everything would be destroyed if no flood control measures had been taken.

A series of measures have to be taken dealing with the agricultural development. In our opinion, drainage is the chief need, because no improvement can be expected as long as soils are saline or saline-alkaline. The next step includes a series of measures like:

application of fertilisers; weed and insect control; crop rotation; intensive cultivation; introduction of fodder crops; mixed farming; better seeds; etc.

Introducing these measures also means the need for more water and improvement of the present irrigation practices. Good results can be expected only when there is basic education, agricultural education, research on various subjects and a Government Advisory Service with a well trained staff of Iraqis.

It must be taken into account that there has been a poor land tenure system, and there are other social and economic factors as well, which greatly influence the agricultural productivity of the country. The agricultural development also depends on communications, marketing facilities, industry, health conditions, etc. Iraq has to find a balanced plan for the development. It will be clear that such a programme will be a long-term programme; this is not always understood.

CHAPTER 3

SOIL FORMATION AND CLASSIFICATION IN IRAQ

3.1. INTRODUCTION

Iraq has soils which are markedly different from one another; this is due to important variations in soil parent material, in climate and in vegetation. If we consider the whole country, it is possible to distinguish three major regions, each with typical processes of soil formation and consequently completely different soil conditions (see Fig. 13).

The Lower Mesopotamian Plain consists of recent river sediments which have been deposited by the Tigris and Euphrates rivers. It is a broad, flat, river plain which is sometimes flooded. The whole region has an arid climate and cultivation is only possible if the soils are irrigated.

The Deserts occupy a very large area; they mainly consist of limestone and gypsum. However the uppermost layer, which is the most important, has been changed intensively. As water is mostly absent, chemical weathering processes are unimportant. Physical processes of weathering and soil formation, in particular, wind erosion, are the most important. Large areas have a crust on top or are covered by desert pavements or wind accumulated material. Deep wadis were etched into the rather flat desert areas during pluvial periods in the Pleistocene (Fig. 101).

The Uplands and Mountains in northern Iraq consist partly of pure rock without any soil, or of rocks with a very thin soil layer. In the valleys and especially on some terraces, fertile soils occur. These soils are formed by chemical, physical and biological processes. Real soils with profiles showing horizons (layers) with differences in colour, structure, organic matter content, etc. can be found here.

The soils of the Lower Mesopotamian Plain are extremely calcareous (20 to 30% lime) and saline, and are Alluvial soils of the arid zone. They have completely different characteristics if compared with soils of fluviatile plains in other parts of the world. It will be learned from Chapter 4.1. that these soils cannot be compared with those of the Nile valley in Egypt. The Lower Mesopotamian Plain is covered by a recent layer of flood material and in particular, irrigation sediment. This layer is several metres thick. In addition there is a complicated process of salinisation. The composition of salts in the soils and in the groundwater is complex. It is difficult to understand the dynamics of soil salinity. The high lime content gives the soils of Iraq typical characteristics.

The soils of the desert regions are of minor importance for agriculture; therefore not much attention has been paid to these soils.

In the uplands and mountain regions of Iraq, soil conditions are much more important, although there are extensive areas of rough mountain land. The important soils for agriculture are the deep brown and chestnut soils. They occur in the rainfed zone and they are non-saline.

The fundamentals of soil science are described in various well-known handbooks. Unfortunately international knowledge on the soils of arid regions is rather lacking. Much work still has to be done. Many problems have to be solved. Many ideas which are generally accepted for soils of humid regions, cannot be applied to soils of arid regions. It is valuable to study results of soil and agricultural investigations performed in neighbouring countries, and in countries where similar conditions are found (i.e. Russia, Australia, United States of America). Attention is drawn to studies on soils in Syria (Reifenberg, 1947, 1948, 1952; Muir, 1951; van Liere, 1953), Lebanon (Gèze, 1956). Algeria (Durand, 1954; Boulaine, 1957), Southern Europe (Kubiena, 1953), Turkey (Oaeks and Arikok, 1956) and Russia (Kovda, 1954; Janetsky, 1957).

It is well known that it is often impossible to apply results of studies in neighbouring countries to the soils of Iraq because the general and local soil conditions are often quite different. Many investigations which have been made in other countries have to be repeated in Iraq. Fundamental research work in the laboratories and in the field cannot be neglected. Great mistakes are made in Iraq by applying methods and techniques which are not suitable for the soils of this country, particularly for the soils of the extensive Lower Mesopotamian Plain.

3.2. Soil formation

Soils are natural bodies with characteristics resulting from the integrated effects of living matter and climate, acting upon parent rock material, as conditioned by relief, over periods of time (Soil Survey Manual, 1951). In other words, the formation of soils depends on five factors: living material (vegetation, microbes, fungi, etc.); the climate (temperature, rainfall and wind); the kind of parent rock material (mineral composition, texture); relief (or topography) and time. Another factor: – men or human activity – has to be added, particularly in Iraq where human influence on soil formation is very marked (irrigation, levelling, drainage, cultivation for thousands of years).

The influence of these factors on the formation of the various soils of Iraq is different. It will be discussed in Chapters 4, 5 and 6.

Most soils in Iraq are secondary soils, i.e., soils which consist of material that is transported from the place of weathering and is accumulated somewhere else. The accumulation is the result of sedimentation. In Iraq material is deposited by wind, high floods, meandering rivers, braided rivers, estuary rivers, sea and by irrigation. The irrigation sedimentation, which is characteristic for extensive parts of the Lower Mesopotamian Plain and which is highly influenced by man, has been described in detail in Chapter 4.3.2.

There is a close relationship between soil science and geology, particularly when immature soils are studied. It should, however, be understood that soil is not the same as parent material because in soils the decomposition of minerals continues, new minerals are being formed and there is often accumulation of organic matter; there is also a translocation of soil minerals and chemical compounds which results in the development of soil horizons; new chemical compounds are formed and structure is developed.

One of the fundamentals of soil investigations is not collecting information, but to study this information and to try to understand the soil formation, the soil characteristics and their importance in agriculture. As soil conditions differ in different localities, due to diverse processes of soil formation, each investigation has to start again with an intensive study of the soils and their relationship to plant growth.

3.3. Great soil groups

As a result of differences in the action of the six soil forming factors, different soils have been formed which are classified in great soil groups. This mostly is done for a better understanding of soil conditions in a general way. A map showing the great soil groups of a country is very important for basic soil research and for reference in soil geography. The most important great soil groups occurring in Iraq are indicated on Map 1 (See Appendix). This map gives much more information as the two previous maps, that are published at a smaller scale by the U.S. Department of Agriculture (1948) and West (1955).

The broad fundamental differences among soils are mainly the result of differences in living matter (vegetation) and climate. In areas with a specific climate and vegetation, soils are formed which are in equilibrium with the environment; such soils are called zonal soils. Soils which have not developed specific soil forming characteristics are called azonal soils; they occur in any region of zonal soils. In many areas soil formation is highly influenced by local factors such as a typical parent material, relief or drainage. The normal processes of soil formation therefore have been modified, and consequently the soil characteristics differ from those of normal soils. Such soils are called intra-zonal soils.

The boundaries between the various great soil groups on Map 1 are not sharp lines because climatological conditions gradually change, both absolutely and seasonally. The boundaries do not coincide with the various types of climate and vegetation due to the local influence of soil formation.

In Iraq eighteen great soil groups and numerous intergrades have been recognised. A brief description of the general characteristics of soils in each group is given below. All soils are mineral soils.

1. *Desert Soils.* These are light grey or light brownish-grey soils with a low organic matter content; they are highly calcareous and usually with a cover of recent and unsorted material as a result of wind erosion; they are often covered with a thin gravel layer (desert pavement, Fig. 104) and sometimes with a gravel, gypsum or limestone crust. The subsoil is lighter coloured and has a high lime content. The biological activity and the chemical weathering are very low.

Desert soils occur in areas with a very low rainfall, generally less than 75 or 100 mm., which is not sufficient to maintain a continuous plant cover. The vegetation consists of sparse desert plants and scattered shrubs. The climate in summer is very hot and dry.

2. *Red Desert Soils* consist of a light reddish-brown surface soil and a more brownish-red subsoil; they are highly calcareous and mostly covered by a recent wind erosion cover. These soils occur in areas with a very low rainfall and the vegetation consists of a few shrubs. According to West (1955) these soils may be found in southwestern Iraq.

3. *Sierozem Soils* are grey soils with a grey or pale greyish calcareous surface soil which is very low in organic matter and less than 20 cm. in depth; this grades into a highly calcareous subsoil with lime or gypsum accumulation. The surface soil is rather uniform, due to the effect of wind erosion. The average rainfall is approximately 150–200 mm.; biological activity and chemical weathering are low. The vegetation consists of perennial shrubs and annual grasses. In early winter and spring there is a green verdure and some flowers. The climate in summer is very hot and dry.

4. *Reddish-Brown Soils.* These have a reddish-brown surface soil, grading into a red or reddish heavier subsoil, overlying a whiter horizon with lime or gypsum accumulation, either cemented or soft. The rainfall generally is 200–400 mm. Short perennial grasses and shrubs are common. The biological activity and chemical weathering are rather low. Minimum and maximum species, respectively light and darker coloured, are common in Iraq. The climate in summer is very hot and dry.

5. *Brown Soils.* These have a brown surface layer of about 25–35 cm., grading into a brownish-grey to whitish horizon of lime accumulation. The topsoil is alkaline and may have 1 or 2% of organic matter. The climate is more humid, and the summers are dry. Natural vegetation consists of mixtures of short and tall coarse grasses. The process of chemical weathering becomes more important. Some lime is leached from the surface soil.

6. *Chestnut Soils* have a dark brown, friable surface soil, usually with 1–4% of organic matter and less than 9% lime, overlying a brown, prismatic, somewhat heavier subsoil and grading into a lighter coloured horizon with whitish-grey spots of lime accumulation, starting at a depth of 30 to 50 cm. below the surface. These soils occur in areas with dry hot summers and a rainfall of approximately 400–800 mm. Vegetation consists of a closed, often tall, grass cover. There is an earthworm fauna and biological activity is an important factor.

7. *Reddish Chestnut Soils.* These are similar to the chestnut soils, with a dark reddish-brown surface soil over a somewhat heavier textured reddish-brown subsoil, grading into the horizon of lime accumulation at a depth of approximately 40–60 cm. The vegetation mostly consists of tall grasses and shrubs.

8. *Chernozem Soils.* These have a dark greyish-brown to nearly black, friable, granular, slightly alkaline surface layer to a depth of 40 to 75 cm., grading through a lighter brownish-grey colour into the whitish-grey horizon of lime accumulation. The upper part of the dark coloured soil usually has a 4 to 8% organic matter content. The climate is dry in summer and humid in winter, generally with 800 or more mm. rainfall. The real steppe vegetation consists of tall grasses and sometimes some trees (oak).

These great soil groups represent the zonal soils of Iraq. In addition to these, some intra-zonal soils occur.

9. *Solonchak Soils* are usually grey soils, often with a salt crust or salt efflorescence at the surface over a fine granular mulch and underlain by a grey or brownish-grey more friable saline soil with a very unstable structure. The salt content varies widely, particularly in the surface soil. As these soils are important in Iraq, they are fully described in Chapter 3.5.

10. *Solonetz Soils* may be with or without a few centimetres of a rather friable surface soil and are underlain by a dense, hard, columnar layer, usually highly alkaline and cracking. Details are described in Chapter 3.5.8.

11. *Soloth Soils* consist of a thin greyish-brown friable surface layer over a whitish grey leached horizon, grading into a brown, much heavier textured, prismatic to columnar horizon. An example is given in Chapter 4.2.

12. *Terra Rossa*, or Mediterranean Red Soils, are formed on calcareous rocks in the 400–600 mm. rainfall zone. They should be decalcified. Similar soils which occur in some small areas in Northern Iraq, however, are highly calcareous. Such soils probably have to be classified with these soils, when a more detailed study has been made (see Chapter 6.4.).

13. *Rendzina Soils* consist of a dark brown to black, granular to blocky surface soil of approximately 30 cm. on a pinkish white or yellowish grey limestone rock.

14. *Hydromorphic Soils*. These are soils which are waterlogged or which have a high groundwater table. They are characterised by gley or pseudo-gley or iron stains in the soil profile. These soils often occur in combination with other soils. Most of these soils are found in the marsh region of southern Iraq.

Finally, the following azonal soils occur in Iraq:

15. *Lithosols*, consisting of a thin soil layer, overlying stony material or consolidated rock, mostly limestone or gypsum.

16. *Regosols*, consisting of dry loose parent material of unconsolidated material, and sediments, without any profile development. Generally sandy and clayey dunes.

17. *Alluvial Soils*, having various stratified layers, with little or no profile development, generally occurring in the river plains. The Alluvial soils of the arid region differ from those of the humid regions.

18. *Man-Made Soils*. These are highly influenced by human activity, resulting in a nearly complete change of the soil profile.

This is the first list of great soil groups of Iraq, which have already been described briefly in an article by Buringh and Kadry (1956). It may be noted that the real Terra Rossa soils which occur in the Mediterranean region do not occur in Iraq; this is in contradiction to the numerous books and articles, mainly on vegetation, where they were mentioned.

The list is almost complete. There is some doubt whether the Reddish Desert Soils do in fact occur in Iraq. Unfortunately I paid only a short visit to the south-western desert area in which they are supposed to exist. A new group of 'grey-brown soils', which could occur in desert regions, has been described by Lobova (1956). This great soil group also may be expected in Iraq. The high parts of the Zagros mountains were not visited either. Possibly some alpine meadow soils do occur there (Chapter 6.6.). For more information on the great soil groups, reference should be made to U.S. Department of Agriculture (1938) and the following handbooks: Joffe (1949); and Kubiena (1953).

Although a few names of the great soil groups refer to the main colours, the classification is not based on the soil colours, but on a set of important soil characteristics in relation to soil formation, mainly climate and vegetation.

In cultivated areas it is often difficult to find a spot having a representative soil for the particular great soil group, as local conditions have influenced soil conditions. Intergrades of great soil groups are also quite common. Some zonal soils also occur as intrazonal soils in areas which are considered drier than normal for these zonal soils. Due to the action of wind and water, many soils are truncated or a younger layer has been deposited on top of an older soil. In irrigated areas human influence is extremely important, but in other areas this soil-forming factor cannot be neglected either (Edelman, 1954).

In Iraq arid soils, saline soils, fluviatile soils and the soils developed in limestone regions cover most areas.

The concept of great soil groups is used all over the world to indicate the type of soil formation over large areas on small scale maps. As far as zonal soils are concerned, few difficulties may be expected. In Iraq, however, the large areas of various kinds of limestone give rise to azonal soils. The southern half of Iraq consists of river deposits with azonal soils, whereas the desert areas are highly influenced by wind erosion forming azonal soils, too. The climate varies widely, both geographically and seasonally and the natural vegetation cover is disturbed by human influences. Cultivation in Iraq is very, very old. Due to these facts, the mapping of great soil groups often is rather difficult. In the international literature, especially in the proceedings of the various congresses of the International Society of Soil Science, several proposals have been made for new classification systems; most of them, however, are developed for specific regions and cannot be applied in other countries. During recent years, much work has been done for a new system of soil classification by leading soil scientists of the United States in co-operation with other countries. The proposals are being discussed on an international level, but at present are not ready for official use.

Small scale soil maps of neighbouring countries, mostly indicating great soil groups, are published by van Liere (1953, Syria); Muir (1951, Syria and Lebanon); Oaeks and Arikök (1956, Turkey); Kovda (1944, Iran); Gèze (1956, Lebanon).

3.4. Soil classification

The number of soil units in Iraq is unknown, but certainly there will be several hundred. In order to unify the soils work done in Iraq it is necessary to classify them in a system of soil classification.

The system adopted by the Division of Soils in Iraq is that of the United States, which is described in the Soil Survey Manual (1951), and which is used in nearly all modern soil investigations in various countries. It is a realistic system which is based on important soil characteristics evaluated in the field and in the laboratory.

In order to have some idea about the subject and the principles on which it is based, some information will be given here.

In classifying soils, two kinds of soil units are distinguished: Taxonomic soil units, and Soil Mapping units.

A soil scientist examines a soil profile in a pit. All characteristics are studied and in addition samples are taken for analysis in the laboratory. The soils studied in this way are grouped in taxonomic units which have specified limits and variations. Numerous taxonomic units are studied in this way. In practice, there is no need for, and it usually will be impossible to map, all these taxonomic units. A very detailed soil survey has to be made in this case and this would cost much time and money. Therefore soil mapping units have been introduced. They consist of a well defined taxonomic unit plus a small proportion of other units up to about 15% of the area of the taxonomic unit. Most soil mapping units consist of a combination of two or more taxonomic units which are generally geographically related, and therefore they can be easily mapped. These units are called soil complexes and soil associations respectively on more detailed and more general soil maps.

On detailed soil maps usually soil series and soil types are mapped. Semi-detailed maps generally show soil series, soil complexes and sometimes soil associations, undifferentiated groups and miscellaneous land types, the latter two particularly when the soils of such units are not important for agricultural purposes.

It will be clear that the taxonomic soil units are the fundamentals of soil investigation and classification. The soil mapping units, indicated on a soil map, must be defined in taxonomic units which are included in each soil mapping unit. It is impossible to map soils if the various taxonomic soil units are not studied beforehand.

The classification of soils in various parts of Iraq is done for practical purposes. In every soil survey of the Division of Soils, the taxonomic units present are grouped in soil mapping units in such a way that these mapping units indicate important differences in soils. The result is a soil map which shows those differences in soils which are important to know for the purpose for which it is made. Most soil maps made in Iraq are semidetailed soil maps, presented on a 1 : 50,000 scale, not showing all details but enough detail for practical application. Besides soil series, soil complexes and associations also soil phases are mapped. The work starts with a general inspection of the area, followed by a detailed study of all soils in a number of sample areas, which represent soil conditions of the whole area. In these sample areas, all taxonomic units are studied, described, analysed and evaluated. Later on, combinations of taxonomic units are made in soil mapping units for the semidetailed soil map. This work is followed by the soil survey of the whole area at a semidetailed scale. Examples are given in Chapter 4.

Up to now this principle has not been followed by the consultants carrying out soil surveys, mostly on a broader scale, for the Iraq Government. However, it has been

TABLE 21. *List of official soil series and soil types in Iraq* (31.12.1957).

Soil Series and Type	Soil Survey	Author	Year
Abu Gharaq clay	Hilla	Buringh	1957
Abu Ghraib clay loam	Abu Ghraib	v. d. Kloes	1955
Abu Sefi silt loam	Abu Ghraib	v. d. Kloes	1955
Aith sandy clay	Naifa	v. d. Kloes	1956
Aith sandy loam	Naifa	v. d. Kloes	1956
Albu Aswad silty clay loam	Naifa	v. d. Kloes	1956
Albu Bas silty clay loam	Naifa	v. d. Kloes	1956
Albu Faraji silty clay loam	Naifa	v. d. Kloes	1956
Albu Jawari silty clay loam	Naifa	v. d. Kloes	1956
Ananah clay	Hilla-Kifl	Buringh	1957
Aquarquf clay	Abu Ghraib	Schilstra	1957
Babylon clay	Hilla-Kifl	Buringh	1957
Babylon silt loam	Hilla-Kifl	Buringh	1957
Babylon silty clay loam	Hilla-Kifl	Buringh	1957
Baghdad silty clay	Royal Palace garden	Buringh	1957
Baghdad silty clay loam	Royal Palace garden	Buringh	1957
Baghdad silt loam	Royal Palace garden	Buringh	1957
Bakluwara clay loam	Naifa	v. d. Kloes	1956
Barnun silty clay loam	Hilla-Kift	Buringh	1957
Buhaira clay loam	Naifa	v. d. Kloes	1956
Dokan clay loam	Sunganar	Buringh	1955
Hilla silty clay loam	Hilla-Kifl	Buringh	1957
Hilla loam	Hilla-Kifl	Buringh	1957
Hilla silt loam	Hilla-Kifl	Buringh	1957
Kantarat Isiela clay loam	Naifa	v. d. Kloes	1956
Kifl silt loam	Hilla-Kifl	Buringh	1957
Naifa silt loam	Naifa	v. d. Kloes	1956
Naifa loamy sand	Naifa	v. d. Kloes	1956
Quadissiyah silty clay loam	Naifa	v. d. Kloes	1956
Saddi silty clay loam	Naifa	v. d. Kloes	1956
Samarra loam	Naifa	v. d. Kloes	1956
Shari sand	Naifa	v. d. Kloes	1956
Sungassar silty clay	Sungassar	Buringh	1955
Sungassar clay	Sungassar	Buringh	1955
Sungassar silty clay loam	Sungassar	Buringh	1955
Sungassar cobbly clay	Sungassar	Buringh	1955
Tahmaziyah loam	Hilla-Kifl	Buringh	1957
Tahmaziyah silt loam	Hilla-Kifl	Buringh	1957
Tell Dhahubah silt loam	Naifa	v. d. Kloes	1956
Tell Al Booggar silty clay	Naifa	v. d. Kloes	1956
Tuwarij silt loam	Hilla-Kifl	Buringh	1957

decided to unify all soils work to be done in the future. The 'soil series' described by K.T.A.M. (1952, 1953, 1953, 1954) and West (1955) are not real soil series but soil complexes or associations. Comparing the description of the 'Rafai soil series' in these five reports shows that at least five different soil series should have been established. In the reports of the Hunting Group (1956), 'soil groups' are mapped. These also are soil complexes and associations.

For further studies on the subject of soil classification, reference is made to the Soil Survey Manual (1951) and the February 1949 issue of 'Soil Science'.

The classification of soils in the higher categories, particularly in the soil families, is difficult. No attempt has been made to distinguish special soil families, because this subject is under discussion on an international level.

The list of great soil groups mentioned in Chapter 3.3. also will need some revision in the near future, because some soils classified in these groups do not have exactly the characteristics of those groups. In particular, the high lime and/or gypsum content play an important role in the soils of Iraq. The classification of Iraq soils into the higher categories (great soil groups and families) finally has to be done in co-operation with soil scientists working in neighbouring countries. Recently Dr. van Liere, who is working with the F.A.O. in Syria, made a preliminary unofficial attempt in this direction.

Up to December 31st, 1957, the soil series and types mentioned in Table 21 have been officially established by the Division of Soils.

3.5. Saline and alkali soils

The principal process in the soils of central and southern Iraq is salinization. It is the accumulation of salts in the soil. According to official reports, 20–30% of cultivated land has been abandoned in recent years and yields in other land have declined between 20 and 50% as a result of salinization (International Bank for Reconstruction (1952); Ali (1955); Salter, (1955)). A general description will be given here in order to avoid duplication in the following chapters. Besides saline soils, which are common in Iraq, saline-alkali, alkali and even soloth soils do occur. Saline soils are called 'solonchak' soils in international literature. It is a Russian term meaning a soil with much salt. 'Alkali' is an Arab term for ashes. This term formerly has been used for all kinds of saline and alkali soils which had a surface looking like wood ashes. At present the term 'alkali' is used to indicate soils with specific characteristics (See Chapter 3.5.9.).

3.5.1. *Nature and Origin*

A saline soil is a non-alkali soil containing soluble salts in such quantities that they interfere with the growth of most crop plants. According to this definition the pH of the saturated soil is usually lower than 8.5; the percentage of exchangeable sodium is smaller than 15% and the conductivity of the saturation extract is more than 4 millimohs per cm. at 25°C. (U.S. Sal. Lab., 1954). (These details are explained later. See 3.5.6.).

The most common salt in saline soils is sodium chloride (NaCl). Some other salts which occur are: calcium chloride ($CaCl_2$), magnesium chloride ($MgCl_2$), potassium chloride (KCl), gypsum ($CaSO_4.2H_2O$), sodium sulphate ($Na_2SO_4.10H_2O$), and magnesium sulphate ($MgSO_4$). In most soils, mixtures of various salts occur.

Gypsum is a salt present in most soils in Iraq; however, it does not have an important influence on plant growth. Its solubility is rather low. The solubility of other salts is much higher, and therefore the water in the soil may have a high concentration of salts. Due to salt accumulation, the soil solution will have an increasing osmotic pressure when more salt is dissolved. The result is a decrease in the physiological availability of water to the plant. In other words, it becomes more and more difficult for the plant roots to take water from the soil. Finally the salt concentration becomes so high that plants cannot take any water from the soil. Some plants withstand a much higher salt concentration than others. Another effect is that the salt cations and anions in a concentrated soil solution prevent the plants from taking nutrients. The ratio of the various ions the plant needs is influenced in an unfavourable way. Sometimes there is an accumulation of salts in the plants in toxic quantities. In particular, boron, often occuring in combination with saline-alkali soils, is very toxic. A boron concentration of a few parts per million is already harmful. Fruit trees, especially, are very sensitive (Kelly, 1951). Soils with a high boron concentration occur in southern Iraq. Due to these influences the productivity of saline soils is very low. Soil salinity is also influencing the micro-organisms in the soil. Their activity stops completely when the salt content reaches 3% (Janitzky, 1957).

Sodium chloride generally does not exceed 50% of the total salt content of saline soils in arid regions, whereas in regions inundated by sea-water this salt may be up to nearly 90% of the total salt content. Even if much sodium chloride is present, the sodium adsorption, and consequently the exchangeable sodium percentage, in a saline soil is relatively low. In the adsorption complex, calcium and magnesium predominate and the percentage of exchangeable sodium in saline soils never exceeds 15%.

The presence of salts in the soil is a consequence of the arid climate. As rainfall is insufficient, the plants have to take water from the groundwater or from irrigation water. Due to evaporation or transpiration, there is an upward movement of groundwater to the surface. Groundwater always contains some salt and in Iraq, very often much salt. As plant roots take water only, these salts accumulate in the soil.

In areas with a deep groundwater table, land is irrigated by river water at regular intervals. The upper part of the soil becomes wet, the water is finally used by plants or evaporated and the salts, which originally were present in the irrigation water remain in the soil. Gradually more salts accumulate and the soil becomes more saline. Even salt crusts can be formed on top of the surface soil. As precipitation is insufficient in central and southern Iraq, the salts accumulated in the soils will not be washed out by rainwater. The salt concentration of the river water in the Tigris and Euphrates is very low (200 to 400 p.p.m. or 0.2–0.4 g./l.). This water is therefore very good irrigation water. However, regular irrigation during many hundreds of years has increased the salt content of the irrigated land. According to Webster (1921) land in Iraq can become saline in 7 to 25 years as a result of irrigation.

The nitrates of sodium, potassium, calcium or magnesium have not yet been mentioned. In Iraq little is known about nitrates in the soils. They may be present in saline soils due to bacteriological processes of nitrification and due to accumulation by bacteria (Azotobacter). As there are many leguminous weed plants in Iraq, the accumulation is sometimes significant. In highly saline soils which are not cultivated, nitrates are accumulated and these salts may become significant in some soils.

Salts present in the soils of Iraq have different origins:

a. Salts from the Groundwater, which is often highly concentrated. If the groundwater contains 2% of salt and the water content of the soil is 30%, the percentage of salt retained by the soil when water evaporates is 0.6%. As soon as there is transpiration or evaporation, more salt will be concentrated. Very deep layers in the Mesopotamian plain may be of marine origin and consequently may contain much salt. Other soil layers, now deep underground, once formed the surface of the river plain in which salts were accumulated in depressions and marshes as occurs at the present time. Groundwater passing through such layers always contains a considerable amount of salt. A part of the groundwater of the adjacent desert areas flows underground into the plain, bringing salts from deeper, salt containing layers in the desert areas. Many small streams from the mountainous land east of the plain carry brackish water. Nearly everywhere groundwater is saline, even strongly saline. In southern Iraq, the deeper groundwater is possibly in contact with the sea. Sometimes there is a layer of fresh water on top of the saline water, particularly in the south. Wells dug in the fresh water layer usually become brackish after a period of some years, when the fresh water is used and the brackish water level rises.

Fresh water is found in some small strips in the Lower Mesopotamian Plain. These strips represent former river courses which have become silted up and covered by recent sediments. Not all ancient river courses contain fresh ground water!

b. Salts from Irrigation Water have also contributed much to the salinization of soils. If, as an example, irrigation water of a good quality, containing 100 parts per million of salts, is used and land is irrigated with 1 metre of water, that means an addition of 1,000 kg. of salt per ha.! De Gruyter (1955) estimates that each year the irrigation water adds 3,000,000 tons of salt to the irrigated soils of Iraq! The salts present in the irrigation water are dissolved in the upper regions of the rivers, where they pass through various rocks, some of them containing salts. Rainwater passing through such rocks enters the rivers or their tributaries and is finally used as irrigation water in the plain. Salinization of irrigated land becomes extremely important when drainage is poor. The earliest irrigation systems were adapted to the natural conditions of the country and natural drainage protected land from becoming saline. It is stated (Buringh, 1957) that the large scale process of salinization started in early Babylonian times when irrigation canals were dug and the drainage became extremely difficult.

c. Salts from the sea-water contribute to soil salinity in the southern-most part of Iraq, where soils consist of sea deposits or where they are regularly flooded by sea-water.

d. Salts Blown by the Wind are transported from areas with salt crystals at the surface. As these salts are mostly deposited on neighbouring land which already is saline, the result is not very important for Iraq. The movement of aeolian salts can become rather intensive, as may be learned from some Russian examples (Janitsky, 1957), and from field observations during duststorms in Iraq.

e. Cyclic Salts may also contribute to soil salinity, particularly in southern Iraq near the coast. The other sources of salt in this area, however, are much more important.

In order to have some idea of soil salinity in Iraq, it can be stated that nearly all soils in the Lower Mesopotamian Plain are saline and large areas are even strongly saline. The Hilla Liwa is probably the most saline district in the country. Non-saline soils occur mainly in the rainfed zone of northern Iraq where rainfall is sufficient for growing crops without irrigation and for washing the soils. In this region only a few depressions without drainage have saline soils.

For the literature on saline soils, reference is made to the book by Kelley (1951), the handbook of the U.S. Soil Salinity Laboratory (1954), an F.A.O. booklet by Greene (1948) and the well known handbooks on soil science. The important literature in the Russian language has been reviewed by Janitsky (1957). A summary of saline soils occuring in Asia is given by Raychaudhuri and Biswas (1954); they did not mention the saline soils in Iraq.

3.5.2. *Groundwater in Saline Soils*

Groundwater in almost the whole of central and southern Iraq is saline, and it generally occurs near or at a relatively short distance from the land surface. As a result of evaporation, transpiration and irrigation, the water rises to the surface and salts from the groundwater solution accumulate in the soil. It is therefore important to know:

1. The chemical composition;
2. The concentration;
3. The depth.

All three characteristics vary widely, even at short distances in the same plot (Fig. 27). The solubility of the various kinds of salt is different. Magnesium chloride, sodium chloride, calcium chloride, magnesium sulphate and sodium sulphate are very soluble, whereas calcium sulphate, magnesium carbonate and calcium carbonate are soluble to a small extent only.

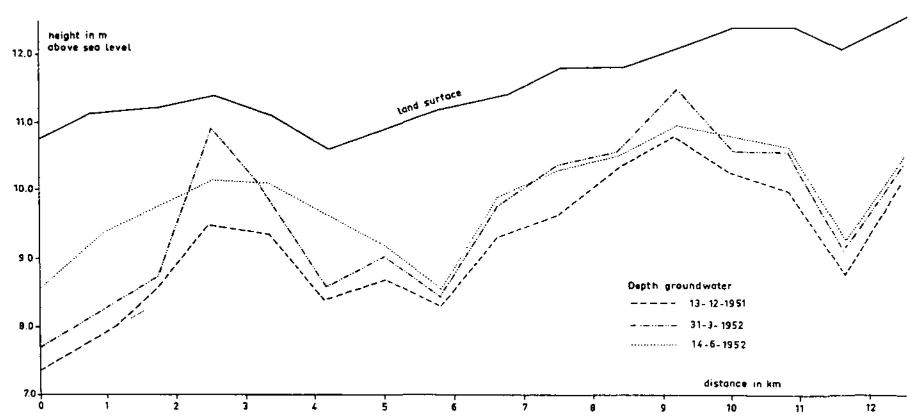


FIG. 27. Diagram of the variability in depth of the groundwater table in a plot (area 8.) in the Dujaila project (after Turcan, 1952). The upper line shows the mesorelief of the terrain.

In most areas the groundwater contains a mixture of salts. In mixed solutions, the solubility and the salt concentration differ, because the solubility of one salt depends on the presence or absence and concentration of other salts. An example is given for gypsum in 3.5.8.

There is also the influence of temperature. For example, the solubility of calcium and magnesium carbonates and bicarbonates depends on the carbon dioxide content of the groundwater. With a decrease in temperature, the solubility of carbon dioxide and consequently of calcium carbonate increases. In arid soils the temperature of the groundwater increases, when it rises to the surface, and consequently lime accumulates and concretions (often of small grain size) are formed.

The ratio of the various ions in the groundwater is also influenced by crops and weeds, which take specific ions.

The influence of evaporation and transpiration is extremely important and both change with the seasons, the air humidity and the wind. The direct evaporation of water in the soil stops at a depth of about 3 metres, whereas in cropped land, water to a depth of 5 or 7 metres (in general) can be taken. As a result, there is an increasing salt concentration in the groundwater. Polynov (after Janitzky, 1957) has introduced the concept of the 'critical depth of the groundwater', which is the depth from which the evaporation and salinization starts to increase. It depends on the mean annual temperature, which is 'x' (in degrees centigrade) in the form: $y = 170 + 8x \pm 15$ cm. For the Lower Mesopotamian Plain, the critical depth of the groundwater (y) is according to this formula $y = 354 \pm 15$ cm. Within areas with the same climate, 'y' depends on the mechanical composition and general condition of the soil. The value 'y' is smaller in heavy and greater in coarser textured soils. In Russian loess soils, which may be compared with the silty irrigation sediments of the Lower Mesopotamian Plain, the evaporation stops at 3.5 to 4 metres below the land surface. During the winter months 'y' is approximately 40 to 50 cm. less than during the summer.

The concentration of the salts in the groundwater varies. In the Lower Mesopotamian Plain it generally varies from 10,000 to 60,000 parts per million. In many areas it may be much higher, up to 80,000 p.p.m. or even more. Some examples are given in Fig. 28. In an area east of the Gharraf, the groundwater is non-saline according to investigations by the R. Parsons Company.

According to Russian data there is a decrease in evaporation and transpiration of groundwater with increasing salt concentration. In desert and semi-desert areas, evaporation and transpiration almost stop if the salt concentration reaches 15–20%.

The effect of evaporation and transpiration of groundwater is an increasing salt concentration in the upper layer of this water. However, this concentration decreases due to a vertical gravity stream of the concentrated solution. The result is an increase of the salt concentration of the deeper groundwater.

In order to define the type and intensity of salinization, Russian scientists have made a classification system for saline groundwater, which is based on the total anions (Cl^-, So_4^{--}, CO_3^{--}, HCO_3^-) and cations (Ca^{++}, Mg^{++}, Na^+ and K^+) (Janitzky, 1957). According to this system, groundwater in the Adhaim and Nahrwan area have to be classified as sodium and chloride salinization.

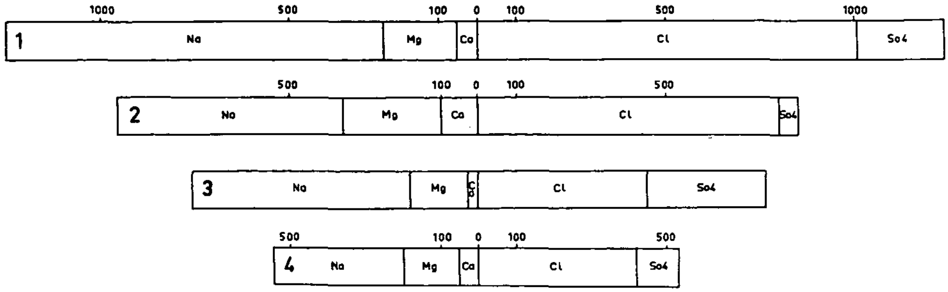


FIG. 28. Chemical composition (in meq./l.) of some groundwater samples:

1. From the Nahrwan area, T.S.S. 8.15%
2. From the Nahrwan area, T.S.S. 6.7%
3. From the Mussayib area, T.S.S. 4.8%
4. From the Adhaim area, T.S.S. 3.7%

Sodium chloride is the dominant salt. Magnesium and calcium chlorides are important in samples 2 and 4; magnesium and sodium sulphates are important in sample 3. (data for 1., 2. and 4. from Hunting's, 1956; for 3., from Nedeco).

For Iraq it seems necessary to intensify the study of groundwater salinity in relation to the corresponding soils and to the drainage problems.

Although the salinity of the groundwater is important for defining the soil, the salinity of the soil solution, from which plants take water, oxygen and nutrients is more directly important for the crop production. The soil solution contains soluble salts, which are a part of the total salts present in a soil. The way in which soils get water determines the salinity of the soil solution. Mostly the salt concentration in the soil solution is much higher (2 or 3 times) than in the groundwater as a consequence of the higher temperature in the upper part of the soil. There is an increase, especially in sulphate (magnesium sulphate and sodium sulphate) in comparison with groundwater. With an increasing chloride content, however, the sulphate content gradually decreases. The dynamics of soil salinity have not received much attention in soils research up to now.

3.5.3. *Pedogenetic Groups*

From a pedogenetic point of view, some types of saline or Solonchak soils, which are all common in Iraq, have to be distinguished.

Internal Solonchak Soils are non-saline in the upper part of the solum and saline in the lower part. As long as salt content is low and plant roots are widespread in the upper part, the salinity will not affect plant growth seriously. This type occurs in combination with some of the other great soil groups in parts of northern Iraq and in some areas in the plain.

External Solonchak Soils are strongly saline and often have a thin white efflorescence of salt crystals, mainly sodium chloride and sulphate and magnesium sulphate on the surface. In Russia they are called 'Crust solonchak'. These soils are saline throughout the profile. Salinity usually decreases with depth in non-cultivated land; in cultivated land it increases with depth. Large areas in the Lower Mesopotamian Plain consist of this salinity type.

Flooded Solonchak Soils have a white salt crust several centimetres thick on the surface (See Fig. 2, 45 and 46). During and sometimes after the rainy season these soils are covered with water; they are dry in the summer and autumn. This type occurs in shallow depressions in the Tigris-Euphrates plain where the groundwater level is high. Due to evaporation, salts accumulate at the surface.

Puffed Solonchak Soils have a puffed or fluffy surface layer (Russian name: Puchlyj solonchak; German name: Schwellsolontchak). When walking over such soils, one's feet sink a few centimetres into the loose, dry soil. The upper layer (5 to 10 cm.) has a very loose, single grain, soft structure, as the soil particles are flocculated in grains of sand size which are very loose. The surface often has a thin crust which is easily broken and which protects the soil from being blown by the wind. This salinity type is very common in the silty irrigation deposits along the irrigation canals in the Lower Mesopotamian Plain, particularly in the non-cultivated desert areas. Puffed soils are characterised by sodium sulphate, and to a smaller extent calcium sulphate and sodium chloride salts. Sodium sulphate is highly soluble at high temperatures (550 g./l. at 34 °C.); the solubility decreases at lower temperatures (at 10 and 0 °C. respectively 90 and 50 g./l.). Therefore sodium sulphate accumulates during the hot season; it precipitates in the autumn and there is hardly any leaching during the winter. Consequently there is a relative increase of sodium sulphate. The crystallised sodium sulphate is $Na_2SO_4.10\,H_2O$. These crystals separate the soil particles, giving the surface soil the puffed or fluffy appearance (Fig. 81 and 85).

Sabakh Soils are saline soils with a high percentage of deliquescent salts and magnesium sulphate in the always moist surface layer, which is much darker coloured than the dry non-sabakh soils of the surrounding area (Fig. 29). These dark brown coloured soils are quite common in central and southern Iraq, particularly in those areas where groundwater is in contact with the surface soil. The soils have a high content of calcium and magnesium chlorides which are deliquescent. Even in the dry, hot summers of Iraq, these soils remain moist. Often they occur in combination with puffed solonchak soils. This type of salinity is only known in the Russian literature. There it is called 'Wet solonchak'. In the U.S., only one small spot has been noticed in Nebraska (Russel, 1957). In the book by Kelley (1951), it is mentioned that soils with highly deliquescent salts (calcium chloride, magnesium chloride, magnesium sulphate) cause soils to appear moist and almost black in colour. Those soils may be mistaken for black alkali. In Iraq these soils are brown to dark brown, the colour of the fluviatile soils when wet. More details on Sabakh soils are given in 3.5.4.

Sometimes a classification of saline soils is made by referring to the chemical composition:

NaCl – soils in which nearly all salts consist of sodium chloride. Such a soil is usually compact, has incrustations and is fine grained.

FIG. 29. Dark coloured spots on a sabakh soil near Abu Ghraib. Sabakh soils are saline soils characterised by the presence of deliquescent salts. They are widespread in Central and Southern Iraq.

Na_2SO_4 – Soils in which sodium sulphate (Glauber's salt) is the most important salt. Such soils also form thin incrustations; they are loose and somewhat puffy and often have long white 'needles'.

$MgSO_4$ – soils in which magnesium sulphate is the most important salt. Such soils often have a thin crust over a loose fluffy layer, without long 'needles'.

$CaCl_2$ and $MgCl_2$ – soils in which these deliquescent salts are most common; as the surface attacts moisture from the air, they are moist and consequently darker coloured than the dry soils.

Mixtures of various kinds of salts, however, are common in Iraq and therefore this chemical classification cannot be used.

The Russian salinity expert, Kovda (1946) has made a general classification of saline soils for the Eurasian continent into 'Salt Provinces', based on climatic conditions and content and chemical character of the main salts. If this classification were to be applied to Iraq, three provinces could be distinguished:

a. The province of chloride salinisation with accumulation of sodium chloride and magnesium chloride and also of some boron. Accumulation of nitrates is infrequent. This province covers almost the whole of southern Iraq.

b. The province of sulphate-chloride salinisation with accumulation of sodium chloride and some gypsum, which can be found in central and southern Iraq.

c. The province of chloride-sulphate salinisation with more accumulation of sulphate (Na_2SO_4) than chloride salts. This province covers the steppe area of northern Iraq in which saline areas occur locally.

3.5.4. *Sabakh Soils*

The farmers in Iraq classify the saline soils into two groups:

Shura soils (all saline soils with a white salt crust or salt efflorescence) and

Sabakh Soils (which have the dark brown colour and a high content of deliquescent salts).

Sabakh soils occur in irregular patterns, generally in silty or loamy textured material in areas where the surface is still in contact with the ground water by the capillary rise of this water, at least during the greater part of the year. They are common in the silty irrigation deposits along old and present-day irrigation canals and ditches, particularly in uncultivated land.

Almost no attention has been paid to these soils and no descriptions or analyses are given in earlier reports. They were first mentioned by Tiwarij (1927) who called them 'dark moist patches of hygroscopic salts, like chlorides of calcium and magnesium'. Webster (1924) has mentioned one soil sample as having a considerable amount of

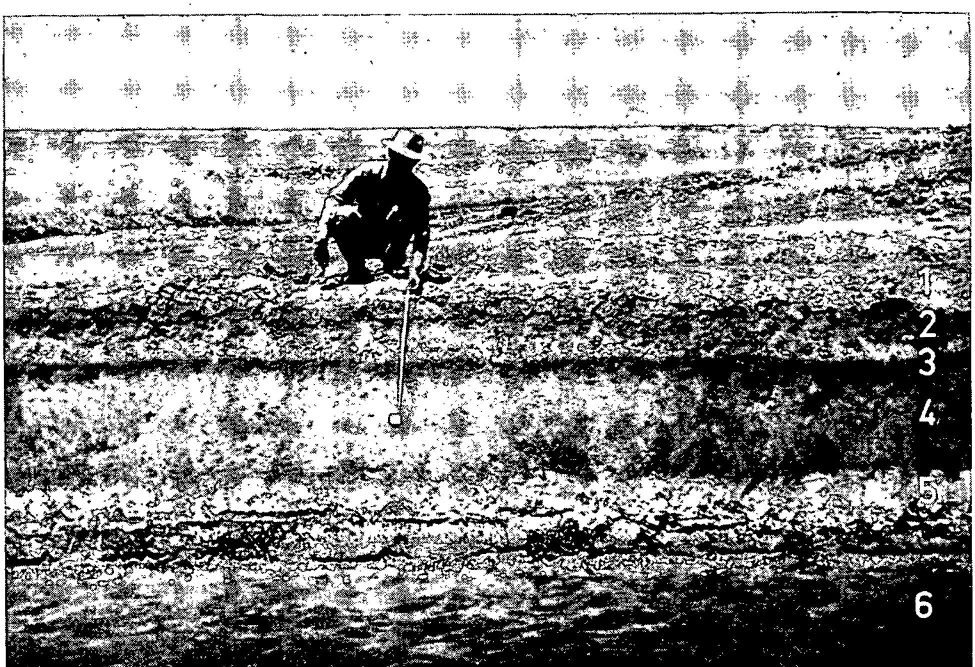


FIG. 30. Soil profile along a newly constructed irrigation canal in the Mussayib project: 1. crusted, saline surface layer; 2. saline soil, with little salt efflorescence; 3. very dark brown coloured 'sabakh' soil; 4. dark brown coloured 'sabakh' soil; 5. layer with white salt efflorescence; 6. water in the canal.

calcium chloride. Recently a study on the chemical and some physical properties of two sabakh soils of Iraq was made by Hanna (1956). He proved that the deliquescent salts of calcium and magnesium chloride are the characteristic salts of the sabakh soils. Although the nitrate content of some sabakh soils may be relatively high, as most sabakh soils are not cultivated, nitrates do not form the typical sabakh soils. The soils are real saline soils; there is no alkalinity and they are not related to any alkaline soil. The deliquescent salts (calcium chloride and magnesium chloride) precipitate only at maximum temperature and lowest air humidity. During the night they attract water from the air and form a moist, dark coloured surface (Fig. 34). Similar results are mentioned by Janitzky (1957). Magnesium sulphate, which is also deliquescent, may also be an important salt in sabakh soils. Hanna (1956) has given the chemical composition of three sabakh soils of Abu Ghraib (Table 22).

TABLE 22. *Chemical composition of soluble salts in meq/l. of three sabakh soils*, (after Hanna, 1956).

Salt	Soil 1.	Soil 2.	Soil 3.
$CaCl_2$	115	187	197
$MgCl_2$	91	53	83
NaCl	12	–	14
$MgSO_4$	–	16	–
Na_2SO_4	24	1	22
$NaHCO_3$	0.4	0.4	0.4
$NaNO_3$	4	17	16
Total	246	275	333

More has been learned about the morphological characteristics of the Sabakh soils, by studying these soils in various parts of the Lower Mesopotamian plain.

A typical sabakh soil has three important layers:

a. An upper layer of about 50 cm., consisting of dark brown to brown coloured material, which is typical sabakh with a high calcium chloride and magnesium chloride content. The upper part is usually somewhat darker than the underlying part.

b. A middle layer of about 60 cm. which shows a white salt efflorescence on a profile wall after a few days. This salt is mainly sodium chloride.

c. A lower layer which is always wet (full capillary zone) and which grades into the soil below the groundwater level (see Fig. 30).

The upper layer is the most characteristic part of a sabakh soil (Fig. 32). In detail it consists of:

A brittle crust of approximately 2 mm. consisting of dark brown (10 YR 4/3) silt loam. The crust often is bubbled; under the bubbles there is approximately 0.5 to 1 cm. of open space. The bubbles are 1 to 4 cm. in diameter and of irregular shape. The lower side of the crust has a somewhat greyish colour as there are many salt crystals (sodium sulphate) hanging from the crust. If the crust, including the salt crystals, is rubbed, the colour is 10 YR 5/3 (M) and 10 YR 6/3 (D). The next layer consists of dark brown

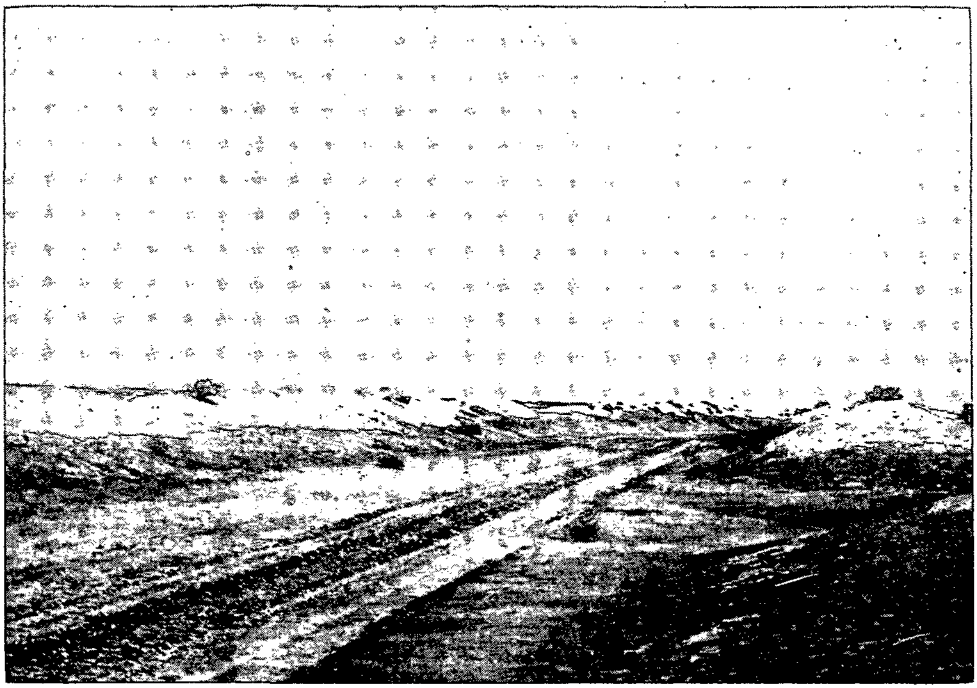


FIG. 31. Dark coloured sabakh soils in an abandoned irrigation canal. The tops of the silt dykes (argubs) on both sides of the canal are puffed solonchaks. The bottom of the canal has been silted up.

silty loam, about 2 cm., very friable, porous and soft. It consists of many thin plates, each approximately 1 mm. thick, which are separated by salt crystals. Many salt crystals are hanging at the bottom of this layer. If rubbed, the colour is almost the same. Under it is a dark brown (10 YR 4/3) silty loam layer with a somewhat platy structure and with salt crystals as in the above layer; they are, however, less clear.

The layer under the crust often has a somewhat fluffy structure; the salt content is very high. In one layer the total soluble salt content was 32.1%! It was the highest quantity of salt analysed in a soil sample in Iraq.

Many sabakh soils are even darker brown than the one just mentioned. In the upper 5 cm., very dark brown colours (10 YR 3/2) occur. The underlying layer is mostly dark brown (10 YR 4/3). The brown coloured material is gluey, especially in the upper layer. As could be seen at many spots, there is pressure of air from the subsoil as a consequence of irrigation practices in adjacent fields. As the sabakh material is viscous, bubbles are formed.

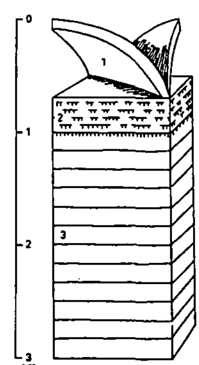


FIG. 32. The upper section of a sabakh soil. 1. bubble; 2. greyish coloured soil with abundant crystals of sodium sulphate; 3. dark brown layer with a platy structure.

In some areas where new irrigation canals or drains and branches were dug, observation could be made on the formation of these soils. This is shown schematically in Fig. 33.

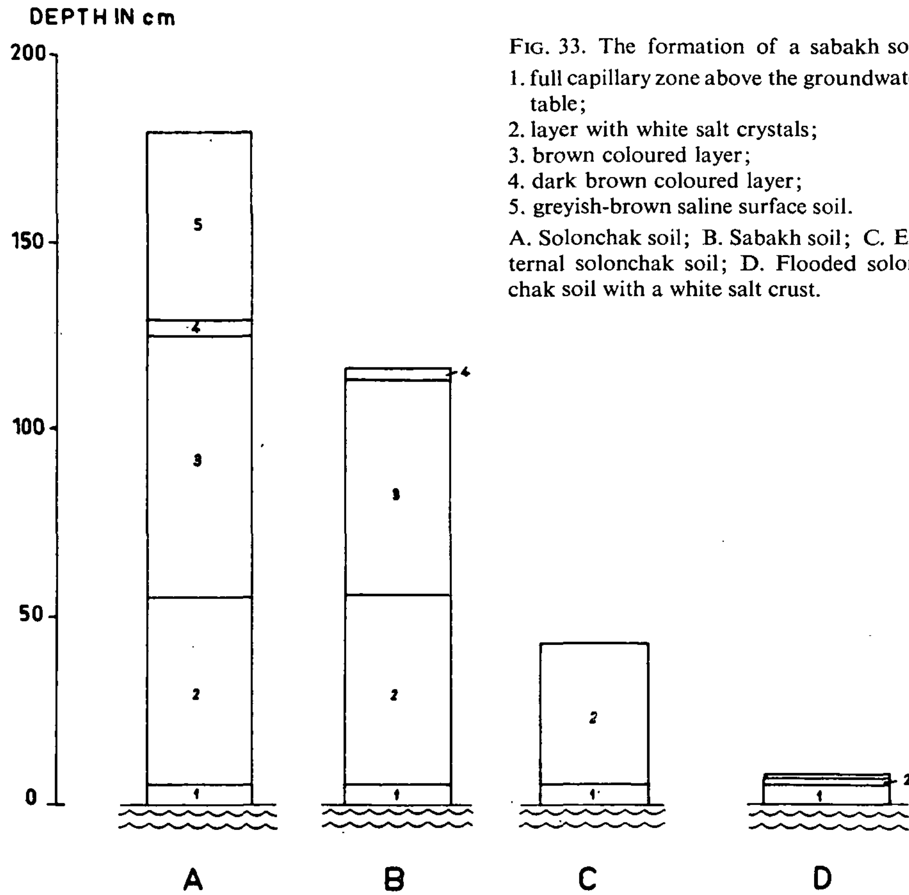


FIG. 33. The formation of a sabakh soil.
1. full capillary zone above the groundwater table;
2. layer with white salt crystals;
3. brown coloured layer;
4. dark brown coloured layer;
5. greyish-brown saline surface soil.
A. Solonchak soil; B. Sabakh soil; C. External solonchak soil; D. Flooded solonchak soil with a white salt crust.

There is a close relationship between the depth of the groundwater level and the capillary rise. In the figure it is assumed that the soil material is uniform and the groundwater level is flat. In the field, soils are not uniform and the groundwater level is not horizontal. The height of the sabakh layer above the groundwater level depends on various factors influencing the capillary rise of groundwater, like texture, structure, density, porosity and consistence. These soil characteristics differ in horizontal and vertical directions, particularly in the river deposits. This is the reason why irregularities in the occurrence of sabakh soils in the field may be noticed. In irrigated areas, big differences in groundwater level may occur, particularly near canals and ditches, which are on a higher level than the land surface. Typical sabakh soils mostly occur in spots and strips due to the micro-relief of the land surface in the river plain. Near Mussayib and in the Abu Dibbis depression, sabakh soils cover extensive areas.

The real dark brown coloured sabakh soils are related to a specific depth of the groundwater table, at least for the greater part of the year. In areas where this relationship only lasts for a part of the year, the colour is more brown or light brown and the content of deliquescent salts is smaller. In many areas $\frac{1}{4}$ or even $\frac{1}{2}$ of the chloride ions belong to calcium chloride and magnesium chloride in the solution; in other non-sabakh areas with a relatively high content of sulphate ions, no deliquescent salts are available in the groundwater, as may be concluded from the data in Fig. 28. Many transitional stages can be observed in the field. At the end of the summer, some of these lighter coloured spots have sometimes disappeared. They gradually became dry and were often covered by a thin dust layer. With the first rains, all spots and stripes appear at once. In November, very large areas consist of sabakh soils. With increasing rainfall, the salts are leached from the surface layer and in spring the areas of sabakh soils seems much smaller.

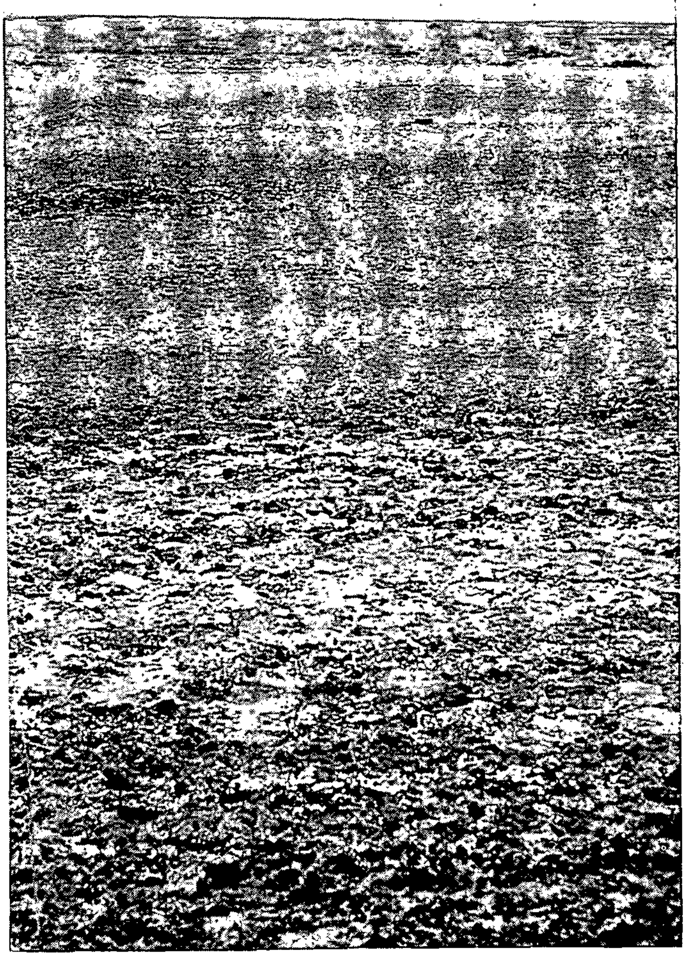


FIG. 34. A sabakh soil in the early morning hours during summer. The soil surface is wet, as it has attracted moisture from the air.

It is quite remarkable to see in the summer a completely wet surface layer during the early morning hours in a dry and hot country. The relative air humidity then is nearly 30% at night and 10% by day. The surface however still remains moist all the day, although temperatures may rise to 50 °C. (Fig. 34).

It seems that salts are easily washed from sabakh soils, however much water is needed for leaching. Sabakh soils, which are ploughed, lose the typical dark brown colour in a few days. Studies on leaching and drainage of sabakh soils have not yet been made in Iraq.

3.5.5. *Occurrence of Saline Soils in the Field*

The various types of pedogenetic saline soils generally do not occur over extensive areas, even when all soils are saline, as they are in the Lower Mesopotamian plain. In the field nearly all types can be studied in small areas (Fig. 35). The flooded solonchak soils are more uniform over large depressional areas. The reasons for the variability are many, e.g. differences in irrigation and farming practices, differences in soil morphology, soil profile conditions, ground water level, internal drainage, quality of the ground water, shape of the land surface and vegetation. Due to such factors, the amount and kinds of salt present in the various parts of an area vary widely. Even over a distance of a few metres, soil salinity is often quite different. Therefore it is practically impossible to show the salt content of the soils on a map. As salinity conditions always change, particularly in the surface soil, such a salinity map can only have a limited value. On the other hand, a general description of soil salinity can be given for each soil unit and general pedogenetic salinity types can be mapped.

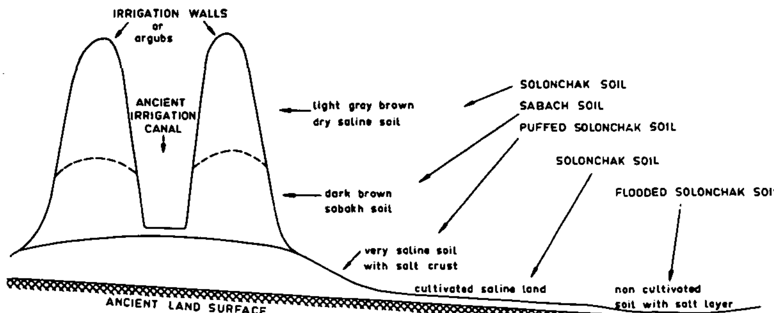


FIG. 35. Diagram showing the relative location of the various soil salinity types.

A general characteristic of saline soils is that they are flocculated and friable and therefore they are usually permeable. However, the permeability often decreases when salts are washed out. The structure of saline soils is often fine granular and soft when wet and hard when dry. The surface layer is mostly somewhat crusted. The soil structure is water-unstable. After rain or irrigation, the structure of the upper few centimetres collapses. In soils with real salt crusts, the infiltration rate is low.

The surface layer of various saline soils was studied in some areas. Very often this layer is crusted and consists of very thin clayey layers, which shrink and curl when becoming dry after a rainy season. Other soils have a dense laminated surface layer a few millimetres to a few centimetres thick. Such layers are the result of the action of rain-drops on a bare soil. As the infiltration rate of these surface layers is very low, some surface runoff and even some sheet erosion occur.

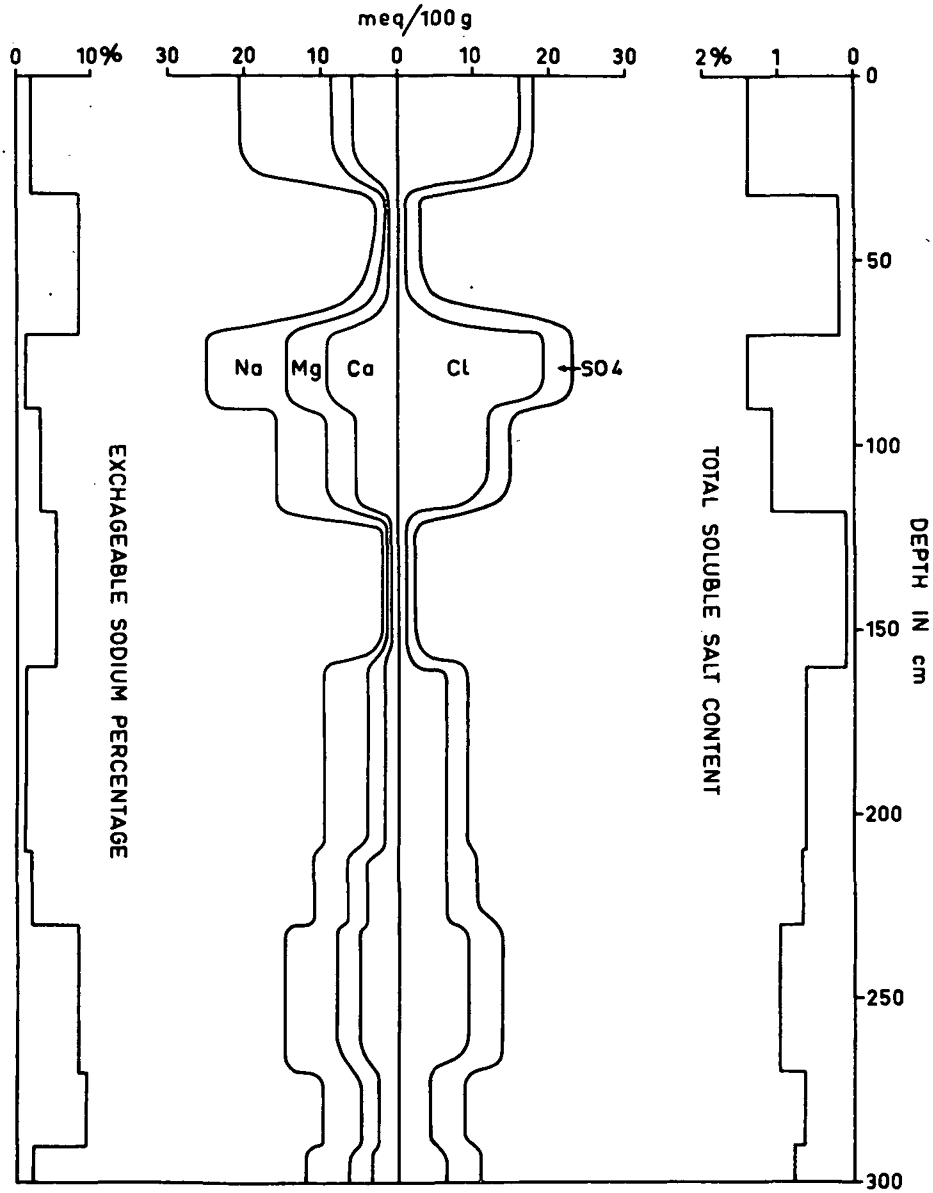


FIG. 36. An example of the distribution of anions and cations in a saline soil (data from the Nahrwan report, Hunting Group, 1956). No data are available to explain the variations.

Many saline soils have a white salt efflorescence on the surface, especially in winter and spring. The efflorescence often disappears or is less prominent during the summer. This phenomenon has already been mentioned by Turcan (1946). According to him the soils absorb air humidity and become somewhat moist as soon as the relative air humidity exceeds 70%. As a consequence of absorption and evaporation of water respectively during the night and day, the salts in the surface layer move towards the surface and white crystals are formed which are the salt efflorescence. These crystals grow and reflect the light. During the next summer the large crystals break up on giving up their water molecules. In addition to this it may be noticed that the efflorescence often is covered by a thin dust layer and the white colour disappears.

In many soils greenish or pale olive (5Y 6/3) colours occur as mottled markings in the substratum and deeper layers. Such mottled markings are probably associated with salinity. Similar colours are known from saline coastal soils in the Netherlands (Kuipers, 1950).

Besides a more intensive study of soil salinity in the field, there is also a need for study of the distribution and quantity of the various kinds of salt in characteristic soil profiles in relation to the depth, salt content and chemical composition of the groundwater. The result of these studies will be valuable for planning the drainage of the soils.

In order to start such work for Iraq, a study has been made of the results of soil salinity analyses in more than 2,200 soil samples from 251 profiles in the Babil Extension project east of Hilla. The soils of this area could be divided into six groups and several sub-groups according to the quantity and salt distribution throughout the profile up to a depth of 3 metres (see Fig. 37).

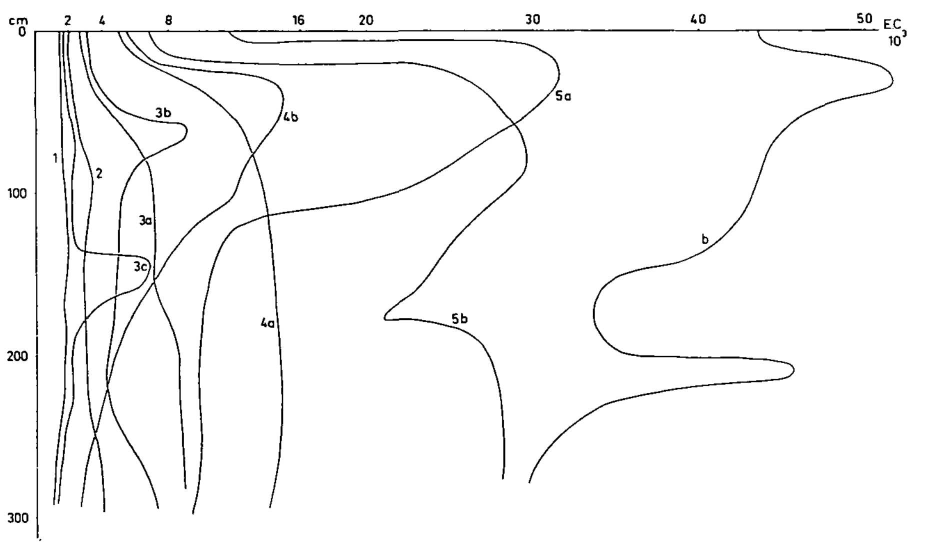


FIG. 37. Variations in salt content in 251 soil profiles of the Babil project. See explanation in the text. Each group of soils is represented by a typical soil of that group.

Group 1: Total 15 profiles (6% of the total profiles) consists of non-saline soils. The distribution of the little salt present is uniform throughout the profile (see line 1 in Fig. 37). In about half the number of profiles, salinity increases slightly at a depth of 250 cm. up to a level of E.C. $10^3 = 4.5$. The salinity is expressed in $E.C._e \times 10^3$, see 3.5.6.

Group 2: Total 66 profiles (26%) consists of very slightly saline soils throughout the profile (E.C. $10^3 = 2$ to 4). The distribution is shown by line 2. Most soils have a uniform distribution or a slight increase in salinity (up to E.C. $10^3 = 5$ or 6) below 2 metres depth.

Group 3: Total 59 profiles (24%) consists of slightly saline soils throughout the profile (E.C. $10^3 = 4$ to 8). In most of these soils there is a slight increase of salt with increasing depth as indicated by line 3a. Others are characterised by a maximum salt accumulation at a shallow depth (in layers from 0–100 cm.), see line 3b, or by a deep maximum (in layers below 100 cm. from the surface), see line 3c. In a small number of profiles, salinity decreases with increasing depth.

Group 4: Total 43 profiles (17%) consists of moderately saline soils, E.C. $10^3 = 8$ to 16. There are two sub-groups. Soils with a rather uniform salt distribution or with some increase with increasing depth (line 4a) and soils with a maximum at a shallow depth (line 4b). The latter type is most common. There are only a few profiles with a deep maximum.

Group 5: Total 41 profiles (16%) consists of strongly saline soils with E.C. $10^3 = 16$ to 34. Almost all these soils have a maximum salt content at a shallow depth, mostly with moderately saline substrata (line 5a), sometimes with strongly saline substrata (line 5b). Included in this group are three strongly saline profiles with two or three layers with a minimum salt concentration. These layers consist of sand and loamy sand, whereas all other layers are fine textured.

Group 6: Total 27 profiles (11%) consists of very strongly saline soils with E.C. 10^3 higher than 30 (line 6). In the upper metre the salinity usually reaches a maximum E.C. 10^3 of from 40 to 50, sometimes even higher! Salinity decreases to a level of 25 to 30 at a depth of more than 200 cm. In a few profiles, salinity decreases to below 16 in the upper metre and below.

This is the only statistical examination that could be made, as no more information is available; therefore no explanation will be given of the facts. The data have been collected in the Miri Sirf Department and the soil analyses were made in the Laboratory of the Irrigation Department. The area of the Babil project is an uncultivated area, silted up by irrigation in ancient times.

3.5.6. *Measurement of Salinity and Evaluation of Saline Soils*

Soil salinity measurements have been made in Iraq since 1919, at first by applying chemical methods (Webster, 1919). Later on new methods were developed in other countries, when more attention was paid to saline soils. The work done in Russia and the U.S.A. particularly is highly important for Iraq. The present methods of analysis are described in detail by the U.S. Salinity Laboratory Staff (1954).

The measurement of soil salinity in order to define the salinity condition of the soil in relation to plant growth is quite difficult. It would be best to analyse the natural soil solution or to measure the osmotic pressure of it. Both are difficult to perform from a technical point of view. Usually a water extraction from the soil is made.

For measuring the soil salinity in practice the soil sample has to be wetted in order to dissolve the salts. The soil: water ratio is then important. Usually a water saturated paste is made. The liquid from this paste is called the saturation extract. Sometimes a 1 : 1 or 1 : 5 soil: water ratio is used in the analysis. If gypsum is present, equal parts of water and pure acetone may be used, this being a liquid in which gypsum is insoluble. No great error is made if gypsum is determined with other salts, because the gypsum percentage will not exceed 0.2% of the total salt content due to its very low solubility.

It is possible to dissolve all salts and to evaporate the water from the extract. A salt residue is left. The residue then has to be dried at a high temperature in order to evaporate the water of crystallisation. Unfortunately some salts may be decomposed during the process; on the other hand the deliquescent salts are difficult to dry. Consequently this method does not give reliable results. It cannot be used for samples from a sabakh soil.

Sometimes the various ions in an extract are determined. The quantities are given in milliequivalents (chemical equivalent weights in milligrams). The total soluble salt content can then be calculated. The method is accurate, but the analysis is intricate and takes a long time.

Nowadays, an electrical method is used, which is fast but not so accurate as the chemical method. It is usually used in routine analysis, for which a special 'salt bridge' is constructed which can also be used in the field. In principle the electrical resistance in a fixed space between two electrodes is measured at a constant temperature (see U.S. Salinity Laboratory, 1954, and Soil Survey Manual, 1951). The measurement is made in the soil paste or in the extract; the latter gives the best results. The salt bridge for field work is constructed for the soil paste.

The modern electrical method for determining soil salinity in saturation extracts has some disadvantages because the result of the measurements depends on the specific salts, their mixtures and concentrations in the extract, the moisture content, the dissocation of the salts, the ratio of the various cations in the adsorption complex, the clay minerals, the organic matter content and the microbiological activity, as well as on the texture of the soil and on the temperature, which should be 25 °C. Corrections have to be made for these factors. At the present time the same corrections are used in Iraq as are determined for American soils. The measurement in saturation extracts gives much more accurate results than in the soil paste. Micro methods have been developed in which the measurement is made in a very small quantity of the extract. In order to get better results, special research work has to be done on Iraq soils to determine the correction factors for the various types of soil salinity in the various regions of Iraq.

The results of salt analyses made in this country are expressed in a few ways:

T.S.S. means the total soluble salt content, mostly expressed in p.p.m. (parts per million), sometimes in parts per hundred thousand, or in percentages. 1% is equal to 10,000 p.p.m. Percentages are given in weight percentages in a dry soil.

Ions in parts per million (p.p.m.) are mostly determined on water samples.

g.eq./million for each ion. These values are the chemical equivalent weights of the ions divided by the ions, given in parts per million (p.p.m.).

$E.C._e$ is the electrical conductivity in a saturation extract. In the determination, the electrical resistance is measured in ohms. The reciprocal value $\frac{1}{\text{electrical resistance}}$ is called the electrical conductance, expressed in mhos ('ohms' spelt backwards). The specific conductance or the conductivity is the conductance per cm., measured with electrodes of 1 sq. cm. Sometimes the results are given as $E.C._e \times 10^3$, which means millimhos per cm. (mmhos/cm.) or in $E.C._e \times 10^6$ (micromhos/cm.). The standard measurement is made at 25 °C.

$E.C._1$	is the electrical conductivity	in a 1:1	soil-water ratio
$E.C._5$	is ,, ,, ,,	in a 1:5	soil-water ratio
$E.C._{10}$	is ,, ,, ,,	in a 1:10	soil-water ratio
$E.C._{iw}$	is ,, ,, ,,	in irrigation water	
$E.C._{dw}$	is ,, ,, ,,	in drainage water	
$E.C._s$	is ,, ,, ,,	in the soil paste	

$E.C._s$ is not the same value as the $E.C._e$ measured in the saturation extract; the ratio of these two is not even constant.

Cl-ion content is the chloride ion content, which is determined by applying chemical methods.

g./l. is the quantity of salts present in one litre of liquid, sometimes used to express salt content of irrigation water. Sometimes mg./l. are given; 10,000 mg./l. or 10 g./l. = 1%.

C value is the quantity of NaCl in grammes per litre of soil water.

B value is the quantity of NaCl in 100 g. dry soil.

The T.S.S. (p.p.m. or %) or the $E.C._e \times 10^3$ values are given in most reports. The U.S. Salinity Laboratory (1954) has introduced a factor 0.064 for calculating the salt concentration in terms of percentages from the $E.C._e \times 10^3$ value. A new factor (0.051) has been proposed for sabakh soils in Iraq by Hanna (1956). Although this proposal is based only on analyses of a few soils, it clearly shows that basic research work has to be done as soil conditions in Iraq are not the same as in the United States of America.

Due to the rapid change of soil salinity in vertical and horizontal directions in the soil, many samples have to be taken. The best results may be expected by sampling and analysing representative soil profiles, at least to a depth of 1.5 or 2 metres. Usually one soil sample is taken in each soil layer or horizon. In uniform soil profiles it is proposed to analyse the layers 0–10, 10–25, 25–50, 50–100, 100–150 and 150–200 cm. If a salt crust is present, this crust should be analysed separately. In addition to the soil samples, a groundwater sample should be analysed. The salts present in a sample of irrigation water should be analysed as well.

The electrical methods of salinity analysis are usually used for the routine analyses, especially if large areas have to be studied. However, it should be realised that this work must be based on intensive research work in order to understand the salinity problem. The salinity type, the various kinds of salt, and their mixtures and characteristics have to be studied first. Soil salinity is a very complex and dynamic soil quality depending on many factors. In the samples of some standard soil profiles, representing typical salinity types, the following analysis should be made:

pH in a saturated soil extract;
the moisture content of the soil;
the electrical conductivity ($E.C._e$);
the gypsum content;
the quantitative analysis of Na, K, Ca, Mg, Cl, SO_4, CO_3 and HCO_3 in a saturation extract;
the cation exchange capacity (clay minerals);
the sodium and magnesium exchange percentage;
the organic matter and lime content;
the field capacity and the infiltration rate;
the chemical analysis and $E.C._e$ of the groundwater.

The evaluation of the results of the soil salinity analyses for practical agricultural purposes is not difficult for the strongly saline soils. It is much more difficult for the slightly and moderately saline soils. Some crops can withstand more salt than others. The salt tolerance of crops also varies in the various phases of the growth of the plants, and with the type of salt. The salinity of the soil varies during the irrigation period. When irrigation starts, the water is non-saline; as salts dissolve, the salinity of the water increases. A general practice is over-irrigation when excess irrigation water is applied. The salts of the upper soil layer in which the seeds will germinate are somewhat washed out for a short period. It is a wonder that crops like barley and alfalfa still grow in strongly saline soils, but the yield is low. In some cases magnesium salts are more toxic than sodium salts (e.g. for beans). There are indeed definite plant differences with respect to tolerance to specific salts (U.S. Sal. Lab., 1946). Chloride salts are mostly more toxic than sulphate salts, except for flax.

Symptoms of salt injury are: reduction in size and yield; leaves dry out and become brown. It starts at the tips of the leaves and extends along the leaf margin. Leaves becoming chlorotic is not specific for salt injury, although it can often be observed in saline areas. It indicates disturbance in plant nutrition, which is often associated with high salt contents. By means of plant-breeding, it is possible to have crop varieties with increasing salt tolerance.

For practical purposes saline soils are grouped into several classes in relation to the agricultural use possibilities. The classification proposed by Tuwarij (1930) was used up to some years ago, when the American system (U.S. Salinity Laboratory, 1954) was adapted, although it has never been checked whether this system can be applied to Iraq.

The level and methods of farming in Iraq are completely different from those in the United States. The crop varieties in Iraq are adapted to physical environment conditions, particularly to salinity. It is therefore expected that the evaluation of soil salinity analysis should be different. According to the United States system, saline soils are grouped into five classes:

$E.C._e \times 10^3$	Crops
0–2	Salinity effect is negligible
2–4	Restricted yield of very sensitive crops
4–8	Restricted yield of many crops
8–16	Tolerant crops only
16 and over	Very tolerant crops only

In soil surveys the approximate limits of the salinity classes are nearly the same.

Soil Class	Name	$E.C._e \times 10^3$	T.S.S. %
0	Salt free	0–4	0–0.15
1	Slightly saline	4–8	0.15–0.35
2	Moderately saline	8–15	0.35–0.65
3	Strongly saline	> 15	> 0.65

Soil salinity analyses can be made in a field laboratory by using a special bridge (S.S. Manual, 1951). A rough determination can be made by tasting the soil; if the soil tastes salty, it is strongly saline (class 3). Moderate salinity is determined by wetting the soil; after it becomes dry very thin salt crystals can be seen on the surface.

In evaluating the results of the salinity analyses, attention must be paid to soil texture. Much more water is needed for wetting fine textured soils (clayey and silty soils) than for coarse textured soils (sandy soils). If the salt content of the soils is the same, the osmotic pressure in the coarse textured soils is much higher than in the fine textured soils. Therefore a salinity of, say, 0.1 % does not influence plant growth in fine textured soils, whereas it is strongly harmful in the coarse textured soils.

In recent years, Russian soil scientists of the Dokutzajev Institute have developed a new evaluation and classification system of saline soils based on salt content, chemical composition, position of the salt horizon and depth of the groundwater table (Janitsky, 1957). It seems to be an improvement on the American system.

The classification of saline soils in Algeria is based on the Cl-content (Boulaine, 1956):

Cryptosolonchaks, less than 0.7 % Cl in the surface
Hyposolonchaks, 0.7–1.8 % Cl in the surface
Solonchaks – more than 1.8 % Cl in the surface.

It was interesting to learn from the farmers in the Lower Mesopotamian plain that a soil is called saline when nothing can be grown and land is out of production due to the very high salt content. Other saline soils, even those with salt efflorescence, are not called saline if crops can be grown (see Chapter 7.1.).

The salt tolerance of various crops is different. A list is published in the Handbook of the U.S. Salinity Laboratory (1954) and proposals for forage crops to be grown in Iraq are made by Ferguson and Kadry (1956).

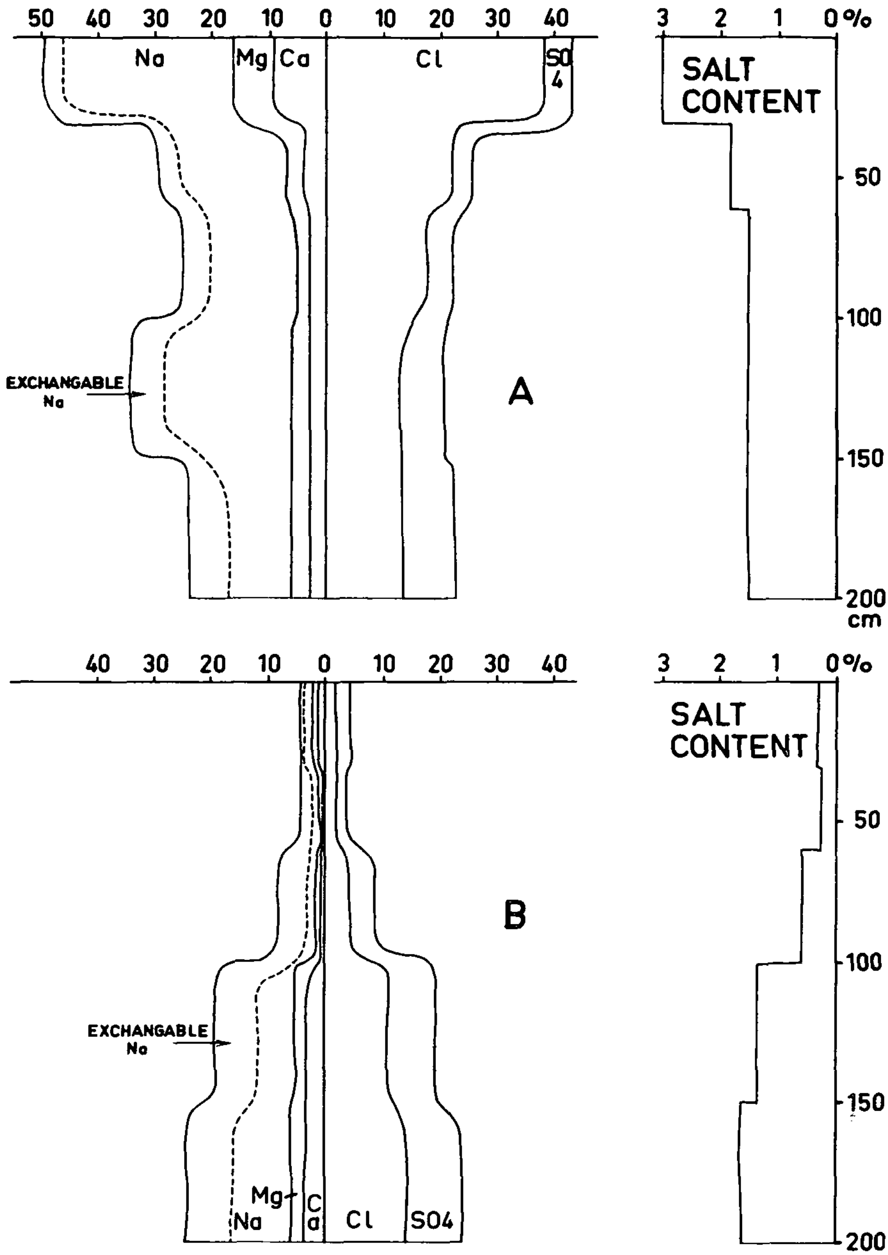


FIG. 38. Distribution of cations and anions (in meq./100g.) in a soil before (A) and after (B) leaching (data from Boumans, 1956). Almost all the salts are removed from the upper metre in one season of washing.

Sometimes indicator plants, usually weeds, are used in evaluating saline soils. Although this can be done to a certain extent, the results are not always reliable. Indicator plants at least have a tolerance range; soil salinity varies over short distances and human activity (cultivation, irrigation, grazing, cutting weeds for fuel) has often changed natural vegetation.

Finally it should be realised that it is not the salt content in the soil but the osmotic pressure of the soil solution which affects plant growth. In special experiments it may therefore be an advantage to determine the osmotic pressure in the soil solution and in the plants at various stages of the experiment.

3.5.7. *Reclamation*

From a technical point of view it is often possible to reclaim saline soils, provided that they can be effectively drained and sufficient water is available for washing and irrigation under a permanent system of cultivation. It is, however, not always economical to reclaim any saline soils, particularly those with rather poor physical characteristics.

The main point in reclaiming saline land is good drainage. Soil drainage is the most important technical problem in Iraq agriculture. Salts have to be washed out by excess irrigation water (Fig. 38). If possible, gypsum should not be leached. The water percolates through the soil, dissolves the salts and has to be carried off by a system of open or closed field drains and finally by drainage canals. In many areas with a high groundwater table, the upper part of the groundwater up to a depth of approximately 3 metres has to be carried off too. Much depends on the possibility of water percolating through the soil, which is called soil drainage; this is a soil quality which, in a dynamic or active sense, refers to the rapidity and extent of the removal of water from the soil in relation to addition, especially by surface runoff and by flow through the soil to the underground spaces. Internal soil drainage and the soil permeability are important factors (see Chapter 7.3.).

The dangerous salts are almost all very soluble ($NaCl$, $MgCl_2$, $CaCl_2$ and $MgSO_4$). Calcium and magnesium carbonate and gypsum have a low solubility; they, however, do not interfere with plant growth. Sodium sulphate is the only salt which, especially during the winter, has a relatively low solubility. Soils containing high quantities of this salt, puffed solonchak soils, therefore cannot be washed easily during winter, which is in general the most favourable time for the washing of saline soils. Sabakh soils can be leached easily if the sodium sulphate content is low.

There are only a few examples in the world of successful reclamation of saline soils. Up to recently it was generally believed that irrigated agriculture was necessarily doomed as soils always become saline. It has now been shown (Green, 1958, gives examples) that it is possible and worthwhile to reclaim saline land in arid regions. It has also been shown that the key to the success of agriculture in such regions is drainage and drainage only. Consequently only those soils which can be drained sufficiently (this depends on many soil characteristics) should be irrigated and methods suitable for local conditions should be applied. If this basic fact of successful agriculture in arid regions were to be accepted in Iraq, the present system of land reclamation would be changed.

A few experiments on reclamation of saline land have been carried out in Iraq; some are in progress (see 7.3.2.).

In the newest agricultural development projects, drainage systems will be made. The first projects were carried out without any drainage and this is perhaps the main reason why these projects became failures (Ali, 1955). If in the future no attention is paid to the results of soil surveys and land classifications of the project areas, the results will be insufficient, at least in about 30% of the project areas.

Carrying out drainage of saline land introduces some new problems, e.g.:

a. After the washing out of salts, the physical and chemical conditions of the soils have been changed. This often results in a decreasing soil permeability and in a lower gypsum and plant nutrient content. Therefore most soils will require the application of chemical fertilisers, particularly phosphate and nitrogen, as is shown by the experiments by Boumans (1955).

b. Bij introducing drainage, more irrigation water is needed, partly for washing and partly for a higher crop production. The additional water also tends to increase the need for drainage.

c. In irrigating land in Iraq, the surface soil will become silted to such an extent as to impede water penetration; this can partly be avoided by ploughing.

d. A drainage project will never become a success and there will be no increase in crop production if the farmer does not know how to make use of and to maintain the higher productivity of the soil. All farm management practices have to be improved. This can be done only if attention is also paid to a series of other measures.

3.5.8. *Gypsum in Iraq Soils*

Although gypsum is a salt which occurs in many Iraq soils, it does not influence plant growth. The reason is that the solubility of gypsum in water is very low (1.8 g. gypsum in 1 litre of water), and therefore the osmotic pressure of the solution never increases beyond 0.5 atmospheres. The solubility of gypsum increases if sodium chloride and magnesium chloride are present in the solution. If the sodium chloride concentration becomes too high (approximately 100 g./l.) the gypsum solubility decreases. This also applies for calcium chloride, sodium sulphate or magnesium sulphate (Janitzky, 1957). The presence of gypsum in saline soils prevents these soils from becoming alkali soils. It is present in Iraq as:

Gypsum, which is hydrated calcium sulphate, $CaSO_4.2H_2O$;
Anhydrite, which is anhydrous sulphate of lime, $CaSO_4$, and is associated with gypsum in rock salt;
Alabaster, a fine grained, light coloured, compact, non-crystalline form of gypsum, (Mosul marble);
Secondary or detrital and reprecipitated gypsum.

The first mentioned types of gypsum are true rocks, usually formed in the Lower Fars in inland seas.

Secondary gypsum is dissolved in the areas of primary gypsum rock and precipitated in younger formations, especially in the Bakhtiari gravels, the river terraces and to a small extent in the Holocene fluviatile deposits. It is crystalline or amorphous. Most secondary gypsum was formed during the pluvial phases of the Pleistocene, at the time that the climate was more humid and the valleys in the gypsum regions were formed. In the older clayey and silty deposits of the Pliocene, which are often somewhat reddish coloured, gypsum often occurs in monoclinic crystals, which are colourless and transparent, and is called selenite.

Some secondary gypsum has been blown from the gypsiferous desert areas and deposited in other areas. Some gypsum has been precipitated from irrigation water, whereas some is also formed by chemical reactions in the soil itself, especially when sulphur is present, which in moist soil reacts with lime ($CaCO_3$) with the help of micro-organisms.

In the soils of the flood plain secondary gypsum is present in both amorphous and crystalline forms. The gypsum content is 1–3 %, sometimes up to 6 % and occasionally even 30 %; the highest quantities occur in the subsoil, where gypsum is often accumulated in crystals. Finer textured soils usually have a higher gypsum content than the similar coarse textured soils. Most gypsum is accumulated in the layer above the capillary water zone of a profile. As evaporation of groundwater in arid areas reaches to a depth of about 2.5 to 3 metres below the land surface, gypsum can be accumulated to this depth. Gypsum horizons at a greater depth occur in buried soils. Gypsum accumulation can also be a result of replacing the Ca^{++} of the soil by Na^{+} or Mg^{++} of the sulphates in the groundwater. The salt concentration of the groundwater can decrease as well, if the water gets a high Ca^{++} concentration, and consequently gypsum will precipitate, even below the groundwater level. As a result the relative Cl content of the groundwater increases considerably.

Some young fluviatile soils show a high gypsum content (up to 30 %) in the surface layer. It is expected that most of this gypsum is formed in the laboratory during the analysis, due to the presence of crystalline sodium sulphate.

A schematic gypsum map of Iraq (Fig. 39) has been prepared. It is compiled from various sources, viz. the geological map of Iraq, data from the Parsons Co., Nedeco (1955), the Division of Soils and field observations. On the map are indicated:

G – primary gypsum, large areas mainly consisting of gypsum rocks (Lower Fars), locally mixed with some marine limestone, shale and mudstone.

(G) – primary gypsum, nearly everywhere mixed with limestone, and locally with some mudstone and sandstone.

SG – Secondary gypsum, mainly in gravelly Bakhtiari and upper river terraces and in other late Pliocene and early Pleistocene deposits.

A – Older and young fluviatile deposits, with a low percentage of secondary gypsum, in the north partly overlying gypsum beds.

L – Non-gypsiferous areas, mainly consisting of limestone.

The map is a provisional one, as gypsum formations have not been intensively studied in Iraq. The map gives an idea of the abundance of gypsum in Iraq.

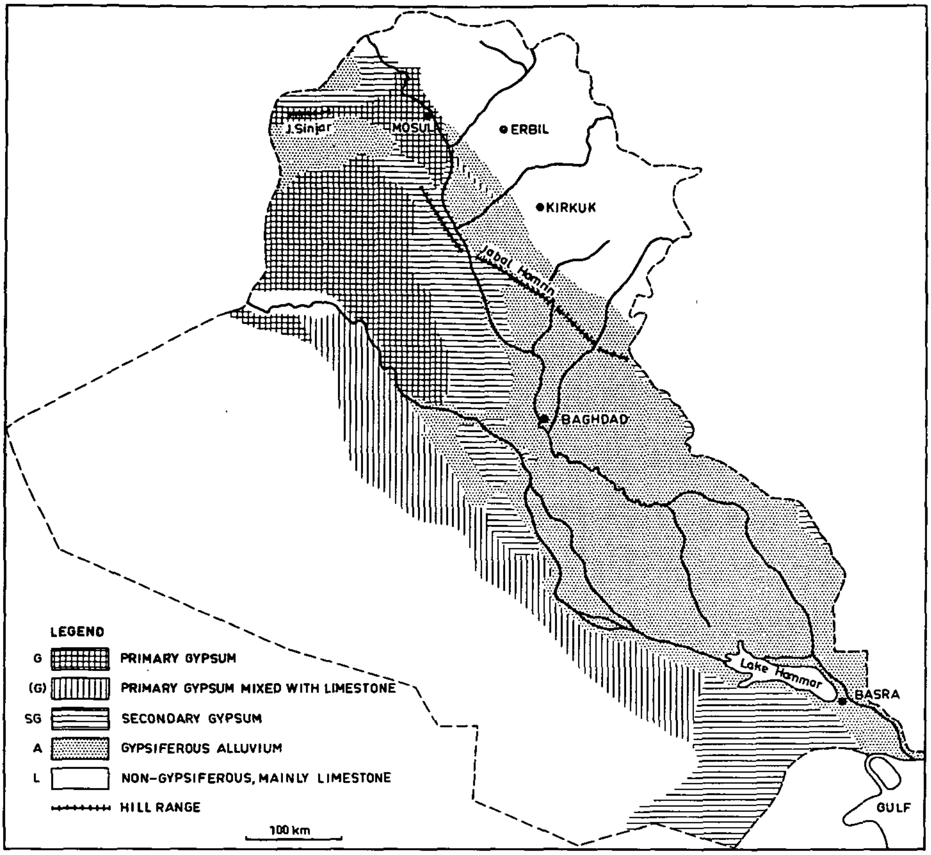


FIG. 39. Gypsum map of Iraq (data from various sources and own observations). Explanation in the text.

The economic significance of the gypsum is:

a. It is used as building material;

b. In ancient times it was used in sculpture (alabaster);

c. It is used to make plaster (juz); often juz pits are dug in secondary gypsum deposits where at least 40% of gypsum is present. The material is burnt at 128 °C.; $CaSO_4.2H_2O$ is transformed into 2 $CaSO_4.H_2O$. The quality of the plaster depends on the salt and clay content of the material.

d. It is present in most gravelly and sandy material of Central and Southern Iraq. This material is used in the making of concrete, and the gypsum decreases the quality of the material.

e. The gypsum present in the river plain soils has a bad influence on the concrete constructions.

f. Soils containing gypsum are prevented from becoming alkaline. Gypsum is often used to improve alkali or saline-alkali soils (see 3.58). Soils containing enough gypsum throughout the profile will not become alkaline. Some soils of the Lower

Mesopotamian Plain, however, contain gypsum in the subsoil or substratum only; it often occurs as crystals. Those gypsum crystals, however, may be covered with a thin layer of $CaCO_3$, making the gypsum ineffective.

3.5.9. *Saline-Alkali and Alkali Soils*

An alkali soil is a soil which contains sufficient exchangeable sodium in the adsorption complex to interfere with the growth of most crop plants; no appreciable quantities of soluble salts are present.

A saline-alkali soil is a soil containing sufficient exchangeable sodium in the adsorption complex to interfere with the growth of most crop plants. In addition to this it also contains an appreciable quantity of soluble salts. In accordance with these definitions, the following limits are accepted (U.S. Sal. Lab., 1954):

For an alkali soil the exchangeable sodium percentage (E.S.P.) is higher than 15%, the pH of the saturated soil is higher than pH 8.5, and the electrical conductivity of the saturation extract is smaller than 4 mmhos./cm. at 25 °C. For a saline-alkali soil these limits are respectively: more than 15%, pH usually lower than 8.5, and the $E.C._e\ 10^3$ more than 4 mmhos.cm., at 25 °C.

The main difference from the saline soils is that Na ions occur to a large extent in the adsorption complex (Fig. 40). The process in which the exchangeable sodium content of the soil is increased is called alkalisation or solonization. The clay in such soils is called sodium clay, which is easily dispersed; this is the opposite of saline soils, in which the soil colloids are flocculated. Due to this dispersing effect, alkali soil is in a puddled condition; consequently it has a low permeability to water and air and there is often an oxygen deficiency. The soil is sticky when wet and hard when dry, and it has a dense, prismatic to columnar structure. Craks are quite common in the surface layer. As soon as most of the available cations are sodium ions, significant amounts of sodium ions are adsorbed. The relatively high percentage of sodium in the cation exchange complex (C.E.C.) decreases the availability of calcium and magnesium ions, as these ions are strongly adsorbed, whereas sodium is weakly adsorbed. The adsorbed sodium is hydrolysed by water, forming sodium hydroxide, which produces sodium carbonate and hydro-carbonate by combining with the carbon dioxide of the soil (soda formation). The activity of the hydroxyl ions may become toxic to the plants. Sodium carbonate is much worse for plant growth than sodium chloride. The carbon dioxide level in alkali soils is low and therefore the availability of phosphates becomes low as well.

The chemical reactions may be written as follows:

$$2\text{Na-clay} + 2H_2O \rightleftharpoons 2NaOH + 2\text{H-clay}$$
$$2NaOH + CO_2 \rightleftharpoons Na_2CO_3 + H_2O$$
$$2\text{Na-clay} + CaCO_3 \rightleftharpoons Na_2CO_3 + \text{Ca-clay}$$
$$2\text{Na-clay} + MgCO_3 \rightleftharpoons Na_2CO_3 + \text{Mg-clay}$$

The alkali soils, known from other countries, are generally dark brown or black coloured as there is a dispersion of organic matter, which is dissolved by sodium carbonate, through the upper part of the soil, forming a dark coating on the soil particles and structural elements. The fine clay colloids are dispersed too; they move downwards and accumulate in the subsoil (B horizon), which therefore has a relatively

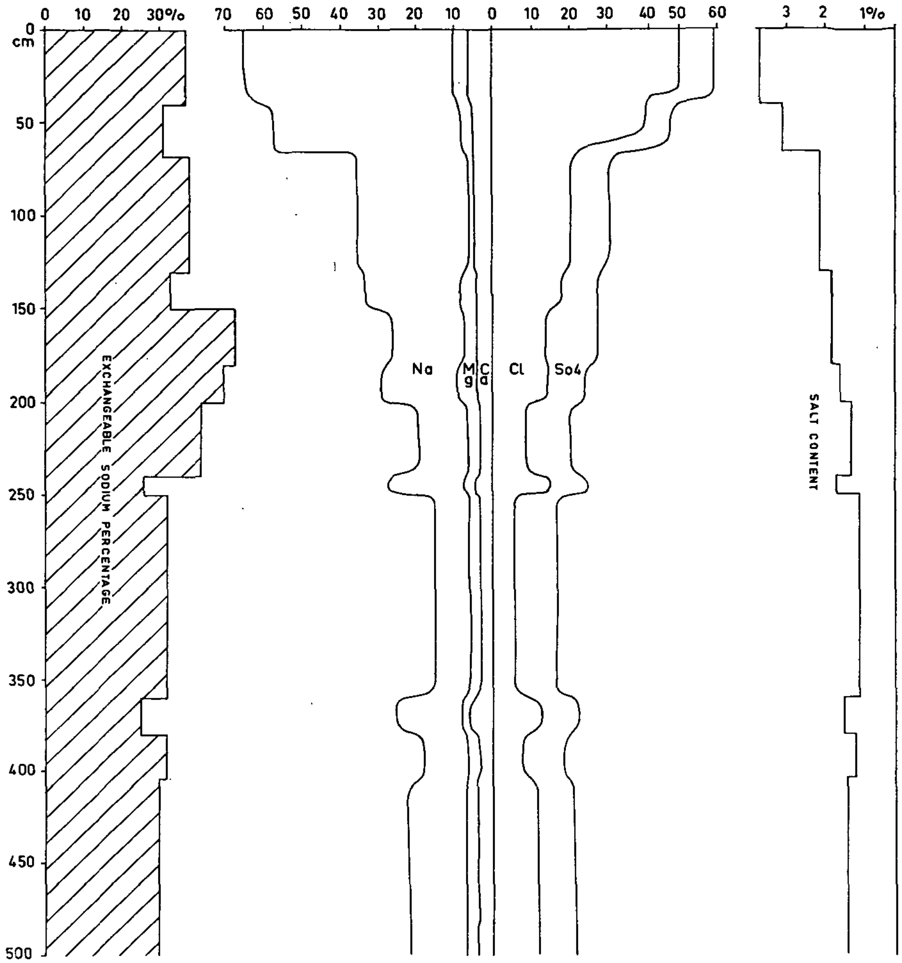


FIG. 40. An example of cation and anion (meq./100 g.) distribution in a saline-alkali soil (data from the Nahrwan report of the Hunting Group, 1956).

high clay content. The structure of this soil horizon is often prismatic or columnar (vertical prisms with rounded caps).

In most solonetz and solonetzic soils of Iraq, the B horizon is prismatic and starts at a depth of less than 3–5 cm., which is rather shallow. This possibly is a result of the arid climate and the flatness of the plain. Real black alkali soils have not been observed in Iraq. Ali (1955) is the only author who mentions the presence of such soils in Iraq. He must be mistaken. Dispersed and puddled clay soils, however, do occur in Iraq (fig. 40).

The saline-alkali soils are more similar to the saline soils, as they also have a relatively high salt content. Neutral salts like sodium chloride hinder the release of sodium from clay; therefore the soil has a less alkaline reaction than when salts are absent.

The saline-alkali soils are usually permeable because the salts maintain the soil colloids in a flocculated condition. The unfavourable chemical reactions of true alkali soils do not occur in the saline-alkali soils; however, in washing out and draining such soils, an alkaline soil can be formed and the deterioration is evident. The adsorbed sodium ions cannot easily be washed out like salts. The only possibility is to replace the sodium ions of the cation exchange complex by calcium ions. This can be done by adding gypsum to the soil. A calcium-clay is formed and the sodium sulphate which remains can be washed out.

In Iraq saline-alkali soils are formed at many places in the saline areas. Real alkali soils fortunately are relatively scarce, but they occur in some areas. One of the main reasons will be the presence of gypsum in most soils of Iraq. The absence of organic matter in the arid soils is another factor. The organic matter content of the soils in the river plain is extremely low (usually lower than 0.5%). Therefore real black-alkali soils do not occur, except possibly with the exception of a few small areas. In many soils the quantity of sodium ions (of NaCl and Na_2SO_4) possibly is not sufficient to start alkalisation.

Sigmond (1938) indicates that the salty soil solution dissolves calcium carbonate and sulphate. The result is that calcium salts are washed down and accumulate in lower horizons. By interaction of calcium carbonate and the sodium chloride and sodium sulphate, calcium chloride and/or calcium sulphate is formed. For Iraq this reaction seems important as lime is present in all soils, generally 20% or more. Sodium chloride is one of the most important salts present in the soils or in the groundwater. The formation of calcium chloride or magnesium chloride in this way may possibly be expected, and consequently the presence of deliquescent salts which are contained in the Sabakh soils, is explained.

In some depressional areas of the Lower Mesopotamian plain, the gypsum and the salt content is low, as both are washed out under natural conditions and alkali-soils occur which are not brown or black, due to a shortage of organic matter. Most of such soils are also saline. The reclamation of such soils is difficult, as permeability remains low; physical conditions are poor and drainage therefore is difficult. True alkali soils, which however are not black, are mainly found in some depressional areas, which are leached by rain and runoff water, and which have a deep groundwater level. Such conditions prevail in the northern part of the Lower Mesopotamian plain and in depressional areas of the uplands (v. d. Kloes, 1956; Hunting Group, 1956).

Until recently hardly any attention was paid to the alkalisation process in Iraq soils, probably due to the facts that gypsum was supposed to be present in all soils, that no black-alkali soils were noticed and that no intensive analytical work was done. In some reports, however, there are clear indications of alkali soils, although they were not recognised and described as such. As an example, reference is made to the K.T.A.M. (1952) report on the Mesopotamian Plain in which 60 out of 1690 soil pits show a pH of 9.0 or more. Gibbs (1954) has reported the presence of true alkali soils.

The alkalinity problem in Iraq was discussed by Buringh (1955) after alkaline soils were mapped in the Naifa area (van der Kloes, 1956), the Adhaim and the Nahrwan areas (Huntings, 1956) and later on in various parts of the plain.

FIG. 41. Gilgai gullies in a basin depression south of the Hindiya Barrage.

The alkalinisation problem is a rather important one in Iraq soils, since the agricultural development programme covers large areas in which soils are present which are tending to become alkaline.

It is clear that the alkalization of soils is a rather complicated process. The definition mentioned in the beginning is generally accepted. The limit of 15% exchangeable sodium is an arbitrary limit. Kelly (1937) states that even from about 7.5% (E.S.P.) the crops grow unsatisfactory. De Sigmond (1938) proposed a 10–15% limit. It is generally assumed that the exchangeable sodium is responsible for a decrease in plant growth. However the exchangeable magnesium also can be responsible. Much magnesium is present in Iraq soils and it therefore will be valuable to study the influence of the exchangeable magnesium too. In stead of the exchangeable sodium percentage 15% limit, sometimes the 2 or 3 milliequivalents of exchangeable sodium per 100 g. of soil is used. This value is probably more useful in some cases.

In Russia, solonetz soils are classified into five groups:

0–5 %	exchangeable	sodium:	non-solonized
5–10%	,,	,,	weakly solonized
10–15%	,,	,,	medium solonized
15–20%	,,	,,	heavy solonized
> 20%	,,	,,	solonetz.

However Russian scientists point out (Janitzky, 1957) that in soils with a high base exchange capacity, the influence of sodium ions is much stronger than in soils with a low base exchange capacity with the same percentage of exchangeable sodium. This is important for the soils of the Lower Mesopotamian Plain, which generally have a rather low base exchange capacity (see Chapter 4).

The pH value is somewhat arbitrary. Summer and autumn draughts and winter rainfall, as well as irrigation, cause typical fluctuations in the alkalinity of the surface soil. An experiment was made by Hauser (1953) in some Afghan alkali soils; the pH ranged from 8.7 in March to 9.4 in December and the salt content from 0.09% after the last irrigation in June to 1.7% in December. The subsoil at 50–60 cm. was not affected by yearly fluctuations.

Sometimes the pH is measured in a 1:1 and a 1:5 soil-water mixture. If the soil is alkaline, there is a clear difference between the two values, which indicates alkalinity, as a high pH value is indicative of presence of exchangeable sodium in the soil. However the pH of a soil also depends on the salt concentration, and the pH measurements can only be evaluated if many other characteristics are known too.

Although it is technically possible to reclaim most saline-alkali and alkali soils, it will not always be economic. In some countries alkali soils are successfully reclaimed by adding gypsum (up to 50 metric tons per ha!) or sulphur, and by washing and drainage (Kelly, 1937, 1951; Greene, 1948; Powers, 1946). Calcium chloride ($CaCl_2$) is sometimes used for a non-saline alkali soil.

Recent investigation in Russia (Janitzky, 1957) indicate that half the quantity of gypsum, calculated from the soil analysis, is sufficient for a complete improvement of the soils, if all the gypsum is not added at the same time.

FIG. 42. Soil profile in a black soil of a basin depression east of Kerbala. The surface is covered by a white salt crust. The upper part of the soil is blackish coloured and in a state of reduction. See also Fig. 90.

The theory of solonization is fully explained in the various handbooks. Recent results of Russian investigations were described by Janitzky (1957). Besides the colloid-chemical formation, much attention has been paid to the biological formation of solonetz soils in Russia, particularly to sulphate reduction in the presence of organic matter. At the same time, hydrogen sulphide is formed and the soil surface becomes black. Such spots with a black to bluish black surface layer and a smell of hydrogen sulphide have been observed in the Mesopotamian Plain in various areas of solonetz or solonetz-like soils. Those soils always have a high groundwater table and are wet up to the surface. They are in an anaerobic condition; some organic matter is present, too, and groundwater also contains sodium sulphate (Fig. 42).

More information on saline-alkali soils and alkali soils in Iraq is given in Chapters 4.2.3., 4.3.2. and 4.3.3.

CHAPTER 4

SOILS OF THE LOWER MESOPOTAMIAN PLAIN

4.1. General soil conditions and soil formation

Mesopotamia consists of two parts, – Upper and Lower Mesopotamia (Fig. 13). Upper Mesopotamia is also called Al-Jezira (= island); it is partly a desert (see Chapter 5.2.) and partly a steppe area (see Chapter 6.2.). The Lower Mesopotamian Plain is located in Central and Southern Iraq. It is the plain of the Tigris and Euphrates rivers, in the Bible referred to as Shinar; later on it was called Babylonia and As-Sawad.

The climate is a real desert climate, except in the northern section near Samarra, which has a semi desert climate.

Natural vegetation does not occur, as almost all soils are or were once cultivated and the environmental conditions have been markedly changed by human activity. As a result of floods and high groundwater levels, almost the whole plain will have had a scarse vegetation cover under natural conditions.

Although the plain seems to be extremely flat, there is a very important meso-relief, which greatly influences soil conditions. This meso-relief is a result of natural floods and of irrigation practices over a period of thousands of years. In large parts of the plain the groundwater level is near the surface or at a shallow depth; some areas are marshy or may even be covered by lakes. Groundwater depth and quality are important characteristics in evaluating soils of the plain.

The soil parent material consists mainly of river sediments, except near the coast of the Persian Gulf, where marine sediments are found. The Lower Mesopotamian Plain is a plain of aggradation. Besides the fluviatile sediment which is carried by the Twin rivers, some material of aeolian origin, blown out of the deserts, is accumulated and mixed with the fluviatile deposits. In some areas, river sediment has been subject to wind erosion and new aeolian deposits have been formed. The sediments in and around lakes and in some large depressions are of lacustrine origin.

A new type of sediment should be named, the *irrigation sediment.* As may be learned from Chapter 4.2. and 4.3., this sediment has been deposited over very extensive areas as the result of an artificial process of sedimentation by a controlled irrigation system. This irrigation sediment forms the top few metres of the Lower Mesopotamian Plain.

Most sediments are erosional products of the Turkish, Iranian and Iraq hills and mountains and of the Syrian, Jordanian, Arabian and Iraq deserts. In the south-eastern part of the Lower Mesopotamian Plain, which is situated in Iran, and which is therefore not included in this study, sediments are accumulated by some Iranian rivers.

The sediments of the Euphrates river (Fig. 43) differ from those of the Tigris river. This was mentioned first by K.T.A.M. (1952). They were also mapped by Buringh and

Edelman (1955). Recently, Harris and Adams (1957) indicated differences in the molluscan fauna. The Euphrates deposits are characterised by Anodon sp., which have never been found in Tigris deposits. It is known from various field observations that the colour of both sediments is slightly different, probably as a result of different mineralogical compositions. Euphrates sediments are greyish brown, whereas Tigris sediments are pinkish brown, probably due to basaltic rock minerals in the parent material (K.T.A.M., 1952). Differences in mineral composition may be expected because there are certainly different types of rock in the catchment areas of both rivers. It can be seen that various kinds of minerals are present in the rather dark coloured fine river sand. The clay minerals are mainly of the montmorillonite type, with some illite in small quantities. Calcite is an important mineral in all sediments. The clays of the Lower Mesopotamian Plain can be considered as montmorillonite clays, although the number of samples analysed up to now is less than ten.

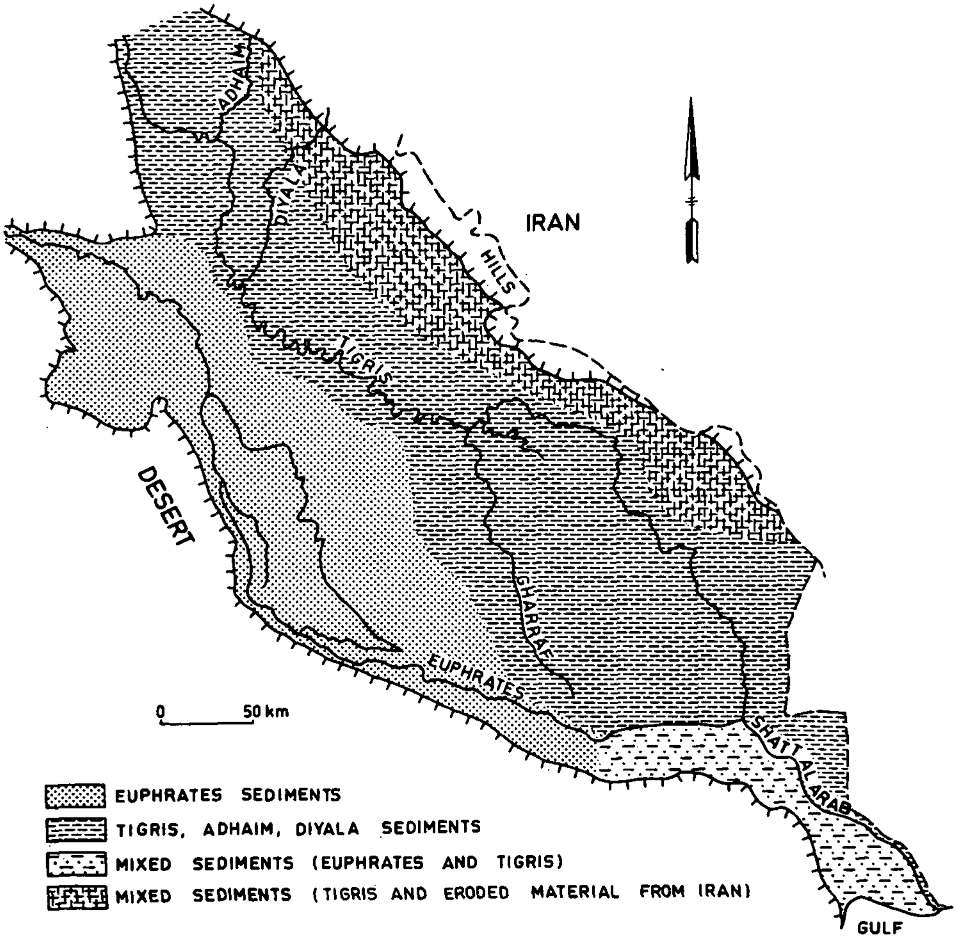


FIG. 43. Map of Euphrates and Tigris-Adhaim-Diyala sediments in the top metre of the soils.

The natural fertility of the soils in the plain is closely related to the mineral composition, the clay minerals and the type of weathering. As the climate is arid, chemical weathering is low, and the organic matter content is extremely low, being 0.5% or less; the C/N ratio is less than 10, usually 4–7. This ratio is very variable because the nitrogen content of soils is also extremely variable. The natural fertility of the soils of the Lower Mesopotamian Plain is also low. This conclusion is in contradiction to the general opinion, written in many articles and books, in which the plain is prized for its high fertility. Young flood and irrigation deposits, covering almost the whole ancient land surface of the plain, have a much lower natural fertility than the buried soil, which is now some metres below the present land surface. The base exchange capacity of the present soils is relatively low, too; values of 20–30 meq/100 g. soil are usually found.

Soil conditions in the Lower Mesopotamian Plain are different from those in the Nile valley in Egypt. In the latter valley, the sediments are the erosion products of Central African mountains, which differ from those in Turkey, Iran and Iraq. Rock weathering in Africa takes place under humid, tropical conditions, whereas in Turkey, Iran and Iraq, continental conditions prevail. Consequently the type of clay mineral is different; in Egypt illite and kaolinite are the most important clay minerals. The base exchange capacity of Nile soils is usually 52 meq/100 g. soil. The C/N ratio in Egypt

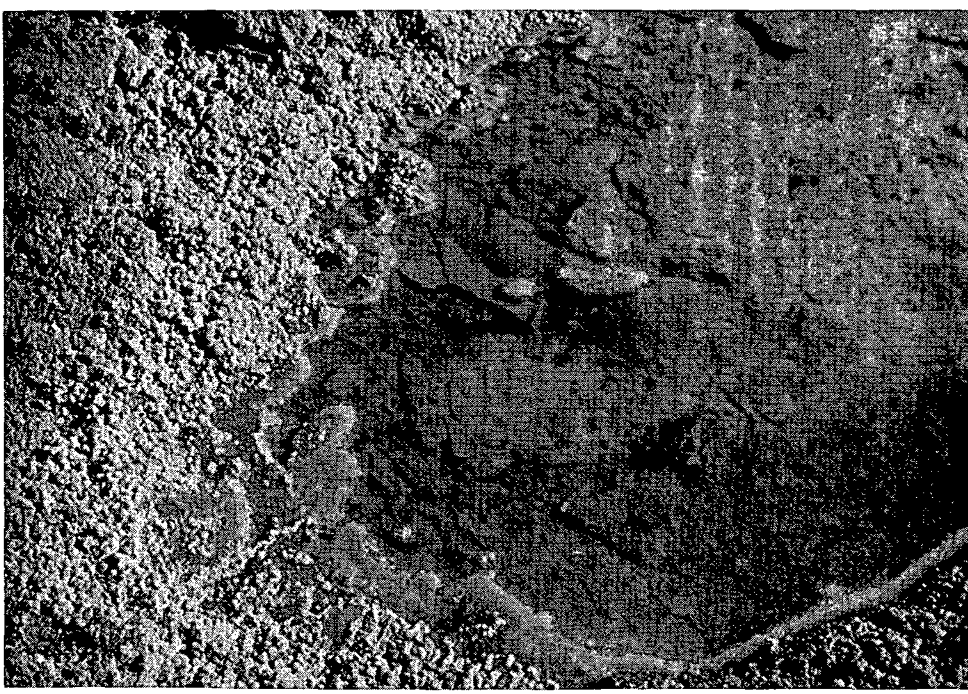


FIG. 44. Salt efflorescence around a small pool. Thin salt plates at the bottom of the pool, in salt saturated water.

varies from 10–14 (Elgabaly, 1950). There is also an important difference in sedimentation, as the Nile has a true delta sedimentation, while Mesopotamia has flood and delta sedimentation. Besides that, the suspended soil material in the Tigris river during floods is four times more than in the Nile river. Egypt has two flood periods per year, but Mesopotamia one only. The consequence of the complete differences in soil and hydrological conditions in both regions is that knowledge and experience on soils, irrigation and agriculture of the Nile valley cannot be applied to Iraq without careful studies.

The general characteristics of the soils in the Lower Mesopotamian plain and of almost all fluviatile plains are:

1. Stratification in the soil profile, consisting of some layers with different textures, often related to differences in mineral composition, clay minerals, structure, consistence and permeability;
2. Important differences in soil conditions in a horizontal direction over short distances;
3. Flat topography, with an important meso-relief (differences in elevation of a few metres);
4. Deep soils, mostly several metres deep;
5. Flooding during periods of great discharge of the rivers, and consequently sedimentation of new soil material in a thin sheet over the older soil;
6. A high groundwater table, at least in the greater part of the area;
7. A relatively high natural fertility, particularly in comparison with desert areas;
8. The presence of good and poor soils in patterns related to the processes of sedimentation and the meso-relief.

In addition, there are some characteristics which are especially typical for the Lower Mesopotamian Plain:

9. The climate is arid and only irrigation cultivation is possible. The type of mineral weathering therefore differs from humid and tropical river plains. Soil formation is of a pedocalcic type, including the effect of a high groundwater table;
10. The fluviatile plain has been and still is influenced by slow tectonic movements;
11. The lime content ($CaCO_3$ and $MgCO_3$) of all soils is extremely high (20–30 %), whereas in the Nile valley it is only 2–7 %!; not all the lime is active, and most of the lime in the soils is chemically inert. It is present as small particles, which influence soil texture. Irrigation water is always concentrated by evaporation and transpiration. Ca and Mg ions are dominant in the Twin rivers; therefore calcium carbonate and magnesium carbonate are precipitated. Due to the very low organic matter content of the soils the amount of carbon dioxide supplied by the decay of organic matter and by root respiration is low. Therefore most calcium carbonate and magnesium carbonate remain insoluble in the soils. A similar explanation was given by Eaton (1950). Consequently, the extremely calcareous fluviatile soils of the Lower Mesopotamian Plain should be classified in a special class, probably in the 'High family' class of the new international system of soil classification to be introduced shortly.
12. Accumulation of salts in almost all soils is a normal process. Na and Cl ions

often become dominant, because most Ca, Mg and HCO_3 ions are removed from the soil solution;

13. The presence of gypsum (a few per cent) in most soils, however not in all soils. Gypsum prevents soils from becoming alkaline;

14. Nearly all soils are covered by a few metres of relatively young irrigation sediments;

15. Soils are or have been irrigated and cultivated for periods varying from 4000 to 6000 years.

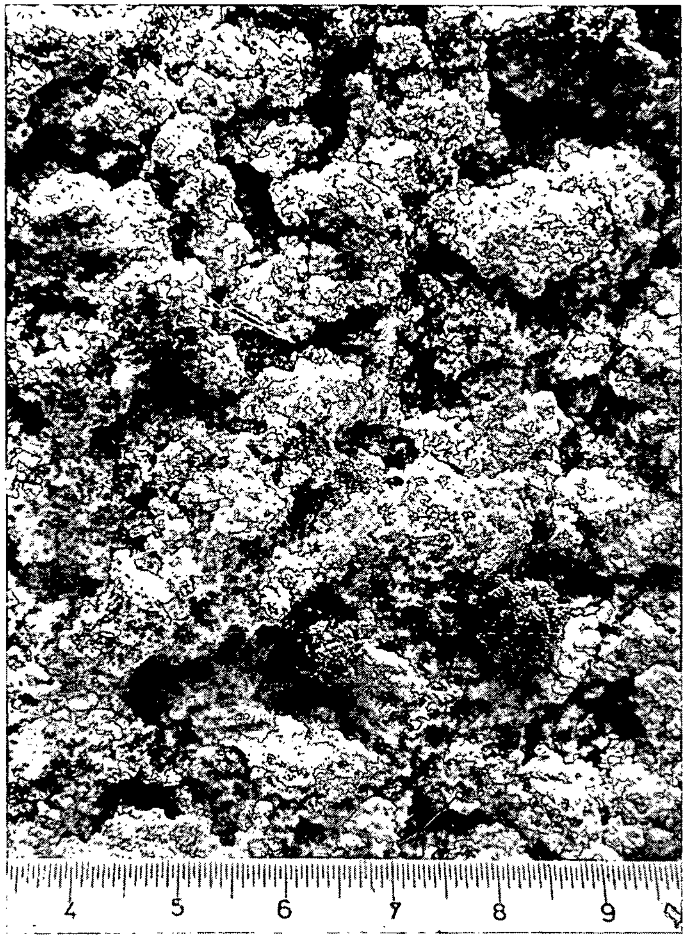
Nearly all soils of the Lower Mesopotamian Plain are classified as Alluvial soils, except those in the most northern section, where fluviatile terraces exist, in which a Reddish-Brown soil has been developed. As most soils in the Lower Mesopotamian Plain are saline or saline-alkali, they could be called: 'Saline-Alluvial soils' and 'Saline-Alkali-Alluvial soils'. It is prefered to call these soils: 'Alluvial soils of the arid zone'. The alluvial soils, which occur in small strips along the rivers in Kurdistan, where the climate is much more humid, are called 'Alluvial soils of the temperate zone' (see Chapter 6).

As a matter of fact the term 'Alluvial' is used here in a pedological sense, indicating a young stratified soil without any soil profile development. In geology and geography the terms 'Alluvial' and 'Alluvium' are used to indicate young sediments of the Holocene period.

Figure 43 gives a general idea about the occurrence of Euphrates and Tigris sedi-

FIG. 45. Salt crust of a flooded solonchak soil.

FIG. 46. Close-up of a salt crust of an external solonchak soil (measure in cm.).



ments in the upper soil layers in the plain. It seems to me that the classes indicated in this figure will not be of primary importance for agriculture. Natural fertility is too low for intensive farming at a normal level and the real differences in mineral composition of the sediments have not yet been studied.

The classification of the Alluvial soils of the Lower Mesopotamian Plain is based principally on soil morphology in relation to processes of sedimentation and hydrology, particularly groundwater conditions. As the soils of the river plains are geographically associated, the geographical distribution and correlation, which are closely related to soil morphology, have to be taken into account. It has been proved by the soil survey of the Netherlands (Edelman, 1950) and later on also in other countries, that this approach is important, especially for the application of the results in agriculture. The classification of soils carried out by Buringh and Edelman (1955) in the Greater Mussayab Project has proved that this method is also very valuable for the Lower Mesopotamian Plain.

First of all the large broad Lower Mesopotamian Plain (approximately 600 × 200 km.!) has to be divided into a number of physiographic units or regions which have completely different soil conditions, due to different soil forming processes, and different hydrological conditions. Soils of each unit (see Fig. 47) will be discussed in more detail later on. First, some general characteristics which prevail under natural conditions and which are important in order to understand soil formation and conditions, will be mentioned.

1. *The Older Fluviatile Terraces*

These terraces have been formed by the Twin rivers during the Pleistocene. The land surface is approximately 15 metres higher than the level of the river water. The river has cut a deep, often steep-walled valley in the terraces. Due to the high topographical position, the terrace plains are never flooded; therefore there are no recent flood deposits on the soils, which are much older than all other soils of the Lower Mesopotamian Plain. As a result, some profile development has taken place and these soils are classified as Reddish-Brown soils, minimum phase. In addition most soils are saline. Another effect of the high topographical position is the great depth of the groundwater level (7–10 metres below the land surface), if there is no irrigation.

2. *The Flood Plain*

The meandering river plain in Central Iraq under natural conditions often has a flood in spring (Fig. 20) covering large parts of the plain, and accumulating a thin new soil layer. Floods ceased in 1956 when the first flood control projects on the Twin rivers were finished. Sedimentation was in a levee-basin pattern, which will be explained in Chapter 4.3. Sometimes the course of the rivers has been changed and consequently sedimentation has changed as well. The groundwater level is relatively deep for most of the year, except in the lowest and most southerly parts of the basins.

3. *The Delta Plain*

Here the rivers split up into many branches. This broad area of land is extremely flat and normal drainage is very slow. Soils are hydromorphic. The groundwater level is high to very high. The deepest and often most southerly parts of the basins are covered by water during a large part of the year.

4. *The Marsh Region*

The rivers and their branches are almost lost in the extensive shallow marshes which are covered with reeds. Groundwater is near or above the land surface and even some organic material on top of the very wet soils has been formed. Most soils are Hydromorphic soils. The area is unstable as water is not controlled.

5. *The Estuary Region*

Due to the tides of the Persian Gulf, there is an important tidal effect on the Shatt-Al-Arab. Consequently the sedimentation on the plain is different from that in the delta area. The water level in the river and tributaries rises and falls twice a day, thus irrigating and draining the land along the rivers, farther inland there are extensive tidal flats with marked systems of inlets. Water in the river is fresh, except near the bottom, where it is brackish.

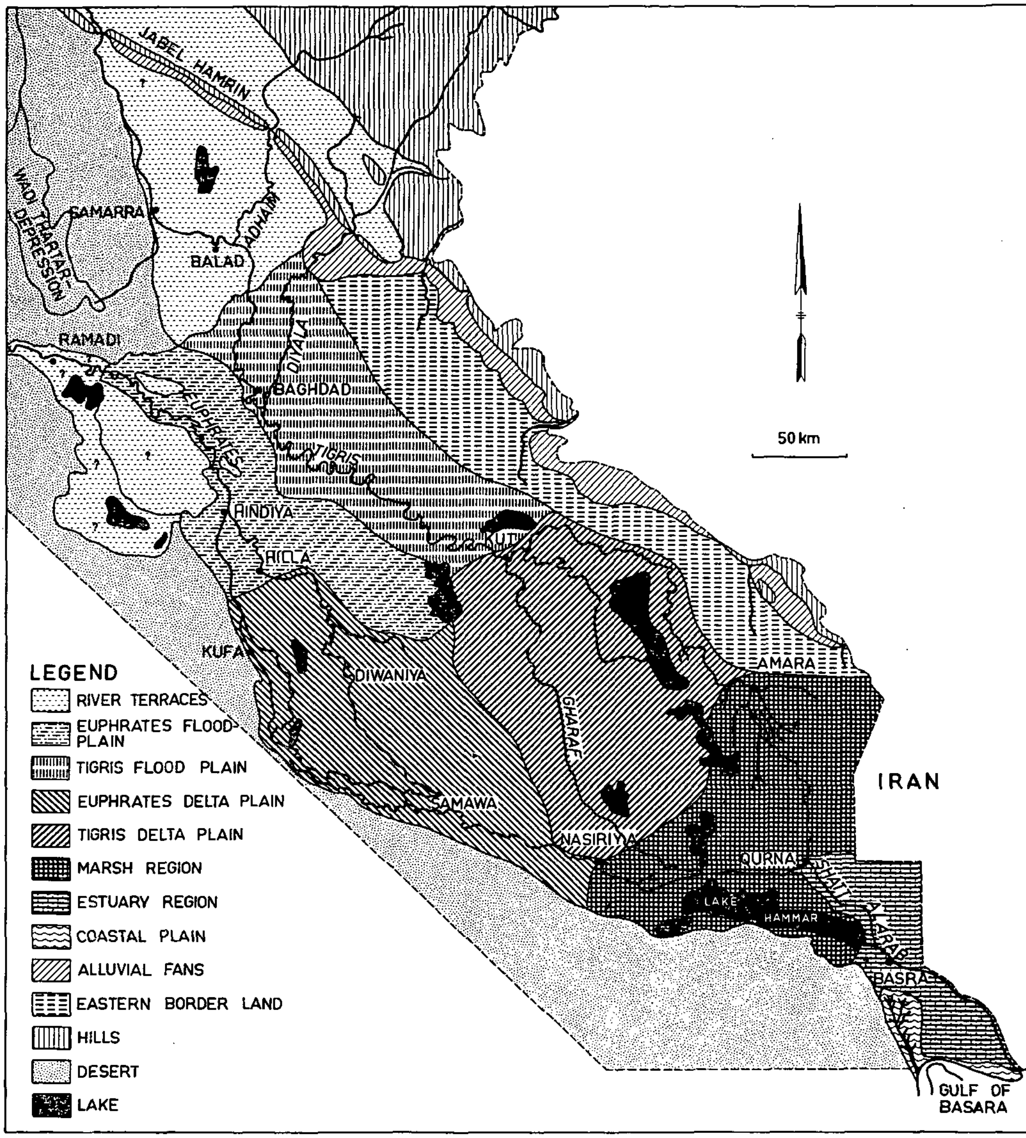


FIG. 47. Map of physiographic units in the Lower Mesopotamian Plain.

6. *The Coastal Region*

This region is characterised by marine deposits from the Basra Gulf. The soils are extremely saline; the groundwater has almost the same chemical composition as sea-water. Land is flooded during storms or specially high tides. Soils are wet, weak and muddy.

7. *The Eastern Section of the Plain*

This is a flat, featureless plain, mainly formed by Tigris sediment, but it is influenced by streams coming down from the Iranian mountains and mostly carrying brackish water, which does not reach the Tigris river. Soils are Saline-Alluvial.

8. *The Fan Region*

A region consisting of material eroded from the Iranian hills and mountains, and accumulated at the border of the Lower Mesopotamian Plain. Groundwater is deep and the land is not flooded.

It may be learnt from studies in other countries that similar physiographic units occur in almost every broad river plain. One of the main differences between river plains of arid and humid regions is that salt is accumulated in and on top of the soils of arid regions, whereas organic matter, particularly peat, is formed in humid regions.

The explanation of the presence of these physiographic units is given by the rivers themselves. They come down from the high mountains, gather more and more water from their tributaries, and enter the plain by eroding a deep valley in the older fluviatile deposits, thus forming terraces, until finally the valley widens into a broad, flat flood plain. In this plain the rivers first meander until a point is reached where the area is completely flat. Here the rivers divert their water through many channels, forming a delta, which gradually comes to an end in extensive marshes. Near the coast an estuary is built up as a result of the tidal effect of the sea (Fig. 48).

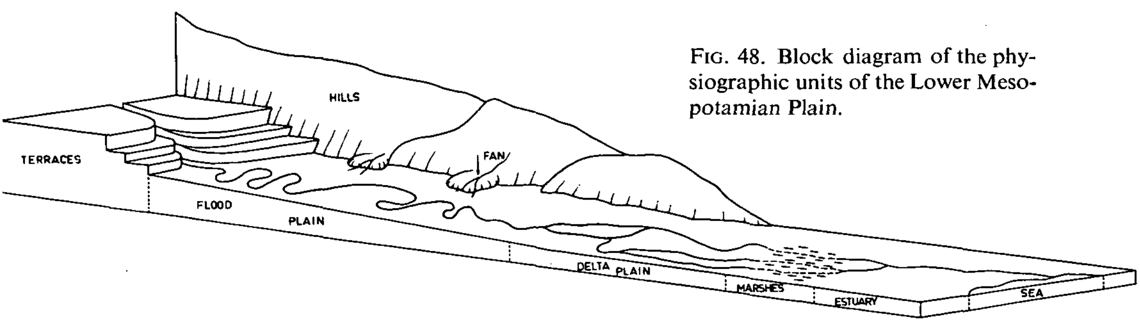


FIG. 48. Block diagram of the physiographic units of the Lower Mesopotamian Plain.

4.2. SOILS OF THE OLDER FLUVIATILE TERRACES

These soils were intensively studied near Samarra and the Adhaim river, where three terraces, formed by the Tigris river, at various periods can be observed. According to Bolton (1954), there are also some river terraces in the Euphrates valley in Iraq. These, however, have not been studied up to now. Dr. van Liere, the F.A.O. specialist in the soils of Syria, showed me three terraces of the Khabour river, one of the main tributaries of the Euphrates. They are similar to those of the Tigris in Iraq, which are given the following names:

The Mutawakkil or high terrace
The Mutasim or middle terrace
The Mahdy or lower terrace

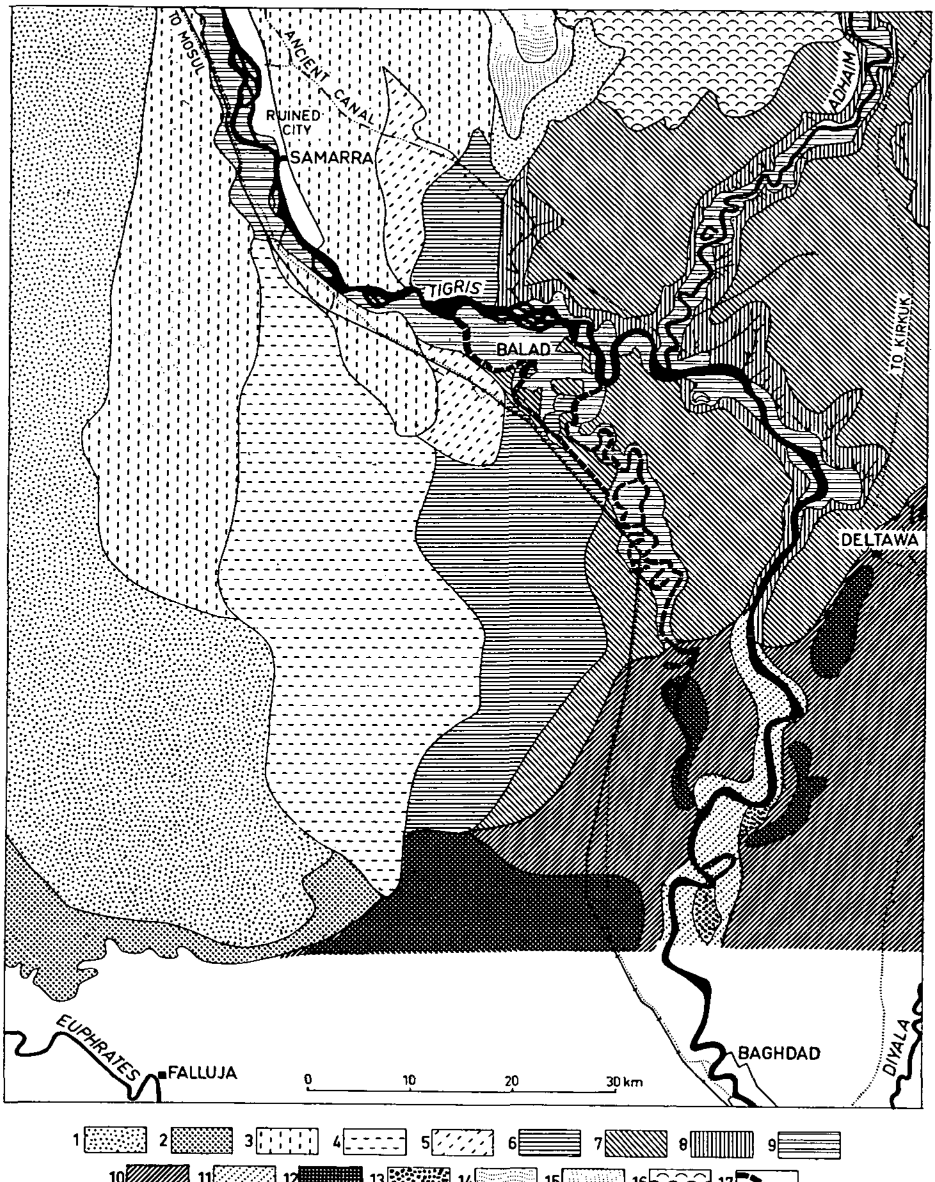


FIG. 49. Sketchmap of Tigris river terraces between Samarra and Baghdad. For explanation, see Fig. 50.

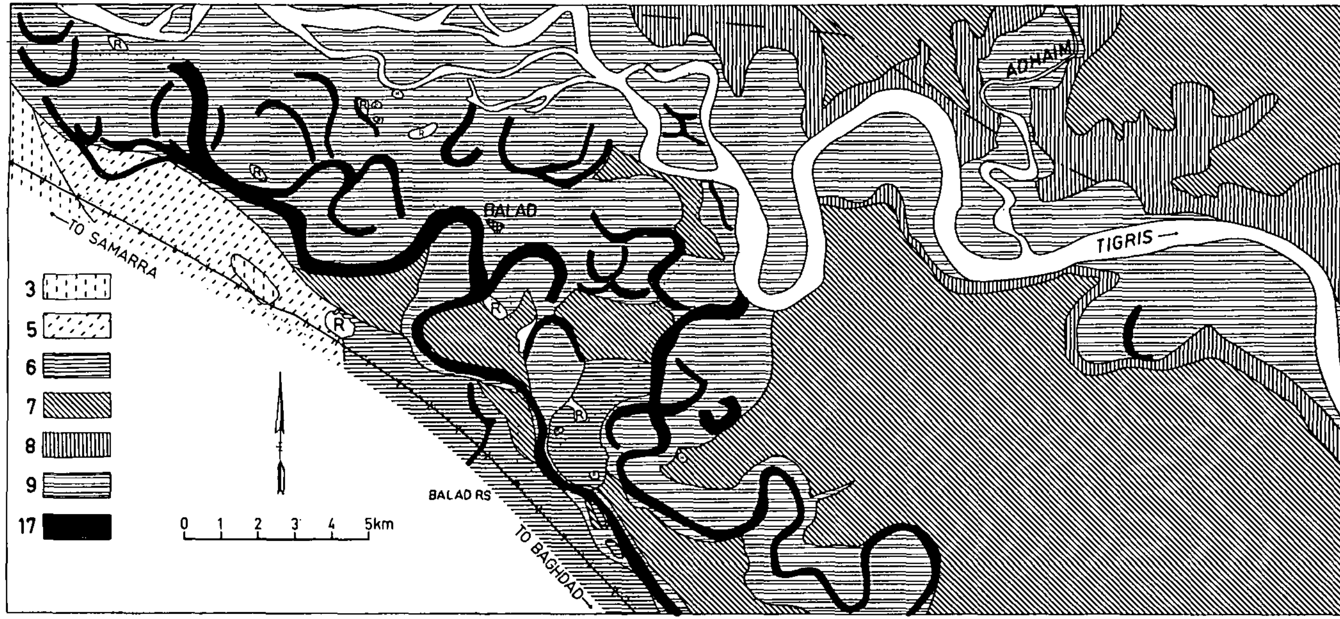


FIG. 50. Map of Tigris river terraces and ancient river courses near Balad.

1. Undulating gypsum desert;
2. Gullied gypsum desert;
3. Covered Mutawakkil terrace;
4. Eroded Mutawakkil terrace;
5. Eroded Mutawakkil terrace with broad, flat valleys;
6. Mutasim terrace;
7. Mahdy terrace;
8. Severely eroded Mahdy terrace;
9. Tigris flood plain;
10. Tigris basin;
11. Tigris levee;
12. Tigris depression;
13. Tigris overflow;
14. lake bottom land;
15. lake border land;
16. active dune land;
17. ancient irrigation canal.

The location of the area covered by this map is indicated on the location map, (map 2).

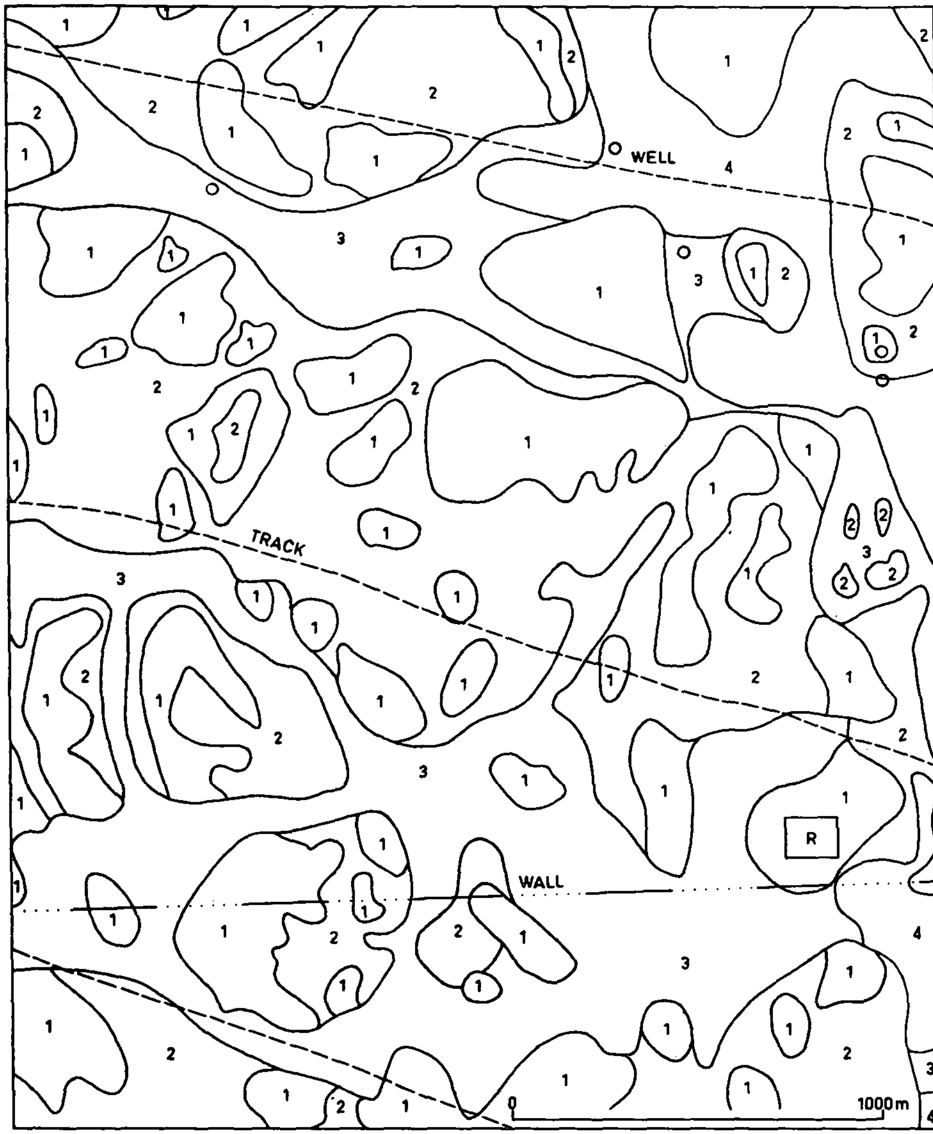


FIG. 51. Soil map showing the location of the various soils of the Naifa complex in an area east of Samarra (after v. d. Kloes, 1956).

1. Samarra gravel-loam (Sierozem soil);
2. Naifa silt loam (Sierozem soil);
3. Bakluwara clay loam (Reddish-brown soil);
4. Quadiniyah silty clay loam (Reddish-brown soil);

R. Ruins

A cross-section is given in Fig. 53.

The formation of these terraces, which are also extensive in Northern Iraq, is discussed in Chapter 6.8. The middle terrace can possibly be divided into a major and a minor terrace, but more detailed field work has to be done to prove this statement.

The location of the terrace soils is indicated in a general way on the exploratory soil map of Iraq (Map 1), whereas the maps in Figs. 49 and 50 give more details. The Naifa area between Samarra and the Adhaim river was studied by van der Kloes (1956) and the Adhaim region by the Hunting Group (1956), Smith and Robertson (1956).

4.2.1. *Soils of the Mutawakkil Terrace*

Most of the soils belong to the Sierozem group. They consist of sandy, loamy and silty material mixed with gravel and have a desert pavement and very often a crust. The gypsum content is very high, up to 60%. 'Juz', a secondary gypsum accumulation, occurs locally; it is used for making plaster for walls and ceilings in the houses. The land surface which lies approximately 15–20 metres higher than the present Tigris plain, is undulating. The top few metres are probably of fluviatile and partly of aeolian origin and overly the real gravel terrace; the latter consists of sub-rounded pebbles and gravels of chert, limestone and metamorphic rocks in an argillaceous and siliceous matrix. Some parts of the terrace are covered by sand-dunes, and others by a thin loess-like deposit less than 25 cm. thick. In the substratum there is an alternation of gravelly, sandy, loamy and clayey, horizontal layers in which gravel predominates. The typical stratification of current bedding in gravel is characteristic for stream deposits in a braided river system. Large, vertical gypsum crystals, hanging like a beard at the bottom of the gravels occur everywhere.

The land is featureless. There are some annual grasses but only in spring. At some points where wells have been dug and soils are suitable, small areas are irrigated and cultivated, although the soils are saline as the groundwater is of a rather poor quality.

The soil map in Fig. 51 gives an example of a typical part of the desert area on the Mutawakkil terrace. Some brief descriptions of soil series are given. Complete de-scripstions and laboratory analyses are available in the Division of Soils, Directorate General of Agriculture, Abu Ghraib, and in the report by van der Kloes (1956).

The Samarra Series consists of highly gypseous, gravelly loam or silty loam with a desert pavement and a hard crusty surface. The series occupies the highest parts of the undulating desert. It is a shallow soil, almost non-saline or slightly saline and consists of yellowish-brown loam with a fine platy structure at the surface, overlying very pale brown and yellowish loamy sand with a massive structure; it gradually grades into light brown gravelly loamy sand which is highly gypsiferous. The lime content near the surface is nearly 20%; it drops to 1 to 3% at a depth of 50 cm. or more.

The Naifa Series consists of loamy sand to silty loam material mixed with some gravel. The soils are highly gypsiferous (up to 40%) and shallow, and most of them have a desert pavement. This series occurs on slopes; the colours are yellowish-brown over very pale brown. It is often a truncated Sierozem soil. The lime content is 20–25% throughout the profile.

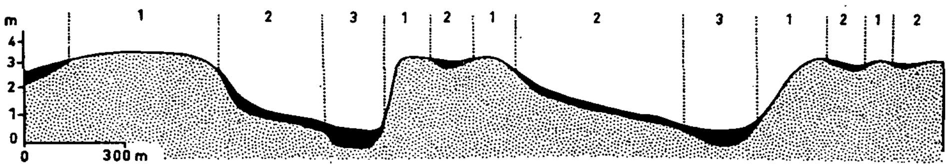


FIG. 52. Schematic cross-cestion through the Naifa plateau. The soil layer is coloured black on the diagram; The gypsiferous gravels are stippled. The above symbols correspond with those of Fig. 51.

Soils of the *Bakluwara Series* occur in the smooth valleys; they mainly belong to the Minimum Reddish-Brown great soil group. The soils are deep, gypsiferous and formed by colluviation. They consist of a reddish to yellowish-brown clay loam, with an angular blocky structure and some gypsum accumulation at a depth of 20 cm. and deeper. Non-cultivated sections are slightly saline; irrigated sections are saline.

Fig. 52 shows these soils series in a cross section, which also demonstrates the typical relief with shallow valleys and depressions, which form the pattern shown in Fig. 53. This valley pattern has probably been formed during pluvial phases of the Pleistocene, when excess rain-water was carried to lower-lying areas. Due to wind erosion the surface soil has been partly blown off and has accumulated, forming a desert pavement.

The gravel material of the substratum has been considered as belonging to the Bakhtiari formation. This however does not hold for those areas mapped as Mutawakkil terrace. This material does not have the characteristics of the Bakhtiari formation. It is a younger braided river deposit of the early Pleistocene. South of Samarra and west of the

FIG. 53. Valley pattern of the Naifa plateau east of Samarra (taken from the soil map of van der Kloes, 1956).

Tigris even the surface deposits have all the characteristics of stream deposits, indicating the course of an ancient (early Pleistocene) Tigris river. (See Chapter 6.8.) It is the oldest river course found in Iraq.

In the younger part of the Lower Mesopotamian Plain, some gypsiferous gravelly desert islands occur, e.g. near Falluja, Iskandria, Kerbala and Haswa. They also belong to the highest terrace, probably of the Euphrates river. These islands lie some metres higher than the flood plain; they have similar soil characteristics, but the gravel is somewhat finer. There are also gypsum kilns and at some places gravel is dug.

The gypsum, known as 'juz' or 'djoz', is a secondary formation. It has been formed by evaporation of water which is rich in dissolved calcium sulphate. It is extremely porous, soft, brittle and needle-shaped, with long vertical crystals. It is completely different from the primary gypsum which is found as hard rock in the Lower Fars formation. The secondary gypsum was first described by Gubbins (see Macfayden, E.A., 1931–1948). He describes the formation as resulting from the combined action of capillarity and evaporation within porous fluviatile deposits and presumes that the groundwater table during its formation was much higher than at present, and therefore the formation does not appear to be active now. Later on Bolton (1954) described secondary gypsum in a similar way. Voûte (1956) considers the formation of secondary gypsum as a result of infiltrating and re-evaporating rainwater, in which gypsum has

FIG. 54. Vertical photograph of gypsum plates in the gypsiferous soils of the Mutawakkil terrace near Samarra. See also Fig. 106.

been concentrated. The 'juz' near the Abu Dibbis depression has been dated as Upper Pliocene or Early Quaternary, as it is older than the former great Abu Dibbis Lake (Voûte, 1956). In this area two juz crusts were observed. Voûte (1957) however is not sure whether they can be correlated with river terraces or not. The juz near Samarra is supposed to have been formed in the Pleistocene on top of the highest river terrace, during the period when the second terrace was formed (see Chapter 6.8.). More investigations in various areas may contribute towards solving the problem of juz formation.

Typical vertical gypsum plates in a polygonal pattern occur. The plates often extend to a depth of more than one metre. The plates consist of almost pure gypsum; they are double, and are separated by a thin vertical soil layer (see Fig. 54). Their origin is not clear. The soil material does not form cracks, for the swelling and shrinkage capacity is low.

Secondary gypsum is often mixed with some sandy, silty or gravelly material. Some salt is also present. The quality of the 'juz' depends on the percentage of gypsum and the chloride content. Sometimes almost pure porous, needle-shaped secondary gypsum is found, e.g. west of Kerbala. A percentage of 50 to 60% gypsum is normal. It is burned in the field in special, simple gypsum kilns.

4.2.2. *Soils of the Mutasim Terrace*

These soils generally belong to the Minimum Reddish-Brown soils. They are mostly saline and consist of silty clay or silty clay loam and are mixed with some gravel throughout the profile. Sometimes there is a thin gravelly layer. The land is flat and the soils are deep; the groundwater is many metres below the surface due to the high topographical position in comparison with the present Tigris valley. The most important soil series, described by van der Kloes (1956) are:

The Sadde Series – A deep, saline soil, with curled crusts at the surface (Fig. 55) and often with a thin cover of recent irrigation deposits. It is a reddish-brown clay to silty clay loam soil, with many gypsum needles in cracks from a depth of about 25 cm. below the surface. It is uniform over large areas. Puffed solonchak soils are widespread in the areas with irrigation deposits.

The Albu Aswad Series is a deep reddish-brown soil, with a somewhat stratified substratum. There is gypsum accumulation from 40 cm. below the surface. The texture is silty clay loam and clay loam; below 2 metres the texture is silty and the material is similar to loess.

The Albu Bas Series is similar, but the substratum is gravelly and less stratified, which gives these soils a better internal drainage and consequently the soils are of a better agricultural quality.

Soils of the Albu Aswad and Albu Bas series are cultivated along the Tigris river where there is pump irrigation and natural drainage to the river.

In the area of the Mutasim terrace there are many isolated islands of gypsiferous gravelly material, belonging to the Mutawakkil terrace. These islands often have a

FIG. 55. Crusted and curled soil surface of a saline soil of the Mutasim terrace east of Samarra.

stream-lined shape (Fig. 56). It is therefore expected that at least a part of the area south and south-east of Samarra has been eroded, whereas afterwards rather uniform material has been deposited during periods of high floods, forming the Mutasim terrace. Irrigation deposits are rather scarce, except in relatively narrow strips along the old Nahrwan canal. A large area of the Sadde series consists of non-cultivated, strongly saline land. Near Balad and along the railroad from Samarra to Baghdad, as well as east of Samarra, areas of good potential agricultural value are available.

The gypsum content of the soils is rather high, up to 5–10%. There are large quantities of vertical gypsum needles in the cracks. There are also accumulations of amorphous gypsum which form whitish spots at a depth of about 40 cm. below the land surface, whereas there is a zone of lime accumulation about 20 cm. below the surface. These two horizons of accumulation at different levels clearly indicate a leaching process, associated with Reddish-Brown soil formation. Gypsum is leached to a deeper

FIG. 56. Map of gravel islands in the Mutasim terrace east of Samarra.

level than lime. Both were precipitated around foci of crystallisation. The more soluble sodium salts follow the movement of soil moisture, especially during irrigation, and rise up to the surface.

Some soils belonging to the Mutasim terrace group are alkali soils, which are described later; some are even Solod soils. The location of the Solod soils is very characteristic as they occur on a rather small terrace strip in between higher soils of the Mutawahhil terrace and lower ones around the Shari lake, which consist of strongly saline lacustrine soils. The Solod soils have been observed in small areas only (van der Kloes, 1956); they are similar to a solod soil described by Smith (1950) in Australia. At many places they are covered by a thin recent aeolian sand layer. As they are saline, they are also solidized-solonetz soils. There is a clear A_1 and a bleached A_2 horizon as well as a columnar clay-enriched B horizon. The soils belong to the *Shari series*.

The position of the Mutasim terrace in relation to both other terraces is not very clear in the Naifa area. It seems that it occurs in an overlapping position, partly on top of the Mutawakkil terrace. Such a possibility has already been mentioned by Wright (1954). Near Balad the Mutasim terrace is the real middle terrace, a few metres lower than the gypsiferous gravel desert of the Mutawakkil terrace and a few metres higher than the Mahdy terrace (see Fig. 50).

4.2.3. *Soils of the Mahdy Terrace*

The soils occupy large areas in the northern section of the Lower Mesopotamian Plain. They have been studied in the Naifa area (van der Kloes, 1956), the Adhaim area north of Deltawa (Hunting Group, 1956; see also Smith and Robertson, 1956), and near Balad and the Abu Dibbis depression, the latter belonging to the lowest terrace of the Euphrates river. The land surface in the northern section is approximately 10–15 metres above the present Tigris and Adhaim valley. The soils consist of fine textured material without gravel. The substrata are fine sandy, loamy or silty; the upper 2–4 metres or so is brown silty clay or silty clay loam. The groundwater level is very deep because near the steep walls along the river valleys of the Tigris and Adhaim rivers there is good natural drainage. The original soil is a Minimum Reddish-Brown soil with some lime and gypsum accumulation. An example is the *Aith Series*, a deep soil, often saline, consisting of a thin surface layer of brown silty clay loam over reddish-brown clay with veins of lime, grading at a depth of about 30 cm. into a horizon with

FIG. 57a. Gully erosion along the Adhaim river in the soils of the Mahdy terrace.

gypsum accumulation, grading into pale brown, somewhat stratified layers with gypsum needles.

Relatively wide strips of the terrace bordering the fluviatile valleys of the Tigris and Adhaim rivers are deeply eroded and completely useless. There are very deep, steep walled gullies (Fig. 57a and b). Non-eroded parts at some greater distance from the rivers are cultivated, however saline.

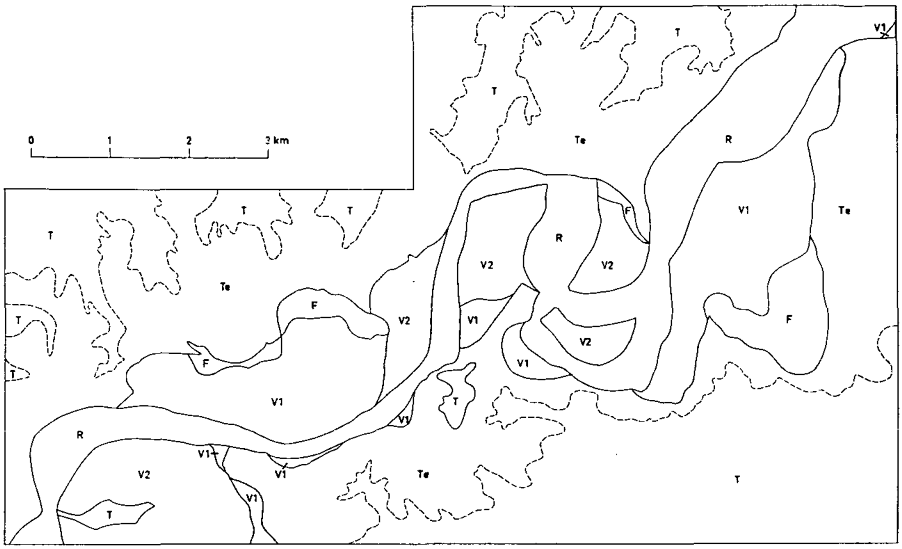


FIG. 57b. Map of a small section of the Adhaim valley east of Samarra.

T Soils of the Mahdy terrace;
Te Deeply eroded and gullied soils of this terrace;
F Fan;
V_1 Valley bottom land, low phase;
V_2 Valley bottom land, high phase;
R The Adhaim river.

On both sides of the Adhaim river, large areas are covered by a thick (2–3 metres) layer of silty irrigation sediment. This results from former irrigation in the area. Water of the Adhaim river at that time was diverted from the point where the Adhaim passes the Jabal Hamrin ridge. Nearly the whole lower Tigris and Adhaim terrace is covered by young sediment, giving the upper part of the soil the character of an Alluvial soil of the arid zone. Buried soil profiles can be observed at many places. The irrigation practice, and particularly the rather modern irrigation canal system have greatly influenced the present soil conditions.

The layer of irrigation sediment consists of very uniform silty material; silt loam and silty clay loam predomenate. The canal system has given a very characteristic meso-relief to the whole area (Fig. 58). The uniform soil texture is the result of a constant flow of irrigation water in the canals and ditches and onto the fields. The particle size of the soil material in suspension is uniform; its deposition is uniform, too, and almost independent of the distance from the river or the main canals. The layer of irrigation sediment is uniform in the horizontal and vertical directions, but the thickness of the layer decreases with distance from a canal or ditch. The rectangular irrigation canal system was such that the whole area was divided into small sections surrounded by canals. Due to constant sedimentation, the strips along the canals gradually became higher, forming irrigation levees, whereas the middle part gradually became a depression, with no cover or only a thin one (irrigation depression). As those depressions have no outlet, they gradually became waterlogged by excess irrigation and runoff water from the irrigation levees. In the depressions fine particles were deposited; the soils therefore mostly consist of clay, which has a poor physical condition, in particular, bad structure.

Besides the important morphological differences in soils, the process of salinization and solonization are dominant soil forming processes.

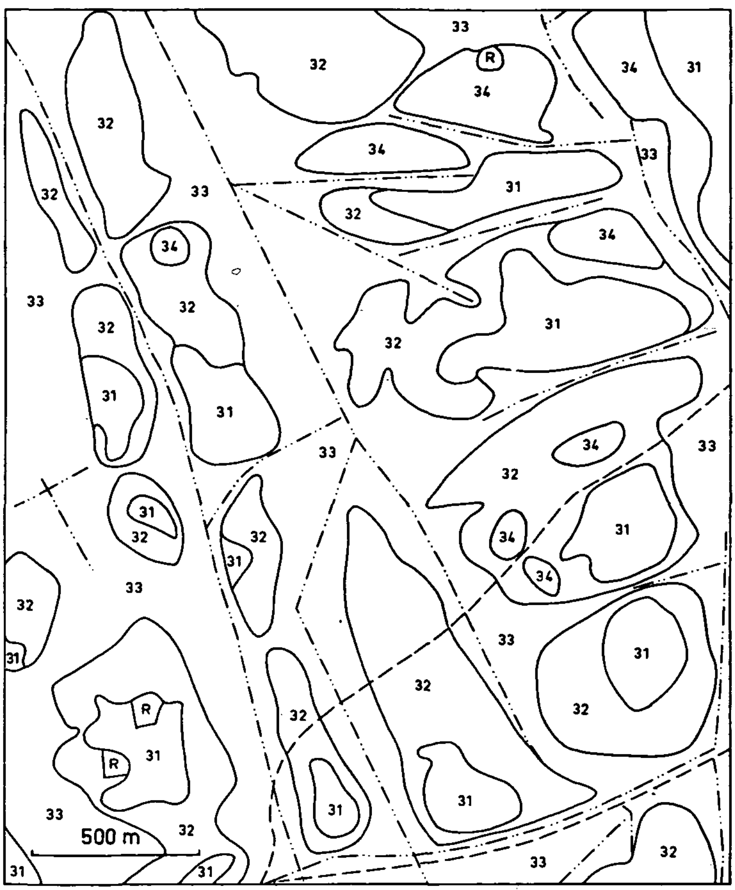


FIG. 58. Detailed soil map of a sample area in the Mahdy terrace, west of the Adhaim river (after van der Kloes, 1956).

31. saline-alkali and alkali irrigation depression soils; 32. saline irrigation depression soils, silted phase; 33. saline irrigation levee soils; 34. leached, transitional soils.

The former irrigation canals are indicated by —··— lines, and roads by – – –.

General soil characteristics of soils of the Mahdy terrace are (v. d. Kloes, 1956; Hunting Group, 1955):

Lime content 20–35%;
pH 7.5–8.6, mostly below 8.0;
(measured in the soil paste); in a 1:5 soil-water solution, the pH may be 0.5 higher.
Organic matter content 0.15–0.95%;
Total N: 0.03–0.09%;
C/N ratio 3–8;
K_2O 0.41–1.38%;
P_2O_5 0.06–0.14%

Soluble salt content (according to the Hunting Group, 1955):

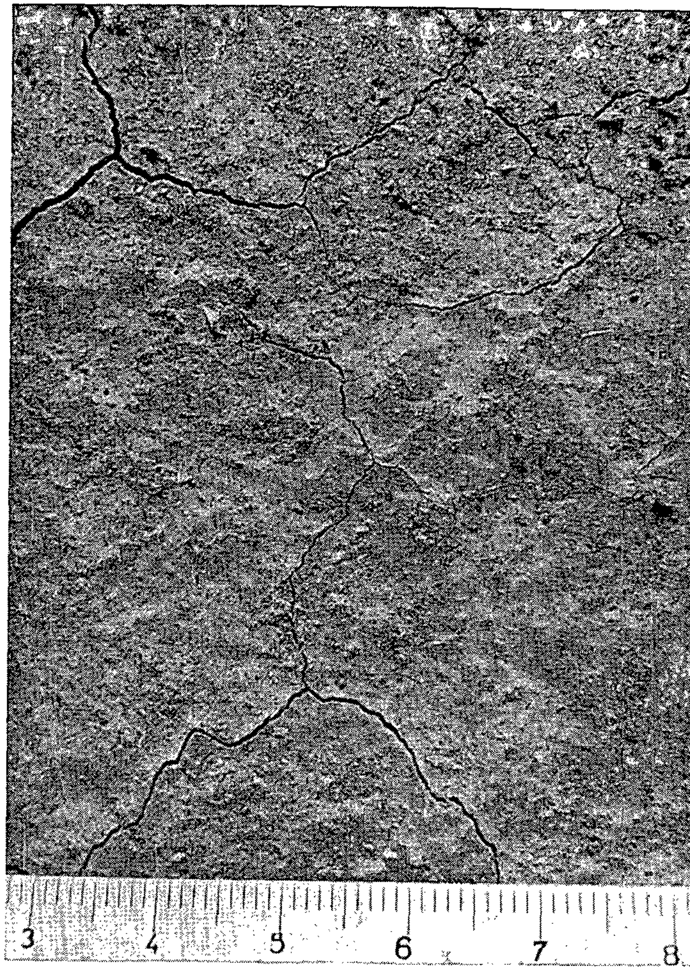
	Adhaim left bank	Adhaim right bank
$E.C._e < 4$	28% of the area	12% of the area
$E.C._e$ 4–8	18% „ „ „	19% „ „ „
$E.C._e$ 8–16 . . .	31% „ „ „	38% „ „ „
$E.C._e > 16$ . . .	23% „ „ „	31% „ „ „

All types of salinity occur; sabakh soils are not widespread; they occur near some irrigation ditches. Gypsum is present in most soils, except in the upper layers of the saline alkali and alkali soils of the irrigation depressions. In the other soils the gypsum content is usually 1–3%, in horizons with gypsum accumulation, up to 15%. The soil structure of the surface soil is platy. A thin dense soil crust occurs almost everywhere; some crusts are markedly curled during the summer; according to Kuron and Janitzky (1957), they are algae takyre; the biological activity is important in these formations. See Figs. 59, 60 and 61. Similar platy structures, as shown in Photograph No. 55, were described by Graçinin (1950) as laminoform and squamose structures. The soil structure of the surface layer is dense (Fig. 59) due to the action of raindrops. As the infiltration rate is low and rain falls in heavy showers, there is always micro transportation of clay particles, which form a very thin surface layer, underlain by somewhat coarser textured material. When the soil becomes dry, the surface layer cracks, contraction of both micro layers is different and the clay sheet curls. Sometimes the layer under the clay sheet contains some organic matter, causing a similar effect. According to Russian soil scientists (Janitzky, 1957) soil biological processes also have to be taken into account for the explanation of this phenomenon. The cation exchange capacity is approximately 20 meq/100 g. soil, varying from 15.4 to 26.4.

The heavier textured soils in the depressions often have a prismatic or columnar structure. Soils crack intensively in the dry season; the crack pattern is pentagonal or hexagonal. Gilgai relief occurs in many irrigation depressions (Fig. 62). Soil permeability is low and the infiltration rate is very low. An example of a detailed soil map is given in Fig. 58.

The irrigation levee soils form a soil complex with silty soils, often with a 1–4% slope to the depressions. Sheet erosion in rainy seasons is levelling the area. The irrigation levee soils are slightly to strongly saline, sometimes with an $E.C._e$ of more

FIG. 59. Puddled and crusted surface layer of an irrigation levee soil. Almost all soils, which possess a layer of silty irrigation sediment on top have this hard non-porous crust (measure in cm.).



than 40; they are mostly puffed solonchak soils. The silt content is high (50–60%); lime content: 25–35%; pH from 7.5–8.0. The soil has a yellowish brown colour; the top 2–3 cm. is platy because the soil structure is water-unstable. The thickness of the irrigation sediment varies from a few decimeters to 2–3 metres. In a detailed soil map, soil depth and slope phases have to be mapped.

All soil types occurring in irrigation depressions were mapped as a soil complex, which was called 'Playa soil' by van der Kloes (1956) and 'Musari soil' by the Hunting Group (1955). I prefer to use the descriptive name: 'irrigation depression soils', as there are important differences. Soils are often saline-alkali or alkali, consisting of silty clay loam or clay over silty clay. There are deep wide cracks in a pentagonal or hexagonal pattern, forming hard prisms or columns. The cracks are always open due to the hard, crusty surface. Soils are similar to the Takyr soils of Russia (Kuron and Janitzky, 1957; Janitzky, 1957), the Kawire in Iran and the Alkali Polygonal soils of Hungary (Sigmond, 1948), which are formed in colluvial surface deposits. The lime content varies from 20–25% in the surface layers, to 25–30% in deeper layers. The gypsum content of the surface layer is very low; gypsum veins occur below 40 cm. In the depressions are also 'takyr-like' soils. The formation of takyr soils is influenced by water, with which they are often covered, by salts and by Na ions, and by algae and fungi occurring on the surface crust. The soil is very dense as a result of the action of sodium ions and the alternation of dry and wet periods. Some of these soils have a very dense surface with micro-solonetz formation, which could be called a 'surface solonetz'.

The biological processes occurring on the surface have been studied by Russian scientists (Kuron and Janitzky, 1957). Most takyr soils are covered by algae; therefore the pH becomes higher; on the surface layer, a thin sheet of algae is formed which dries up in the summer. It curls and forms 'desert papyrus', which is blown off by the wind. If the algae are followed up by fungi, the surface becomes more crumbly and liable to wind erosion.

This process, and the soils described, also can be observed in Iraq.

Soils occurring in a small strip at the transition from the ridges to the depressions are slightly to moderately saline; they are often cultivated (barley) in a dry farming system, (Fig. 63).

Some of the smaller depressions were gradually filled up with erosion material from the irrigation ridges. The soils are now slightly to moderately saline. Their agricultural value is higher than that of the real depressions. In order to improve soil conditions in takyr soils, some Russian farmers cover them with sand from neighbouring dune land as a kind of soil improvement. If they are covered by aeolian sand, they are called 'ala' in Russia (Margulis, 1956).

The soils of the irrigation depressions are leached to a certain extent, depending on the quantity of rain and runoff water. Due to this leaching process, alkali soils could develop. Some depressions are filled with water for some months during winter and spring. In wet conditions, much clay is in a dispersed condition, particularly in the many cracks or gilgai gullies occurring in these depressions in a radial pattern (Figs. 41, 78). The presence of these shallow gullies in the typical pattern is a characteristic which is clearly visible on aerial photographs. Usually, but not always, such a radial pattern in a depression of the Mahdy terrace indicates saline alkali or alkali soils. Another characteristic is the gilgai relief. The intensity of the leaching process is often indicated by the intensity of the gully and gilgai pattern.

Harris (1958) has made a study of the gilgaied soils and their bad structure. He compares the gilgaied soils of Central Iraq with those of Australia (see Hallsworth et. al, 1955) and he introduces a new type of gilgai, the 'Depression Gilgai' which occurs in Iraq. The poor structure would be the result of alternate wetting and drying, possibly also dispersion of clay which causes a down-packing of soil particles.

The exchangeable sodium percentage is often high, up to more than 60%; the pH is usually less than 8.0 due to the presence of salts. In true alkali-depressions, the pH rises up to 9.5. The Hunting Group (1956) considers a soil to be alkali when the exchangeable sodium is more than 2.5 meq/100 g. soil; a maximum of 8 meq/100 g. soil occurred in the Adhaim area. Usually this figure is 3 to 5 meq/100 g. soil.

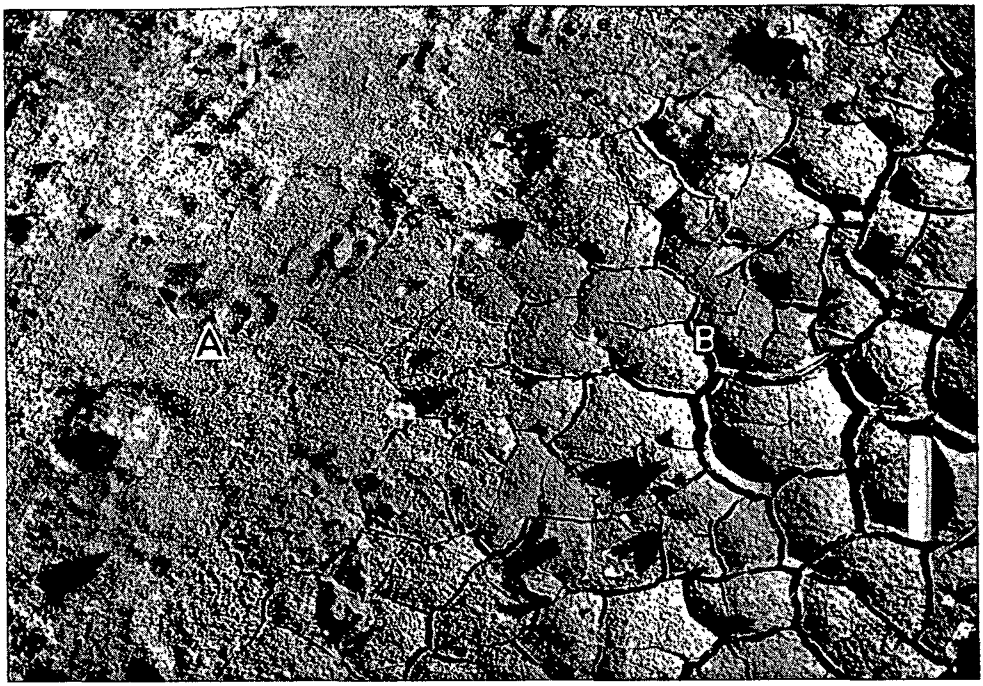


FIG. 60. Differences in the surface structure of saline soils within a small area: (A) Flocculated surface with some salt efflorescence; (B) hard, dense, cracked surface in a micro depression, approximately 5 cm. lower than the surrounding land. The surface of area (B) consists of a dispersed clay layer of about 1 cm., which cracks during desiccation.

A groundwater analysis from the left bank of the Adhaim area is given by the Hunting Group (1956):

Total soluble solids	37,200 p.p.m. (see also Fig. 27)
Cations in meq/l.	Ca 50; Mg 155; Na 339; Total 544
Anions in meq/l.	HCO_3 5; SO_4 117; Cl 117; NO_3 6; Total 550.

This gives the following soluble salts (hypothetical):

$CaCO_3$ 5; $CaSO_4$ 45; $MgSo_4$ 72; $MgCl_2$ 83; NaCl 339; KNO_3 6 meq/l., Total 550 meq/l. This analysis demonstrates the dominance of Na and Cl ions.

Pure sand dunes ('erg' in the Sahara) up to 20 metres high occur between the Shari Lake and the Adhaim river. They are Regosols in true active dune land. These sand dunes, including those areas with low dunes of 1–3 metres high, cover large areas of the Mahdy terrace; they even exist in the Adhaim valley on top of the young soils of the valley bottom. There are also areas with a sheet of aeolian sand. The sand of the dunes is supposed to have been washed from the Jabal Hamrin hill ridge, which mainly consists of sandstone in this area. The lime content of the sand is about 10%; the pH is up to 8.2; sand is medium to fine grained, rounded, and of a yellowish-brown colour. The dunes are completely dry and without any vegetation.

In the steep high walls of the Mahdy terrace along the Adhaim river and in the many steep gully walls, soils can be studied to at least 10 metres under the present surface. At some places, e.g. north of the former crossing of the Nahrwan canal and the Adhaim river, ancient river beds can be studied over a distance of about one hundred metres. The upper few metres of such a profile are uniform over het whole area and much younger than the stratified deposits in the former river bed. Typical clay balls occur at the bottom of the river bed. They are round, with a diameter varying from 2–10 cm., and consist of somewhat reddish coloured clay, covered with coarse dark greyish sand grains. They are lumps of clay, formed by rapid erosion of the banks, which have rolled downstream; sand grains have been impressed into the softened surface of such balls. Similar balls were described by Bell (1940) and Pettijohn (1948). According to these authors, the diameter of the balls is related to structural strength and they may furnish means of estimating the velocity of ancient streams. A further study of the clay balls and ancient river beds in the Adhaim area could be undertaken in order to find out something about stream conditions during the last pluvial phases of the Pleistocene in which they were probably formed.

Almost the whole Mahdy terrace consists of non-cultivated, saline, desert land. It is an extensive, featureless, flat plain. In Abbasid times and probably from Sassanian times, the plain has been a flourishing agricultural region with an extensive and quite

FIG. 61. A thin (about 1 mm.) curled clay layer on top of a saline soil. The thin clay layer has been formed after rain.

modern irrigation system. There are many ancient canals, tels and villages, as well as some ruins, mostly of Abbasid age. As the land surface is high above the water level of the Adhaim river, cultivation could not start before irrigation practices were developed to a stage where dams and other constructional works could be carried out (Buringh, 1957).

Gully erosion in the Mahdy terrace, particularly on both sides of the Adhaim river, is very severe and still going on (Fig. 57). The result is a considerable loss of potentially good agricultural land. No soil conservation measures are taken or planned, although good proposals for forestation are made in the Adhaim report (Huntings, 1956). It is strange that the Iraq Government does not stop the severe soil erosion of good land, whereas much is being done to reclaim fair and even potentially poor land at a relatively high cost elsewhere in the Mesopotamian Plain.

Sheet erosion is widespread in the non-cultivated areas with a silty irrigation cover. Sheet and even rill erosion were observed on the dykes of excavated material (Argubs) from the Nahrwan and other main irrigation canals. The dykes on the Mutawakkil and Mutasim terraces consist of gravelly material. They were not much eroded because a gravel layer was soon formed which has protected the dykes from further erosion. Therefore the ancient canal dykes are much higher on the Mutawakkil and Mutasim terrace than on the Mahdy terrace, where gravels are absent.

There are many ancient sites, particularly on the Mahdy terrace. The gypsiferous

FIG. 62. Gilgai relief in an irrigation depression of the Mahdy terrace. The clay of the surface layer of the alkali soil is in a dispersed condition; small elevations and depressions have been formed.

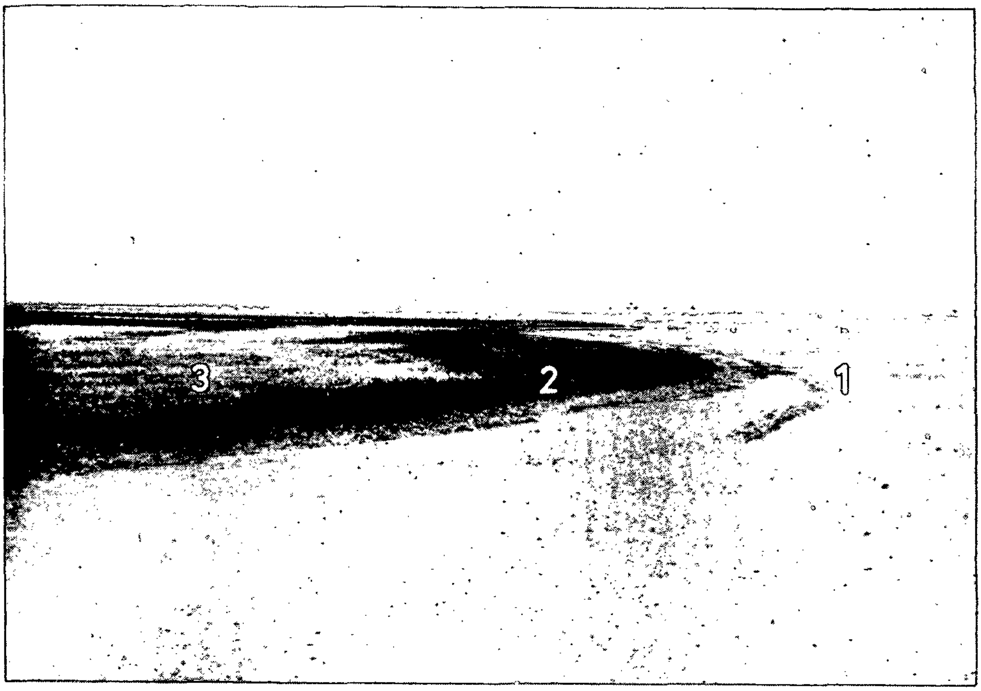


FIG. 63. A strip of barley (2) is grown in a dry farming system at the transition between an irrigation levee (1) and a leached, alkali irrigation depression (3), of the Mahdy terrace, west of the Adhaim river.

desert soils only have a few sites, one of them being very old and dated as Tell Hallaf or Samarra. It is situated on the border of the fertile Tigris valley. The extensive ruins of the Abbasid city of Samarra are described by Herzfield (1907, 1911, 1912, 1923/30); Viollet (1909, 1911) and the Directorate of Antiquities (1940). Nearly all the sites on the Mahdy terrace date from Sassanian to Abbasid times; their number is relatively low in comparison with the number of sites on the young river plain. The location of the sites in the Naifa area is closely related to soil conditions (compare the soil map published by v. d. Kloes, 1956).

Some ancient river beds are shown on the maps in Figs. 49 and 50. Some have already been mentioned by Le Strange (1905) and Crawford (1929), and mapped by Soussa (1947). According to Le Strange (1905) the Tigris followed the old course west of Balad up to the 10th century. There is no evidence of an Adhaim river joining the Tigris near Balad, as shown on Soussa's map (1947). Both rivers joined at a point some 25 km. north of Baghdad. At present the Tigris flows through a rather narrow strip in the terraces east of Balad before reaching the Adhaim (Fig. 49). This young part of the present Tigris river was probably an old irrigation canal. In this area there were and still are remnants of large canals running in an east-west direction. During one of the floods, the Tigris has probably followed such a canal, widened its channel, and eroded parts of the terraces. This is also proved by the presence of many meanders and light-textured soils near Balad. The famous ancient city of Opus which has never been found, may have been eroded away too, as it should have been situated on one of the terraces; otherwise it would have been flooded many times.

The Nahrwan canal is the largest, deepest and longest irrigation canal ever built in history. It did not irrigate large parts of the area between Samarra and Deltawa or north of Deltawa, as can be learned from its irrigation deposits. It mainly served for the irrigation of land south of Baquba up to Kut, and east of the Tigris.

The Nahrwan canal was probably dug by Sassanian kings (Le Strange, 1905). In the 11th, 12th and 13th centuries it gradually silted up and finally all the land which was once irrigated by that canal became unproductive until the present time. The northern sections of the canal, called Katul and Tamarra, were difficult to maintain, as they crossed the gypsiferous desert. These parts were out of use in Abbasid times, when people tried to re-dig it; this, however, was not successful (Soussa, 1947).

In Abbasid times, a dam was built in the Tigris south of Samarra and new canals feeding the Nahrwan were dug in an easterly direction. Much land south of Samarra on the west side of the Tigris was also irrigated by canals following the borders of the terraces.

The agricultural potentialities of the soils of the Mutawakkil terrace are very low, due to poor soil conditions. The soils of the Mutassim terrace, except those which are strongly saline, e.g. around the Shari lake, have more potentialities. In the less saline areas, drainage canals could be made easily, as all land is high above the river plain. The deeper substratum consists of gravel, which, however, is cemented by lime and gypsum. Well-drainage (see 7.3.2.) could have possibilities if the permeability of the gravel layer is sufficient; the groundwater, however, is too saline for irrigation. The soils of the Mahdy terrace, which occupy a large area on both sides of the Adhaim river, have a low value due to salinity, alkalinity and a meso relief formed by ancient irrigation practices. It will be necessary to follow the excellent recommendations made in Huntings' reports (1956) concerning pilot schemes before starting the reclamation of the area. It is expected that such a scheme will be a success, and that large parts of the Mahdy terrace, except the saline-alkali and alkali irrigation depressions, can be economically developed. Land levelling, washing of salts, drainage and suitable farm management practices are necessary. In the Adhaim area 54% of the land, being 783,000 donum, has been classified as arable land (Hunting Group, 1956).

4.3. Soils of the flood plain

The original soils which have been formed under natural conditions, are built up during flood periods by sediment deposited in the meandering rivers.

The discharge of water and the quantity of sediment in suspension are high during floods (see Chapter 2.3.). There are soil particles of different size varying from fine sand to clay in suspension. At the beginning of a flood period the water level in the river rises, the velocity of the water in the stream bed increases and consequently almost all the sand, silt and clay is in suspension, giving the water a yellowish-brown colour. After a while the water rises higher than the river banks and the land is flooded over a very large area. As a consequence the velocity of the water decreases rapidly and the largest particles (sand) are deposited first. At some distance from the stream bed the speed of the flood water is still decreasing and silt, and finally clay particles, will be deposited too. Soils near the river therefore are much coarser textured than soils at a greater distance. The volume of the coarse particles is greater than that of the small particles, and therefore the accumulation of sediment near the river is more than that some distance away. Consequently, low natural banks are formed which are some metres higher than the land a greater distance away. These banks are called '*river levees*', which form strips on both sides of the river. The areas where the fine particles are deposited form large natural depressions, surrounded by and separated from the river by the levees. These large depressions are called '*river basins*' (Fig. 64).

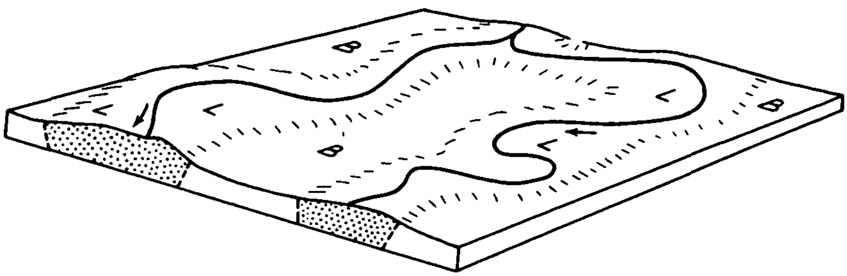


FIG. 64. Block diagram of river levees (L) and river basins (B) in a flood plain under natural conditions.

The levees do not consist of fine sandy material only, but of a mixture containing silt and clay, because during the sedimentation there is also some accumulation of fine particles, as all particles are mixed when in suspension. In the basins, however, hardly any sand particles are present, as they have already been deposited on the levees. The sedimentation of clay is particularly important in backwaters. After the flood, when the river follows its own course through the bed, the basins are still filled with water and clay can be deposited.

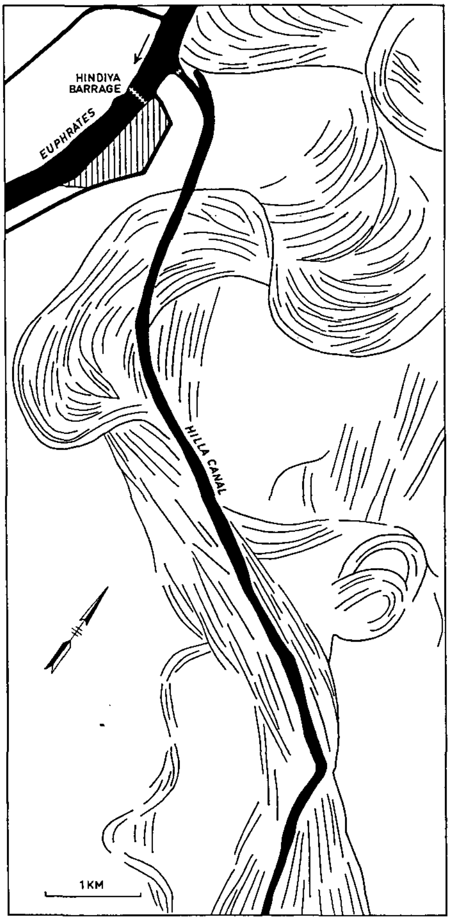
Besides these differences in meso-relief and soil texture, there are many other differences, all closely related to these two and to the process of sedimentation.

The soils in the basins are waterlogged or submerged for at least part of the year after the flood. Their natural drainage is slow and the groundwater table is high. These factors influence soil structure, consistence, porosity, density, aeration, etc. As a result of these differences, there was also a different natural vegetation on river levees and basins which has also influenced the soils.

A meandering river is always eroding the banks, particularly in the bends, whereas it is silting up at other places. Therefore there are sections of land along the present streams which consist of silted-up stream beds. The material is mostly coarse textured (sand) and the sections thus formed are called '*meander belts*'. They consist of various coarse textured layers in a concentric pattern (Fig. 65). The sand layers are directly connected with the river, and the groundwater level in the meander belt fluctuates with the level of the water in the river.

The river bed itself is not deep but it is wide and some sandy islands occur. Some-

FIG. 65. Map of the meander belt of a former Euphrates course, south of Hindiya Barrage.



times the stream follows a completely new course and the former bed silts up gradually. Shifting of the river bed over the plain is a normal process. The levees gradually become higher, the river itself rises above the plain and during a flood, water may break through one of the levees, especially at a spot where bank erosion occurs and flood gullies are formed. The river then enters a basin area, makes a new stream bed, and the building of new levees starts afresh, now on a firm foundation of basin clay. The levees of the original river are almost dry during floods and if the flood is very high, there is probably some sedimentation of finer particles. This explains why the soil texture in a levee is somewhat finer at the surface.

The new levees formed on top of the basin will have soil characteristics which differ from those of the original levees. Sedimentation is the same, but the location of the various types of sediment is different.

A continuous sedimentation over a very long period will raise the level of the land surface of the plain. A former levee may finally be covered by clay, when it becomes a part of a basin (Fig. 66). New levees and basins are formed over the old plain. In this way highly stratified soils are formed. This stratification extends to the very deep parts of the plain. It therefore can be understood that the fine sand content of soil layers in the same plot varies from 31–81 %, as was found by Turcan (1946) near Abu Ghraib. Coarse sand is rare in the Lower Mesopotamian Plain. If it is found, it usually consists of fine sand cemented by gypsum or granules of crystalline limestone. River sand is almost free from gypsum and salt but it is very fine textured.

Studying deep profile pits, various phases in sedimentation can be distinguished. One could say that various plains are lying on top of each other. As the various phases have little or no connection, it is never known which type of substratum will occur in a certain area. Even deep borings 1 km. apart, often made for hydrological investigations, cannot give reliable information.

Sedimentation was not a continuous process for the whole plain. Only parts and not the whole plain were flooded during one flood (see Fig. 20). From various soil studies I even gained the impression that sedimentation was quite considerable during some periods, whereas in other periods there was hardly any sedimentation. The various sedimentation periods can probably be correlated with post-pluvial periods, mentioned by Butzer (1957).

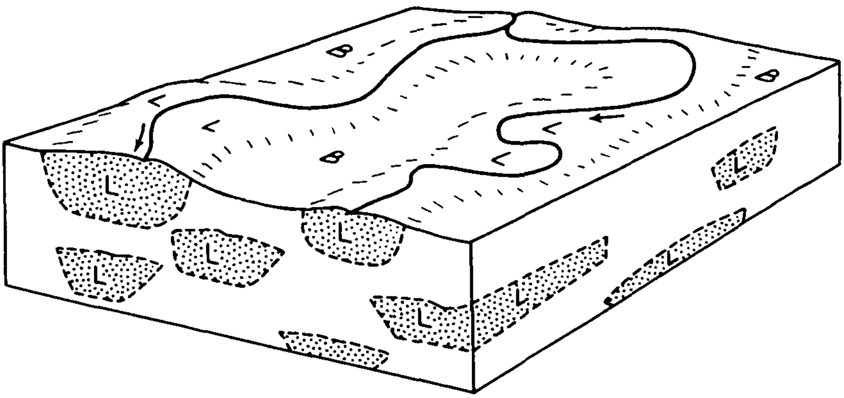


FIG. 66. Deep cross-section through a flood plain showing various river levees and basins which were formed during different stages of sedimentation; compare with Fig. 64.

During the last periods vegetation could grow for a fairly long time on the same soil and darker coloured ancient soil surface horizons were formed. Such layers also could be observed at different levels in the deeper strata of the plain. An example is given in the following profile description from a soil west of Hilla.

0–0.5 m. dark grey-brown silty clay loam;
0.5–2 m. brown loamy sand;
2–3 m. dark grey-brown silty clay loam;
3–4 m. brown loamy fine sand;
4–5 m. brown fine sandy loam;
5–6 m. dark grey-brown silt loam;
6–10 m. brown fine sand;
10–12 m. grey-brown clay;
12–16 m. pale brown coarse sand (500–1000 micron);
16–18 m. grey-brown coarse sand (500–1000 micron);
18–20 m. very pale brown sand (600–1000 micron);
20–21 m. very pale brown fine sand (210–300 micron);
21–23 m. dark grey-brown fine sand (150–210 micron).

Vegetation under natural conditions in the river plain was adapted to climate, soils and hydrology. The levees would have been covered by bushes and trees, if the roots could reach the ground water. The basins were partly waterlogged, and vegetation consisted of shrubs, grasses and weeds adapted to such conditions. Those parts which were not reached by the floods were almost desert areas.

At present the 'natural' vegetation along the rivers is a riverain forest, consisting of *Populus*, *Salix*, *Tamarisk* spp. and Liquorice *(Glycirrhiza glabra)*. In cultivated land,

FIG. 67. Profile of a silted basin soil near Hilla.

1. Silty clay loam layer sedimented during a long period of irrigation;

2. A darker coloured former surface soil, now buried by irrigation;

3. Clay of the sub soil.

Buried soils are common in the flood plain of the Twinrivers.

Shok *(Prosopis stephaniana)*, and Camelthorn or Agul *(Alhagi maurorum)* are common (Fig. 22 and 23). The most common annual leguminous weeds are: *Melilotus indica* and *Medicago hispida;* furthermore several *Trigonella*, *Trifolium*, *Vicia* and *Lathyrus* species occur. Wild oats *(Avena sterilis)* is common in barley and wheat fields where it often exceeds 50% of the stand! The characteristic plants for saline soils are (Springfield, 1954):

Camelthorn, *Schangina baccata, Suada vermiculata, Atriplex dimorphostegium, Halocharis sulphurea, Statice spicata, Cressa cretica, Spergularia salina, Nitraria retusa, Frankenia pulverulenta, Arthrocnemum glaucum*, and others.

The Euphrates-Tigris flood plain has been built up according to the principles of sedimentation in meandering rivers. Since the time when man first occupied the plain and started irrigation-agriculture, much has been changed, particularly in the basins (see Chapter 4.3.2.), where all original soils have been covered by several metres of silty irrigation sediment. In Tel Asfar, north-east of Baghdad, the lowest horizons showing signs of human occupation, dating from about 3000 B.C., are now about eleven metres below the present land surface.

4.3.1. *Soils of the River Levees*

General characteristics of river levees are:

a. Soils consist of relatively coarse textured layers (fine sand to silty clay loam; true coarse sand is absent); the texture gets lighter with increasing depth.

b. The topographical position in relation to the river and the basins is high (2 or 3 metres above the basins).

c. The groundwater table is deep; it fluctuates with the water level in the river and it is almost non-saline.

d. Soils are well drained, as excess water can flow to the river or to the basin, except when the river is at an artificially high level, e.g., near barrages, Hilla district.

Owing to these characteristics, the physical conditions of the soil are excellent or good and soils are suitable for many crops. Capillary water does not reach the surface if the soil is continuously covered by crops, for example in date and fruit gardens. Irrigation has to be done by lifting the water, e.g. pumps and norias. The soils are therefore non-saline or only slightly saline, which is exceptional in Iraq. This has, however, already been observed by Webster in 1921.

An example of an excellent river levee soil is given by the following descriptions of the *Baghdad silty clay*, occurring in the Tigris river levees near Baghdad:

0–20 cm. Dark grey-brown, angular blocky porous silt loam, hard when dry, friable when moist.
20–75 cm. Dark brown, subangular blocky, porous silty clay, hard when dry, very friable when moist.
75–135 cm. Brown, subangular blocky, porous silty clay loam, friable.
135–225 cm. Dark yellowish-brown silty clay, friable and porous.
225–285 cm. Brown, friable, porous loam.
285–350 cm. Dark brown, friable, porous clay loam and water table at 340 cm.

The profile was described in a date orchard behind the new Palace at Baghdad. Many roots occur to 75 cm.; some roots reach 135 cm. or even 200 cm.

TABLE 23. *Soil sample analysis of the Baghdad silty clay, silted phase.*

Depth (cm.)	pH	Lime %	T.S.S. %	Soil texture				PO_4 p.p.m.	NO_3 p.p.m.
				Sand	Silt	Clay	name		
0–20	7.7	23.7	0.06	23	51	26	SiL		
20–75	7.5	22.1	0.07	10	46	44	SiC	7.5	4.7
75–135	7.5	24.0	0.05	18	45	37	SiCL		
135–225	7.8	25.7	0.03	9	46	45	SiC		
225–285	8.0	25.6	0.03	41	42	17	L		
285–350	8.1	25.9	0.02	23	48	29	CL		

The upper 20 cm. of the soil is young irrigation sediment. The soil is a non-saline Alluvial soil of the arid zone with an extremely high lime content. There is natural drainage to the Tigris river. Land is irrigated by a motor pump. Chemical and physical soil sample analyses are given in Table 23.

The soils of this Baghdad series are the best soils of the Lower Mesopotamian plain. Besides the Baghdad silty clay, there are some other types like the Baghdad silty clay loam and the Baghdad silt loam. Soil texture analyses of six profiles of the Baghdad series are shown in Fig. 68.

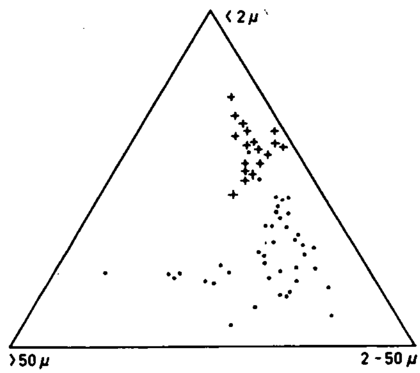


FIG. 68. Graph, showing the soil textures of the (·) Baghdad silty clay (river levee soil) and the (+) Aqar Quf clay (river basin soil).

Soils of the Hilla series, which are saline and also occur in river levees, are described by Buringh (1958).

Non-saline levee soils are used for date and fruit gardens, sometimes in combination with an undergrowth of vegetables or alfalfa. A really good fruit garden has a combination of various fruit trees (dates, oranges, pomegranates, grapes, figs) and various kinds of vegetables (water melons, egg plants, etc.). Cultivation is permanent and relatively intensive with several harvests per year! Examples are given in Chapter 7.4. Most important of all factors influencing these soils is the specific climate of the date and fruit gardens. The soils are always in the shade. The soil temperature is therefore much lower and soil moisture content is higher than in non-fruit soils. The trees are deep rooted; soil biological activity is relatively high and intensive, soils do not have crusted surface layers and there is a constant homogenization of at least the upper metre of the soil. The homogenization of levee soils in Iraq has already been studied by Buringh and Edelman (1955). Owing to the production of carbon dioxide, the soils are porous and water and air can easily penetrate the soil. Such soils belong to the best of the world.

Levee soils have to be considered as a soil association, consisting of various soil series and types. The classification of soils is mainly based on differences in soil layers, texture of the subsoil and substratum, mineralogical composition, soil drainage, salinization and physiographic position.

There is always a gradual transition from the levee to the basin soils, which can be well observed in the date gardens, as height, diameter and quality of the date trees decrease towards the basins. Near the river basins the soils become somewhat finer textured, the topographical position is lower, the groundwater level is higher, salinization becomes more important and soil drainage decreases. The levee soils bordering the river are generally well-drained, non-saline, and in the best physical condition.

In general, levee soils are at present the best agricultural and horticultural soils of the flood plain. Irrigation can be carried out independently from the water level in the river and at any time. Pump-irrigation was started a few decennia ago, and from that time the value of the levee soils has increased rapidly.

Although most levee soils are not used in the way they could be used, production is high in comparison to the basin soils. The agricultural potentialities are very high, except when soils become saline as a result of too high a groundwater level, caused by barrages.

Foreland Soils are mostly included in the river levees in small scale mapping. They occupy small strips of land between the stream and the high banks. In the flood season they are nearly always flooded, except when the floods do not reach very high levels. In summer the soils are used for vegetable growing. They have almost the same characteristics as the levee soils, non-saline but not covered by gardens, and very well drained when the water level in the river is low. They can easily be irrigated by pumps.

River Bank Soils are non-saline, fine sandy and silty soils along the streams and on islands in the river; non-flooded during the summer, they are moist due to capillary water. Starting in June-July, these soils are used to grow vegetables etc., particularly near Baghdad (Fig. 69). As soon as the water in the river rises, these soils are submerged.

Meander Belt Soils are very variable soils in meander belts of the rivers (See Fig. 65).

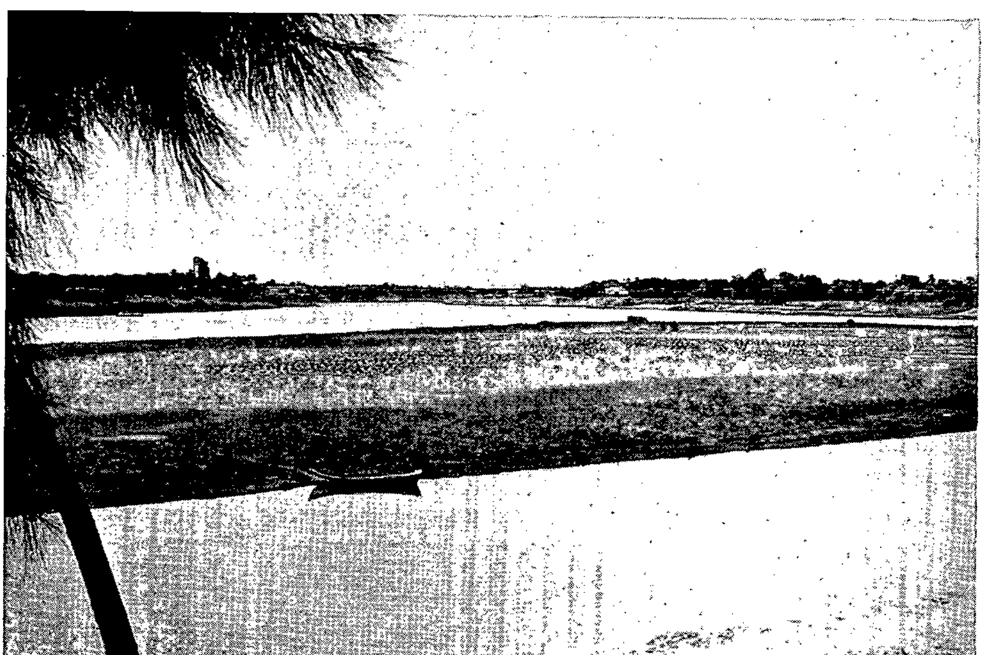


FIG. 69. View on the Tigris river near Baghdad. There are some sandy and loamy islands during the summer months which are used for cultivating vegetables. Soils are non-saline, which is quite an exception in Central and Southern Iraq.

As far as river levee soils have been studied, they seem to be quite uniform, at least more uniform than in other river plains of the world, where often gravelly layers occur near the surface. In Mesopotamia, fine sandy layers are the coarsest sediments.

Former land surfaces do occur at some depth in some levee soils, but biological homogenization is fairly intense and irrigation deposits are limited; therefore most levee soils do not show buried soil profiles. Some levee soils have a thin (10 to 20 cm.) layer of silty irrigation sediment on top; the soil structure of this layer is rather poor.

Detailed descriptions of various soils in the Euphrates levees are given by Buringh (1958).

4.3.2. *Soils of the River Basins*

General characteristics of basin soils are:

a. They are fine textured (silty clay loam, silty clay and clay), with up to 50 or 70% of clay particles. This seems a low percentage, but it is a consequence of the high lime content which is significant in the silt fraction and consists of calcite grains;

b. The topographical position in relation to the levees is low (2 or 3 metres lower than the levees);

c. The groundwater table is high, particularly in the most southerly sections of the basins;

d. Soils are generally poorly drained, sometimes even waterlogged.

Owing to these characteristics, the physical condition of the soil is fair to very poor. Nearly all the soils are saline or strongly saline. Most basins are irrigated by gravity irrigation.

River basins mostly occupy very large areas in which different kinds of soils occur. These differences are closely related to the physiographic position of the various soils in a basin (Fig. 70).

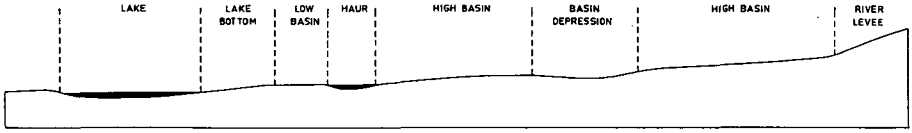


FIG. 70. Sketch of the various units of a river basin.

The relatively *high basin soils* occur near the levees, particularly in the northern section of each basin, as the whole plain is slightly sloping to the south. Soils are waterlogged during and a short period after the flood but there is always some drainage to lower parts.

The *basin depression soils* occur in deeper parts of each basin; they are mostly situated in the southern section. They are often waterlogged and poorly drained.

Haur soils occur in the deepest parts of the depressions; they are covered by water for the greatest part of the year.

Lake bottom soils occur around shallow lakes. These soils consist of clay, often with a dense, poor structure; they are often submerged.

The real basin soils are silty clay loam, silty clay and clay soils, with a groundwater level at 1.5 to 2.5 metres below the surface. Except during periods of floods, they are moderately well drained. If the soils are not being cultivated nor irrigated, the groundwater level may drop to a few metres below the surface. They gradually grade into basin depressions, forming waterlogged, lower-lying parts with clayey soils and a groundwater level at 0.5 to 1 metre below the surface at the end of the dry season. The soils are poorly to imperfectly drained, slowly permeable, somewhat prismatic and often strongly saline.

When man started cultivation in the flood plain, the real basin soils were most suitable for it, as they were irrigated naturally by uncontrolled flood irrigation through flood gullies. As soon as the excess water had gone, the fields were sown. The groundwater level dropped gradually and enough water was available for the crop. Floodwater percolated through the soil and therefore there was little or no salt in the soil. Cultivation however was somewhat risky, because floods did not occur each year. In order to be more independent of floods, a gap could be made in a river levee and more water could enter the basin during a longer period. Thus basins could also be irrigated when no floods occurred. Such gaps could best be made in a bend of the river, where the levee was rather small and where the direction of the stream was nearly the same as the direction of the gap in the levee. In the basin a kind of natural stream was formed;

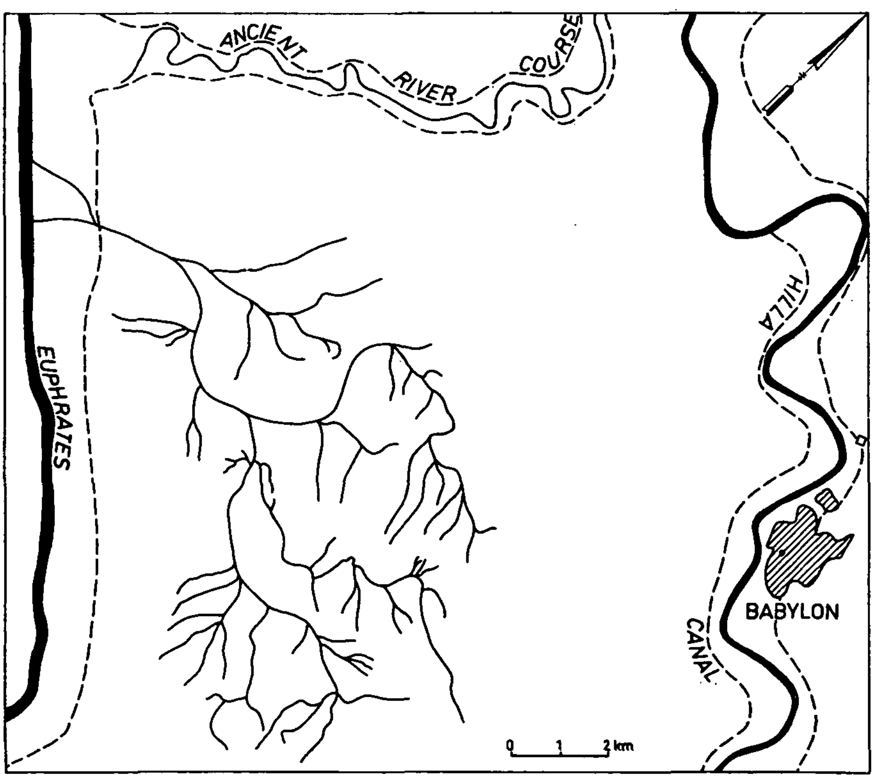


FIG. 71. An ancient natural flow irrigation system in a river basin west of Babylon. There is natural drainage to the south.

it had many branches directing the water to large parts of the basin. These basin streams gradually developed small levees and conditions for cultivation gradually became more favourable, particularly at the transition of those small levees and the real basins. The main basin stream, its branches and the small levees form a typical pattern (Fig. 71); they end in the depressions and haurs. It may be expected that the course of the stream or of some of the branches was directed by man by digging some gaps in the small levees or by constructing simple canals or ditches.

The influence of man on uncontrolled flood irrigation became more important and finally canals were dug to bring river water to specific parts of a basin. The first simple type of canal irrigation, which was an improvement of the natural basin irrigation by natural streams, was still uncontrolled. The canals were irrigating the upper section of the basins and at the end of the canals there was a free flow of water into the lower sections. Here such a canal was altered into a small meandering stream (Fig. 72). During floods, much water was directed through the canals and silty particles were deposited on both sides, forming a kind of levee, which is called an *irrigation levee*. Canals and ditches were gradually silted up and re-dug, the material from the canals being put on both sides, finally forming huge dykes or argubs, some 5–8 metres high (Fig. 31). Sometimes a new canal was dug parallel to the old one a short distance away. The irrigation levees and the argubs along all canals greatly influenced the topography of the basins, which were divided into many smaller basins, surrounded by these irrigation levees (Fig. 73). Irrigation became controlled by building

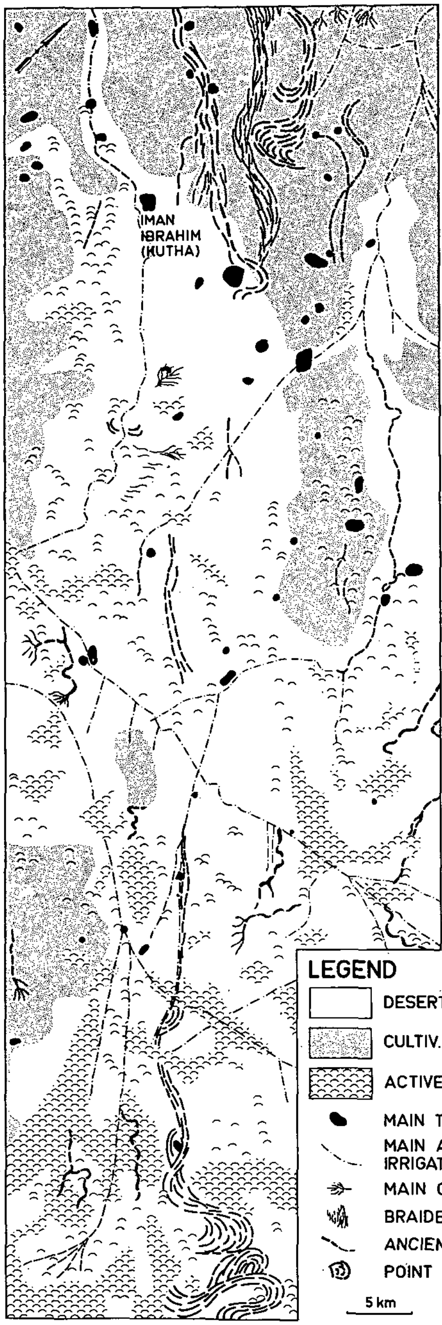


FIG. 72. Sketch of ancient river courses in the Mussayib-Babil Projects. (The sketch has been made with the help of a series of photo-mosaics; it only indicates the main channels).

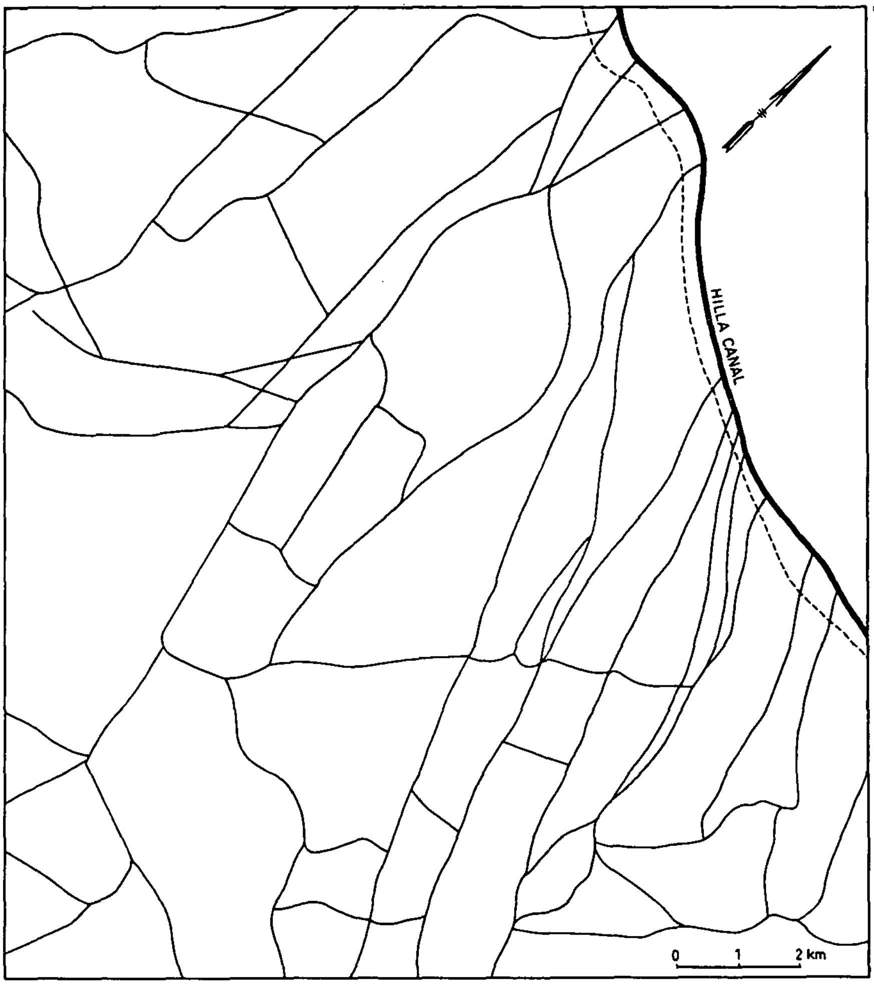


FIG. 73. Former system of controlled, canal irrigation in a large basin south of Babylon. In this way a large natural river basin is divided into numerous small irrigation basins, without drainage.

simple dams or sluices in the canal intake. Canals became deeper and large parts of the basins could be irrigated by gravity irrigation during the greater part of the year.

It is evident that all types of irrigation have influenced the soil topographical and hydrological conditions of the basins. The large flat basin areas acquired an important 'secondary meso-relief' consisting of the higher irrigation levees and the lower lying irrigation depressions which have already been described in Chapter 4.2.3. This phenomenon is also mentioned by Janitzky (1957) for the Vachs valley in Russia. Instead of the original clay soils, young sediments of silty character were deposited, especially along the canals and ditches, on top of the older soil. Instead of one flood per year during a short period, there was now a more continuous gravity irrigation by canals.

As a consequence of a more continuous irrigation and the secondary meso-relief, natural drainage became difficult, the groundwater level came nearer to the land surface and groundwater could evaporate, causing soil salinity. Most irrigation canals and ditches are on a higher level than the adjacent land surface; therefore seepage zones occur in strips on both sides of the canals at a distance of 100–500 metres. The irrigation levees became extremely saline, and most gypsum has been removed from these seepage zones. A fallow system of agriculture was practised in order to allow the groundwater level to drop.

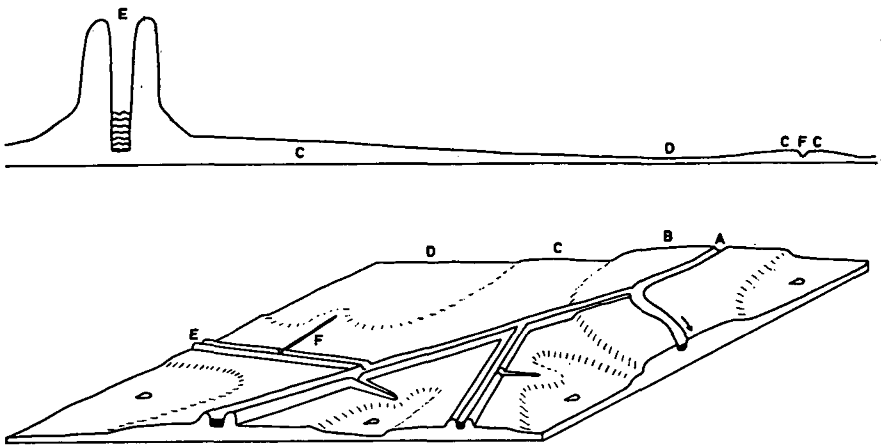


FIG. 74. Cross-section and diagram of irrigation levees and basins. A. river; B. river levee; C. irrigation levee; D. irrigation depression; E. irrigation canal with argubs (dykes); F. irrigation ditch.

The rather uniform soil texture of the irrigation deposits is explained by the irrigation sedimentation, which differs from flood sedimentation (see Fig. 77). Water is diverted into canals and gravity irrigation is employed. Therefore canals are constructed in such a way and in such positions that the flow of water is almost constant. This water keeps all silty and fine sandy material in suspension. Most fine sandy material is deposited in the first kilometre of the canals. The dykes along this part of the canals therefore consist of fine sandy material. Even at a great distance from the river, the water flow in the canals is still constant and therefore silty particles are deposited on or near the irrigated land. At such places only clay particles were deposited during natural floods before man started cultivation of the basins.

One basin or at least a large part of it, was an irrigation unit. All farmers in such a unit had the same interest and they therefore had to co-operate in digging canals and branches, and in building small dams. Only in this way could water be diverted to specific areas during specific periods of the year. Such a co-operation is possible only if there is a strong organisation as well, e.g. a tribe or a clan. An irrigation unit was at the same time an administrative, economic and social unit. This is still important at the present time.

Cultivation in the original basins of the flood plain may have started some 6,000 years ago. Almost the whole area of the Euphrates, Tigris and Diyala river plains is covered by irrigation sediment in a layer varying in depth from 0.5 to 5 m. or even more. Some of the original basin depressions and haurs did not change much; others, however, have also been silted up and new irrigation depressions have been formed.

Some of the most important soils of present silted river basins will be described briefly; more details are given in the Hilla-Kifl report (Buringh, 1958).

The *Babylon Series* is an important soil series in the Euphrates area. The soil consists of a dark brown to brown silty clay loam, often grading into clay loam, silty clay or clay. The soils are porous, angular blocky and the structure is water-unstable. The soil surface is mostly crusted, dense, platy and non-porous. There are deep cracks when dry. At a depth of 20 cm. there are often whitish, amorphous gypsum spots. The soils are saline or slightly saline. The important soil types are: Babylon silty clay loam and Babylon silt loam.

The *Abu Gharaq Series* includes the heavier textured silted basin soils, which are often imperfectly drained.

As an example, a full description is given of the *Babylon Silt Loam:*

0–2 cm.	Dark grey-brown (10 YR 4/2) silt loam; structure platy, very fine, moderately weak, slightly hard;
2–4 cm.	Dark grey-brown (10 YR 4/2) silt loam; platy, medium, weak structure; firm consistence with only a few pores;
4–15 cm.	Dark grey-brown (10 YR 4/2) silt loam to silty clay loam; subangular blocky, medium, moderately weak structure; friable; a few white amorphous gypsum spots;
15–55 cm.	Similar, gypsum spots common and distinct;
55–70 cm.	Similar, without gypsum spots;
70–130 cm.	Brown (7.5 YR 5/4) silty clay; angular blocky, medium, moderately weak structure, friable. Some rust and manganese spots. There is an alternation of thin layers with somewhat heavier and lighter textures;
130–150 cm.	Grey-brown to brown (10 YR 5/2.5) silt loam; angular blocky, fine, weak structure; very friable. Rust spots, with a concentration at 140 cm.;
150–180 cm.	Grey-brown (10 YR 5/3) clay with rust and gley;
180–230 cm.	Similar, with more gley;
230–290 cm.	Light grey-brown (10 YR 6/2) clay, with rust and gley;
290– cm.	Light grey-brown (10 YR 6/2) silty clay loam. Groundwater at 180 cm.

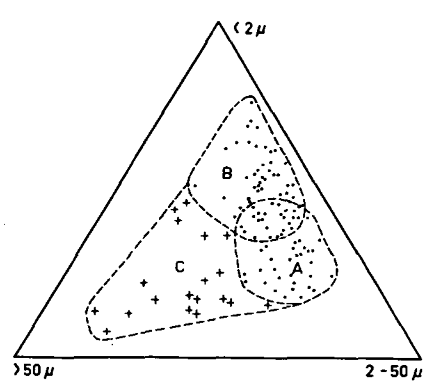


FIG. 75. Graph, showing the texture of soils of the Babylon series. A. most surface soils; B. most subsoils up to 250 cm.; C. deeper substrata.

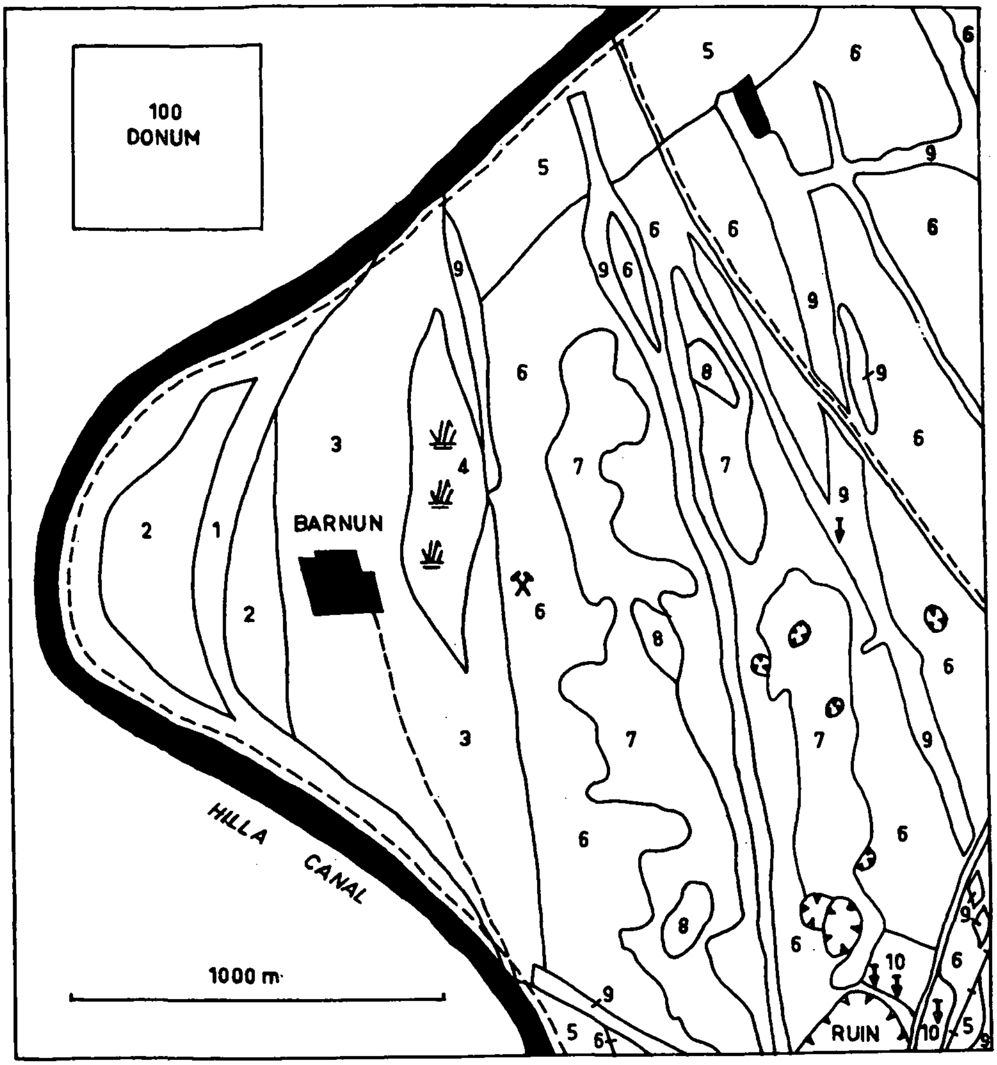


FIG. 76. Detailed soil map of Barnun village, 5 km. north of Hilla.

1. Foreland, low phase;
2. Foreland;
3. Barnun silty clay loam;
4. Barnun silty clay loam, poorly drained phase;
5. Hilla silty clay loam;
6. Babylon silt loam;
7. Babylon clay;
8. Babylon clay, imperfectly drained phase;
9. Argubs (canal dykes);
10. Ancient wall of Babylon.

This map is an example of a detailed soil study in a sample area, on which studies for semidetailed soil surveys are based. The same area is shown as a semidetailed soil map in the upper right hand corner of the map in Fig. 142.

TABLE 24. *Soil analysis of Babylon silt loam.*

Depth cm.	Texture			Lime %	pH	T.S.S. %	Gypsum
	Sand %	Silt %	Clay %				
0–25	11	44	45	22	8.1	0.90	3.0
25–60	9	48	43	21	8.2	0.24	Nil
60–80	5	33	58	22	8.4	0.15	Nil
80–120	2	39	59	26	8.4	0.15	Nil
120–150	9	42	49	20	8.4	0.16	Nil
150–200	10	49	41	19	8.3	0.19	Nil
200–250	11	33	56	31	8.3	0.07	Nil

Remarks: The soil texture analyses are not reliable; the organic matter content is lower than 0.5%. Gypsum data are in meq/100 g. soil.

Soil texture analyses of a number of Babylon soils are shown in Fig. 75. The soils are shown in a detailed soil map of Barnun village (Fig. 76).

The *Tamaziyah soils* form the main series of the irrigation levees in the Hilla-Kifl project (Buringh, 1958). A description of a Tamaziyah silt loam is given below:

0–20 cm. Dark grey-brown to brown (10 YR 4/2.5) silt loam, angular blocky, fine, very weak structure; friable; plenty of salt crystals on the dry profile wall (somewhat puffed);
20–30 cm. Similar, without salt crystals;
30–60 cm. Similar, very friable, some salt efflorescence;
60–90 cm. Similar, texture grading into silty clay loam; friable;
90–105 cm. Brown (10 YR 4/3) silt loam; angular blocky, medium, weak structure; friable;
105–170 cm. Dark grey-brown to brown (10 YR 4/2.5) silt loam, angular blocky, medium and weak structure; friable;
170–200 cm. Brown clay, with rust spots;
200–290 cm. Grey-brown (10 YR 4.5/2) clay, with many medium, prominent rust spots;
290– cm. Brown (10 YR 5/3) clay, with rust.

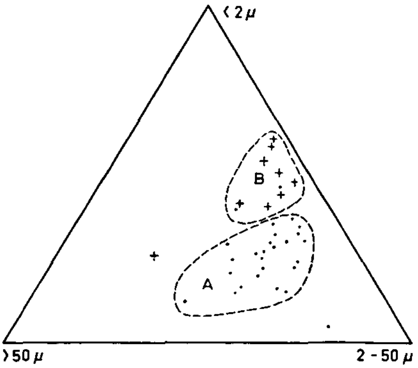


FIG. 77. Graph, showing the texture of soils of the Tahmaziyah series. A. samples of the upper metre (irrigation sediment); B. samples of the substratum.

Groundwater at 140 cm. The upper part of the soil (0–170 cm.) represents the irrigation deposit, overlying the clay of the former river basin.

Soil texture analyses of soils of the Tamaziyah series are shown in Fig. 77.

The enclosed irrigation depressions of the river plain are similar to those of the

Mahdy terrace, described in Chapter 4.2.3. However, there are a few important differences. On the terrace the natural groundwater level is low, and the excess rain and runoff water leaches the soil. On the river plain, however, the groundwater level, particularly in the irrigation depressions is high; there is some leaching, but often there is more evaporation and capillary rise of water which brings soluble salts to the surface, making the soils strongly saline or saline-alkali. In addition, soils of the flood plain are much younger than those of the terraces.

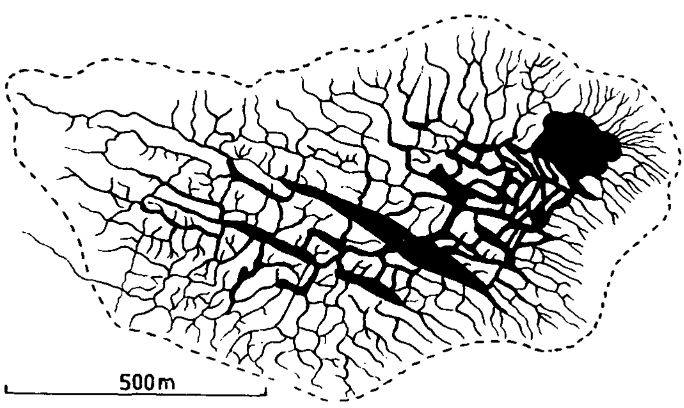


FIG. 78. Pattern of gilgai-gullies in an irrigation depression east of Baghdad

On the other hand, cracking of soils in hexagonal patterns (Polygonal soils), some gilgai relief, dispersive sodium clays, and the presence of many gilgai gullies in a radial pattern (Fig. 78) are similar in the depressions of both areas. Alkali soils take up water very slowly. After a heavy shower, only a few millimetres of the soil are wet. Therefore there is much runoff to the middle of the depression, which may explain the formation of the radial crack pattern (see Fig. 78). The recent paper by Harris (1958) on the depression gilgai soils of Iraq (see Chapter 4.2.3.) is an important contribution to the knowledge of these soils.

During the wet season, clay in the gilgai gullies is dispersed. The salt content in these soils is relatively low. There is often an intense dark bluish or blackish, sticky clay layer at the surface, which in summer has a thin dry surface crust. This clay layer is in an anaerobic condition; it has a strong smell, as there are sulphides present (Fig. 42).

Some solonetzic soils in depressions which have a rather low sodium percentage are probably magnesium-solonetzic soils.

The irrigation depression soils in the Hilla-Kifl project (Buringh, 1958) are mapped in the *Ananah series*. A description is given of the Ananah clay, severely gullied phase:

0–25 cm. Light brown-grey to grey-brown (10 YR 5.5/2) clay, strong, coarse angular blocky to columnar structure; extremely hard when dry, sticky and dispersed when wet; only a few wide pores;

25–35 cm. Grey-brown (10 YR 5/2) clay; prismatic, medium, moderate structure with some wider pores; very firm; some shell fragments;

35–50 cm. Grey-brown (10 YR 5/2) clay; angular blocky to prismatic, medium, moderate structure; very firm; no micro pores; shell fragments;
50–100 cm. Similar, very firm or sticky, some rust;
100–120 cm. Brown (10 YR 5/3) clay; sticky; rust;
120–130 cm. Pale brown (10 YR 6/3) clay; sticky; rust and gley;
130–150 cm. Brown (10 YR 5/3) clay; sticky; rust and more gley;
150–170 cm. Dark grey-brown (10 YR 4/2) silty clay loam; rust and gley;
170–200 cm. Grey-brown (10 YR 5/2) clay, more gley;
200–260 cm. Brown (10 YR 4/2.5) clay, with abundant reduction (gley) spots.

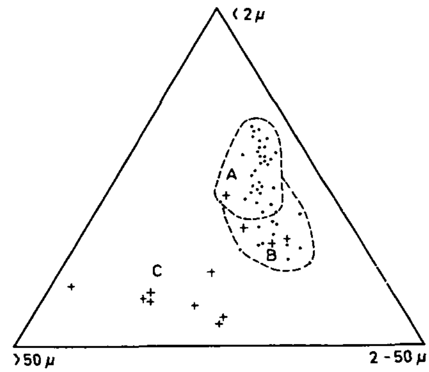


FIG. 79. Graph, showing the textures of soils of the Ananah series.
A. samples of the upper 150 cm. layers;
B. samples of the 150–250 cm. layers;
C. samples of the deeper substrata.

Groundwater at 130 cm; capillary water to about 50 cm. above groundwater level. The soil below 150 cm. represents an ancient soil, covered by clay during floods and irrigation. As the Ananah clay occurs in irrigation and basin depressions, which are often submerged by water, shell fragments occur, indicating lacustrine conditions. Soil texture analyses of Ananah soils are shown in Fig. 79, and in Table 25.

TABLE 25. *Soil analysis of Ananah clay.*

Depth cm.	Texture			Lime %	pH	T.S.S. %	Gypsum
	Sand %	Silt %	Clay %				
0–35	11	36	53	26	7.8	0.20	Nil
35–130	7	29	64	28	7.9	0.30	1.45
130–150	6	31	63	29	7.6	0.55	2.0
150–300	18	44	38	28	7.5	0.13	Nil

The organic matter content is less than 0.8%. Gypsum is expressed in meq/100 g. soil.

The Haur soils are lacustrine clay soils. Some Haurs have been silted up by regular irrigation, mostly in relation to rice cultivation. This practice is still followed in the delta region. Shallow haurs are large saline depressions with a thick (1 cm.) white salt crust at the end of the summer. The soil is always wet up to the salt crust. If the crust is mixed with or covered by dust, its colour becomes light yellowish-brown. The soils are clay soils throughout the profile. From the surface to about 80 cm. they are brown to dark brown, with white salt spots; deeper they are often dark grey-brown with gley. Here, too, there are many spots with dark bluish clay which is in an anaerobic condition under the crust. This clay has the smell of sulphides.

Some of the former haurs have been silted up rather intensively. At present there are

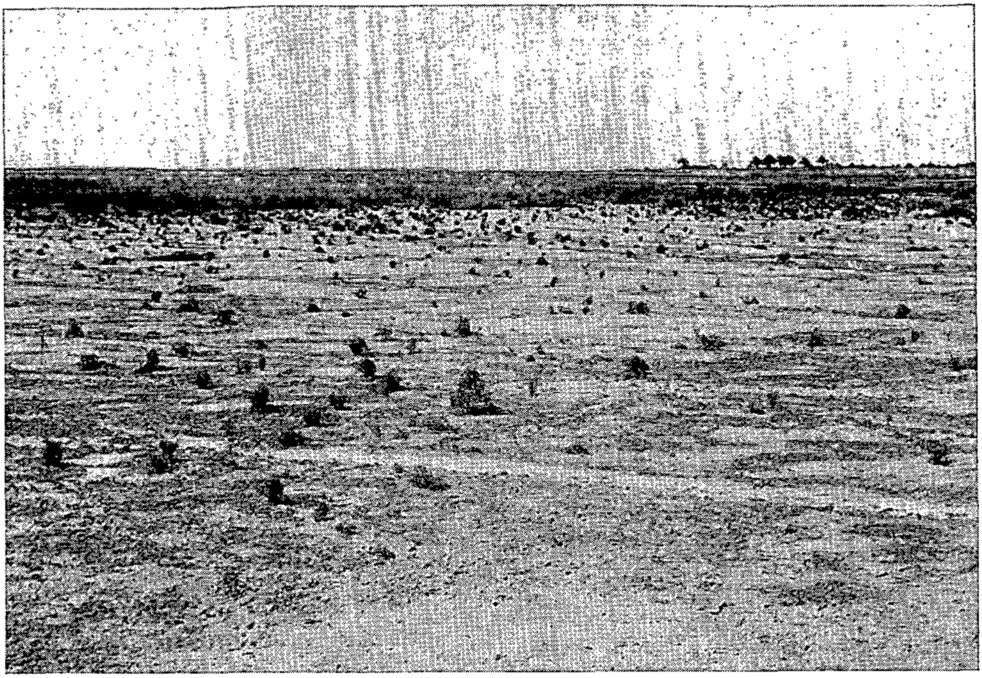


FIG. 80. Area around Haur Ibn Najem.

many large ancient irrigation canals, with embayments, small and steep irrigation levees (up to 5% slopes), and many irrigation depressions with strongly saline or saline-alkali soils. These depressions predominate in silted up Haur areas.

An example is given by Buringh (1958) for the southern half of the Hilla-Kifl project area. The flat areas of clay soils around the Haurs often have a normal gilgai relief with depressions and elevations (Fig. 80).

The whole river plain has never been cultivated at the same time. Areas which have been under irrigation for a very long time became uncultivated desert land. Soils were attacked by wind erosion as the soils are light textured irrigation sediment, often belonging to the Puffed Solonchaks (Fig. 81). Therefore the upper part of most soils was blown off, the material being accumulated elsewhere as a continuous sheet of aeolian products (Fig. 82) or as low dunes. Such aeolian sheets and dunes occupy extensive areas in the Mussayib and Babil projects, east of Mussayib and Hilla. They were studied, described and mapped by Buringh and Edelman (1955), Fig. 83. These authors introduced the name 'Pseudo-sand' for the material, because most dunes consist of clayey and silty material, which occurs as aggregates, with the size of fine sand grains (50–100 microns). 'Pseudo-sand' dunes occur also in Russian desert areas (Kovda, 1954); they also have a barkhan form. This pseudo-sand also occurs in the saline soils of Algeria. Boulaine (1956) has classified them as 'Solonchak vifs', which are subdivided according to deflation or accumulation. In both cases these soils of

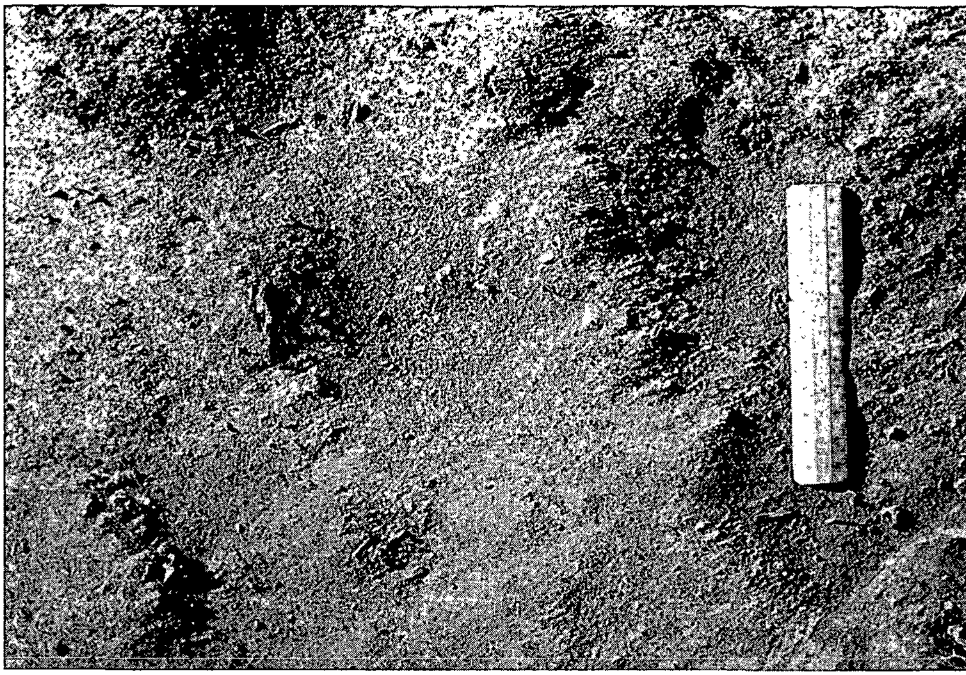


Fig. 81. Flocculated surface soil of a puffed solonchak formed in silty irrigation sediment. The upper 5–10 cm. consist of a mixture of flocculated soil and salt crystals, which are liable to wind erosion. A soil profile is shown in Fig. 85.

Algeria tend to become solonetz soils. Recently similar material was found in South-east Australia (Butler, 1956); it was called 'Parna' and over there it is probably of Pleistocene age. It indicates that desert conditions in Australia during the Pleistocene were similar to those at present prevailing in Central Iraq.

Floods in the plain are endemic rather than exceptional. Therefore there are still broad strips of land over which floodwater runs to lower parts of the plain. Since controlled canal irrigation became a common practice and river basins were subdivided by argubs and irrigation levees, the floods could not spread their water over extensive areas. Flood strips came into being. Soils of such strips are not yet studied in detail. They are observed near Shaklawiya, in the Aqar Quf depression and in the Greater Mussayeb Project, where they were mentioned by Buringh and Edelman (1955). Such a flood strip is characterised by shallow gullies in a braided river pattern (Fig. 84). There are innumerable small and large beds, which are clearly visible on aerial photographs. Those beds are shallow depressions with a width of about 10 metres or less, in which irrigation water stagnates and the crop (barley) fails. They are characterised by a dark coloured soil of a spongy structure, – a kind of marsh sediment, surrounded by light brown (dry) desert soils. The external and internal drainage is very poor. The authors concluded wrongly that such an area could be a remnant of a Pleistocene

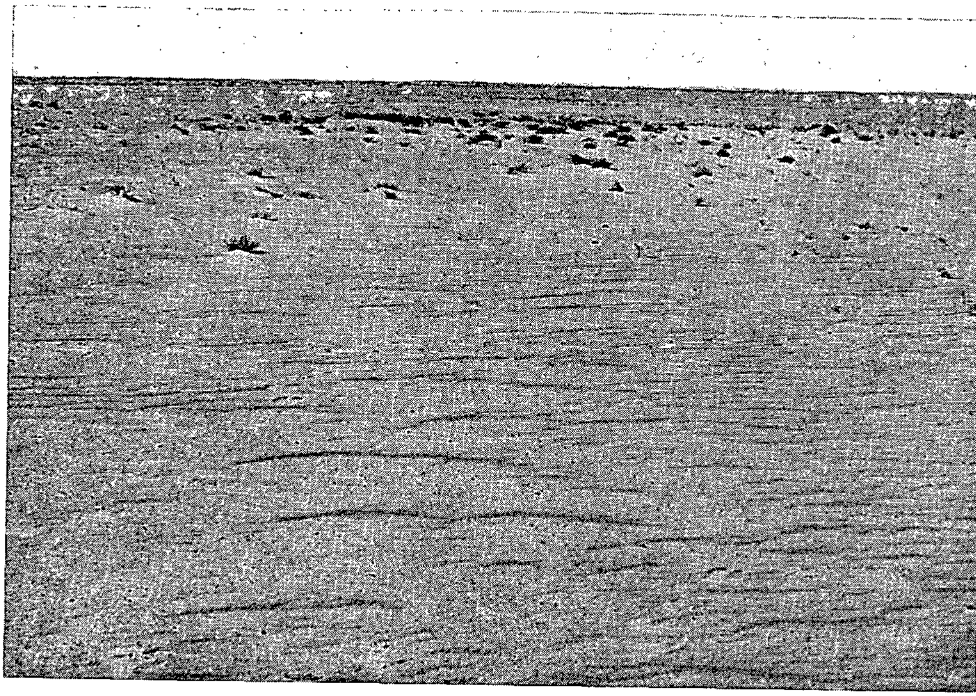


FIG. 82. Desert area in the Euphrates river plain north-east of Kerbala, consisting of fluviatile soils, covered by a layer (10 to 20 cm.) of 'pseudo sand'.

terrace. Although such soils could not be studied in detail and no analyses are available, it is clear that such soils occur in rather recent flood strips.

In an area north-east of Baghdad, approximately 1 cm. of silty flood deposit was accumulated during a period of two months in 1954, when it was covered by a slowly running layer of water approximately 2 metres deep. After the flood the surface soil of approximately 10 cm. was salt free, and good crops were growing in 1955.

Salinization is a normal process in all soils of a river basin, which are or have been irrigated and cultivated. Almost all soils have or had an artificially high groundwater table and soils became saline or even strongly saline.

All types of salinity occur. External solonchak soils can be seen everywhere; puffed solonchak soils are mainly found on the irrigation levees, (see Fig. 85), argubs and tels; sabakh soils are extensive in those basin soils which have a relatively high groundwater table. Flooded solonchak soils are found in deeper depressions and haurs. Saline-alkali and sometimes alkali soils may occur in the irrigation depressions. Seepage water from high level irrigation canals causes long strips of strongly saline soils along such canals, often as puffed solonchak soils or sabakh soils.

Shok and camelthorn are the most common weeds of cultivated land and of desert land with a groundwater table at a depth of less than 5 or 6 metres. Both are perennial leguminous plants, deep rooting and important for grazing and fuel. It is questionable

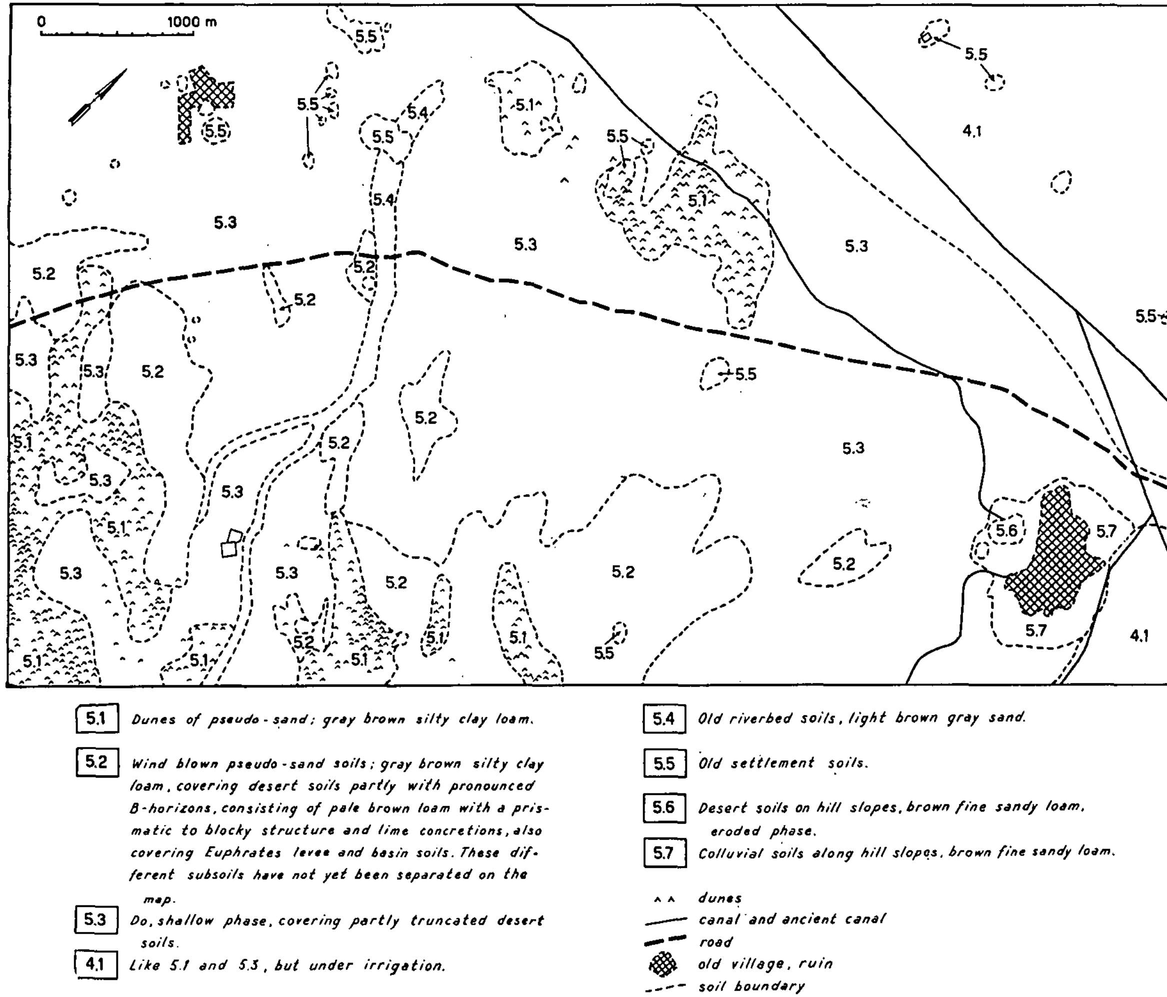
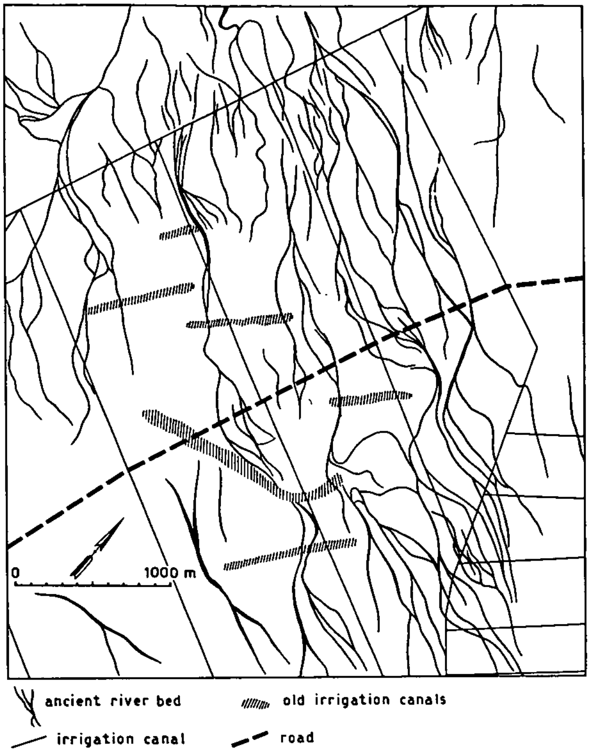


FIG. 83. Semidetailed soil map of Iman Ibrahim in the Mussayib Project (After Buringh and Edelman, 1955). The hills, in the lower right-hand corner represent the nucleus of the ancient city of Kutha.

FIG. 84. Gullies in a braided river pattern in the Mussayib project area (after Buringh and Edelman, 1955).



whether a significant amount of nitrogen is fixed by these weed plants or not. According to Springfield (1954) shok is supposed to indicate relatively fertile soils of high potential agricultural value, whereas camelthorn indicates poorer soil conditions. This, however, will not hold true.

In uncultivated land, both plants lower the groundwater table and keep the upper few metres of the soil dry, thus preventing salt from rising to the surface. On such land no salt efflorescence occurs at the surface; this, however, does not indicate that the soils are non-saline. As the soil is dry to a great depth, salts can easily be washed out from the surface during the first irrigation, if some extra irrigation water is applied. In this way most farmers try to remove the salts from the upper part of the soils to deeper layers, which will not affect the growth of the crops. In this way shok and camelthorn help to improve soil salinity conditions, which is very important for present irrigation agriculture without artificial drainage. More details on saline-farm management are given in Chapter 7.1.

The agricultural potentialities of the various river basin soils vary from very low to high. Haur soils and silted haur soils generally have low potentialities. The basin and irrigation depression soils also have low agricultural potentialities; this is caused by their physiographic position, poor drainage conditions and poor physical, chemical and biological characteristics. They occupy approximately 25 to 30% of the flood plain region. It is questionable whether these soils can be washed and drained, and if so, it wil be extremely difficult and uneconomical (very deep drains and special pumping stations have to be built). Even after a complete reclamation, the soils will still be poor for agricultural production.

It seems to me that there is no reason to improve soil conditions of poor land, if there is enough land with a much higher potential agricultural value. At present most depressional soils are not cultivated.

FIG. 85. Profile of a puffed solonchak near Abu Ghraib. The upper layer (1) consists of loose flocculated soil material, often with a 1 mm. soil crust on top; (2) saline silty clay loam with an angular blocky structure; (3) salt efflorescence on the lower part of the profile wall.

The normal silted basin soils (e.g. Babylon series) are rather good soils, – if salts are washed out, the land is levelled and drained, fertilisers are applied and farm management practices are improved. This will all be possible in the near future. The transitional soils to the river levees can be improved in the same way. For the soil hydrologist and drainage specialist, it will be necessary to study the influence of the buried land surface on soil drainage, but this layer will probably not cause serious difficulties.

Large basin and irrigation depressions, included in a drainage project (the main drains mostly have to cross these depressions) will derive some benefit from it. The better ones probably could be used for rice cultivation.

The various reports of K.T.A.M. (1952–1956) on irrigation projects in the Lower Mesopotamian Plain give too optimistic an idea of the real potentialities of this plain. In particular, the percentage of land in Class 2 is always much too high.

A few other problems concerning river basin soils in Iraq have to be discussed briefly. The soil structure is very water-unstable, biological activity is very low and the organic matter content is also very low (0.5%). These characteristics are closely related to the arid and hot climate of the Lower Mesopotamian Plain, and hence quite normal and adapted to nature. Therefore it will be extremely difficult and probably impossible, to improve soil structure and to increase the organic matter content and the biological activity on a more permanent basis, even if the soluble salts are washed out, and the soils are well and deeply drained. Adding organic material to the drained, non-saline soils does not increase the organic matter content for a long time and it therefore has almost no effect on soil conditions, except in date and fruit orchards.

The soils are mostly used to grow winter crops in a fallow system of farming. For a long period, the soil is exposed to the intensive heat of the sun. Examples are given in Table 5, Chapter 2.2.

In winter there is no frost, which could give a better structure to the surface soil. On the contrary, there is rain, often in heavy showers. Raindrops easily destroy soil structure, forming a dense, compact, platy surface crust (Fig. 59). During irrigation the soil structure collapses as well.

There is hardly any macro-fauna in these soils, but some ants' nests do occur. Nothing is known about soil micro-organisms in Iraq. It is expected that their influence is extremely low in all river basin soils. Soil homogenization by mixing is unimportant. Many basin soils have a porous structure in layers above groundwater level, except in the dense surface crust. Most pores occur in irrigation levee soils; they are formed by carbon dioxide production in the soils as a consequence of root decay.

Another subject is the capillary rise of the groundwater to the surface, which according to measurements in the laboratory is slow, but high in clay soils and rapid but low in sandy soils. In the field, however, it is lower in the heavier textured basin soils than in the thick layers of silty textured irrigation ridges. The explanation is given by the fact that the soils are hot, the air is dry and there is nearly always some wind. Evaporation of water in the soil is therefore very rapid, and even more rapid than the capillary rise of groundwater in clayey soils. As most soils are covered with irrigation sediment, in which the capillary rise is rapid and therefore relatively high (porous structure), salt accumulation is increasing.

If soils are covered by a crop, salt will rise to the zone under the plant roots where water is taken and salts are left behind. A permanent vegetation as in orchards, protects the soil from deterioration. The vegetation cover can improve the biological activity, lower the soil temperature, protect the soil from direct sunshine and from becoming saline. It can also improve the organic matter content and soil structure.

4.3.3. *Regional Soil Studies*

A series of investigations on soils and related subjects has been carried out in the flood plain during recent years. Some data will be mentioned here, as most of the reports have not been printed and distributed. The Nahrwan project area (Hunting Group, 1957), the Hilla-Kifl project area (Buringh, 1957), the Diyala project area (Hunting Group, 1957) and the Kerbala-Kifl project area (Schilstra, 1958) are the best known areas for which soil maps and reports are available. Examples for a soil map of the Greater

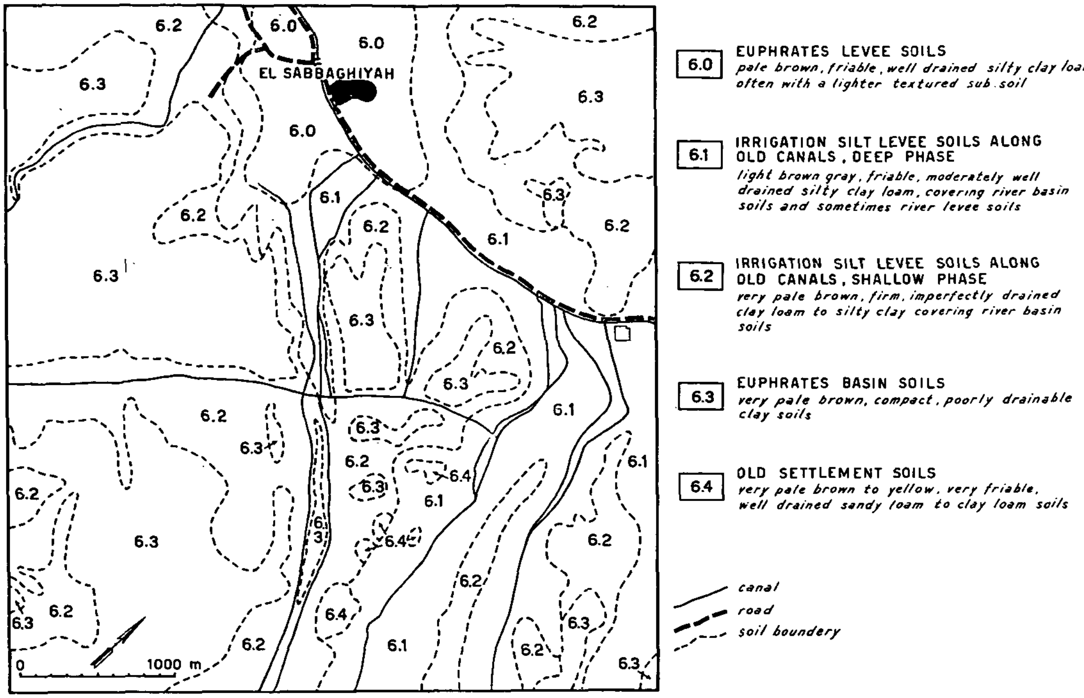


FIG. 86. Semidetailed soil map of a section of the Mussayib project (El Sabbaghiyah), after Buringh and Edelman, (1955).

Mussayib project have been published by Buringh and Edelman (1955). (see fig. 86).

A simple general soil map (Fig. 87) of an area east of Baghdad shows the main soil complexes and associations in the river plain area, which is subdivided into:

a. Tigris levee and basin region along the river (soil units 1–8 in Fig. 87);

b. The desert region of the ancient Nahrwan canal and its branches (soil units 9–11 in Fig. 87);

c. The extensive marshes and idle land in the area bordering the Iranian foothills (soil units 12–14 in Fig. 87).

The mapping units of Fig. 87 are:

1. Tigris river levee soils, well drained, silty clay loam soils, with light textured substrata, non-saline, deep groundwater table, excellent for orchards;

2. Tigris river levee soils, moderately well drained, slightly saline;

3. Tigris river basin soils, silted and imperfectly drained, moderately to strongly saline;

4. Tigris river basin soils, silted moderately well drained, moderately to strongly saline;

5. Recent crevasse soils, gullied phase, formed as a result of breaks in the Diyala dykes in 1954;

6. Older crevasse soils;

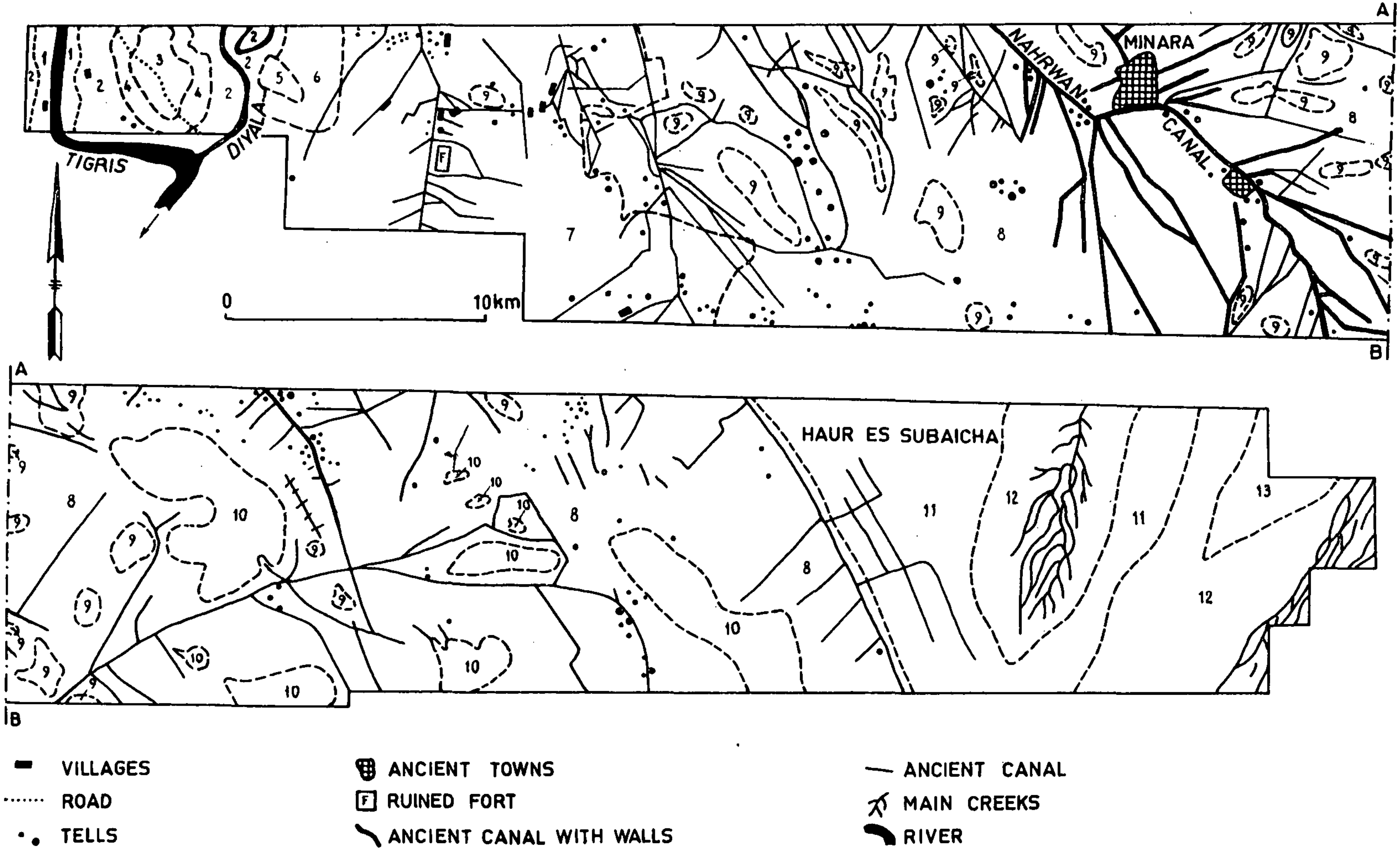


FIG. 87. Map of the area east of Baghdad. An explanation is given in the text. The tels are indicated by black dots; two ancient cities occur near the Nahrwan canal. Only the land up to 10 km. east of the Tigris is under cultivation; the rest was abandoned in the thirteenth century.

7. Tigris river basin soils, silted phase, moderately saline, including a few irrigation depressions;

8. Nahrwan irrigation deposits, non-cultivated desert land, strongly saline, including many small irrigation depressions;

9. Irrigation depressions soils (large areas indicated only), saline-alkali and alkali soils, often with gilgai relief;

10. Haur soils;

11. Marsh land, saline, grey, gleyed clay soils with creeks;

12. Periodically flooded land, with stream influence from the foothills (see Fig. 99);

13. Idle land, saline, gleyed clay soils (Fig. 98).

The Nahrwan area east of the Tigris river is a desert area which was once irrigated by the large Nahrwan canal which ran from Deltawa to Kut. Soil conditions generally are as described before, with thick irrigation deposits in a former river basin area.

The overall soil characteristics in the Nahrwan area are, according to the Hunting Group (1956):

Abundance of lime (20–35%);
pH 7.6–8.9 (almost all samples were below 8.0);
organic matter content 0.07%–0.91%, average 0.55%;
total N 0.06%;
C/N 6;
K_2O 0.53–1.21%, average 0.94%; which is rather high;
P_2O_5 0.01–0.19%, average 0.14%;

The soils are mostly silty and fine sand is generally less than 20%; the cation exchange capacity is approximately 25 (from 15 to 30) meq/100 g. soil. There was one sample with 43.6 meq/100 g. soil. The soils are saline, mostly sodium chloride, but some Sabakh soils do occur. Crystalline gypsum was particularly present in fine textured saline soils, with large crystals about 1 metre below the surface and powdery near the surface. The gypsum content is up to 3%; 13% of the surface soils and 8% of the subsoils were non-saline; 80% of the soils had $E.C._e = 8$ or more. There are also many depressional saline-alkali soils with E.S.P.'s up to 55%. The groundwater (Fig. 28) is saline, and in the southern Nahrwan area its salt concentration is twice the salt concentration of sea water! The soil structure is usually angular blocky; the soil density is high – 1.41 to 1.99 g./cm.^{3}; the field capacity is 17.7 to 30.0%; soil permeability is mostly low, less than 1 cm./hour, except in silty soils (1 to 3 cm./hour).

The irrigation depression soils are solonetzic; they were called Tabra soils; the leached phases have a somewhat greyer colour and they are alkaline because salts, including gypsum, have been leached to lower horizons. Gilgai relief is most pronounced in the large clay depressions near the tail of old irrigation canals; the hummocks are 1 or 2 metres in diameter and 30 cm. high. In the Nahrwan project area, which totals 1,521,575 donum, 39% has been classified as irrigable land (Class 2 and 3); more than 70% of this irrigable land is in Class 3 and requires special treatment before it can be developed (Hunting Group, 1956).

The right bank of the Diyala, north of Baghdad, was studied by Webster (1921). It was one of the first regional soil investigations in Iraq, and at that time an excellent study of soil salinity and soil fertility. The area is partly irrigated by the Diyala river, the water of which contains much larger amounts of salts than the Tigris river (Table 26), and by the Khalis canal west of the Diyala, which takes water from this river near the Jabal Hamrin. The water is particularly rich in magnesium salts. Some parts of the region were sometimes flooded by the Tigris. The Diyala river is stable; it is somewhat entrenched in the river plain and it does not flood adjacent land.

TABLE 26. *Soluble salt content of river water, October 1920* (After Webster, 1921).

	T.S.S.	$CaCO_3$	$CaSO_4$	$MgSO_4$	Na_2SO_4	$MgCl_2$	NaCl
Tigris	550	150	63	53	–	53	29
Diyala	1000	230	176	211	–	91	153

Remarks: The results are expressed in parts per million.

In another article, Webster (1921) has mentioned the non-saline area between Khorassan and the Diyala (near Baquba), which is an important fruit district (oranges). Irrigation water is brought in through the Khorassan canal which comes down from the Diyala Weir. After the land has been irrigated, the water drains away to the lower lying Diyala river which therefore has a higher salt content. The importance and the effect of good soil drainage is clearly shown in this area. It is a practical example of a type of drainage which has already been known for more than 25 years and which is worth while studying in more detail. A greater distance away and south-east of the Diyala, the land is silted up by irrigation sediment and the soils are similar to those of the Nahrwan area.

Recently the Hunting Group has made a 'Reconnaissance Soil Survey' (Macdonald and Partners, 1957). Although the 'soil map' is not a soil map at all, because it does not show soils, the investigation, which has been continued afterwards, shows saline and saline-alkali soils over almost half of the area.

The flood plain area between the Euphrates and Tigris rivers has been silted up by the following main canals (from north to south):

a. The Dujail Canal, north-west of Baghdad;
b. The Isa Canal, north-west of Baghdad;
c. The Sasar Canal, west of Baghdad;
d. The Malik Canal, south-west of Baghdad;
e. The Kusha Canal, south of Baghdad;
f. The Nil Canal, east of Babylon.

Their location is shown on a small map published by Le Strange (1905). The exact location can be found on aerial photographs. All areas once irrigated by these canals and their branches, are silted up and strongly saline, and large parts are now uncultivated.

An old river bed of the Euphrates occurs in the Saqlawiya area, north-west of Baghdad, which was formerly irrigated by the Dujail canal, which first took water from the Euphrates and later on from the Tigris. At present nearly 70% of the land is uncultivated due to salinization. There has been an interesting drainage experiment, the first in Iraq, by Turcan (1946), see Chapter 7.3.

The Aqar-Quf depression, an area of approximately 40,000 ha. west of Baghdad was once an extensive, shallow lake. At present it is a very large basin almost without irrigation sediments. The soils are of lacustrine origin, with many shells on the surface and in the soils; the soils are clayey. They are for the greater part non-saline or only slightly saline and the deeper substratum seems to be fine sandy and permeable (Turcan, 1946), which is a promising factor for the future, as the whole depression will have a drainage system. Excessive water could always drain through the Washash canal near Baghdad airport. The low salinity content of the soils is a result of regular floods, the absence of old irrigation canals and the absence of cultivation until recently. The groundwater level is relatively deep under non-irrigated conditions. Without an adequate drainage system, salinization will soon become a problem.

A small area of the depression has been mapped in detail by Schilstra and Adthari (1957). A brief description of the *Aqarquf clay* is given below:

0–0.5 cm.	Grey-brown (10 YR 5/2) clay; very fine moderate angular blocky structure; hard, compact and non-porous, with polygonal cracks; highly saline.
0.5–2.5 cm.	Grey-brown (10 YR 5/2) clay, coarse angular blocky, hard, porous, polygonal cracks, highly saline.
2.5–15 cm.	Grey-brown (10 YR 5.5/2) clay, strong angular blocky, slightly porous; shell fragments; highly saline.
15–50 cm.	Dark grey-brown (2.5 YR 4/2) slightly porous clay, moderate angular blocky; friable; fairly fine rust spots.
50–130 cm.	Dark grey-brown (2.5 YR 4/2) clay; fine, weak angular blocky; friable; many fine rust spots; some shell fragments; some reduction spots.
130–160 cm.	Grey-brown (10 YR 5/2) clay; distinct rust and grey reduction spots; 74% clay.
160–170 cm.	Very dark grey (10 YR 3/1) clay; ancient surface layer;
170–180 cm.	Dark grey (2.5 YR 4/0) clay, with gley.
180–200 cm.	Dark grey-brown (2.5 YR 4/2) clay, with gley.

The clay content varies from 50–60%, T.S.S. from 0.6 to 1.4%, lime from 20.7 to 27.4%, gypsum from 0.12 to 0.90%, the pH from 7.1 to 7.6. Soil texture analyses are shown in Fig. 68.

The Aqar-Quf depression is one of the rare areas where soils have not been cultivated up to recent times. It is believed that King Cyrus diverted the Euphrates temporarily through this depression in order that the Euphrates bed near Babylon would be dry. In doing this, his troops could easily enter that famous city (Lloyd, 1947; Rawlinson, 1949).

The Abu Ghraib area, west of Baghdad, where the Agricultural College and Experimental Station are situated, is at the western border of the Aqar Quf depression. This area was formerly irrigated by the Isa canal. Most of the soils are saline, especially those with irrigation deposits. The groundwater table is relatively low and therefore the area does not need drainage as badly as does Shaklawiya. The upper part of the soil (about 100–150 cm.) consists of Euphrates flood and irrigation sediment (Fig. 88 and 89). Most soils near Abu Ghraib are silty clay loams, with 17–25% lime, pH 7.6–

FIG. 88. Stratified profile near Abu Ghraib College.
1. Silty clay loam with some salt efflorescence;
2. Fine, loamy sand layer with much more salt efflorescence;
3. Silty clay loam.

8.0, cation exchange capacity 32 meq/100 g. soil; clays are montmorillonite clays with some illite, kaolinite and calcite (analyses made in 1956 in Zürich by H. Deual, and in the U.S.A. by Booya, 1956). E.S.P. is 4.6–6.2%; gypsum 5–12 meq/100 g. soil. Sabakh soils occur in some areas near Abu Ghraib; three samples were analysed by Booya (1956):

	Soil 1	Soil 2	Soil 3
Exchangeable Ca	13.2	15.6	13.2
Exchangeable Mg	6.5	3.7	3.5
Exchangeable K	0.55	0.39	0.25
Exchangeable Na	5.1	4.6	6.3
Total	21.4	20.5	18.2

The first investigation of Abu Ghraib was made by Tiwary (1930), who classified the land according to the salt content. In an area of 59,000 ha, approximately 43% was non-saline, but with salt in the subsoil (internal solonchak). He also noticed that the salt content was high near the canals (seepage). During recent detailed soil studies in some experimental fields south of the road from Baghdad-Falluja, some soil series and types were described. Two predominate soils are mentioned below:

Abu Ghraib Clay Loam – an Alluvial soil in the flood plain, irrigated, without a drainage system. During the fallow and in the summer, the groundwater is below 2 metres; moderately to strongly saline, external solonchak with some salt efflorescence at the surface.

0–57 cm. Brown clay loam; fine, weak, subangular blocky structure; friable (moist) or slightly hard (dry); 24% lime; T.S.S. 0.4%, gradually grading into:

57–86 cm. Brown to dark brown clay; fine, weak, subangular blocky structure; very friable; a few fine faint rust spots; few, fine distinct gypsum spots; T.S.S. 0.5%; grades into:

86–107 cm. Brown to dark brown clay; fine, moderate angular blocky; very friable; a few, fine, distinct gypsum spots; common to many, coarse, distinct, light greenish-grey gley spots; T.S.S. 0.6%; grades into:

107–140 cm. Brown to dark brown clay; fine, weak angular blocky; very friable; a few fine distinct gypsum spots; T.S.S. 0.5%; grades gradually into:

140 cm. and deeper Brown to grey-brown clay; fine, moderate angular blocky; firm consistence, many medium to coarse, distinct gypsum concretions; T.S.S. 0.8%; lime 28.1%; with some potsheards at a depth of 150 cm.

The clay content of these layers is approximately 53%. The organic matter content of all layers is less than 0.8%. The soil structure is weak and unstable; the layer from 86–107 cm. is more compact and less permeable. Fine pores occur throughout the profile. Permeability is moderately slow. The greenish gley spots have a lime content of 24%; the T.S.S. is 0.61% and the phosphate content is very low, $P_2O_5 = 1.6$ p.p.m. Soil texture analyses:

Layer in cm.	Sand %	Silt %	Clay %
0–57	35	30	35
57–86	11	38	51
86–107	9	36	55
107–140	17	30	53
>140	37	23	40

Abu Sefy Silt Loam, with the same general characteristics:

0–19 cm. Brown silt loam; with a fine, weak subangular blocky structure; slightly hard and a few, fine, faint rust and manganese mottles; many pores; T.S.S. 0.16; grading into:

19–61 cm. Brown silty clay loam; fine weak subangular blocky structure; slightly hard; many pores; a few, fine, faint rust mottles; T.S.S. 1.75; gradually grading into:

61–80 cm. Brown clay loam; fine weak subangular blocky; friable; a few, fine, faint rust mottles; a few, distinct gypsum spots; T.S.S. 0.73; clear grading into:

80–104 cm. Dark grey-brown to brown sandy loam; structureless; loose; porous; a few fine, faint rust mottles, and a few, fine distinct gypsum spots.

104–125 cm. Dark grey-brown to brown clay; fine, weak, subangular blocky; friable; a few fine, faint rust mottles; T.S.S. 0.71; abrupt grading into:

125–142 cm. Brown clay loam; fine, moderate, angular blocky; firm; common, fine, faint rust mottles; T.S.S. 0.47, abrupt grading into:

$>$ 142 cm. Dark grey-brown kilsiyah clay loam; fine, moderate, angular blocky, friable; at a depth of about 150 cm. some potsheards.

The lime content of all layers is between 22 and 27 %; the organic matter content is less than 0.7 %; soil structure is water-unstable; the 125–142 layer is more compact and less permeable; fine pores throughout the profile. The soil texture of the various layers is:

	Sand %	Silt %	Clay %
0–19 cm.	20	55	24
19–61 cm.	17	54	28
61–80 cm.	25	42	32
80–104 cm.	55	35	10
104–125 cm.	26	29	44
125–142 cm.	23	40	36

A small area, indicating the location of both soil series, is shown in Fig. 89.

In addition to these soil types, which represent river basin soils with an irrigation deposit on top, there are many other soils near Abu Ghraib, e.g. irrigation levee soils, irrigation depression soils and soils of the Aqar-Quf depression.

The Latifiyah project area, south-west of Baghdad, which is 25,000 donum in area, is also a large silted up river basin area, irrigated by Euphrates water. The groundwater table is high, drainage is poor and there are low permeable clay layers (Ali, 1955). A drainage system is planned; the settlement was started in 1952.

The Latifiyah estates (60,000 acres), started by a private British Company in 1928 for large scale crop production, has not been a success (Garbutt, 1944), because capital costs were high and the production of barley and wheat alone was not sufficient. Other crops should be grown, but the soils are not suitable for such crops, except when the drainage is efficient.

The Greater Mussayib Project (303,000 donums) is situated in the arid-fluviatile, non-cultivated, saline, silted up area, east of Mussayib and both sides of the ancient Kutha canal. See Figures 83, 84 and 86. When irrigation (without drainage) started, the groundwater level was rising to the surface (Ali, 1955). A drainage system is now

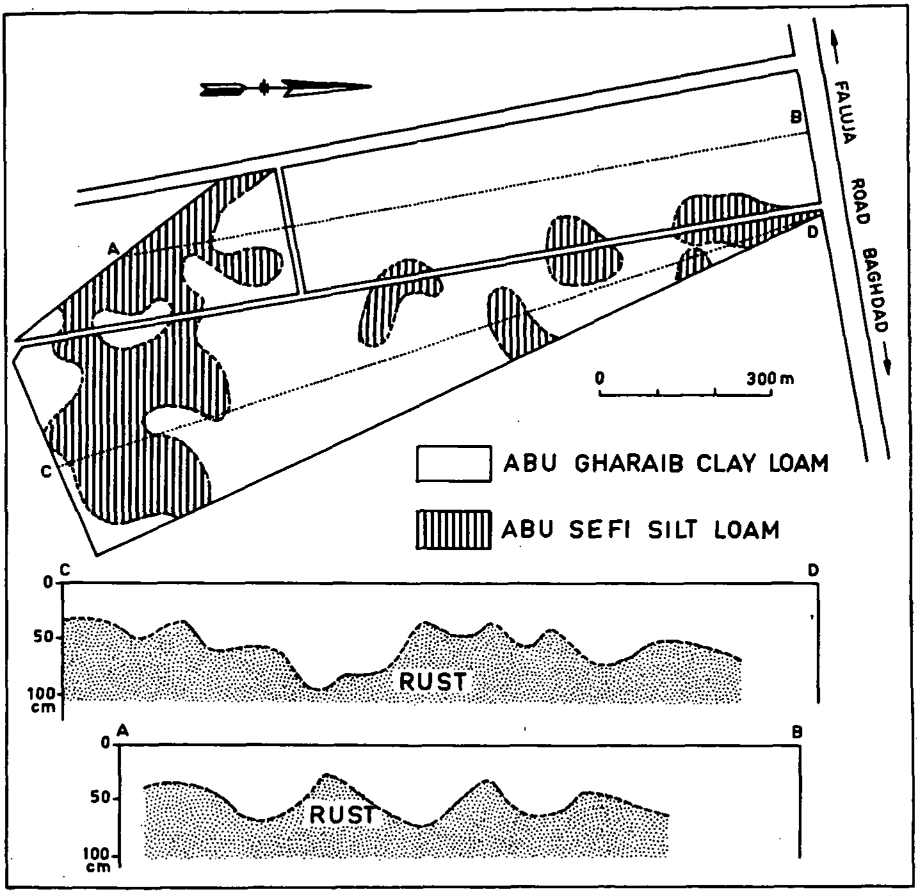


FIG. 89. Detailed soil map of pasture plots near Abu Ghraib. The two cross sections indicate the irregular upper boundary of rust spots. The soils are rather uniform. The upper 1.40 metres consist of young irrigation sediment, covering an ancient land surface (with potsheards). The soils are slightly to strongly saline and the T.S.S. varies from 0.18 to 3.0 %.

planned. As the soils are similar to other silted up river plain areas, it is clear that drainage will not be feasible in some parts of the project, and it is expected that approximately 25 % of the reclaimed land will be abandoned after some years of cultivation.

In addition to the soils of the old irrigation canals, irrigation levees and depressions, basin soils, etc., there are extensive active dune lands and 'overblown' areas consisting of 'pseudo sand', (Fig. 82 and 83) which has already been described. Such dune land cannot be reclaimed and there is always a great danger that the blown-off material will fill the irrigation canals and drains.

Near the drainage pumping station under construction in the neighbourhood of the ruins of Kish, the chemical composition of the groundwater in the summer of 1956 was (by courtesy of NEDECO):

E.C.$_i$ > 15,000; T.S.S. 47,910 p.p.m.; Ca 650, Mg 1818, Na 13,269, Cl 16,000, SO_4 15,500, HCO_3 366 p.p.m., and pH 7.1.

The Babil project area (385,000 donums) east of Hilla, is a similar uncultivated area, which will be reclaimed. Here, too, there are old canals (Nile canal) with irrigation levees, depressions, basins, and extensive 'pseudo sand' areas, mostly in active dune land; 538 out of 868 soil profiles have horizons with a pH of 8.7 or more (K.T.A.M. 1953). Unfortunately no E.S.P. analyses have been made. It is evident that there are many large irrigation and basin depression areas, with saline-alkali conditions. The permeability of the soils is poor and drainage will be difficult.

The irrigability land classes in the Babil extension project were estimated as follows:

	Class					
	1	2	3	4	5	6
In 1952 (K.T.A.M.)	3%	87%	10%	–	–	–
In 1953 (K.T.A.M.)	0.2%	21%	53%	5%	2.8%	18%

It is quite certain that the estimation of 1953 is still much too optimistic.

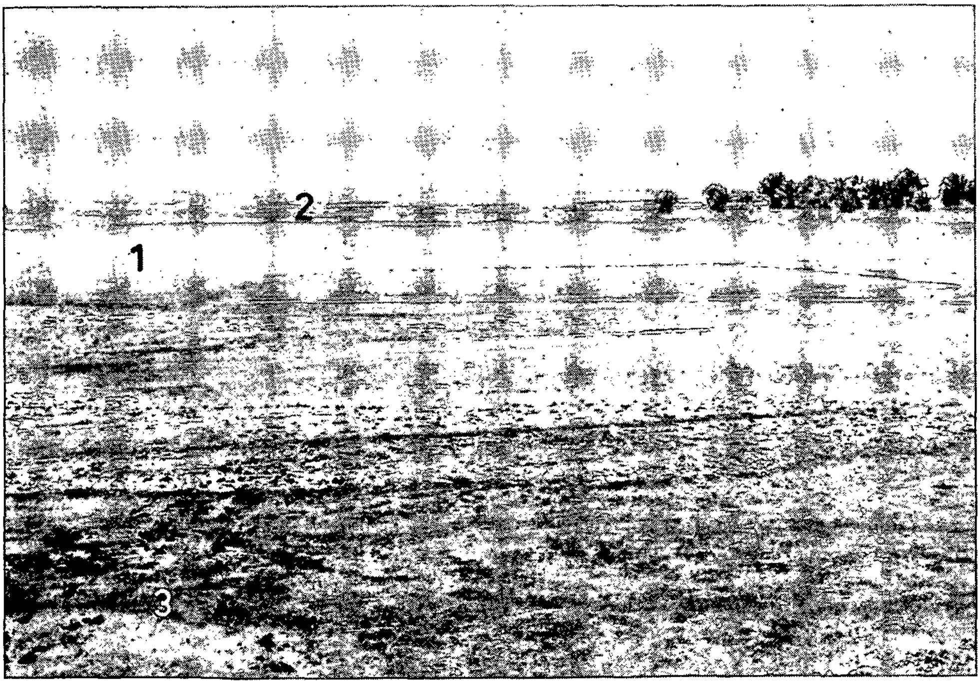


FIG. 90. Large irrigation depression (1) east of the ruins of Babylon (2). Flooded solonchak soils with a 2 cm. white salt crust on the surface in the depression. Bluish-black, anaerobic soils (3) at the border of the depression (see the soil profile in Fig. 42).

The Hilla-Kifl area which has already been mentioned before, is an irrigated and cultivated district with similar soil conditions to those in other parts of the flood (Buringh, 1958). An important difference is the light textured deeper substratum, which will prove to be favourable for drainage. Soil suitability studies were made in this area (see Chapter 7).

The Hilla district is extremely saline (Fig. 90), which is caused by the Hindiyah Barrage. Even all river levee soils are saline and the date and fruit gardens are in a rather poor condition. Salt rises to the surface in the gardens at spots not covered by dates. As the water level in the Hilla canal is artificially high, there is hardly any drainage from the levee to the river. A special soil report and semidetailed soil map of this area will be published in due course (Buringh, 1958). There are many ancient sites in this project area; they are all shown on the semidetailed soil map, and an archaeological study carried out on a regional basis would be worth-while. A small part of the map is shown in Fig. 91.

The Kerbala area is being studied; the soils are similar to those near Hilla. There are more Haurs and flooded solonchak soils and there are transitional soils to the desert, highly gypsiferous and with sandy substrata.

The fertility of all soils in the flood plain is rather low, especially as regards nitrogen and phosphorus. Potassium seems to be sufficient under the present low intensity of

FIG. 91. Section of the map of ancient sites of the Hilla-Kifl drainage project. This map demonstrates the intensity of ancient sites in some areas of the Lower Mesopotamian Plain. Ancient sites always occur on the best land. On poor land no signs of occupation or cultivation were found. In the area covered by this map there were found: 44 sites with a diameter of more than 100 metres, and 173 smaller sites, giving a total of 217 sites in an area of approximately 12 km.² In the whole Hilla-Kifl project area (380,000 meshara or 95,000 ha), 653 ancient sites, of which 102 with a diameter of more than 250 metres, were mapped. Many very small sites, as indicated in this section of the map, are not included in this figure of 653.

farming. It may, however, be expected that potassium fertilisers will be needed if crops other than barley and wheat are grown, and when agriculture is on a higher level on non-saline, well-drained soils. As long as the soils remain saline, there will be no good response to fertilisers.

A general review of land classes for irrigability has been made by K.T.A.M. (1952) for all non-cultivated areas in the Lower Mesopotamian Plain. The paper by Powers (1955) is on the same subject. Although the report of 1952 was much criticised a few years later, it should be understood that this report was only a first approach, and that the results have to be improved by carrying out more detailed studies.

It seems quite characteristic that no coarse textured and gravelly layers occur in the plain; in fact, they were never found in the many borings made down to 5 metres. There is only one exception, viz: near Balad, where the Tigris enters the Holocene plain and some coarse sandy layers can be found. The fact that all layers are relatively fine textured (fine sand to clay) indicates that no torrential streams have entered the plain since the upper layer of at least 5 metres of sediment has been deposited. It is probably the result of the great length, minimum slope and great width of the Mesopotamian plain over which water could be spread in a relatively thin layer over a very large flat plain.

The rivers are not confined in a narrow valley or plain surrounded by high embankments.

4.3.4. *Soils for Industrial Use*

Soil material from the upper few metres is used for brick and cement making. Brick making has been practiced since ancient times. Cement factories were established a few years ago.

Small areas near many towns have been excavated and the bricks were made in simple kilns. Since 1950, many modern brick works, particularly north of Baghdad, supply often a rather poor quality brick for building houses etc. The soil material is usually silty clay loam, silty clay or clay loam, and sometimes some silt loam, which is mostly taken from the higher basin soils, with no irrigation cover or a rather thin one. The poor quality of the bricks is caused by a combination of various factors (burning temperature, skill of labourers, mixing of raw material), some other factors being related to the soils.

In studying the problem of Mesopotamian bricks, the typical characteristics of the soil material have to be kept in mind:

a. The high content of soluble salts, and consequently the flocculated condition of the raw material. A scum is formed at the surface of the sun-dried bricks, and after burning there is a bad surface of incrusted salt. If the bricks become wet, a layer of white crystals appears at the surface after subsequent drying. This can be seen in many houses and brick gates.

b. The high lime content ($CaCO_3$ and $MgCO_3$), 20–30%. The lime contracts but little in burning and the shape of the bricks can be good. When there is much lime, however, the bricks require rather hard firing. Underfiring is a normal practice in most brick works, even in those with modern installations.

c. The rather low plasticity of the material, when it is wetted. There is not enough cohesion in the brick and it is also difficult to make hollow bricks (insulating material).

d. The typical mechanical composition of the raw material, which lacks coarse sand particles. On the other hand the clay content does not exceed 55%.

The colour of the brick is light yellow, caused by the low iron and high lime content. Mostly the brick colour is spoilt by salt efflorescence, differences in iron-lime content and burning at different temperatures. In practice no bricks of a uniform good quality are produced.

Interesting notes on Mesopotamian bricks were made by Webster (1924). He advised that:

a. Non-saline material should be used, or salt should be washed out before using it;

b. The period of soaking and wetting of the material, which is generally one day, should be extended to 4 or 5 days.

c. The plasticity can be improved by adding some sodium carbonate, particularly after salts have been washed out. After some experiments, Webster got the best results when non-saline material was puddled with a 0.02% to 0.05% solution of sodium carbonate. In practice the material is often mixed with dung, straw or reed in order to increase plasticity. A much better result is obtained by deflocculation of the clay. Webster also suggested that in ancient times the fine ashes of the brick kilns were added to the raw material. As this ash is alkaline, it will have had a similar effect to sodium carbonate.

Nothing more needs to be added to this advice. It would probably be worthwhile to investigate whether there is some coarse textured material in the deeper subsoils in the neighbourhood of brick works. It also seems practical to wash out all soluble salts from the raw material before it is excavated. A special drainage system and a small pumping installation are required.

In the cement industry, the chemical composition of the limestone and of the clay which are usually used in a 3 : 1 ratio are important. Salts, if present, should be washed out as magnesium is particularly harmful. Magnesium is present in some limestone varieties (as $MgCO_3$) and in soluble salts in soils as $MgSO_4$, $MgCl_2$ and as Mg in the base exchange complex. The soluble salts can be easily removed and here, too, it seems to be economical to wash out all salts before the material is excavated.

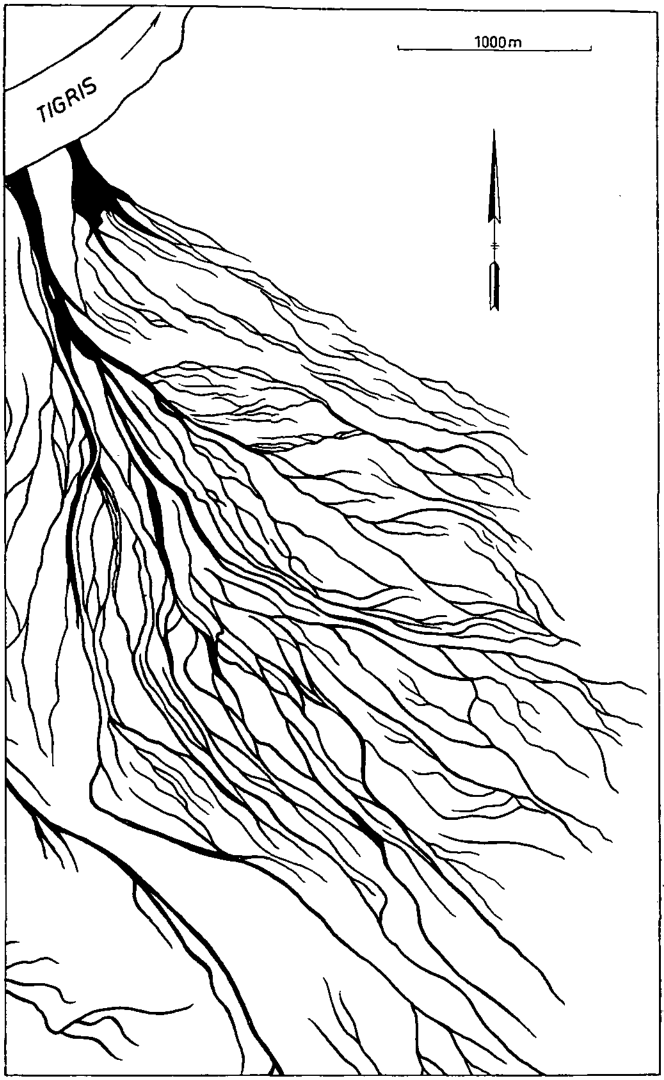
The industrial use of soil material, particularly for brick works, is a type of mis-use of soils which is not quite so serious in a thinly populated country; however, as mostly good agricultural soils are concerned, this soil mis-use will become of increasing importance.

4.4. Soils of the delta plain

The general physiography has been given in Chapter 4.1. One of the principal differences from the flood plain is that in the delta nearly all soils are greatly influenced by a high groundwater table. The various branches of the Euphrates and Tigris are relatively small and only low river levees occur. The river basins are extensive, haurs are numerous, and towards the south there is a gradual transition to the marsh region.

There are natural overflows (flood gullies) in the river levees at many places, which

FIG. 92. Flood gullies of the Tigris river east of Kut.



are narrow in the levee proper and widen into a typical braided stream pattern in the river basin (Fig. 92). Sedimentation is still in progress in such areas.

The silted up areas which result from irrigation practices are less extensive than in the river plain. They mainly occupy the highest part of the original basins. As the canals end in the haurs and marshes, these are gradually silted up, especially during rice cultivation. For the understanding of soil conditions in the delta plain, the mesorelief, sedimentation and hydrology are of the utmost importance.

Salinization is a normal process. Saline soils occur everywhere. The river levee soils are saline or slightly saline, too, as their groundwater level is rather high. Soils of the irrigated areas are often strongly saline. There are also irrigation depression soils.

Soil conditions in the river levees and in the areas with thick irrigation deposits are the same as in similar areas of the flood plain, only with the exception that salinity increases and the groundwater level generally is higher. Sabakh soils occur over wide areas.

A large depression, called the 'Great Swamp' is situated in the western part of the delta plain, south-east and east of Kufa. The area is not a swamp, but rather a marsh. Originally this depression was much larger, but owing to rice cultivation at the borders, large sections have been silted up. The middle part is still an extensive haur, called 'Haur El Nejm', with lacustrine deposits. According to Le Strange (1905) the Great Swamp originated from neglecting the dykes along the Euphrates and its branches at the end of the fifth century A.D. After repairing the dykes they were again destroyed during a large flood in 636 A.D. The soils of the Great Swamp were considered as fertile (probably non-saline) when they were drained. A part of it was drained in Omayad times (Le Strange, 1905). Large parts are haurs or marsh and covered with reed, forming a hiding place for outlaws throughout history. When dykes along the rivers were built, the land was protected from flooding, and many haurs became dry waste land; some of them were flooded in such a way that they could serve for rice cultivation. In such haurs, the land gradually was silted up.

There is much evidence of changes in hydrological conditions in the delta plain. Rivers and their branches became silted up easily and new courses were formed. Streams were shifting more frequently in the delta than in the flood plain. An example of old stream beds has been given by Goetze (1955). The shifting of river beds in the delta plain may be considered important for the explanation of the abandoning of ancient cities. Subsidence of the earth's surface is another important factor (Lees and Falcon, 1952). Both processes are still influencing this part of the Lower Mesopotamian Plain and therefore the delta area is not in a final stage. Since floods are controlled (since 1956) the situation will change and flood sedimentation will decrease, whereas soil salinity will increase.

The Gharraf or Shatt-Al-Hay was once the main stream of the Tigris river system. It has been considered as being a canal, dug at the time of Etemea to bring water to the ancient city of Lagash (Lloyd, 1947). It should be the oldest canal for which a written record is available. Soil conditions, however, are those belonging to a normal delta plain, and therefore it is just a branch of the Tigris which was probably deepened when it became silted up. The Dujail river, south of Kut was once the main stream, and since the 16th Century the present Tigris course has again been the main river (Le Strange, 1905) and most land along the Gharraf, which was silted up by irrigation sediment, has been turned into desert. Since the Kut barrage has been completed (1939), it is possible to irrigate land in the Gharraf area again. At the southern end of the Gharraf, the land is badly waterlogged, and much of the land has become too saline. 21 % of an area of 640,000 donum, investigated by K.T.A.M. (1953) has become unproductive in recent years. According to the same report, alkali soils, which are characterised by high pH-values, do occur in this area.

The Dujaila project area, south-east of Kut, is the first large scale reclamation project of modern Iraq. Unfortunately the project is not a success. Many technical, economic, social and political mistakes have been made. It has been an expensive experiment. For general information see: Ali (1955) and Warriner (1957). It usually happens that many mistakes are made in the first project, but I gained the impression that many of them could have been avoided, if independent consultants had been employed. Not to have made a drainage system was a very fundamental mistake. After a few years, about 20 % of the farmers left their land, which they had been given free of charge, together with irrigation water. The land was damaged by salinization. At present a drainage system is being planned and made (Boumans, 1954, 1957). Some excellent drainage investigations (see Chapter 7.2) are carried out.

The salt-content of the soils in Dujaila nearly always increases with depth (Turcan, 1952), which is appropriate for cultivated land. The Cl-ion percentage also increases, but not in the same way (Fig. 93). This indicates that it will also be important to determine the Cl-content of the soil. Booya (1956) has made a study of some Sabakh soils in Dujaila, and he found 6.3% salt in the surface soils, decreasing in deeper layers to 1.4% at 100 cm. A non-sabakh soil had 0.2% in the surface layer, increasing to 1.1% at 100 cm. This is explained by the capillary rise of the groundwater to the surface in the uncultivated Sabakh soil.

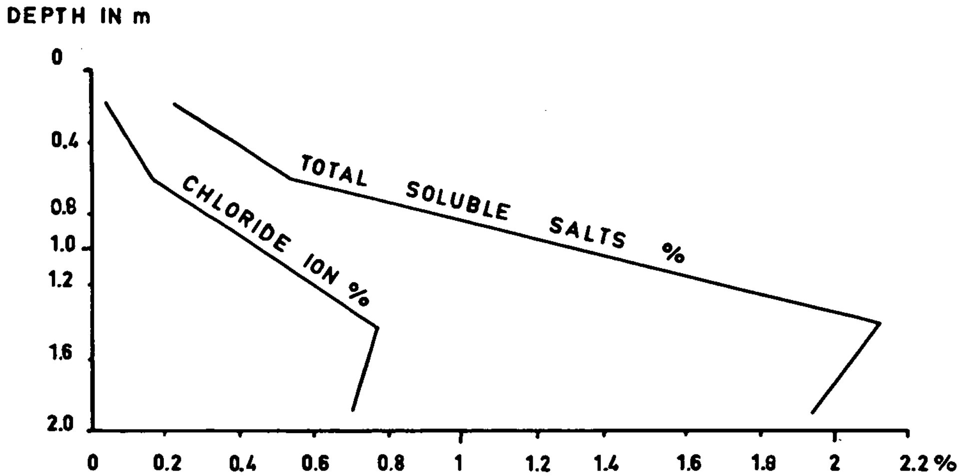


FIG. 93. Salt and chloride ion distribution in a Dujaila soil (after Turcan, 1952). A similar distribution was found in most other soils of the Dujaila project. The example shows an overall increase, but a relative decrease in Cl-ions in deeper soil layers. The groundwater depth is 1.8 metres; the Cl-content of the groundwater is 3.12%.

Some soil characteristics were mapped on a reconnaissance basis and published by West (1955). This is the only report dealing with soils which had been printed and distributed until recently. Many remarks could be made on this report. They are all related to a very fundamental point: no intensive and detailed study of the soils, their characteristics, formation, salinization and alkalinization, location and general environmental conditions has been made.

A general study of the Dujaila area shows that it can be divided into some areas, with different soils (Fig. 94).

The ancient streams, now silted up, shown in Fig. 94, indicate clearly the splitting up of the river into many branches, which is a characteristic of a river delta. The ruined city of Wasit, famous in early Abbasid times, is situated on the former Dujaila river.

Originally most depressions between the streams were Haurs, but most of them have been silted up, probably by rice cultivation. The many irrigation depressions in the

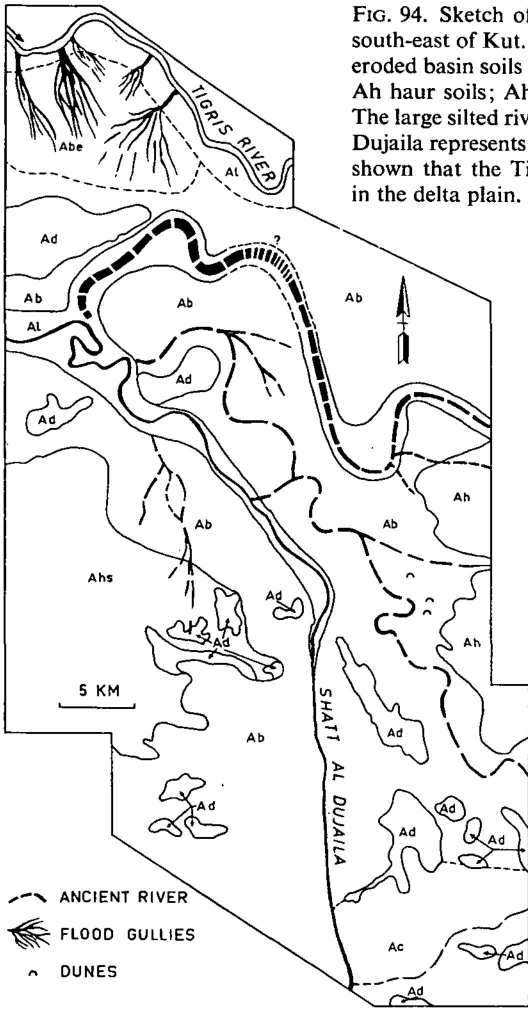


FIG. 94. Sketch of an exploratory soil map of the Dujaila area south-east of Kut. Al Tigris levee soils; Ab silted basin soil; Abe eroded basin soils with flood gullies; Ad basin depression soils; Ah haur soils; Ahs silted haur soils; Ac 'creeked' waste land. The large silted river between the present Tigris and the Shatt Al Dujaila represents a former course of the Tigris river. It is clearly shown that the Tigris river is splitting up into various branches in the delta plain.

former basin area are characteristic. Most are saline or saline-alkali and some even non-saline alkali. The soils are relatively heavy textured (Fig. 95). Boumans (1956) found sodium clays, mostly with E.S.P.s 25–35% and one sample with 51%, although the pH (paste) was 7.5, due to salinity.

It may be expected that there is a considerable flow of Tigris water through the deeper soil layers of the ancient streams, and that there is still a natural drainage of water to the Haurs, even to those which are silted up and cultivated. Such phenomena make soil hydrology in the delta plain rather complicated.

Soil conditions in the delta plain are more complicated than in the meandering flood plain, which is a result of shifting streams, changes in sedimentation, higher salinity and difficult hydrological conditions in relation to deeper soil layers. It is difficult to predict agricultural potentialities with the present state of knowledge and experience. From a point of view of soils, it is evident that reclaiming land in the delta plain is more difficult, that the percentage of potentially productive agricultural land is lower (30% by estimation) and that this land occurs in a much more intricate pattern mixed with non-productive land than in the flood plain.

4.5. Soils of the marsh region

There is hardly any difference between the water and land areas in the extensive marsh regions of Iraq which occupy an area of more than 35,000 km.[2] One soil investigation has been carried out in this area (Fig. 97). Salim (1955) who made a very interesting social-economic study of a marsh village from which much information has been obtained for this chapter, divides the real marsh region of Iraq into three belts:

a. The belt west and east of the Tigris, extending into Iran;

b. The Hammar Lake belt;

c. The belt between the Hilla canal and the Euphrates.

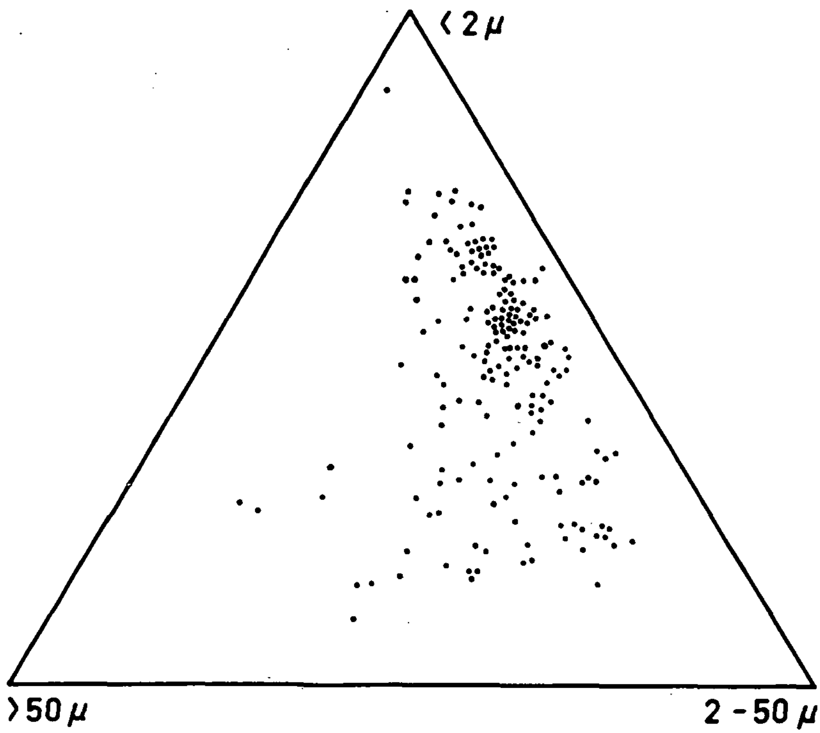


FIG. 95. Graph of the texture of various soils of the Dujaila project area (data from West, 1955).

The marsh area is completely flat, except for a few mounds of ruined cities in the two desert barriers separating the three belts.

The rivers do not have dykes and from March to July, when the rivers are in flood, large areas are covered by water. The shallow marshes become dry land in summer while the deeper ones remain lakes. Generally the depth of the water is 1 to 2 metres, at some places up to 7 metres, which means that part of the lake bottoms are below sea level, e.g. in the Hammar Lake. The land is mostly less than 4 metres higher than sea level. The permanent marsh is approximately one quarter of the flood marsh. As no data concerning the boundaries of permanent and flood marsh are available, this important subdivision of the marsh region could not be indicated on the exploratory soil map of Iraq (map 1).

The borders and shallow portions of the marshes are thickly grown with reeds and rushes. Rice and millet are grown on the marsh borders, which are periodically flooded. Along some streams, narrow low levees occur.

The Euphrates and its branches enter the Hammar marsh belt, but only a small part of this water passes the Hammar Lake and is carried through a new canal, which connects this lake with the Shatt-Al-Arab some 8 km. north of Basra.

The Tigris is also losing almost all its water in the marshes (see Chapter 2.3.).

The silty water of both rivers, which enters the marsh region, returns as almost clear water into the Shatt-Al-Arab, after most of the silt has been dropped. The lower part of the Euphrates is often changing its course because the stream bed is silted up. There is a chain of marsh islands in the Hammar Lake; most of them are parts of river levees of an ancient Euphrates river, as can be deduced from recent aerial photographs (map 1).

In comparison to other sections of Central and Southern Iraq, the climate in the marsh region is more humid in summer (relative humidity 15%); in winter the nights are colder and in July and August, temperatures are higher in the afternoon.

According to Salim (1955), soils near Echchbaysh, situated on the northern side of the Hammar Lake, are mainly loam, porous, friable, with large amounts of lime. There is also a considerable quantity of fine sand. The soils all have a high salinity.

There are hundreds of inhabited islands which have been artificially formed by a constant raising of the land surface due to the laying down of layers of reeds, rushes and earth. They are often used for dates and vegetable growing. Most of the houses (reed huts) are built on the narrow levees beside the rivers.

Approximately 88% of the total marsh regions is uncultivable (Salim, 1955). The cultivable land (Amar) can be used for late summer crops only, because of floods. Rice ($\frac{1}{3}$ of the area) is grown on irrigated or flood land, mostly on or near the banks of the larger streams or canals. A description of the rice cultivation is given by Alghita (1956). Millet ($\frac{2}{3}$ of the area) is grown on non-irrigated land. Sometimes small dykes are built around a few small areas to keep them free from flooding, and barley can be grown. Cultivation of land in the marsh region, however, is rather risky as a consequence of early frost in the autumn and damage by birds and buffaloes. In 1951 approximately 81% of the millet crop was destroyed by frost.

Before cultivation starts, the rushes are cut at about 15 cm. under the water surface. When the water recedes the remaining parts of the plants and other weeds are removed and the soil is exposed to the sun to dry. Immediately after the harvest, the land should be ploughed before it is flooded again. In the non-cultivates semi-marsh areas, a considerable amount of organic material, up to 25 cm. thick, is left behind when floodwater recedes. A common practice is to burn the organic matter in order to get better grazing land. Therefore there is no uniform deep peaty layer over large areas (K.T.A.M., 1954). Most surface soils have an organic matter content of 2 to 3%; subsoils often consist of greenish-grey clay, gleyed, with a pH ranging from 7.9–9.0. The olive-grey soil layers in the marsh soils indicate saline and anaerobic conditions.

A tall (generally 8 m. high) thick reed variety *(Phragmites Karka Trin.)* covers nearly all permanent marshes where there is a dense growth of it. The growing of reeds starts in January; up to June, fodder for cattle and buffaloes is produced. After one year they become dry and yellow and then they are suitable for mat production. If they are older than 18 months, they are not used any more and the plant dies after an average of 4 years. Old reed areas are mostly burned before January to give a chance to the young reeds (Salim, 1955). Burning the vegetation in order to get better grassland and reed beds gives rise to extensive marsh-fires which often get out of control.

The bulrush *(Typha angustata)* is also used for making mats.

The people of the marsh region are pastoral nomads (water buffaloes), reed gatherers (mats and fishing) or cultivators. Their life is hard.

The constant flooding and accumulation of silt does not greatly influence the marsh region. One should expect that the marshes would be gradually silted up, but this does not happen because of subsidence of the earth's crust. It even appears that the Hammar Lake came into existence in about 600 A.D. (Le Strange, 1905). According to Lees and Falcon (1952), synclinal subsidence is still going on, which explains the presence of the extensive marshes. As subsidence is episodic, the depressions tend to fill up with sediment during the intervals. General subsidence, however, is still dominant.

The area south of Amara is a real rice area where the fields are silted up. Most fields are surrounded by low small earth dams. If irrigated, a breach is made, which afterwards will be closed. Surplus water is drained off at the lowest side of the field. The rice is flooded until it becomes yellow. Each farmer tries to get as much silt as possible on his land. More silt means better rice land, according to the farmers. Large floods make rice land good. Although the flooding is not a controlled flooding, much is done to direct the water through canals to the land. The canals finally end in the marshes into which excess water is drained. When land at the beginning of the canal is silted up to a too high level, rice-growing is abandoned and new fields towards the end of the canal are used. In this way new land has been made in the marsh area (see Fig. 96). This type of land reclamation probably dates from Archeamenian times, when rice cultivation was introduced in Mesopotamia (Ghirshman, 1954).

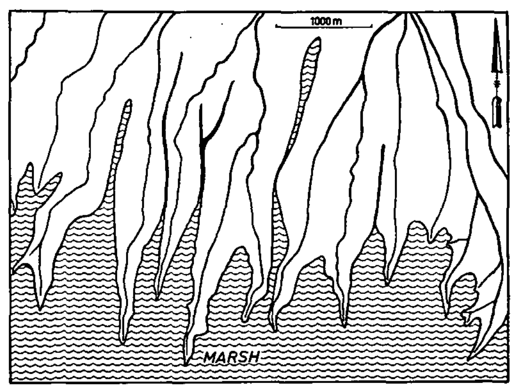
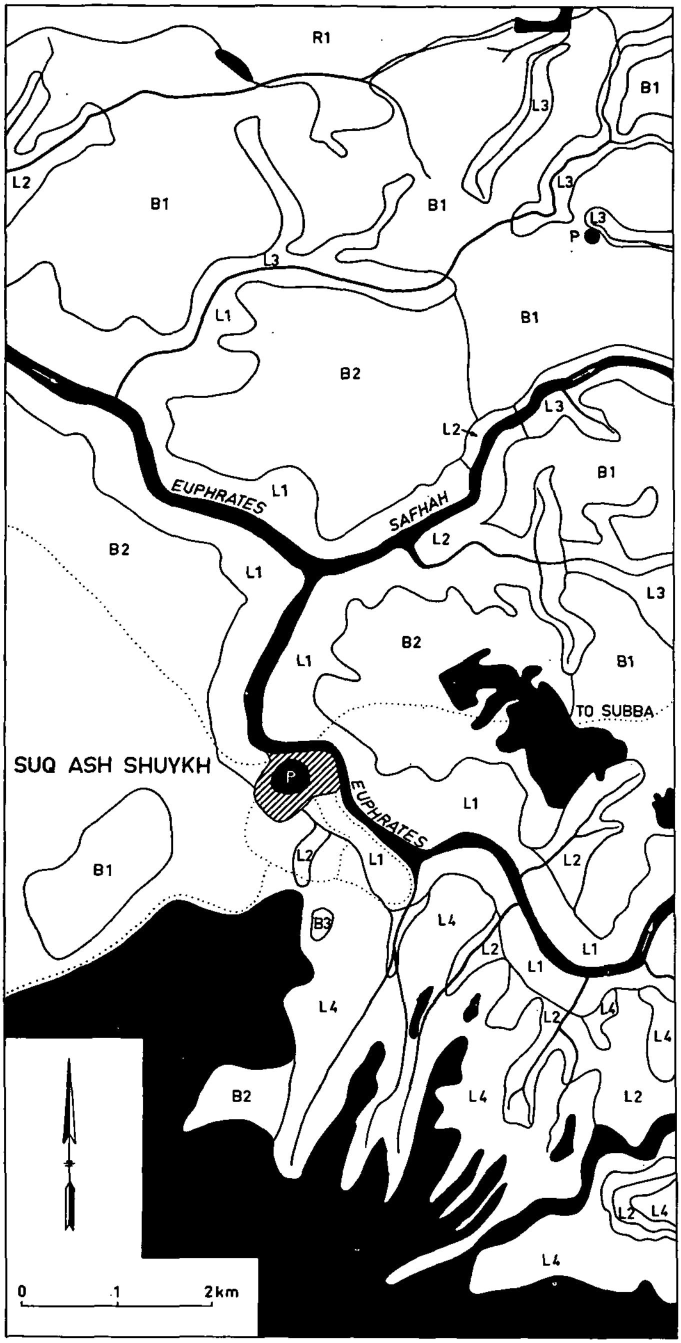


FIG. 96. Map of an area south of Amara. Marshes are gradually being silted up as a result of rice cultivation. Large areas of land are formed in this way. It is probably the oldest system of land reclamation in the world.

The marsh people depend on spring floods, which in the near future will decrease and be more controlled, when all the dams and barrages in Iraq are built. Some flooding can and has to be permitted in the marsh region but rice cultivation in Southern Iraq has to face several problems in the near future.

The deposition of silt probably is not the most important factor for good rice land. It may perhaps be the excess flood water which streams slowly over the rice fields, bringing fresh water to the plants and carrying off salts to the marshes. The silt itself does not produce the fertility; this can also be learned from the farmers who turn over the young layer of sediment, which is, according to Russel (1957), to get a better soil structure.



Many canals have to be dug and cleared in connection with rice cultivation. The soil material from the canals raises the level of the canal banks, which then become suitable for date palms (Zeki, 1957).

It is sometimes suggested that parts of the marsh areas could be reclaimed. There are however, probably other areas with better soil conditions which can be reclaimed or improved at lower costs. Perhaps the marsh region will become more important in the very distant future. A better industrial use probably could be made of the reeds, rushes and the papyrus, which, according to Fisher (1950), also occurs over quite large areas.

FIG. 97. Schematic map of the Suq Ash Shuykh, area 25 km., south-east of Nasiriyah. L1 Euphrates levees; L2 Silt levees, high phase; L3 silt levees, medium phase; L4 silt levees, low phase; B1 delta basins; B2 delta basins with a salt crust. The marsh area is coloured black. Some sections of the marsh are silted up during rice cultivation. P tel.

4.6. Soils of the estuary region

At present this is mainly the Shatt-Al-Arab region, where hydrology and soils are influenced by the tides. The effective area of the tides reaches up to Qurna. At a greater distance small differences in water level can still be observed, e.g. near Echchabayah (Salim, 1955) on the northern border of the Hammar Lake, where farmers make use of a few centimetres of tidal water to irrigate and drain their rice-fields. The tides in the Shatt-Al-Arab are approximately 50 cm. during periods of river floods, and 2 metres during the rest of the year (K.T.A.M., 1954 and Vaumas, 1956).

The sedimentation pattern in an estuary region is different from the rest of a river plain. Levees are formed along the rivers and along the many creeks and canals from the river to the extensive tidal mud flats behind the levees.

The river levees along the Shatt-Al Arab which are situated at about 3 metres above sea level, are used for date gardens (14 million date trees), sometimes with a vegetable undergrowth. The mud flats with intricate crack systems are waste land, about one metre above sea level.

The tidal effect in the river is important for agriculture. Date gardens are irrigated and drained twice a day. The principal date district extends as far as Seebach (opposite Abadan) where river water is mixed with salty seawater.

There are numerous silt ridges throughout the area as a result of the piling up of surface soil material in between the date trees to lower the land. This is done to facilitate irrigation. The creeks and irrigation canals in the Basra zone have to be cleaned regularly, as there is silt deposition.

The river levee soils along the Shatt-Al-Arab are non-saline or only slightly saline, as a result of the tides. This was already observed by Webster (1921). It is expected that salinization will increase, particularly near Qurna, as a consequence of flood control upstream. Salt accumulation is a problem in the transitional zone from the estuary levee to the mudflats, especially at the lower end of the canals and creeks.

There are wide areas with alkali soils west of the Shatt-Al-Arab according to K.T.A.M. (1954); more than 85% of the soil samples have a pH of 8.6 or higher. The sodium and boron content of the soils also seems to be high.

An old channel of the Shatt-Al-Arab has been silted up and is now cultivated land. The river has shifted to the north-east. According to Lees and Falcon (1952) there are many old channels and canals, even south of Basra. Abandoning the former irrigated area seems to be a result of the general subsidence of the area (Lees and Falcon, 1952). The old course of the Euphrates east of Zubair has already been mentioned (map 1).

Little is known at present about the real soil conditions of the estuary region. It seems, however, that most of the extensive tidal flats do not have any potential value. The date gardens on the levees are world famous.

4.7. Soils of the coastal region

Soils near the sea consist of extensive mudflats at the same level as the sea. They are often submerged by seawater over a distance of many kilometres inland. Sedimentation is marine; clays are sodium clays (K.T.A.M., 1954). The soil contains sea shells or their fragments.

Lees and Falcon (1952) have proved that parts of these flats were once cultivated; there are also abandoned irrigation canals, probably dating from Abbasid times. The area is abandoned and submerged as a result of gradual subsidence of the earth's crust. The Khor Zubair tidal embayment is likely to be a subsidence phenomenon too, according to the same authors. They also explain and prove that the Twin rivers are not building forward a normal delta as is often stated. The rivers are discharging their sediment into the tectonic basins of the geosyncline, mainly into the marshes.

The soils near Fao are extremely saline and soft, and the erection of high or industrial buildings requires much attention.

The potential agricultural value of the coastal region seems to be very low.

4.8. Soils of the eastern section of the plain

On the map in Fig. 87, a few soil units belonging to this land type are indicated. The soils are saline to strongly saline, often flooded, marshy and almost waste land. The distance to the Tigris river is too far for irrigation; the amount of water from the Iranian mountains and hills is small and it is not suitable for irrigation because it has a high salt content. There are many large depressions with gully patterns (Fig. 99), clayey soils and gilgai relief.

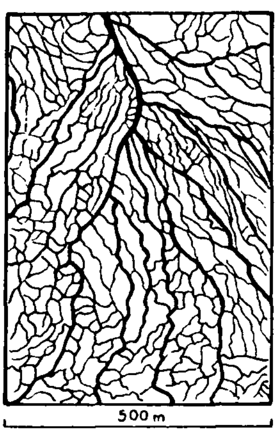


FIG. 99. Gilgai gully pattern in large flats east of Baghdad. The area shown is a section of unit 12 in Fig. 87.

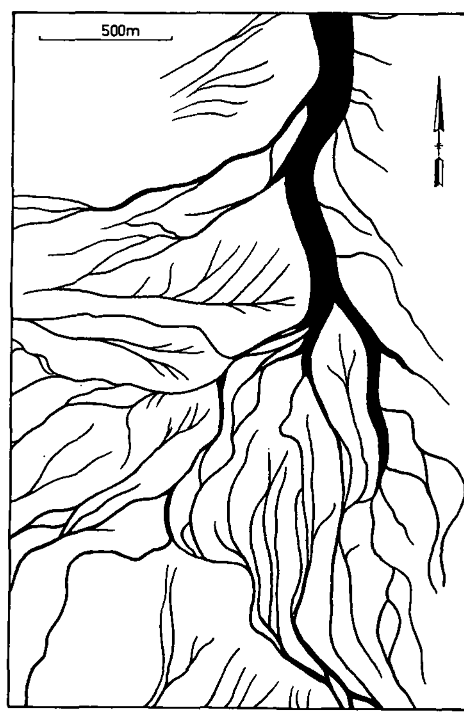


FIG. 98. Flood creeks in periodically flooded land bordering the Iranian highlands, east of Baghdad. The area shown is a section of the Haur es Subaicha, represented by unit 13 in Fig. 87.

The water coming down from Iran into the area east of Amara is also very brackish (Webster, 1921). It is spread over the valley bottoms, forming a typical flood pattern (Fig. 98). As a consequence of these factors, the potential agricultural value of this section of Iraq is low.

Hardly anything is known about the soils of the fans at the foot of the hills. There are a few towns and villages in this area with small irrigated areas. Irrigation water is mainly from wells which are limited in number, and also somewhat brackish. The potential agricultural value of the fans therefore seems to be quite low.

CHAPTER 5

SOILS OF THE DESERT

5.1. General soil conditions and soil formation

More than half the land surface of Iraq consists of deserts. Hardly any attention has been paid to the soils of these arid areas because the agricultural potentialities are extremely low. First of all the climate, which is very dry and hot, is a limiting factor. Besides this, large areas consist only of barren rocks or stony plains, or the surface may be covered by a desert pavement.

The deserts of Iraq are parts of the extensive Syrian and Arabian deserts. A subdivision is made into:

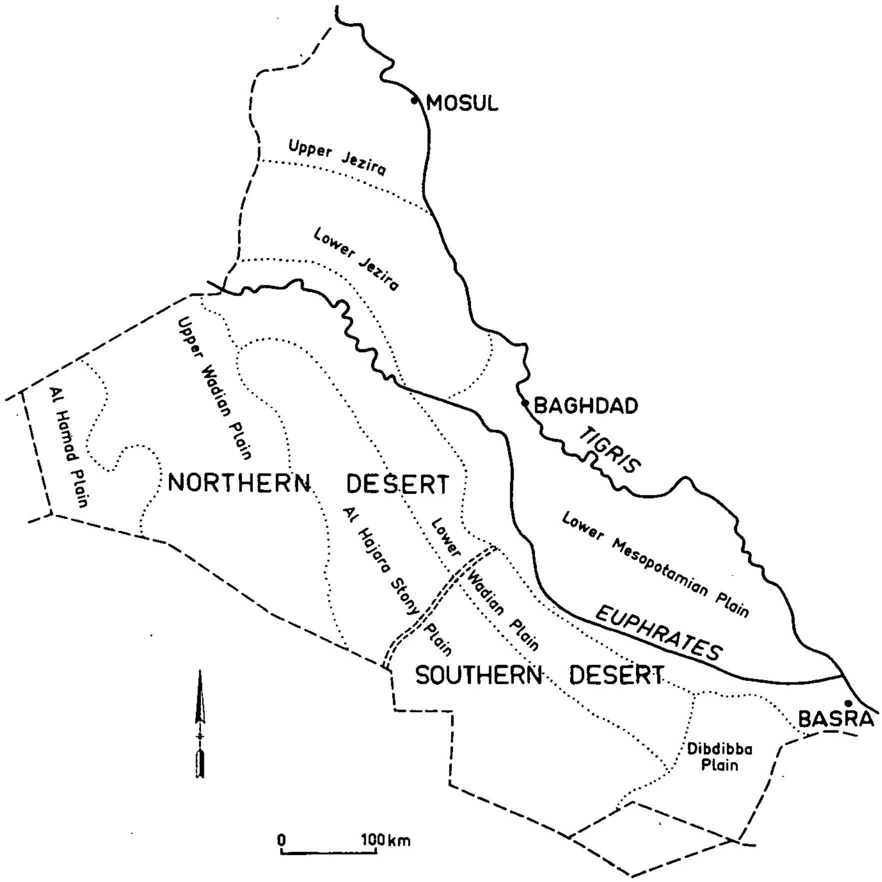


FIG. 100. Map of physiographic units of the desert areas.

1. *The Jezira Desert*, which is an extension of the Jezira desert of northern Syria. It is mainly a gypsum desert.

2. *The Northern Desert*, sometimes called the Western Desert, which is similar to the adjacent desert in Syria and Jordan. It is a limestone desert.

3. *The Southern Desert*, which to a certain extent is similar to the Arabian desert. The northern portion is a limestone and the southern and eastern portion a sandy and sand-dune desert.

From a geomorphological point of view the following classification could be made: (see Fig. 100)

1. *The Lower Jezira Plain*, mainly developed on gypsum, level to slightly undulating with many depressions. The northern half has a semi-arid climate; it grades into the steppe area of the Upper Jezira Plain.

2. *The Lower Wadian Plain*, developed on limestone and gypsum, level to undulating with shallow wadis.

3. *Al Hajara Stony Plain*, a flat, stone covered desert on limestone, with some wadis.

4. *The Upper Wadian Plain*, developed on limestone, with an intricate pattern of deep, often steep-walled wadis (Fig. 101).

5. *Al Hamad Plain*, also developed on limestone, almost level and featureless.

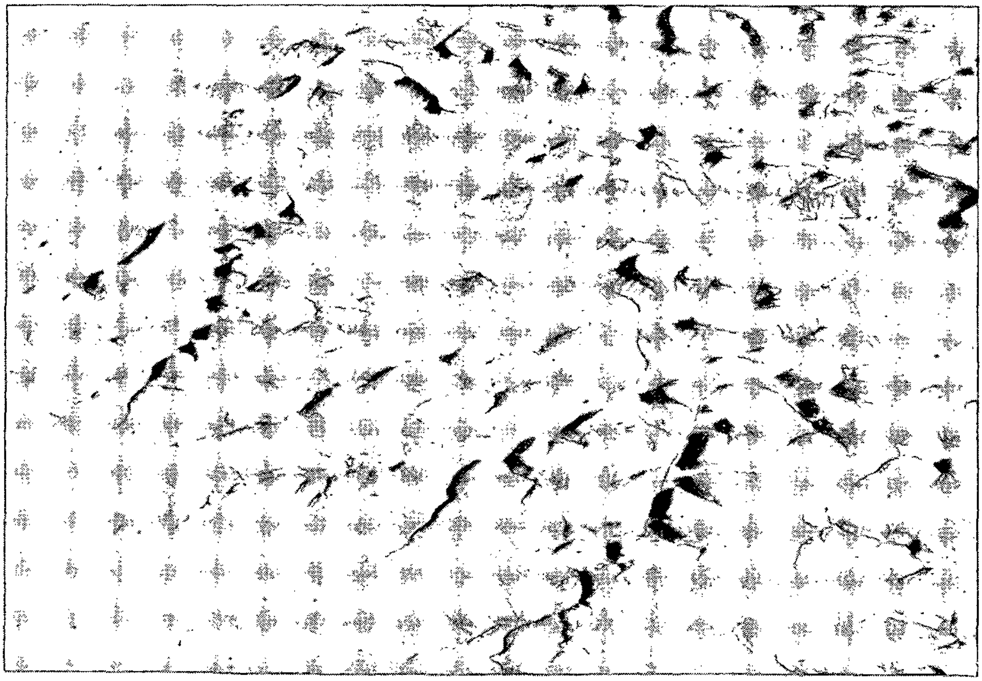


FIG. 101. Aerial photograph (oblique) of a section of the Upper Wadian Plain (Northern Desert). The steep, high walls of the dry wadi are clearly visible.

6. *The Dibdibba Plain*, developed on sand and gravel, slightly rolling to completely level.

7. *The Sand Dunes*, dune land, up to 35 metres high dunes, rather stable at present.

Each of these physiographic units has its particular soil conditions which are closely related to lithology, topography and drainage. In the following descriptions, much information on these subjects is taken from the unpublished reports of the Parsons Company (1955), which has done intensive groundwater surveys in these desert areas. Mitchell (1956) has published an article on the physiographic provinces, the stratigraphy and structure of the Northern and Southern Deserts.

The physical weathering of rocks predominates as the climate is arid, and consequently only a small quantity of water is available for hydration, solution and leaching. There are big diurnal changes in temperature, – even daily variations of 40°C. are not rare. The barren land surface becomes intensively heated in the daytime, whereas there is a high radiation during the night. Gautier (1946) has observed that soils in the Sahara Desert are much hotter during the day and much colder during the night, than the air. Generally speaking, chemical and biological weathering are unimportant.

In arid areas, clay formation is an extremely slow process. Even in older soils, no textural B horizon can generally be observed, but on some spots a weak textured B horizon may be formed. Soils which are rich in clay occur in depressions. This clay is a lacustrine deposit from weathered mud and siltstone; it is often colluvium, which is accumulated in shallow, closed basins. The clay accumulation is a result of occasional torrential rains. The fine textured material dries out quickly; it shrinks and cracks intensively in summer. Similar soils are called 'polygonal soils of torrid, arid deserts' by Sigmond (1938) and salted bottom lands or 'Sebkhas' in African deserts.

Well developed soils were not observed in the desert regions of Iraq. This is mainly a consequence of wind erosion, which is the most important soil forming factor in these desert regions, where the surface soil is not stabilised, due to the absence of a vegetation cover. Water erosion is another important factor in transporting surface soil material. Finally a desert pavement (surface accumulation of gravel), a crust or a stone or pebble layer is formed, which protects the soil beneath from being blown off.

Very large parts of the Iraq deserts are affected by water erosion during violent rainstorms in spring. Outwash fans and wide, deep gullies and wadis can be observed from the air on the flight from Baghdad to Beirut (Fig. 101). The effect of water erosion, whether recent or Pleistocene, cannot be overestimated. Many sediments in the deserts could be called 'fluvio-arid' sediments, a term introduced by Gautier (1946) for similar sediments in the Sahara desert.

Aeolian sediments are extensive in the gypsum and sand deserts, forming thin sheets of sand, and low and high dune land. (Figs. 102 and 103). Large areas are barren rock land or covered with rather sharp-angled pebbles and gravel. In contrast to humid areas, where the pebbles are rounded, the angles on the pebbles in the Northern and Southern desert are often sharp.

Vegetation is very sparse or almost absent and biological activity is low. Thornton (1952) states that arid soils are often porous as a consequence of carbon dioxide production by bacteria, actinomycetes, fungi and even algae, which mostly occur at some

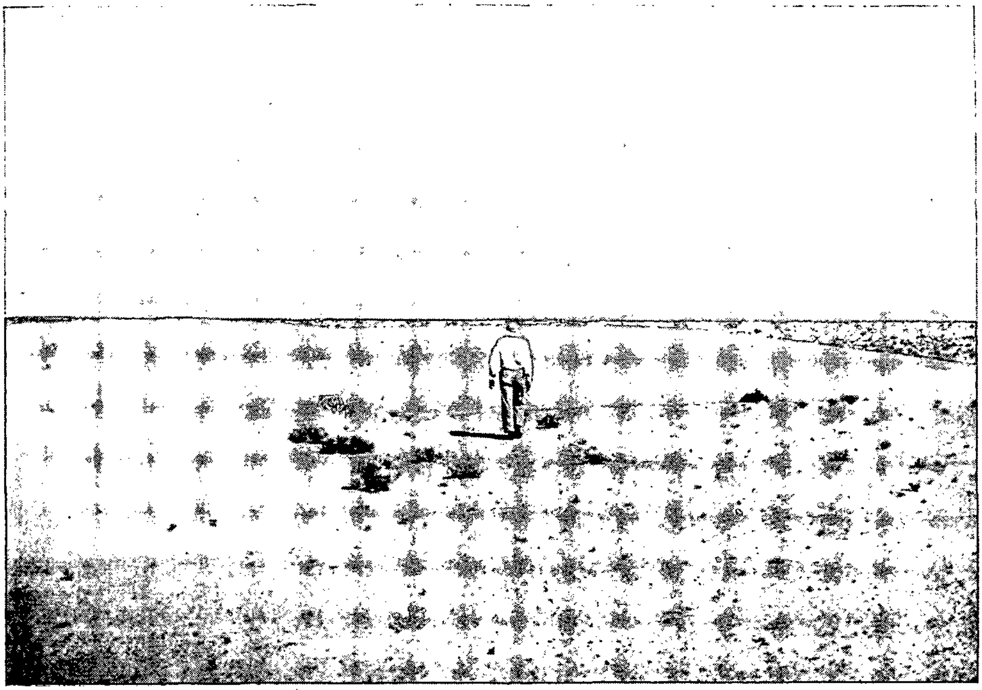


FIG. 102. Low barkhan sand dunes in the Northern Desert near Kerbala.

depth and not near the surface. He also indicates that the normal methods of microbiological soil investigation for humid soils cannot be applied to arid soils.

Where vegetation is present, xerophytic shrubs and some annual grasses occur. In the semi-desert areas, some perennial grasses *(Poa bulbosa* and *Carex stenophylla)* are the most widespread (Zohary, 1950). There is a significant difference in vegetation in the sandy, more clayey and saline areas. Bushes only occur in areas where their deep roots can reach the groundwater.

Differences in relief are important in the desert regions. Slight depressions have a thicker soil layer and they receive an extra amount of water due to runoff from the surrounding slopes. In the deeper and larger depressions, young sediments have accumulated and soils are marshy and saline because the groundwater level is high.

It has already been explained (Chapter 2.2.) that annual and regional variations in rainfall are important. In addition, there are also local differences in soil humidity due to differences in relief. Therefore it is impossible to map somewhat detailed boundaries in the deserts. There is always a gradual transition to the steppe area which is characterised by a continuous grass cover.

For Iraq a subdivision could be made into:

a. Real desert areas with generally less than 150 mm. rainfall;
b. Semi desert areas with generally 150–250 mm. rainfall;
c. Steppe areas with generally 300–500 mm. rainfall.

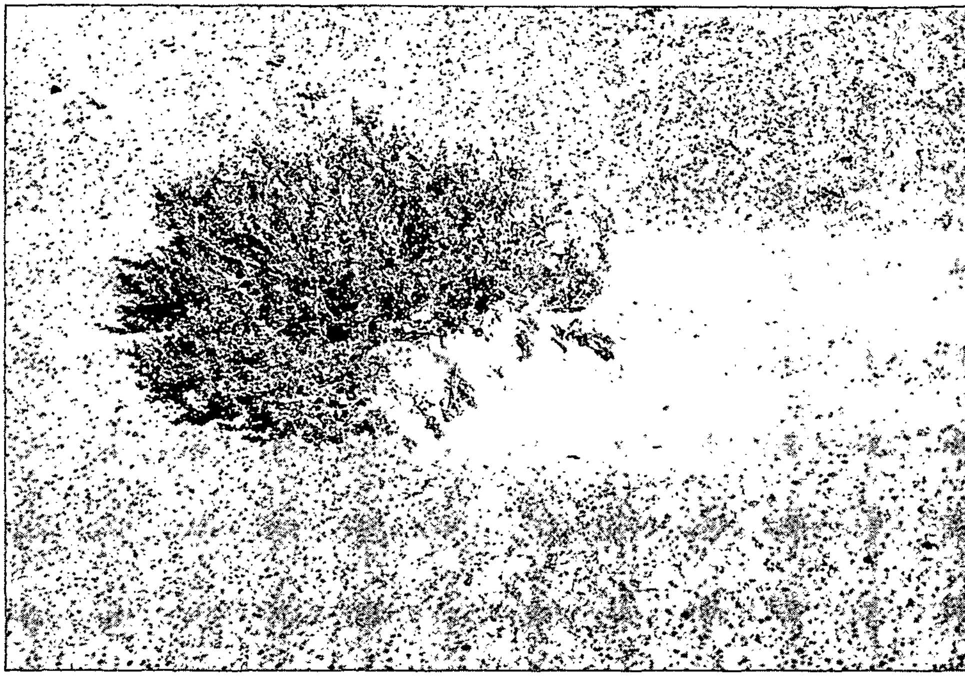


FIG. 103. Small sand dune behind a bush in the Northern Desert. Around the dune the soil is covered by a desert pavement.

This subdivision can be correlated with that introduced by Zohary (1950) for the phytogeography of Iraq. It must be realised that a large portion of rainwater evaporates immediately. Therefore the amount of water available for plant growth and soil formation is much less than is indicated by rainfall data.

Soil formation, and particularly land morphology of the deserts, cannot be understood without taking into account the changes in climate during the Pleistocene. There have been at least a few pluvial periods; during the Palaeolithic period there has been at least one (Voûte, 1957). Arguments are:

1. The existence of large, wide wadis and deep gullies in the Northern Desert, indicating periods of high stream activity;
2. The presence of extensive drainage systems in all deserts, also indicating periods with a more humid climate;
3. The existence of former inland lakes, which are now dry;
4. The occurrence of terraces, indicating alternation of more humid and more arid periods.

As a result of the typical characteristics of climate and vegetation in the desert areas of Iraq, some properties are common to all soils, although there are slight differences among soils developed in the extreme dry desert of the south and the relatively more humid semi-desert in Jezira. The organic matter content of the soils is extremely low, but there is a slight increase in the direction of the semidesert, where a little organic matter is accumulated in the surface soil, forming a weak A-horizon. This is mainly a result of the presence of a thin grass cover. In the direction of the semidesert, there is also a slight increase in depth of the solum. Accumulation of lime and gypsum (if present) in the surface soil increases in the direction of the real desert soils. Some leaching of lime or gypsum can be observed in the semideserts.

Generally the lime accumulation horizon becomes harder in the direction of the driest deserts. Although oxidation of iron is low, there is a slight increase in the relatively more humid soils, causing an increasing redness.

The layer of loose soil material is thin and soils are shallow, except in some depressions and wadi bottoms.

Where normal soil development has not been interrupted by erosion, soils may be classified into the following Great Soil Groups of which a description is given in Chapter 3.3:

Desert Soils, Red Desert Soils, Sierozem Soils, Minimum Reddish-Brown Soils, Lithosols, Regosols.

Some typical soils, almost without profile development are:

Hammada Desert Soils, – soils which are covered by stones and pebbles;

Gravelly Desert Soils, – with a gravel desert pavement at the surface, often without vegetation;

Desert Dust soils, – Consisting of almost loose soil material, covered by a slight hardened, very thin (1–2 mm.) soil crust of a somewhat dusty grey colour. It has been formed by fungi and algae under the influence of slight rainfall. Various specimens of different coloured fungi can be observed on the land surface.

In addition to the reports of the Parsons Company (1955), an article by Mitchell (1956) there are some unpublished reports by the Oil Companies, the vegetation studies by Zohary (1940, 1950) and Springfield (1954) and some books on general geography (Grand, 1937; Fisher, 1950). The Russian literature on similar desert soils has been summarised in French by Kovda (1954). The small-scale topographical maps, the geomorphological map of Raisz (1951) and the geological map of Iraq (1938) are not accurate. The report by Gibbs (1954) gives a general idea on soil erosion. The proceedings of the International Symposium on Desert Research (1952) are also important for the study of Iraq desert soils.

5.2. Soils of the lower Jezira

The southern portion is a true desert, with an annual rainfall of approximately 125 mm; the northern part is a semidesert (225 mm.) grading into the steppe zone of Iraq.

Vegetation is sparse and increases in a north-easterly direction. A salt tolerant sagebush is rather common. In winter and spring nearly the whole desert and especially the northern portion, is covered by short desert grasses, which provide grazing land for camels and sheep. In the extreme north-eastern section, some areas are under dry farming (wheat, barley) and mechanical methods of cultivation are employed.

Almost the whole region consists of massive Lower Fars gypsum and anhydrite with some silt- and mudstone and occasionally limestone. In the central and southern

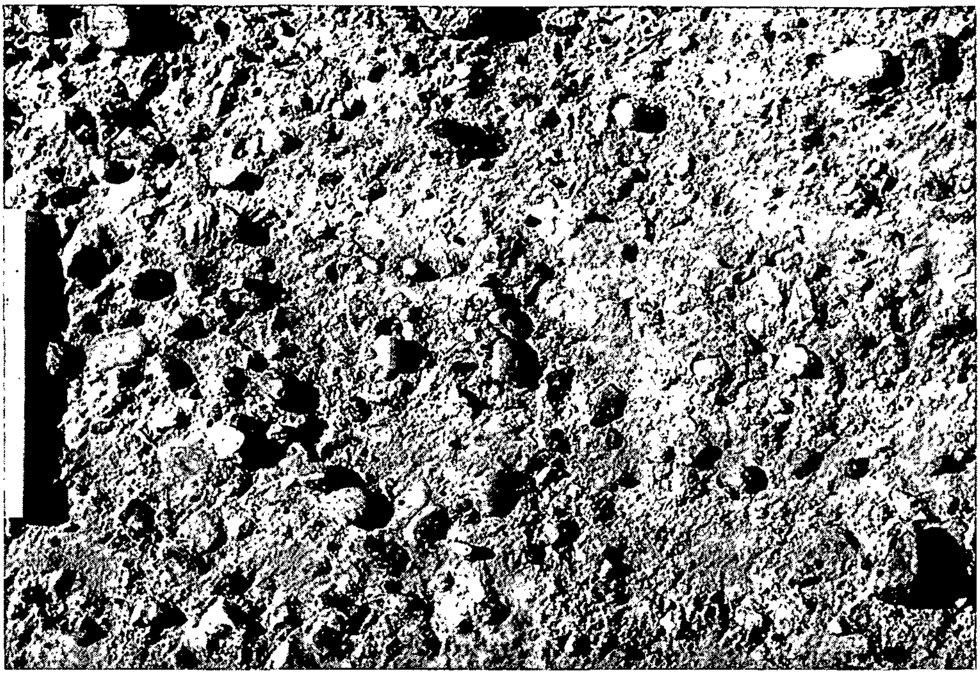


FIG. 104. Close-up of a desert pavement (the ruler is 10 cm. long).

sections of Lower Jezira the gypsum, which often has a marble-like appearance, is often exposed at the surface. In many parts of the desert, vertical gypsum plates in a pentagonal pattern occur near the surface (Fig. 54 and 106). Desert pavements (Fig. 104) are common.

The Lower Jezira plain is flat with little relief, except in the north-east where it grades into rolling land. There are many depressions, marshes and shallow saline lakes. In most depressions the surface is covered by a salt crust. Some of the larger depressions are real playa lakes. The Wadi Tharthar depression is the largest in Iraq. Since 1956 it has been used to store excess Tigris water which was diverted near the Samarra Barrage in order to prevent flooding of the Lower Mesopotamian Plain. The origin of this depression was attributed to down-faulting (Williams, 1945) or to wind erosion (Kitchen, 1948). The whole area of the depression is now being studied by the NEDECO consultants.

The drainage pattern, characterised by smooth valleys, is inconsequent; most valleys end in playa lakes. The Wadi Tharthar pattern is subsequent.

The soils are of aeolian, lacustrine and fluviatile origin. They are underlain by bedrock (gypsum) at a shallow depth. Most soils consist of weathered gypsum material with a high salt content. The depth is a few decimetres only. The somewhat yellowish-grey coloured soil material is susceptible to wind erosion, forming sheets of sand-like,

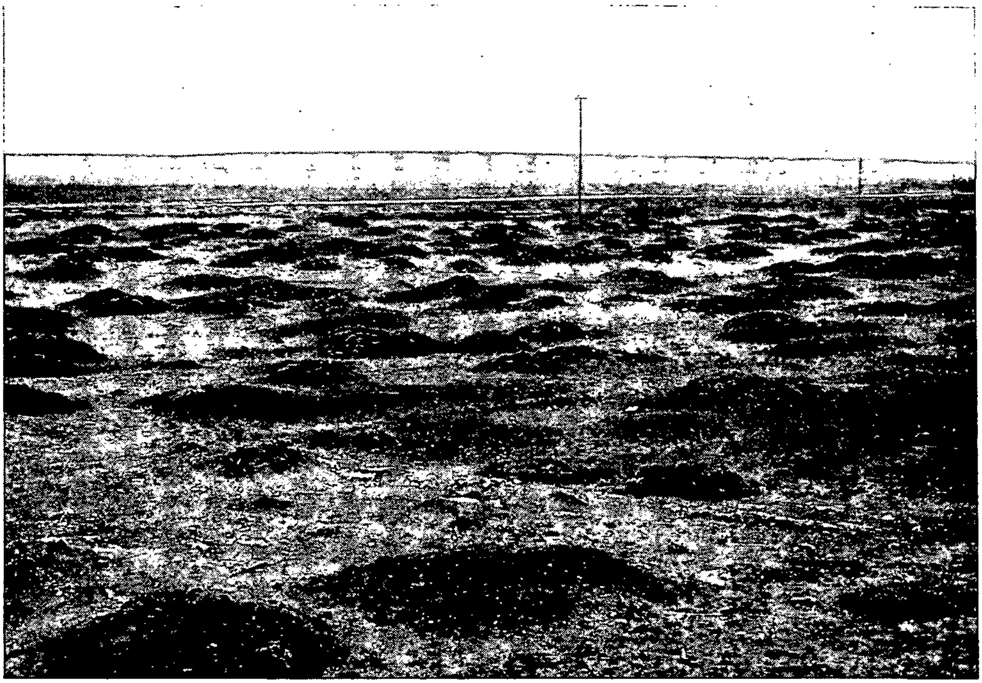


FIG. 105a. Typical micro topography of gypsum land, Jezirah, near Tel Afar. The sandy weathering products of shallow gypsum soils are liable to wind erosion and small hummocks have been formed.

highly gypsiferous grains. Extensive areas of small sand dunes, 20 to 30 cm. high and 0.5–1 metre in diameter are characteristic for the gypsum desert (Fig. 105). In some areas, secondary gypsum (juss) is accumulated on the surface. In central and southern Lower Jezira, some areas where the gypsum is not directly on the surface have somewhat reddish coloured silt and clay soils. In the west and north-west portion of Lower Jezira, aeolian sands occur in small dunes, scattered with bushes, they are derived from sand and siltstone outcrops of the Upper Fars. In the north-eastern portion of the desert, greyish or reddish-brown soils of loamy sand, loam and silty clay occur in the smooth valleys. In the depressions, hydromorphic clay and silty clay soils with a high salt content are found. Normal soils in the Lower Jezira belong to the Sierozem and in the north-east to the Minimum Reddish-Brown soils.

5.3. Soils of the northern desert

There is a gradual increase in rainfall from south to north. Vegetation (grasses and occasionally bushes) is scarse. Grasses and wonderful wild flowers grow in the wadi bottoms in spring. In some shallow wadi bottoms, even dry wheat farming is practiced, but these areas are very small indeed. According to Zohary (1950), the northern section of this desert is phytogeographically nearer to Jezira, whereas the southern section resembles the Southern and Saudi Arabian Desert.

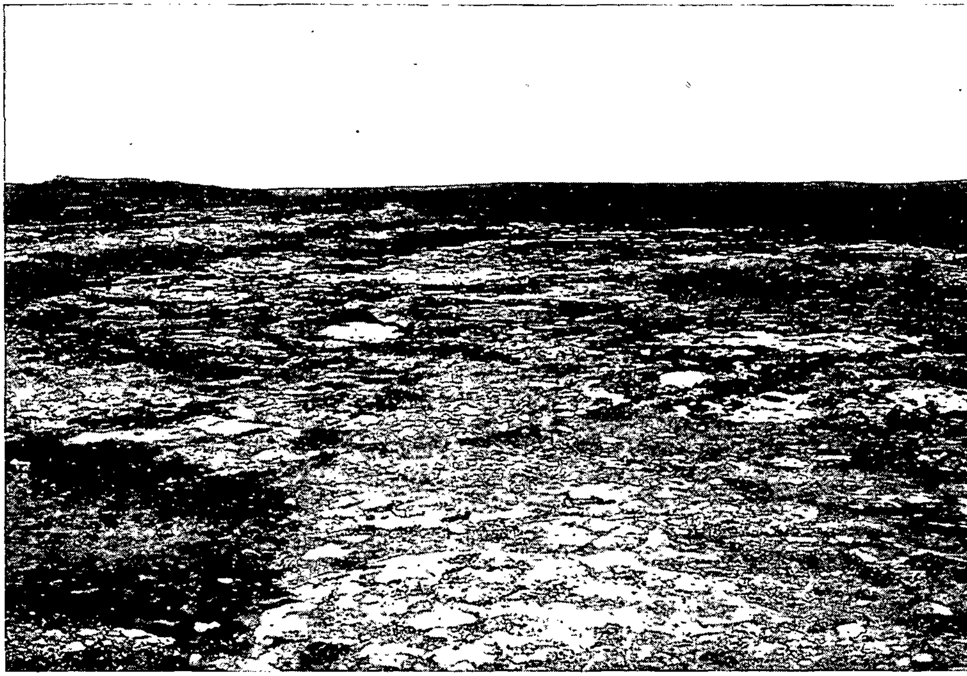


FIG. 105b. Shallow gypsum soils near Tel Afar. Gypsum outcrops at many places. Sometimes a gypsum crust is present, too.

From a physiographic point of view, the Northern Desert from west to east consists of:

1. *The Al Hamad Plain*, a featureless plain, with a few wadis, draining to the north.

2. *The Upper Wadian Plain*, with many steep walled wadis which have a dendritic pattern. Some cliffs are 70 or more metres high (Fig. 101). There are some terraces along the large wadis (e.g. Wadi Tubal and Wadi Musad), which, according to Parsons (1955) record several cycles of erosion, partly due to regional uplift of the whole area and partly to fluctuations in climate. The large Ga'ara depression north of Rutba is filled with lacustrine and fluviatile material. A morphological study of this area has been published by Boesch (1949).

3. *The Al Hajara Stony Plain*, a stony desert, slowly rising to the west. The surface is covered with pebbles and cobbles of limestone, flint and chert, which are dark coloured on the surface due to desert varnish. Flint often occurs as nodules in limestone in irregular beds. It is formed by chemical precipitation of silica.

4. *The Lower Wadian Plain*, with many shallow wadis, draining into the Abu Dibbis and Habbaniya Lakes. The buttes are characteristic of isolated remnants of hard resistant limestone (Parsons, 1955). A few minor wadis have cliffs. The large Abu Dibbis depression is mainly filled with fluviatile and lacustrine sediments.

Nearly all wadis of the Northern Desert have an easterly or north-easterly direction; most of them do not have a connection with the Euphrates. The original wadi system must have already been present in the Tertiary, but it has been influenced during the pluvial phases of the Pleistocene (Boesch, 1949; Voûte, 1956).

The soils in the wadi beds contain subrounded, pink and white coloured cobbles and pebbles of limestone and siliceous rocks, mixed with brownish calcareous sand, silt and clay (Parsons, 1955). The areas in between the wadis have a shallow or very shallow soil layer, often mixed with or covered by cobbles and pebbles with a dark brown to blackish desert varnish. In shallow depressions, the soils are heavier textured muds, showing typical cracks in the dry summer; sometimes more sandy and silty soils occur. The fluviatile or lacustrine layer is approximately 3–7 metres thick, and near the surface often stained with iron rust (Parsons, 1955). Some soils in depressional areas have characteristics similar to those occurring in Russian deserts and described by Lobova (1956) as Grey-Brown Soils, a new Great Soil Group. Some of the depressions are bituminous and have yielded asphalt from ancient times up to the present day. There are gravel crusts, cemented by calcium carbonate. Water erosion, particularly sheet erosion, has transported much material. Aeolian deposits are not extensive in this desert, although in and near some wadis, mixtures of finer grained quartz and somewhat coarser grained limestone and dolomite do occur (Parsons, 1955). Locally there are small sand dune areas. The soils of the extensive monotonous stony areas are often called 'Hamada Soils', a name often used for similar soils in other countries and for Iraq also applied by Zohary (1950).

The desert varnish, which colours the surface of the stones dark, is often associated

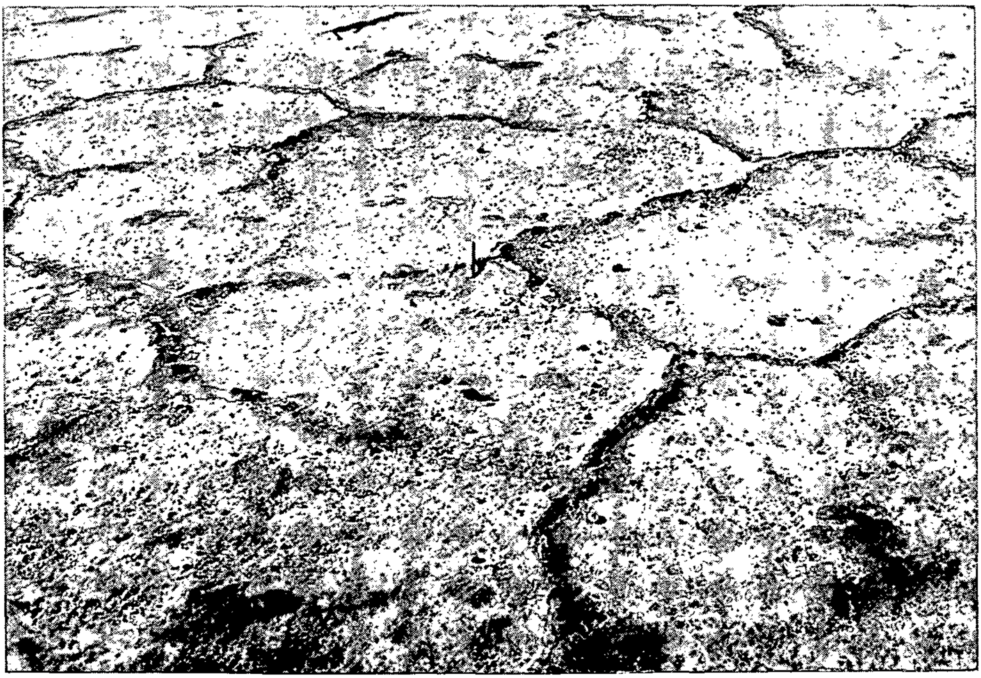


FIG. 106. Polygonal pattern of vertical gypsum plates (see Fig. 54) in gypsiferous soils near Samarra.

with limestone deserts. It consists of a very thin (0.5–2 mm.) dark brown to black coloured material on hard stones or rock masses, not on marl or gypsum. Sometimes it is called 'Desert Lac' or 'Desert Rind'. Durand (1954) and Laudermilk (1931) explain this hard coating, which resembles enamel, as being formed by rain. Water penetrates into the upper part of the rock, and due to evaporation, salts come near the surface. It seems that the precipitation mainly consists of iron and magnesium hydroxide and possibly silica.

The soils of the extensive Abu Dibbis depression north-west of Karbala are strongly saline soils, mainly of the Sabakh and External Solonchak type. Since the lake is used to store excess flood water from the Euphrates, which is diverted near Ramadi via the Habbaniya Lake, it is now much larger than before. In the spring of 1955 the salt content in the Abu Dibbis Lake was 9000 p.p.m., and at that time there was approximately 50×10^6 metric tons of salt in the lake. (Nedeco, 1956). Around the shores of the depression, the soils are sandy and clayey and often mixed with gravel, whereas the lake bottom soils are mixtures of fine sand, silt and clay. According to Voûte (1956, 1957), who made a geological study of this area, the depression is of palaeolithic age and its origin is due to tectonic movements. Formerly there was a connection between the lake and the Lower Mesopotamian Plain through the Razzaza valley north of Kerbala, which is now filled up with younger sediments.

Voûte (1956, 1957) found evidence of recent tectonic movements south of the Abu Dibbis depression. He also describes some new geological formations.

5.4. Soils of the Southern Desert

The Southern Desert has a true desert climate. Rainfall is extremely variable. As Salam has an average annual precipitation of 71.4 mm. (1936/53), with a maximum of 132.9 mm. in 1938 and a minimum of 33 mm. in 1950.

Vegetation is very sparse with some short grasses in more humid years and small bushes in low lying areas. The vegetation in the desert west of Basra has been described by Zohary (1941).

The Southern Desert includes the southern parts of the Al Hajara Stony Plain and the Lower Wadian Plain, which were described in Chapter 5.3. The Lower Wadian Plain in this desert consists of limestone. Hardly any gypsum is present. Another difference is the occurrence of an extensive sand dune area near the eastern side of the desert, bordering the Lower Mesopotamian Plain. The dunes are up to 35 metres high; the major part is stable; there is only local movement of sand and barkhan dunes occur in small numbers on the western and eastern sides of the dune range (Parsons, 1955).

A new land type is the Dibdibba Plain in the southernmost part of Iraq, which extends into Saudi Arabia and Kuwait. It is an undulating to extremely flat (south-eastern part) plain consisting of sand and gravel. According to Parsons (1955) the Dibdibba formation is of continental origin and is probably Upper Miocene.

The north-western part of the Southern Desert has many shallow depressions, some abrupt limestone escarpments and extensive areas of angular limestone boulders. Towards the south-west the desert is covered by sand. There are consequent and in-consequent dry streams. In the rainy season there are many pools of various sizes.

Desert dust soils consisting of aeolian sands are widespread in the south-west. Similar soils in the Sahara desert are called 'Erg'. Soils in the central portion are mainly sandy and silty loams. Clay and silty clay soils occur in the larger depressions which are also saline. Gravel is common along some wadis. Almost all the soils of the Dibdibba Plain are sandy to gravelly. Soil samples of the Zubair areas show 87–96 % sand. Near Zubair well-pump irrigation is practised; however, after a few years the groundwater tends to become brackish and the soils become saline. If the sandy soils of Zubair are irrigated with well-water containing 1000–2000 p.p.m. soluble salts (mainly sodium chloride and sulphate), which are not harmful, the soils will become saline in a few years time, as the salinity level of such soils is much less than 0.15 % (see Chapter 3.5.5.). The reason is the osmotic pressure, which is much higher in sandy than in clayey soils. At present Tamarisk bushes grow in large areas on abandoned saline land. In some wells the water became as saline as sea water. There is probably a layer of fresh groundwater over the saline deeper groundwater, which will be in contact with sea-water. When pumping starts, the fresh water layer is used first and the level of the brackish water rises and finally reaches the bottom of the well. This phenomenon is common in coastal areas and it is being intensively studied in the horticultural districts behind the coastal dunes of the Netherlands.

It is evident that soil conditions in the Southern Desert differ completely from those of the Northern Desert. Sand layers and sand dunes are characteristic of the Southern Desert; they are formed from erosional products of sandstone areas in Saudi Arabia. The colour of the sand dunes is white to reddish-orange; the sands consist predominantly of quartz mixed with some limestone (Parsons, 1955). As the sand dunes are stable at present, it may be concluded that they are fossil dunes and that they have probably been formed in an arid interpluvial phase of the Pleistocene.

5.5. Potentialities of desert soils

As a result of the specific character of the arid climate and the absence of rivers, cultivation of the deserts of Iraq is impossible. Groundwater is available at a few places, but unfortunately most groundwater, especially in the Jezira desert, has a high salt content (Parsons, 1955).

Recent groundwater investigations by the Parsons Company (1955) indicate that most groundwater occurs in a strip along the Lower Mesopotamian Plain. Dry farming in wadi bottoms can be practised in a few minor areas only.

Those desert areas which have a grass cover in winter and spring are often used as grazing land for camels and sheep of the Bedouins. Their drinking water is supplied by wells. Some well-water is used for irrigating vegetables.

The quantity of grass depends on rainfall. Overgrazing is evident near the wells. Bushes are cut, dried and used for fuel.

The agricultural potentialities of the soils of the three Iraq deserts are extremely low, primarily as a consequence of the absence of irrigation water.

CHAPTER 6

SOILS OF THE UPLANDS AND MOUNTAINS

6.1. General soil conditions and formation

Soil conditions in northern and north-eastern Iraq are completely different from those of the deserts and the Lower Mesopotamian Plain, as a consequence of a more humid climate, different vegetation, relief and parent material. Chemical processes of weathering and soil formation become increasingly important. This implies a different approach in the systematic study of the soils and their agricultural evaluation.

Winter rainfall increases from the deserts in a north-easterly direction and it reaches over 1000 mm. near the Iranian border east of Ruwanduz (Fig. 16). The summer, however, is dry and hot, but shorter than in central and southern Iraq. Agriculture is carried out on a dry-farming system in areas with deep soils. Small areas along the rivers and near springs are irrigated during the summer. The dry steppe vegetation of Lower Jezirah gradually grades into the moist steppe with tall grasses and finally into the low forest in the mountain areas.

The parent material of the soils in the uplands and mountains has been derived mainly from various types of limestone, except in Upper Jezirah and in the areas bordering the desert and the Lower Mesopotamian Plain where gypsum, mudstone and sandstone also occur.

The chemical and biological soil forming processes are more important than in the deserts, where physical processes predominate. Real soils with distinct soil horizons have been formed in Northern Iraq. The main characteristics of Northern Iraq soils are:

a. The absence of processes of salinization, except in a few small areas.

b. The presence of some soil horizons, as a result of soil forming processes.

c. A slight process of leaching in the surface soil, accompanied by accumulation of lime (in gypsiferous areas, also of gypsum) at a certain depth below the surface. The horizon of lime accumulation occurs at a greater depth with increasing rainfall.

d. The presence of some organic matter, up to a few per cent. in the surface soils. The soils therefore have a brown to dark brown colour.

Concerning the physiography and geology of the uplands and mountains, which have been discussed in Chapter 2.1., it should be pointed out that normal or geological erosion has influenced and remodelled the whole area, particularly during the last phases of the Pliocene and the beginning of the Pleistocene. Large parts of the parallel mountain chains, forming the anticlines of the Zagros mountains, have been eroded, and the erosional products have been deposited in the valleys, the foothills and the plains. The folding has been very intensive in the mountain region and less so in the zone west of the mountains up to the Jabal Hamrin and its extension to the Sinjar. This explains the physiographic differences between the mountains and uplands.

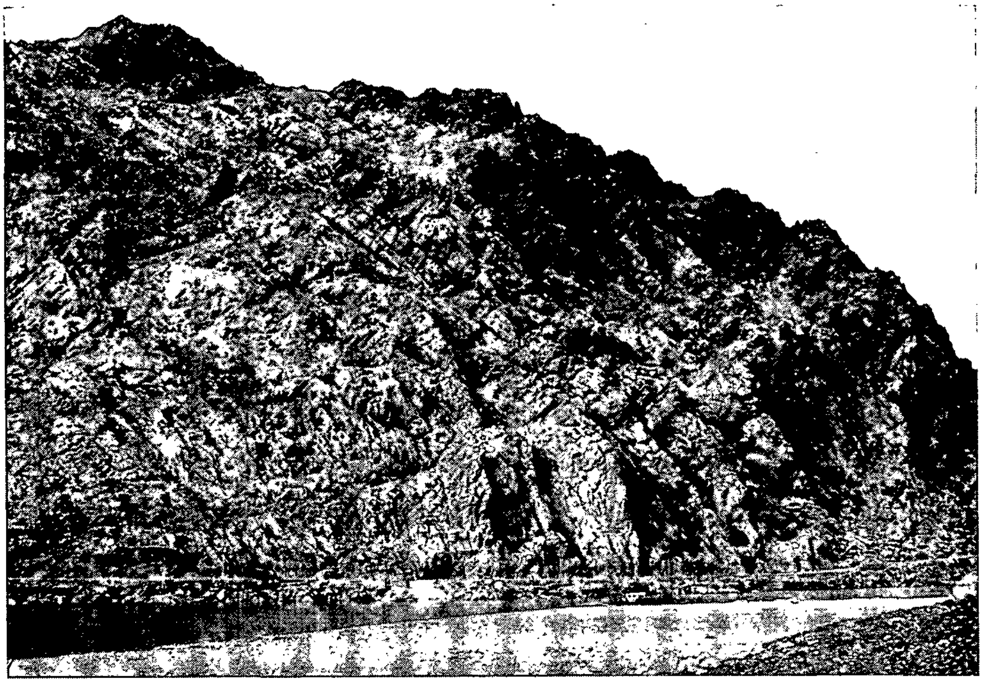


FIG. 107. Part of an anticline mountain in the Sungassar Gorge (Lesser Zab river). The various limestone layers have a dip of approximately 45°.

The remains of the eroded anticlines form the present mountain ranges in Kurdistan (Fig. 107). These mountains have an assymetric character with scarp-like faces on the south-western side which consist almost of bare rock; there are more gentle slopes on the north-eastern sides which mostly consist of very strong grazing land and poor forest land. The anticlines consist of layers of different kinds of rock; consequently different types of soil have been developed which now occur in strips parallel to the mountain crests.

The mountain valleys, which are generally synclinal, are filled up with different kinds of material. The bottom is often filled with gravel of the Bakhtiari formation, which is covered by several metres of fine textured sediment, forming fertile deep soils. During the Pleistocene there have been some periods with intensive erosion in all valleys.

Along the rivers there are small strips of young fluviatile sediments. There are only a few large valleys; most are small and irregularly filled up, often only with small areas of deep soils.

Lithosols, shallow and medium Chestnut soils and Rendzina soils are the dominant Great Soil Groups of the mountains; shallow to deep Chestnut soils in the valleys. In the foothill zone the soils mainly consist of Bakhtiari gravel; Brown soils predominate. The land is hilly or rolling with shallow soils on the hill tops and slopes and gravelly medium to deep soils in the deepest parts of the valleys, which are generally small. Due to geological erosion, deep gullies occur which separate remnants of older terraces with deep Brown soils. These terraces occupy small areas in the foothill zone (Fig. 119).

Over to the west and south-west, these foothills grade into an extensive plain on which the towns of Kirkuk, Erbil and Mosul are located. This plain was the centre of the world in Assyrian times. It is an undulating to rolling plain, the most important dry-farming area of Iraq, with deep Brown soils, underlain by gravel, sandstone and mudstone, and locally by gypsum in the western section.

A similar, although somewhat drier area is the Makhmour plain, north-west of Kirkuk, which is also characterised by Brown soils. South of Kirkuk these soils gradually grade into Reddish-brown soils, making dry farming more risky. Here, some plains occur which are separated by elongated anticlinal hill ranges. The hills, and even extensive parts of these plains, are severely eroded.

The area west of the Tigris river in north-western Iraq is a part of Jezirah, which extends into Syria. It is called Upper Jezirah, and it is an extension of the Lower Jezirah, the desert and dry steppe region, described in Chapter 5.2. Most soils are Reddish-brown to Brown soils with shallow and deep phases. It is more or less divided into a northern and southern section by the Sinjar mountain. Soils of Upper Jezirah are developed mainly in gypsum and limestone. Crust soils are common.

From an agricultural point of view, soil conditions become better with increasing rainfall, when soils change from Reddish-brown to Brown and finally to Chestnut soils. Soil depth is an important factor too, as deep soils prove to be much better than medium and shallow soils. Stoniness, rockiness and soil slope are also significant characteristics in evaluating soils for agriculture.

Soil conditions are closely related to the morphology of the landscape, in which terraces are an important element. The best agricultural land with high potentialities is situated on two of the three terraces which occur throughout the northern part of the country. Although the investigation of the formation and geographical extension of these terraces is in an initial stage, an attempt has been made at the end of this Chapter (6.8.) to describe them.

The processes of soil formation are reflected in the various Great Soil Groups which have been observed and studied in this part of Iraq. Reference is made to the exploratory soil map (map 1).

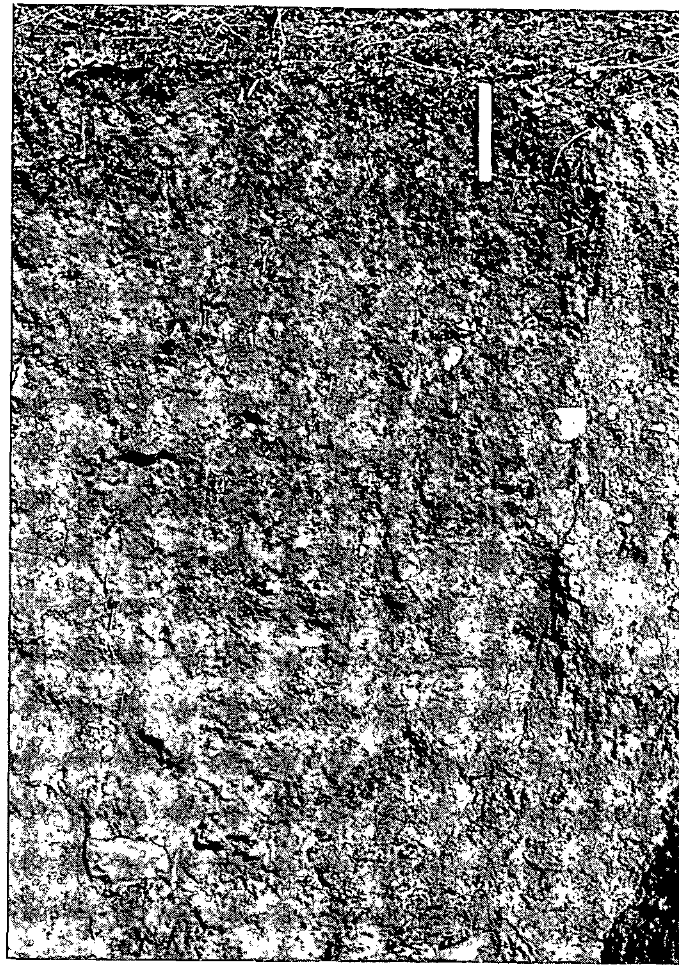
Reddish-brown soils mainly occur south of Kirkuk and near the Sinjar mountain. Only the deep phase has any significance; the shallow and medium phase soils are grazing land.

Brown soils, occurring mainly in the Mosul-Erbil-Kirkuk plain as deep soils, have relatively good possibilities for dry land farming. The extensive areas with shallow soils in the foothill zone, overlying the Bakhtiari gravel, form relatively good grazing land.

Chestnut soils are mostly found in the mountain valleys in a level position on the terraces, and on the lower mountain slopes. The former, being deep soils, are excellent for winter crops; the latter often occur as shallow and/or gravelly phases and are good for grazing.

Reddish Chestnut soils have not been developed over wide areas. They are related to a particular kind of limestone in the mountain region.

FIG. 108. Profile of a man-made soil near a tel, east of Chemchemal. The whole profile up to 2 metres is dark coloured, homogeneous and often mixed with potsheards.



Chernozem soils occur in a few areas as intrazonal soils in the zone of the Chestnut soils.

Saline and solonetzic soils are only found in some depressional areas in the uplands.

Rendzina soils, often with a dark brownish coloured A-horizon, occur throughout the mountain region.

Lithosols are widespread in the mountains and on the low mountain and hill ranges.

Alluvial soils occur near the rivers in the lowest parts of the plain; these are the more Humid-Alluvial soils which differ from the Arid-Alluvial soils of the Lower Mesopotamian Plain.

Hydromorphic soils have been observed in a few depressional areas and small valley bottoms.

Man-made soils occur near tels and ancient towns (Fig. 108).

There are many intergrades. Truncated soils occur everywhere on mountain and hill slopes and buried soils in the valleys.

6.2. Soils of upper Jezirah

The soils of Upper Jezirah are mainly derived from gypsum, particularly in the southern section. More to the east and north, lime and sandstone also occur. The area is relatively flat; some hill and low mountain ranges do occur which are extensions of the anticlines in Central Iraq. In Upper Jezirah these mountains have an almost east-west direction. In between these ranges the land is level to undulating and sometimes rolling. The Sinjar mountain is an important feature in which many wadis commence. These wadis give the land its undulating to rolling character.

The rainfall increases from south-west to north-east from 200 to 500 mm. Sinjar town has an average of 461 mm., but the rainfall is somewhat higher in the vicinity of this mountain. The regional and seasonal distribution of rain is extremely irregular; consequently cultivation becomes risky. Many years are failures as regards crops. There are a number of wells, but this water is needed for human and animal consumption. Crop production depends completely on rainfall. South of Sinjar there is one crop failure in three years; north of it one in five years. This is caused by droughts and sometimes also by locusts (Ali, 1955). The natural vegetation is a steppe vegetation. Upper Jezirah has been a large natural grazing area, occupied by Bedouins. During recent years the land has been ploughed and cultivated; this has not always been a success. Wheat and barley are the main crops in a dry farming-fallow rotation.

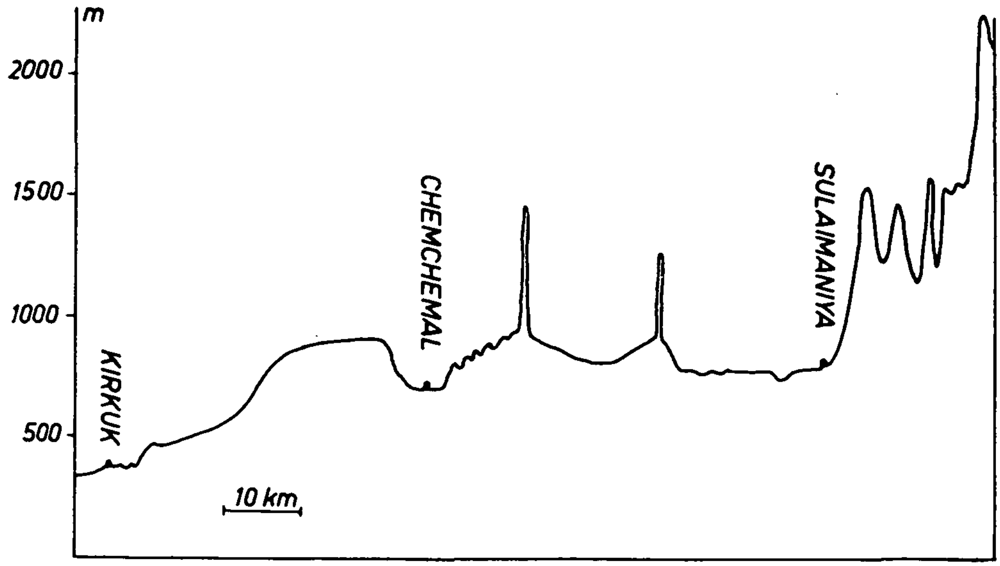


Fig. 109. Cross-section through the uplands and mountains from Kirkuk over Sulaimaniyah to the Iranian border (data from the quarter inch to 1 mile topographical maps, 1942).

FIG. 110a. Profile of shallow Brown soil over Bakhtiari gravel. Only suitable for grazing land.

The soils of the southern half mainly belong to the Reddish brown group, those of the northern half to the Brown soil group. There are many areas with Lithosols on gypsum and limestone.

Limiting factors for agricultural production are:

a. The low and variable rains,
b. The relief of the land,
c. The shallow depth of many soils,
d. The soil crusts.

In undulating areas much water is lost by surface runoff; consequently less water is taken by sloping soils as may be expected from rainfall data. Small strips of soil in the lowest parts of the terrain often get some extra water, although most runoff water is carried off by wadis. The relief factor therefore influences the crop production, which is always at a critical point and it increases the number of failure years on sloping land.

Fig. 110b. Profile of shallow Brown soil over gypsum. Only suitable for grazing land.

For rolling land the situation is much worse and the land is almost unsuitable for crop production.

The third factor (soil depth) is related to relief, because many hilltops are barren rocky land with very shallow or shallow soils or with crust soils. The slopes mostly have stony and rocky shallow to medium deep soils, whereas deep soils are found in the valleys (Figs. 110 a + b and 111). The areas with deep soils are relatively small. In some almost level parts of Upper Jezirah, deeper soils occur over somewhat larger areas. Fig. 111 demonstrates soil conditions in undulating land in relation to topography.

Crust soils (lime and gypsum crusts) occur in this part of Iraq. These crusts are secondary formations, mostly occurring several decimetres below the land surface, but the thin upper soil layer has often been eroded away and the crust is at the surface. No soil investigations have been made in this part of the country; therefore the special characteristics of lime and gypsum crusts, which are well known from various countries in the Middle East and North Africa, where they have been formed under similar conditions, have not been studied so far. Some parts of central Upper Jezirah are similar to the area south of Alep in Syria, where such soils were studied and mapped by Buringh and van Liere (1954). Valuable descriptions of similar soils have been published by Blank, Passarge and Rieser (1926). For the study of crust soils, reference is made to: Aubert (1937); Durand, (1949, 1952, 1954); Flandrin, E.A., (1948); Gillam (1937); Kubiena (1953); and Schokalskaja (1953).

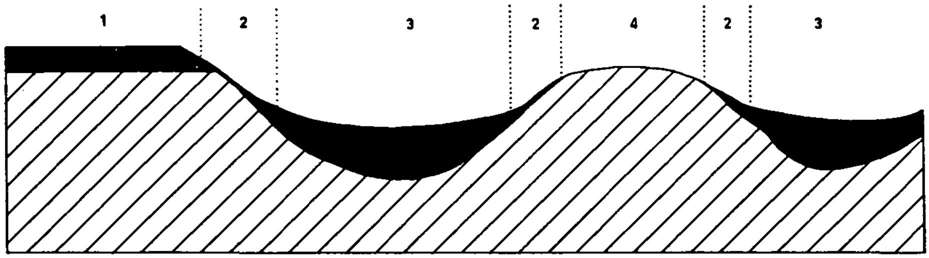


FIG. 111. Schematic cross-section in the undulating land of Upper Jezirah.
1. Flat land, with deep Brown soils;
2. Sloping land, with shallow and medium deep, rocky and stony lighter coloured soils (truncated Brown soils);
3. Deep, Brown soils of the valley bottom;
4. Very shallow, rocky soils of the hill tops.

The soil layer is indicated in black; the substratum consists of gypsum, sometimes mixed with limestone rock.

Cultivation is particularly risky in the zone of the Reddish brown soils on sloping land, hilltops, on shallow and medium deep soils and on crusted soils. The deep Reddish brown soils sometimes produce reasonable crops in rainy winters; in normal and dry winters the crops often are a failure. The deep Brown soils are much better. Wheat is the principal crop; north, east and south of the Sinjar mountain, the yield is 1400 kg./ha. of wheat on the best land. More to the south, production decreases to 900 kg./ha. Even land with a wheat production of 500 kg./ha. in normal years has been cultivated during recent years (Ali, 1956). According to Warriner (1948), wheat in Jezirah gives a tenfold return in a good year, sevenfold in a normal year and in a bad year the equivalent of the seed.

There is a quite extensive area south of Sinjar and Tel Afar with deep soils. According to the report of Kuljan (1957) 20% of the borings in this area shows soils of more than 200 cm. deep, 4% of the borings shows soils of less than 60 cm. which is considered to be a minimum depth. The area seems to be suitable for irrigation, when the Eski-Mosul dam has been built. Attention then has to be paid to drainage.

North of the Sinjar mountain the percentage of deep soils increases and the soils grade into Brown soils.

There is an extensive flat area consisting of deep Brown soils east of Tel Kotchek. Present agriculture is dry-farming. This area has high potentialities for future development. Land can be irrigated when the Eski-Mosul dam has been built (Kuljan, 1957).

The area west of the Tigris and south of Mosul is an interesting area, mainly on gypsum, partly on sandstone, with Brown soils. The hilltops are almost white (gypsum rock); the upper slopes have shallow stony and rocky soils, yellowish-brown coloured, and the deepest parts have deep Brown soils.

West and north-west of Mosul, Brown soils predominate and limestone becomes more important than gypsum. Crust soils occur on hilltops and slopes. In the area where the Tigris river enters Iraq, soil erosion becomes important. Rather extensive areas are seriously affected by water erosion because here rainfall becomes more intensive and exceeds 500 mm. The relationship between precipitation, landform, parent material, and Great Soil Groups on one hand and severe erosion on the other hand is discussed in Chapter 8.3. Wind erosion occurs north and south of Sinjar in the sandy and highly gypsiferous areas.

Tels are widespread in Upper Jezirah, even south of Sinjar. They are always found in areas with deep soils. Their presence indicates that the Upper Jezirah has been inhabited for thousands of years. According to archaeologists, people were already living here in Neolithic times. In Assyrian times, it was quite a densely populated region. All the tels were connected by roads, most of which are abandoned now. These ancient roads radiate from the main tels to the smaller ones in the neighbourhood, as can be seen on aerial photographs (Fig. 112a and Fig. 10). Upper Jezirah may be compared with High Jezirah in Syria, where soil investigations have been carried out by van Liere. Van Liere and Lauffray (1955) have made a systematic archaeological study of that region. Their map shows the location of all tels, the

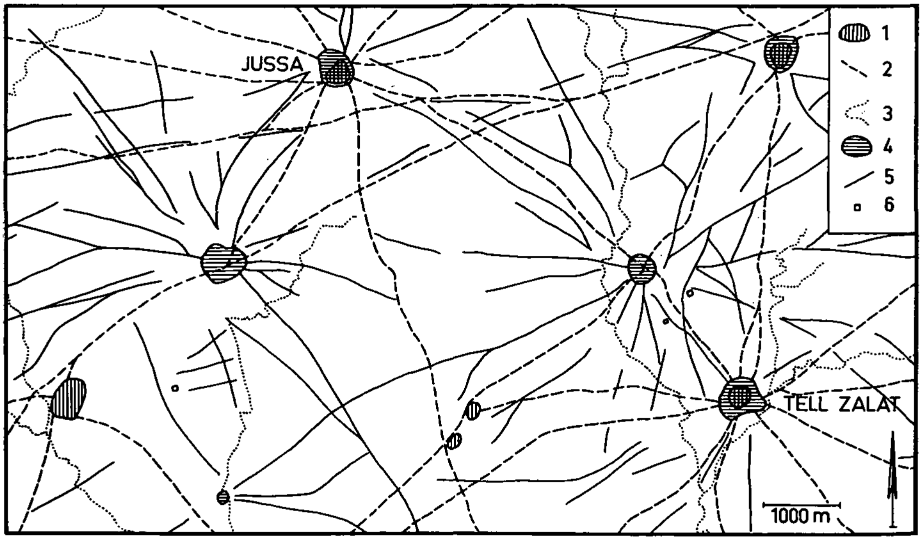


FIG. 112a. Map of tels and ancient roads in a section of Upper Jezirah (approximately 20 km. west of Mosul). The figure is drawn from aerial photographs. 1. present village; 2. present road; 3. small valley; 4. tel; 5. ancient road; 6. ancient farm.

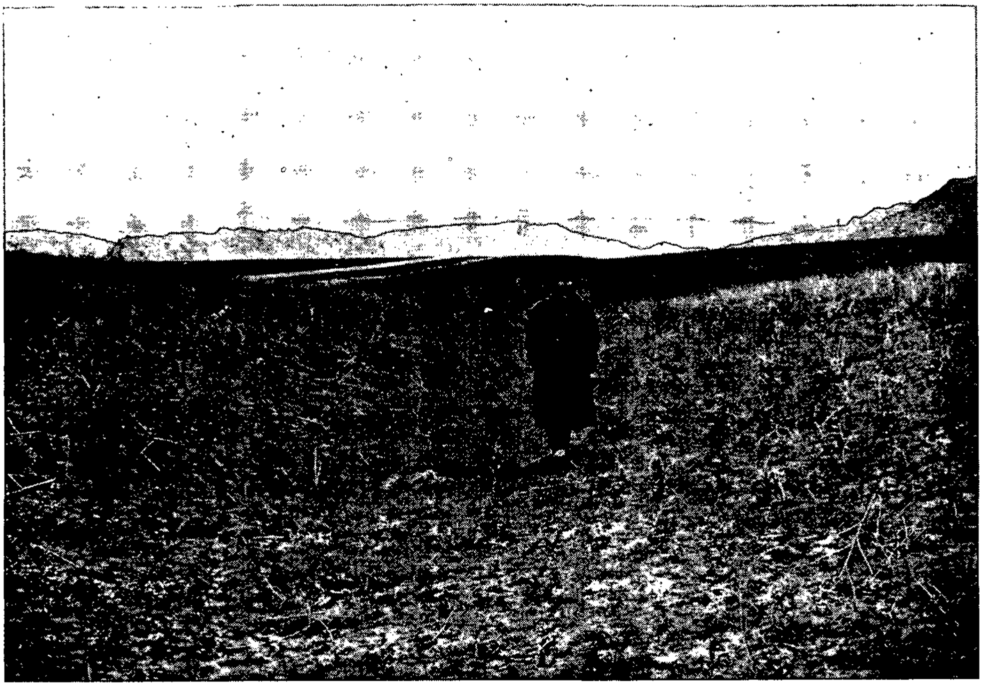


FIG. 112b. Ancient road, characterised by a straight line and by a smooth cut through the elevations in the undulating terrain. These roads always connect tels. The presence of tels and ancient roads indicate good soils.

ancient roads and canals. They also succeeded in classifying the tels according to size and shape. Similar work could be repeated in Upper Jezirah of Iraq. Aerial photographs of a large area are available. A small example has been made to demonstrate the result (Fig. 112a). One of the conclusions of van Liere and Lauffray was that the climate has become slightly drier since Neolithic times; consequently the area near the present 200 mm. isohyet became too dry and all tels in that zone have been abandoned. This has already been stated by Fisher (1950). The same may be found in the region south of the Sinjar mountain.

The agricultural potentialities of Upper Jezirah are fair, particularly in the southern and western sections. The deep soils are relatively the best; Brown soils are better than Reddish brown soils for dry land farming. Cultivation is precarious in the Reddish brown zone, particularly for small scale farming in settlement projects. There are probably some possibilities for extensive large scale farming in large units, but the results chiefly depend on climate and the prices of the products on the international market.

Wheat is doing well on the best and deepest soils. Barley may also give reasonable yields on the medium deep soils of the Brown zone. The depth to which the soil is moist at the end of the rainy season is an important soil characteristic. A relatively good wheat crop may be expected if the soil is moist to a depth of nearly one metre.

An important problem of Upper Jezirah is the extensive cultivation of natural grazing land during the last decade. Most of this land is unsuitable for cultivation. The introduction of farm machinery has accelerated this process. Tribes have lost their grazing land and an important part of their income. The natural vegetation cover has also been destroyed. It is extremely difficult to restore the natural grass vegetation. This problem will be discussed in Chapter 8.2. as for Iraq it is of nation-wide importance. If the areas east of Tell Kotchek and south of Sinjar and Tell Afar can be irrigated, these areas will have a prosperous future.

6.3. Soils of Makhmour and the area east of the Jabal Hamrin

This area is bordered by the Jabal Hamrin range and the Tigris river in the west, and the mountain range of Khanaqin-Kifri-Kirkuk up to the Greater Zab. It is a zone in Central Iraq between the Lower Mesopotamian Plain and the Jezirah desert in the west and the foothills in the east. It consists of flat and undulating plains, separated by anticlinal hill ridges which have a south-east–north-west direction. These hills mainly consist of soft sandstone and gypsum and partly limestone, with Lithosols. Large parts are severely eroded, particularly in the southern half of the area.

The climate is similar to that of Upper Jezirah. Rainfall increases from south-west (150 mm.) to north-east (400 mm.). The Sierozem soils of the Jezirah desert gradually grade into Reddish-brown soils and these finally grade into Brown soils in the area west and north-west of Kirkuk. (See the exploratory soil map of Iraq). Soils are developed in fluviatile deposits (south of Kirkuk) and in mixed weathering products of sandstone and gypsum (north-west of Kirkuk). These soils are underlain by gypsum, sandstone and Bakhtiari gravel. There are deep and shallow soils. West of Tuz there are large areas which have been severely eroded by water erosion, forming completely gullied land areas.

The soils in the plains south of Kirkuk are formed in material which belongs to the Muthasim and Mahdi terraces (see Chapter 4.2.). The Mutawakkil terrace is seen along the Tigris river west of Makhmour.

The Hunting Group (1956) has investigated the soils of the Makhmour area (2,455 $km.^2$), east of the Tigris, south of the Greater Zab, north of the Lesser Zab and west of the Jabal Qarah Chauq. Data mentioned below were derived from the Hunting Group report and personal observations.

The Jabal Qarah Chauq consists of limestone, gypsum and siltstone, with many gravel fans at the foot of this mountain; this Jabal reaches 870 metres and is approximately 600 metres above the Makhmour plain. This plain has a bedrock foundation consisting of Fars and Bakhtiari formations (gypsum, limestone and highly gypsiferous siltstone, mudstone, sandstones and gravels). It is covered by soil material ranging from a few centimetres to about 10 metres (generally 2 to 3 metres) in thickness. This has been called 'Mesopotamian Alluvium'. As it has nothing to do with the Tigris, nor with Mesopotamia and as it is not 'Alluvium', this name should be abandoned.

There are a number of low gently sloping ridges on the plain with sandstone and reddish siltstone close to the surface. In other areas gypsum rock is present at a shallow depth. The soil material has been derived from these parent rocks. It is often mixed.

Accumulation of crystalline secondary gypsum in the subsoils and substrata to a depth of 1 or 2 metres is common. Many soils have an extremely high gypsum content (up to 60%) in the substratum. The lime content is generally between 20 and 30% and above the horizon of gypsum accumulation, a lime accumulation horizon occurs, beginning at a depth of 20–35 cm. below the surface. The sand particles in soils over gypsum are mainly fragments of gypsum crystals. The original soil material, a weathering product of the underlying rock, has been mixed in most places as a result of water and wind erosion and colluviation. An important part of the soil parent material is probably of aeolian origin, blown from the Jezirah desert. Besides gypsum and lime accumulation, there is a slight eluviation of clay particles from the surface to the subsoil; clay coatings on structural elements also occur.

Crust soils only occur in a few places where gypsum is near the surface.

Saline soils, including some saline-alkali soils, occur in small depressional areas; some of them are internal, other puffed solonchak soils.

The pH of most of the soils ranges between 7.4 and 8.1; the organic matter content is low (average 0.7%); the C/N ratio is between 6 and 10. There is, however, a great deal of variation in the C/N (3 to 45), due to wide variation in the nitrogen content of the soils (0.01 to 0.13%); the K_2O content is generally high – 0.8 to 0.9%; total phosphorus is low (0.12 average). The soil texture varies widely; most soils are silt loams and silty clay loams.

The soil structure of the surface is often platy and somewhat crusted. Under the thin surface layer the soil is porous, subangular blocky. The structure is unstable. The soils have a moderate to rather rapid permeability, except for the surface where it is slow. Some deeper strata are very permeable, others almost impermeable (consolidated and dense sandstone and mudstone etc.).

A deep soil of the Makhmour plain has the following general characteristics:

The surface soil consists of brown silt loam or silty clay loam, platy in the upper 5 cm.; the rest is porous to subangular blocky, with a weak structure. It grades into yellow-brown silty clay loam, porous, subangular blocky, with distinct lime concretions (maximum concentration between 25 and 60 cm.). At a greater depth lime concentrations become scarce and the soil becomes more yellowish-brown. At 130 cm. gypsum crystals occur in the soil. The gypsum content in this layer is less than 8%. The soil is slightly hard when dry and friable when moist. It belongs to the Brown soils group.

A number of soil texture analyses from the tables in the report are presented here in triangular graphs (Fig. 113). The medium and shallow soils clearly show differences in soil texture because they are derived from different parent material. The graph showing the deep soils represents soils consisting of mixed parent material. Unfortunately all these deep soils are classified in one group, although they are derived from different parent material.

There are some terraces parallel to the Tigris river. The highest or Mutawakkil terrace consists of gravel with shallow soils. The gravels are from igneous (gneiss, granite, schist) and sedimentary (limestone, sandstone, siltstone) rocks, which come from the Turkish and Iranian mountains. The terrace gravel layer covers the Bakhtiari gravels. Often it is not easy to separate both gravel types, but there are some instructive sections. Two other terraces occur on a lower level, both with mainly deep Brown soils. The soils of the Muthasim terrace are mixed with a certain amount of gravel.

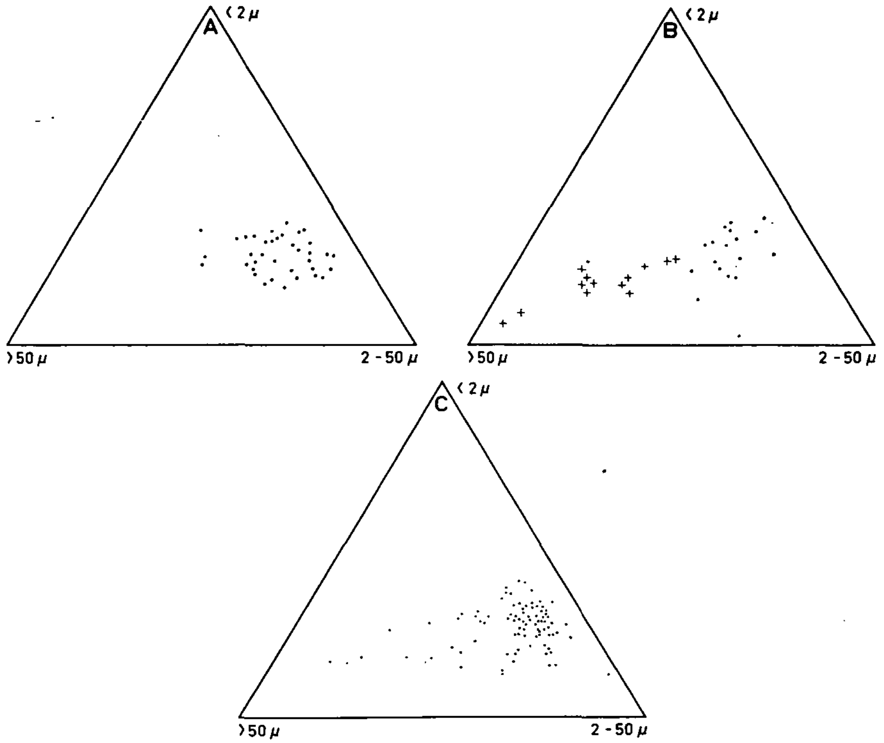


FIG. 113. Graphs of textures of soil samples from the Makhmour area. (data from Hunting's, 1956).
Graph A: shallow soils over gypsum (30–60% gypsum);
Graph B: shallow soils over mudstone (·) with 30–60% gypsum and over sandstone (+), with 1–8% gypsum;
Graph C: Deep soils (Dingawa soils).

The lime accumulation horizon begins at 26 cm. The soils of the lowest or Mahdy terrace are also deep Brown soils, but without gravel. The terraces, particularly the highest and middle ones, are locally deeply eroded by small intermittent streams. Along the Tigris river, there is a strip belonging to the present flood plain with Alluvial soils which are often quite sandy. Sometimes this strip is small or even absent. There are crescent-shaped plains as a result of the meandering of the river course. This land is often irrigated with Tigris water.

The height of the Mutawakkil terrace near the mouth of the Greater Zab river is 270 metres and near the Lesser Zab river approximately 210 metres which is approximately 170 metres above the present Tigris river level. The two other terraces are approximately 25 and 15 metres above the river level.

The Hunting Group found 46% of the Makhmour area arable, of which 27% belongs to Class 2 and 19% to Class 3. The Class 2 land is level to smooth with deep Brown soils, whereas Class 3 land is undulating, sometimes with gullies and medium deep soils. Areas with shallow, gravelly, stony and rocky soils are only suitable for grazing land. Soil depth and slope are characteristics of primary importance. Rainfall is a limiting factor due to large regional and seasonal variations, as has been explained in Chapter 6.2. Here also, land unsuitable for crop production is under cultivation. Crop failures, particularly in dry years, are common on such land.

Under the present conditions, agricultural potentialities are relatively low. However, rather large areas with deep soils and a level or undulating topography can be irrigated with water from the Greater and Lesser Zab rivers. At present wheat and barley are the main crops. If an irrigation system with an adequate drainage system is to be constructed as proposed, other valuable crops may be grown. Some areas could be afforestated and irrigated in order to stop erosion. Well water in the Makhmour plain is unsuitable for irrigation because it is highly saline. The presence of saline groundwater at a depth of 10 to 30 metres from the surface is a real danger for irrigation in the future. Therefore a drainage system will be needed.

Near Makhmour town there is a spring with water containing sulphur; the water is greenish blue with a smell of hydrogen sulphide. It is used for irrigating approximately 200 mesharas of land which form a part of a 7200 meshara settlement project in the vicinity of Makhmour town. The new village consists of 52 brickhouses and the farm units are $66\frac{3}{4}$ meshara (500 × 333.3 m.). In this project, farming chiefly depends on precipitation (Ali, 1955).

The soils in the plain east of the Jabal Qarah Chauq are similar to those of Makhmour; the rainfall is somewhat higher.

South of the Lesser Zab and east of the Tigris is the Hawiya project (15 × 7.5 km.), also with shallow, medium and deep soils. Approximately half of the project area consists of deep soils, mainly intergrades of maximum Reddish brown and Brown soils. Out of 181,600 mesharas, 38,315 mesharas are irrigated. The farm units are 72 mesharas (300 × 600 m.). According to Ali (1955), the project settlers are enjoying a higher income than the average Iraq farmer; their economic condition, however, is in no way satisfactory. Some areas are saline (0.25 to 0.75% salt). The project was completed in 1951. After a few years 30,000 mesharas had already been abandoned. The abandoned areas mainly consist of soils unsuitable for cultivation. A few soil analyses of the Hawiyah project have been published by de Gruyter (1953). They show high salinities (3.5 and 5%) and even high E.S.P.-values (71 and 49%!) indicating the presence of saline-alkali soils.

The land on the plain south of Kirkuk is used for dry farming; locally some small areas are irrigated by spring water. East of Tuz and Kirkuk a very extensive area has been severely eroded; it is now gullied land (Fig. 114).

Near Tuz deep Reddish brown soils occur on the Mahdy terrace. Between Tuz and Tauq many valleys containing small and intermittent streams occur which give the area an undulating character. South of Kirkuk some underground irrigation canals

FIG. 114. Photograph of gullied land east of Kirkuk. Most of the erosion is geological erosion, possibly dating from pluvial stages in the Pleistocene.

(karezes) are still in use (Fig. 21). The soils gradually grade into Brown soils. The deep soils also contain some gravel; they probably belong to the Muthasim terrace. Considerable areas with medium and shallow soils also occur. Agricultural production depends chiefly on rainfall. Irrigation would promote many improvements.

6.4. SOILS OF THE KIRKUK – ERBIL – MOSUL PLAIN

This plain is the most important part of the dry farming area of northern Iraq (Fig. 10). Most of the land is under cultivation and the rest is grazing land. Wheat is the principal crop, producing reasonable yields on deep Brown soils. The plain has an undulating to rolling relief, due to the many intermittent streams which come down from the foothills and mountains. The Greater Zab river crosses the plain in a rather deep valley. Two terraces can be distinguished. They have to be correlated with the Muthasim and Mahdy terraces; the latter only occurs in the valleys.

The deeper strata of this plain consist of Bakhtiari gravel and limestone, which are covered by a soil layer of varying thickness, the average thickness being 2–4 metres. There are a number of limestone hills and low anticlinal ridges with shallow Brown soils or Lithosols, often surrounded by gravel fans.

In comparison with Upper Jezirah and the area south of Kirkuk, the climate is rather more humid. Winter rainfall increases from 400 mm. in the south-western part

FIG. 115. Profile in a deep, Brown soil, east of Chemchemal.

to about 700 mm. in the north-eastern part of the plain. There are annual variations. In dry years the north-eastern part may have less than 400 mm. Such dry years may be expected once in seven or ten years; crop yields then are very low.

Brown soils are well developed over the whole plain. In smooth valleys stronger brown coloured soils occur; some even intergrade into Chestnut soils, for example North-West of Dohuk. Along the rivers small strips of alluvial soils were observed.

Soil depth varies with relief, the deepest and best soils occurring in the smooth valleys and on the level parts of the plain. Shallow and level soils occur on the upper slopes and rounded summits of the hills. Most of the soils are a somewhat stronger brown than in Makhmour and Upper Jezirah (Fig. 115). The horizon with lime accumulation is at a depth of 30 or 40 cm., with maximum accumulation at 40 or 50 cm. Gypsum accumulation has not been observed because hardly any gypsum rocks occur here. There is some eluviation of clay.

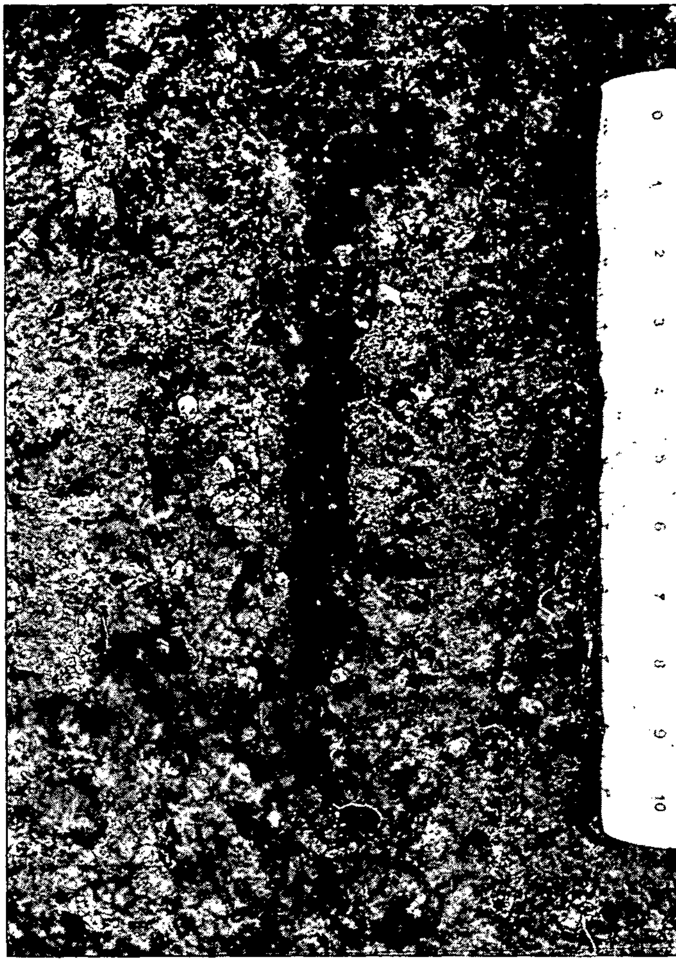


FIG. 116. Close-up of a worm-hole in the B-horizon of a deep Brown soil, east of Chemchemal. The soil material around the hole is much darker coloured than the soil of the B-horizon. Biological soil processes are already quite important in Brown soils.

The soils are non-saline, except in a few depressions and in some small areas which are being irrigated with water from small streams, e.g. near Nineveh. Crust soils have not been observed, except for some gravel crust in the gravelly substratum.

According to Lebon (1953) the soil parent material is loess. Zohary (1950) mentions that soils near Mosul and Dohuk, as in the northern part of Upper Jezirah, resemble loess. Examination of the soils in the field shows that they do indeed resemble loess. However, soil sample analyses do not show all the characteristics of loess. The silt fraction varies from 55 to 70%, mainly 55 to 60%. The material is similar to that of Makhmour and is probably mixed material, partly fluviatile and partly aeolian, blown from the deserts. The soil sample analyses of some deeper layers clearly demonstrate a fluviatile origin for that material. In the valleys there is much colluviation.

It was mentioned by Kuljan (1957) that the soils, overlying the Fars formation, consist of fluviatile deposits with a mantle of loess. The upper layer is considered being loess, because there is no statification, depth is limited, and texture is uniform. Both types of sediment are shown in Fig. 15.

Soil erosion is not a serious problem in this plain, except north of Mosul. Some water erosion occurs on sloping land, particularly during heavy showers. The gravelly sloping soils are protected by the gravels on the surface. The extensive, severely and deeply eroded area north of Mosul, extends into the northern part of Upper Jezirah.

There are some relatively small areas (north-east of Kirkuk) where the soils are red and tend to become Terra Rossa soils. Similar soils were seen in the mountain region at a few places, for example near Shaklawa. According to Zohary (1950), these soils are formed on hard limestone of the Upper Cretaceous as well as on some Tertiary limestones. Some authors have mentioned Terra Rossa as being the principal Great Soil Group in north-eastern Iraq. This, however, is wrong. There are some small areas with fairly red soils which are highly calcareous and not decalcified at all. They are quite different from the real Terra Rossa soils which occur along the Mediterranean sea. There are probably two explanations: one explanation regards these soils as fossil Terra Rossa, formed in a pluvial phase of the Pleistocene, which have been recalcified or truncated during the present arid climate. The other suggestion is that these soils are the old weathering products of a particular soil parent material. The first theory would indicate a type of Mediterranean climate in ancient times which may also explain the presence of some weeds, that form a Mediterranean element in the present Iraq vegetation. These weeds are relics of the Tertiary-Palaeo-Mediterranean vegetation (Zohary, 1950; and Springfield, 1954). (See Chapter 2.4.).

So far, no systematic soil investigations have been carried out in the Kirkuk-Erbil-Mosul plain, except near Mosul where prospecting is in progress. Therefore no detailed information on the soils is available.

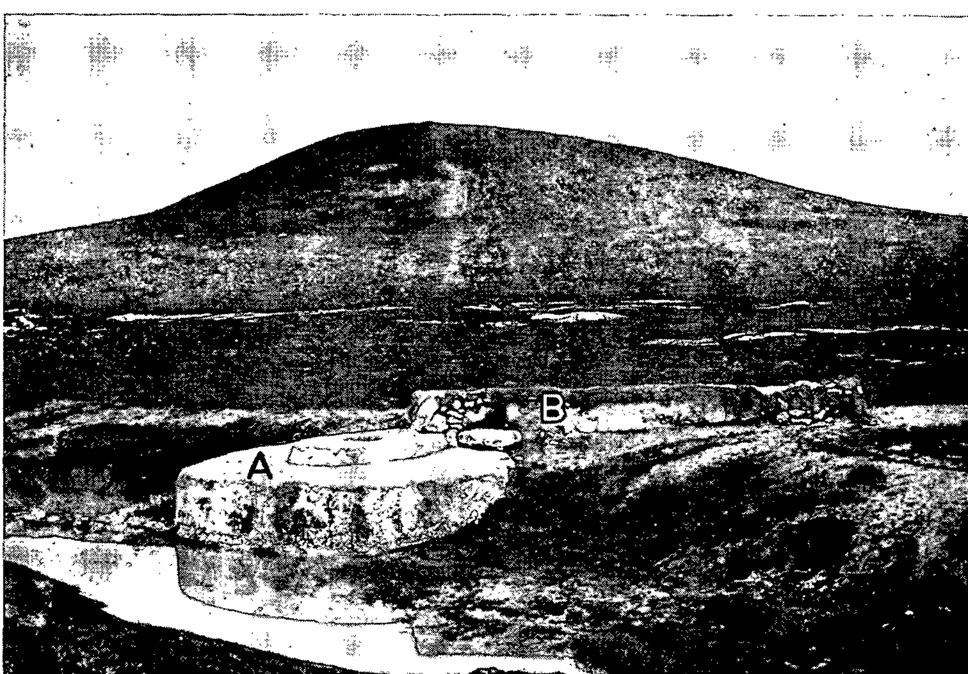


FIG. 117. Tel near the road from Mosul to Dohuk. There are numerous tels in Upper Jezirah and in the Mosul-Erbil-Kirkuk area. They are always located on good soils and near a small stream. Here a concrete well (A) is made and sheep and goats can drink from the gutter (B) at the foot of the tel.

Many tels and several ruined cities are located on this plain. Erbil is considered to be the oldest continuously inhabited city in the world. The old city is situated on a high (50 metres) flat tel, surrounded by fertile land. At the foot of this tel the soils are irrigated and used for growing vegetables. They are very dark brown down to a great depth and are man-made soils. They are probably the oldest horticultural soils in the world!

The agricultural potentialities of this plain are high. There are good deep soils in level and slightly undulating areas which could be irrigated. Under the present conditions only winter crops can be grown. Yields always depend on rainfall, although cultivation is less precarious than in Upper Jezirah or Makhmour. The depth to which the soils are moist at the end of the rainy season is an important factor in predicting crop yields. Irrigation projects, including some drainage, will provide new possibilities for the agricultural development of this plain.

6.5. Soils of the foothills

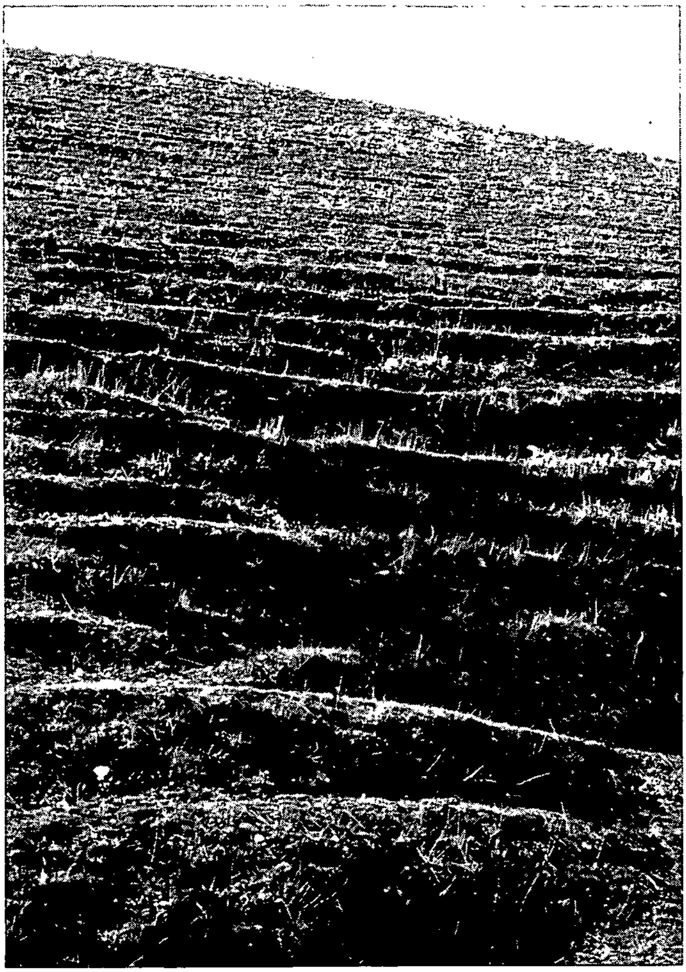
The foothills form a broad zone south-west of the high mountains of Kurdistan and mainly consist of gravel of the Bakhtiari formation. These gravels were deposited during the intensive erosion of the mountains, following the intensive folding process in the Pliccene (see Chapter 2.1.). At present it is a hilly area and is mainly grazing land (Fig. 118), intersected by various deep valleys which contain streams coming down from the high mountains. The gravel and conglomerate layers alternate with narrow layers of reddish loam and clay, the strata are often folded. At some places these red layers are at the surface, mostly forming deeply gullied land. The hills are rounded and the soils generally shallow, sloping and gravelly. There are level parts in small areas which are remnants of Pleistocene terraces (Fig. 119). In some areas older rock formations (limestone and sometimes sandstone and shale) are at or near the surface. Deeply eroded and gullied areas also occur locally. There are some broader valleys, e.g. near Chemchemal, with medium and deep Brown soils (sometimes grading into weak Chestnut soils), forming fairly good dry farming land with wheat as the main crop. Water in the small streams is used for irrigation of small plots in the valleys; rice, vegetables, cotton or tobacco are grown there.

At the bottom of some small valleys, strips of rather dark coloured hydromorphic soils with rust and gley are observed.

Winter rainfall reaches 800 or even 900 mm. near the mountains. The summer months are dry and hot. In winter and spring the foothill area is green and there are many lovely flowers. In summer the grasses dry up and the landscape is yellow.

A deep soil, studied on a convex hill slope of approximately 15%, has a rather dark brown surface which consists of silt loam mixed with some gravels, grading into brown silt loam at 14 cm., with lime accumulation beginning at a depth of 30 cm. This soil has been classified as Brown soil. On some other hill slopes soils are reddish-brown and lime accumulation begins at a depth of 15 cm. Those soils which receive less water as a result of runoff, should be classified as Reddish-brown soils, maximum phase. Chernozomic A-horizons do not occur in soils of the foothills. Lime nodules are at many places found at the surface due to soil truncation.

FIG. 118. The rolling land of the Bakhtiari gravels in the foothills have shallow and gravelly soils that form good grazing land. Sheep and goats have made numerous small paths on the slopes. These paths look like micro-terraces; they prevent soil erosion.



Wright (1952), who has made geological investigations near Jarmo, the famous prehistoric village east of Chemchemal, has described some terraces which record the cycles of stream erosion and deposition and which he has tentatively correlated with climatic fluctuations in the Pleistocene. Both terraces are former erosion surfaces covered by fine textured soil material. They have been called Chemchemal and Jarmo terraces, the latter lying 20 to 30 metres lower than the former. They are sharply dissected by gully systems. Gullies in the Jarmo terrace are 30 to 70 metres deep. In these gullies a third terrace (a small one) has been recognised. The terrace formation will be discussed in Chapter 6.8.

The erosional surface of the Jarmo terrace is covered by 10 to 25 metres of silty clay loam, in which a Brown soil has been developed; a lime accumulation horizon beginning at a depth of 25 cm. also occurs. The thickness and degree of development of the nodules have been used by Wright for a relative dating of the deposition of the

FIG. 119. Landscape between Kirkuk and Chemchemal, which was eroded during pluvial phases in the Pleistocene. Originally the land was almost flat; the remains of two terraces (1 and 2) can be observed.

soil layer. In studying the same profiles, this is rather questionable. Exact dating of the Jarmo village was later performed by applying the C^{14} method (Libby, 1955).

A soil investigation in combination with a soil conservation classification has been made in the hilly area west of Chemchemal in relation to a proposed soil conservation project (Gibbs, 1954). Afforestation in this project has not been successful, probably because this area belongs ecologically to the grasslands and the soils are often shallow and gravelly. The soil conservation classification and conservation plan set up by Gibbs for the Chemchemal farm are the first, and so far the only ones, made in Iraq. Unfortunately the soil conservation plan has not been carried out. In this area the wheat and barley yields are approximately 200 and 250 kg./donum respectively on an average, with 100 to 300 kg./donum in respectively poor and good years, depending on rainfall. It is estimated that about 15 donums of grassland for each mature cow are needed in the grazing period from April to August. In dry years very large numbers of livestock are brought from the desert and dry steppe into the grazing lands of the foothill zone, because there is always some grass. This causes overgrazing.

The agricultural potentialities of the foothill region are low. It only provides good grazing land. Some small areas in the vicinity of small streams could be irrigated. If the cultivation of rice were to be limited, more water could be made available for other summer crops which need less water. Soil conservation measures would be useful, but other areas in Iraq probably have a higher priority for this work.

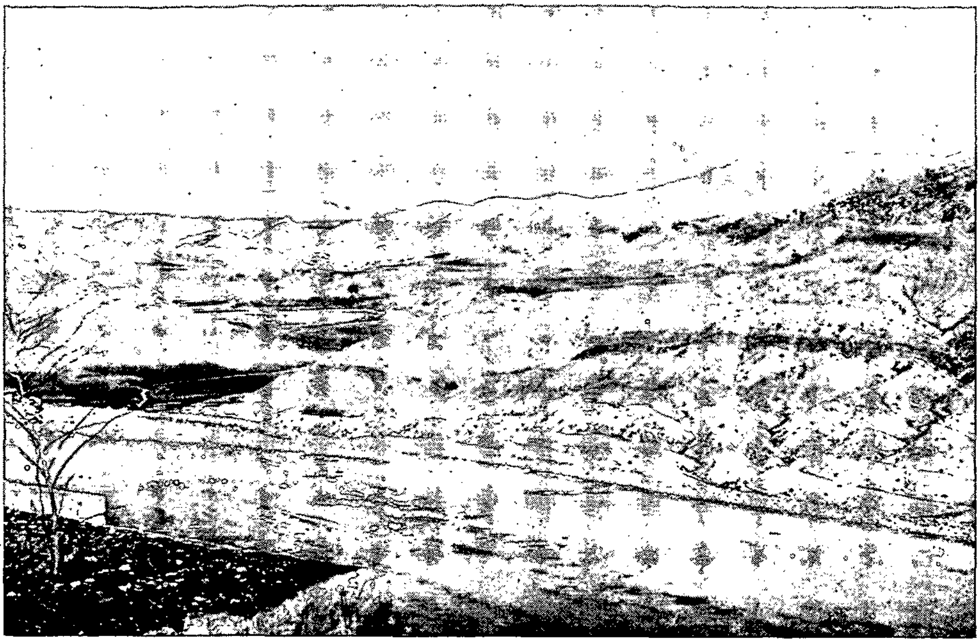


FIG. 120. Mountains near Dokan. Those in the background are covered by snow and ice during the greater part of the year.

6.6. SOILS OF THE MOUNTAINS

The mountains in north-eastern Iraq mainly consist of various kinds of limestone, except the peaks of the highest mountains on the Iranian border, which belong to the Nappe area and consist of various metamorphic rocks. The whole mountain region consists of rough, broken, stony and mountainous land (Fig. 120) and some mountain valleys (see Chapter 6.7.).

The rough broken land consists of very steep land, broken by numerous intermittent drainage channels; there is often a cover of vegetation. The stony land has enough stones and boulders to submerge other soil characteristics. Rough mountainous land is predominantly stony, but includes small areas suitable for cropping or grazing.

The physiography has been discussed in Chapter 2.1. The mountain ranges in Iraq are a part of the Zagros mountains, which form a section of the Dinarid branch of the Alpine mountain system (Lees, 1950). Most of the soils are Lithosols and are gravelly and shallow soils. The topography is rough. Where the rocks are not completely barren, the vegetation consists of grasses on the higher mountain slopes and low forests of oak, walnut, almond and pistachio on the lower slopes. Zohary (1950) refers to a wide variety of valuable forage plants in the meadows, mixed with clover on wetter soils and wild alfalfa on well drained soils of the narrow valleys and mountain slopes. There are a few small stands of Pine forest which are found on red marls (Smith, 1944 and Zohary, 1950), whereas oak forests grow on Brown and Chestnut coloured soils. The forest map, published by the Forest Department, shows the various

FIG. 121. Rendzina soil. The profile consists of approximately 40 cm. black or very dark brown clay overlying hard limestone rock. These soils, often with a thinner soil layer, are common in the Zagros mountains of north-east Iraq.

types of forests in the mountain regions of Iraq (Chapman, 1957). Guest (1953) has also given an extensive ecological description of this region.

The winter rainfall varies from 900 to 1000 mm. The highest annual precipitation in Iraq is recorded in Penjuin, east of Ruwanduz (1340 mm.). An ecological subdivision, which may also be valuable for a soil classification, has been given by Guest (1933):

a. Lower mountain slopes (500–2000 m.), mainly oak forest;
b. Higher mountain slopes (2000–3000 m.), mainly with grass vegetation;
c. The alpine region (over 4000 m.).

The soils of the Kurdish mountains are very variable as a consequence of differences in soil climate (exposure, runoff), relief (sloping soils), parent material (folding and erosional processes; colluviation), soil depth and maturity. Soils belonging to the following Great Soil Groups have been found:

FIG. 122. Chernozem soil south of Mirza Rustam. A description is given in the text. It represents the highest stage of soil development in Iraq. The upper 60 cm. is quite homogeneous, with many grass roots.

Lithosols, Rendzina and Brown Rendzina soils, Chestnut soils, Reddish Chestnut soils, Brown soils, and Chernozem soils.

The Chestnut soils represent the zonal soils, while the others have to be considered as intrazonal. Intergrades and variations due to truncation and colluviation are common. There are numerous different soil series and types; if mapped, they would demonstrate an intricate pattern on a detailed soil map.

Rendzina soils (Fig. 121) occur at many places; some are real Rendzinas; others have a brown to Chestnut-Brown coloured A-horizon on white limestone blocks; the vegetation consists of tall grasses. Brown soils occur on sloping land on limestone and chert, in various colluvial material and in sandy weathering products of sandstone. These soils are probably immature and in a phase of development into Chestnut soils. Another explanation could be given by surface runoff; consequently the water intake of these soils is much lower than may be deduced from precipitation data.

Lithosols mostly consist of hard white limestone, dolomitic limestone, platy brown limestone, blocky bluish-grey limestone and white chalk.

Chernozem soils (Fig. 122) have been observed in small areas only, often at the foot of a convex mountain slope near the valley bottom soils, where the water intake is generally higher than precipitation data indicate. A typical profile has the following characteristics:

A_1 0–30 cm. Very dark brown, friable silty clay loam; calcareous; medium angular blocky structure.

A_3 30–46 cm. Dark grey-brown to grey-brown, calcareous, friable clay loam, with a few lime accumulation spots.

B_{ca} 46–65 cm. Yellowish-brown calcareous clay loam, friable, medium subangular structure with many lime accumulation spots.

C_{ca} 65–more than 150 cm. Light yellowish-brown, friable, calcareous silty clay loam. Medium subangular blocky, with some lime accumulation.

Analytical data are given in Table 27.

TABLE 27. *Analytical data of a Chernozem soil.*

Horizon	Mechanical Analysis			Lime %	pH	Organic Matter %
	Sand %	Silt %	Clay %			
0–30 cm.	20	41	39	13	7.6	2.5
30–46 cm.	21	44	35	30	7.5	1.4
46–65 cm.	23	44	33	57	7.6	0.5
65–150 cm.	15	50	35	28	7.6	0.3

The various kinds of limestone on which soils have been developed should be studied in co-operation with geologists. The main types of limestone are:

a. Dolomitic limestone, dark bluish coloured when fresh, dark brown to brown when weathered, hard to very hard, mostly occurring in the centre and therefore highest part of the anticlines. Most Lithosols.

b. Pinkish-white limestone in blocks of about 30 cm., hard, used for building material, with a yellowish red to brownish surface when weathered; soils are mainly Rendzinas and medium deep or truncated Chestnut soils with a grass vegetation. This limestone often covers the dolomitic limestone. It occupies rather large areas.

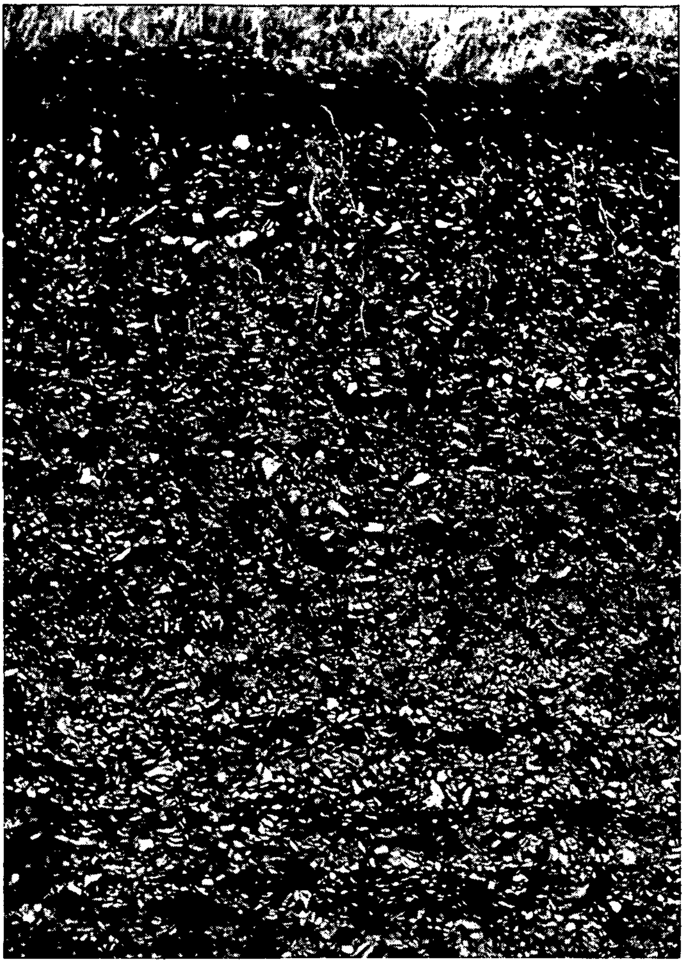
c. Light bluish-grey limestone, which cracks easily; it is soft and consists of small blocks of 0.5 to 1 cm. Hardly any soil formation has taken place on it. Sometimes the upper few centimetres have a reddish-brown colour, or a Reddish Chestnut soil has been developed. It occurs in some anticlinal valleys.

d. Light brown limestone, also soft with a platy structure; pieces are mostly 10 cm., thickness 3 cm. The land is barren; sometimes thin Brown soils have been formed under a grass cover.

e. White chalk, soft and earthy, white coloured, sometimes a thin and weak A-horizon of approximately 5–10 cm. has been developed, overlying the white chalk.

f. Dark grey coloured shale; soft with small blocks.

FIG. 123. Shallow soil in cherty colluvial limestone near Dokan. Together with Rendzina soils (Fig. 121) and Lithosols, these soils are the most common mountain soils in north-eastern Iraq.



It has been observed that soil formation on these different kinds of parent material is different; therefore a more detailed lithological study has to be made. The various kinds of limestone also have a different effect on the hydrology of the region. Some are porous and consequently there is a slow percolation through these rocks, resulting in a continuous flow of water into the rivers. Other rocks are non-porous; there is a high runoff and streams become torrential rivers in a few days.

The alpine region, the highest part of the mountain, has not been visited. Here some meadows and alpine meadow soils may be expected. Some mountain peaks have a perpetual ice cover. Small glaciers occur on shaded, north-facing slopes. According to Wright (1954) at least two stages of older glaciation can be distinguished.

Geologically, the highest parts of the mountains near the Iranian border consist of the Nappe formation, which according to Heron (1943) and the Site Investigation Company (1954) can be divided into a:

a. Lower division (limestone, shale, basalt and tuff);
b. Middle division (phyllite, limestone and marble);
c. Upper division (epidionite, serpentine, volcanic rocks).

The climate conditions, vegetation and parent rock in the high mountains are completely different from the rest of the country. Some typical soils, belonging to Great Soil Groups other than those mentioned in this chapter and in Chapter 3.3. could be expected. But they are of academic value only.

Chapman (1957) has given the results of some soil sample analyses of high mountain soils. One soil has a pH of 6.0; it was 'from the turf-covered bank of an alpine lake, well above the tree zone at 3,500 metres. This sample also showed the highest nitrogen value, which, considering also the coolness of the climate and abundant ground moisture, suggests that the cause of acidity is due to extreme humification on the topsoil lying over moderately alkaline rock'. According to Chapman (1957) there is an indication of podsolization in the mature soils of the high mountains, and acid soils may possibly be of a fairly frequent occurrence in wet places.

The agricultural potentialities of the soils of the mountain region are very limited but the forests could be extended. A soil map indicating the various Great Soil Groups could be valuable for an afforestation programme, but soil depth, slope, general relief, stoniness, rockiness and exposure are factors which are often of more practical importance. The Forestry Department has started an afforestation programme.

6.7. Soils of the mountain valleys

There are numerous small and a few broad valleys in the mountain region (Fig. 124). Soil conditions in the small valleys are very variable; in the broad valleys they are more uniform and for agriculture much more important. Most valleys are synclinal valleys but some are anticlinal valleys, for example near Rania. The valleys are filled up with gravel and conglomerate belonging to the Bakhtiari formation which now lies horizontally and forms terraces, except near the foot of some mountains where it may have a sloping position. The surfaces of these gravel deposits are erosional surfaces, which have been covered by 2–3 metres of fine textured soil material. Some gravel fans and the highest terrace have a very thin layer or no soil layer at all. The terraces are dissected by streams and deep wadis, which come from the mountains and by steep walled gullies near the flood plain. The process of terrace formation will be discussed in Chapter 6.8.

The climate is wet in the winter and dry and hot in the summer months of June, July, August and September. The annual rainfall varies from 900 to approximately 1000 mm. The natural vegetation is a tall grass vegetation. The deep soils of the terraces are mostly cultivated, wheat being the most important crop. It is grown once in two years in a dry farming-fallow system.

Along the rivers there are strips of light textured Alluvial soils with gravel substrata and riverwash. The flood plain soils are irrigated by lift irrigation, cotton and tobacco being the principal crops. Small plots of irrigated land along the numerous small streams also produce tobacco. Some small parts of the terraces are irrigated by spring

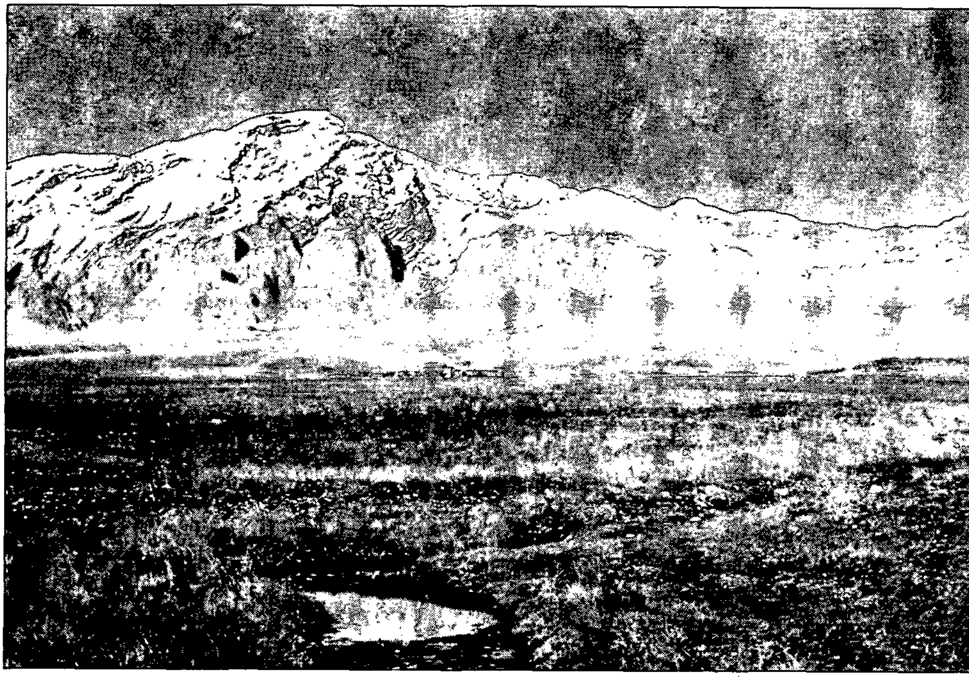


FIG. 124. A mountain valley with deep Chestnut soils near Sulaimaniyah (winter photo).

water to grow rice, cotton and tobacco. Fairly extensive areas in the Rania plain are irrigated by spring water. Drainage is good, due to the high topographical position and general relief.

The Alluvial soils near the rivers are flooded in winter; they can only be used for summer crops. Saline or alkali soils do not occur. All soils are calcareous, with lime accumulation horizons at a depth of 50 cm. or deeper.

The soils, except those of the flood plain, belong to the Chestnut soils, developed in the soil material on top of the erosion surfaces. This soil material is of fluviatile origin, deposited during high floods in the Pleistocene. In some valleys remnants of the original rock formations are at or near the surface, giving such a valley an undulating to rolling character, often with medium and shallow soils (truncated Chestnut and Rendzina soils). Such land is mostly grazing land; sometimes it is cultivated, forming rather poor arable land. Rather blackish coloured soils with a hydromorphic character are sometimes formed in narrow valley bottoms. They often consist of eroded Rendzina material.

Man-made soils were observed in some small areas. They occur on slightly sloping land near tels and small streams and consist of a metre of friable very dark brown to blackish homogeneous clay or silty clay loam, often mixed with some gravel. This layer gradually grades into very dark grey-brown, friable silty clay loam, changing into dark brown soil at a depth of 125 or 150 cm. Such soils are excellent tobacco soils, particularly if they are somewhat gravelly. The organic matter content is

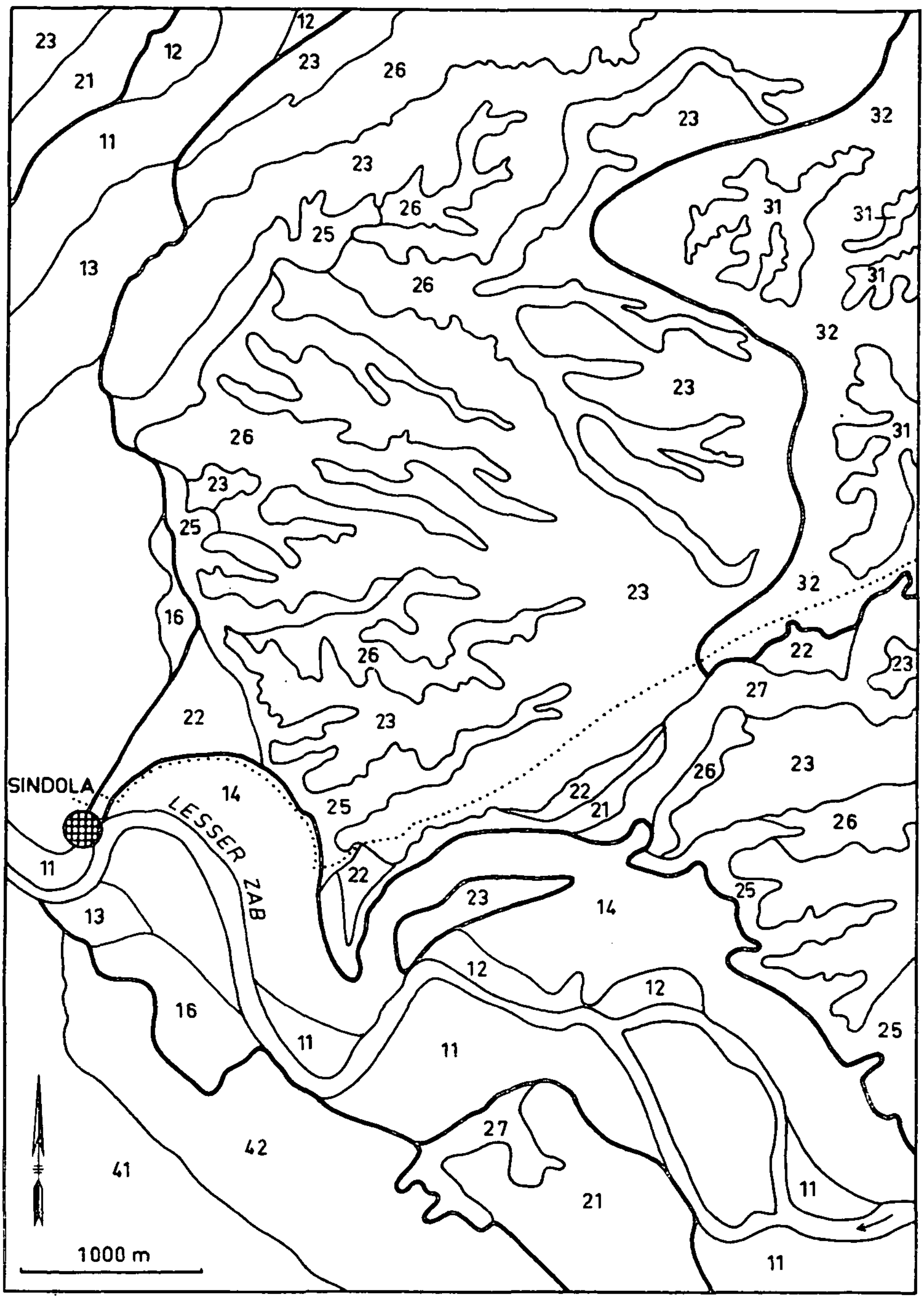


FIG. 125. Section of the semidetailed soil map of the Sungassar-Qala Dizeh valley. Soils of the river plain (Alluvial soils): 11. Riverwash; 12. Shallow, loamy soils; 13. Medium, loamy soils (irrigated summer crops); 14. Deep, loamy soils (irrigated summer crops); 16. Gravel fans. Soils of the terraces (Chestnut soils): 21. Deep, loamy clay soils; 22. Sindola clay (winter crops); 23. Sungassar clay (winter crops); 25. Steep gravel soils, with crusts; 26. Sloping, gravelly clay soils (see Fig. 128); 27. Undifferentiated sloping and bottom lands. Soils of the gravel terrace: 31. Flat, gravel land, shallow with crusts; 32. Sloping, gravelly clay soils. Soils of the limestone mountains (Lithosols, Rendzina): 41. Shallow soils and rock, steep land; 42. Colluvial soils.

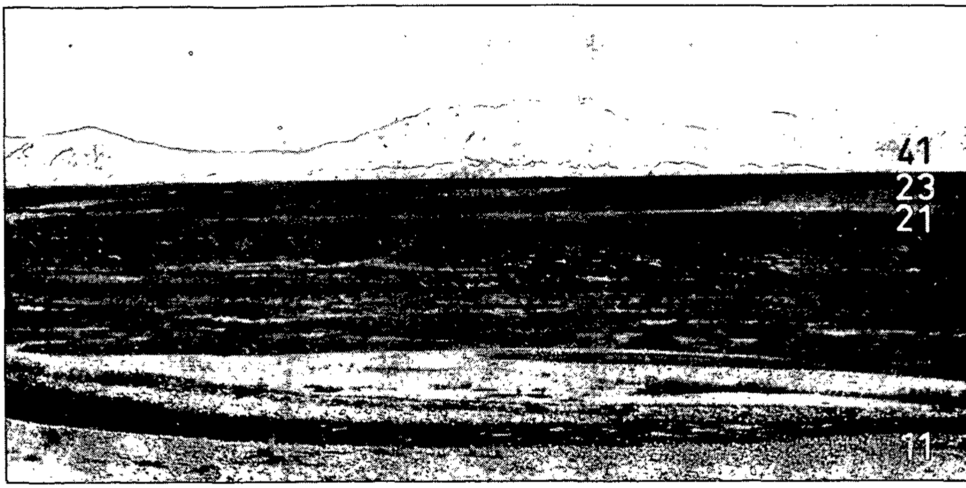


FIG. 126. Terraces in the Sungassar valley, 75 km. north of Dokan. 11. river wash of one of the branches of the Lesser Zab; 21. Jarmo terrace with deep Chestnut soils; 23. Sungassar clay of the Chemchemal terrace; 41. Limestone mountains, covered by snow and ice.
The numbers are the same as those in Fig. 125.

approximately 4% in the A-horizon, decreasing to about 2% at a depth of 100 cm. Such soils have been formed by putting manure and home refuse on the land during a very long period of cultivation.

Soil conditions are best known in the Sungassar valley (Figs. 125–128) where a semidetailed soil survey has been carried out (Buringh, 1955). Some reconnaissance work has been done in the Rania valley. Both valleys have considerable areas of arable land. They are located north-east of the Dokan dam on the Lesser Zab. Within a few years, when the Dokan dam has been finished, large sections of both valleys, particularly of the Rania valley, will be flooded over an area of approximately 20,000 donum (Ali, 1955). Unfortunately this land is the best land for agricultural production. The dam will be made for flood protection and water storage (6.8 milliard cubic metres).

The terraces are very pronounced and extensive in the Sungassar valley (Fig. 126); the description and hypothesis of their formation (Chapter 6.8.) are mainly based on observations made in this valley. These terraces are located at approximately 15, 25 and 50 metres above the present flood plain of the Lesser Zab which flows about 490 metres above sea level. The soils on the middle and lower terraces are Chestnut soils, uniform over large areas and classified as Sungassar soils. The textural differences are very small; there are only two soil types in the Sungassar series, a silty clay and a clay type. The distinction, however, is not very clear, as textural differences are very small. Soil depth decreases on smooth slopes; here soils are often mixed with stones (see Fig. 26).

A characteristic profile of a deep cultivated soil of the Chestnut Soil group, situated on the middle terrace in the Sungassar valley, is given below:

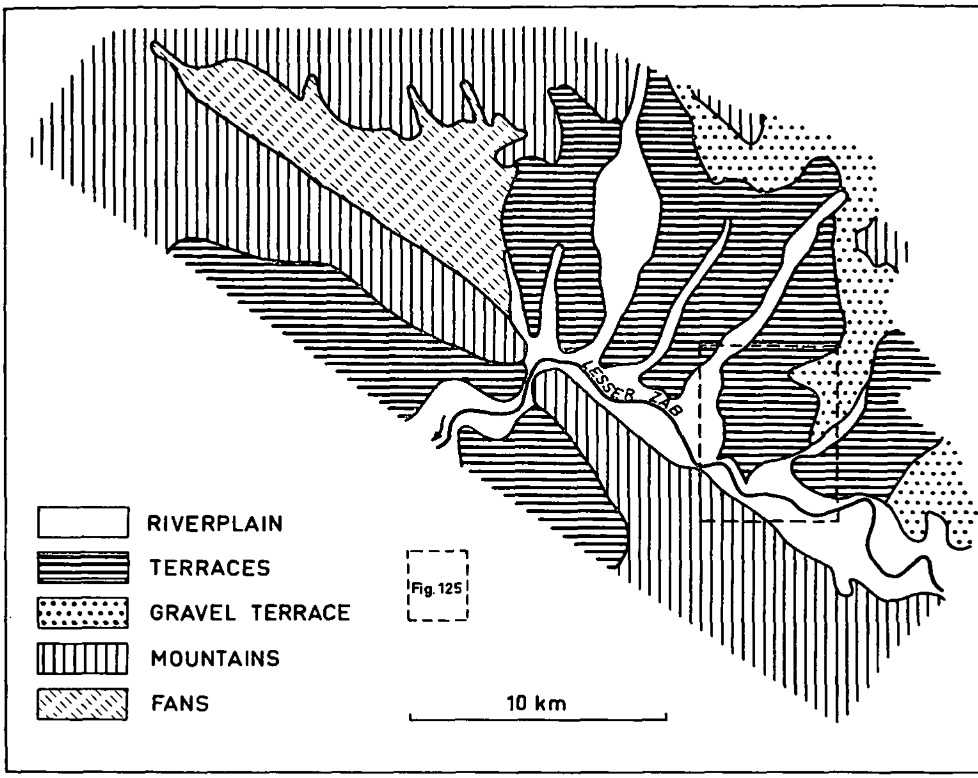


FIG. 127. Sketch of the Sungassar-Qala Dizeh mountain valley. A section of this map is shown in Fig. 125.

Soil Type: *Sungassar silty clay;*
Great Soil group: Chestnut Soils;
Parent material: clay layer on top of the middle terrace;

Cultivated flat land, winter crop: wheat once in two years. Estimated yield: approximately 2,500–3,000 kg./ha.

Ap, 0–20 cm. Dark brown silty clay; fine to medium subangular blocky structure, with moderately well formed structural elements, calcareous; sometimes the surface soil is very dark grey-brown; texture is sometimes silty clay loam or clay.

A_3 20–43 cm. Dark brown to brown silty clay, medium prismatic structure of moderately well formed peds; calcareous and friable.

B_2 43–85 cm. Dark yellowish-brown silty clay, medium prismatic structure with moderate well formed peds, friable and a few distinct white spots of lime accumulation. There are vertical strips of somewhat darker coloured material in the upper section of this horizon.

C_{ca} 85–170 cm. Yellowish-brown, friable silty clay with many medium and coarse prominent white spots of lime accumulation.

C 170–250 cm. Yellowish-brown, friable clay loam, almost without lime accumulation.

All horizon boundaries are diffuse. The analyses of soil samples of this profile are given in Table 28.

TABLE 28. *Analytical data of a Sungassar silty clay soil.*

Horizon	Mechanical Analysis			Lime %	pH	Organic Matter
	Sand %	Silt %	Clay %			
0–20 cm.	8	48	44	8	7.1	1.5
20–43 cm.	7	47	46	10	7.1	1.0
43–85 cm.	12	44	44	14	7.6	0.9
85–170 cm.	21	37	41	9	7.4	0.6
170–250 cm.	–	–	–	9	7.1	0.6

Typical characteristics of these Sungassar soils are the self-mulching of the surface and the physical homogenization or churning of the soil to a depth of 50–60 cm. below the surface. Both are of great agricultural significance.

The self-mulching and homogenization process can best be observed in arable land at the end of May and the beginning of June, a few weeks after the end of the rainy season, when the soil begins to crack intensively, with deep cracks (up to 50 or 60 cm. deep and 4–6 cm. wide). These cracks are filled up with soil material of the surface (Fig. 130, 131, 132), which is in a mulched condition. Within a few weeks, all the cracks are filled up with the mulched soil material from the surface as a result of the combined action of wind, sheep, goats, crops, weeds and gravity. When the rains start in the autumn, the soil becomes wet and swells, but the cracks are already filled. The soil material is pushed upwards. The surface material, which has filled up the cracks, is mixed with soil from deeper horizons. The result is that the original dark coloured A-horizon is mixed with the browner coloured B-horizon. Consequently, the upper 50 cm. or more of the soil consist of homogeneous dark brown

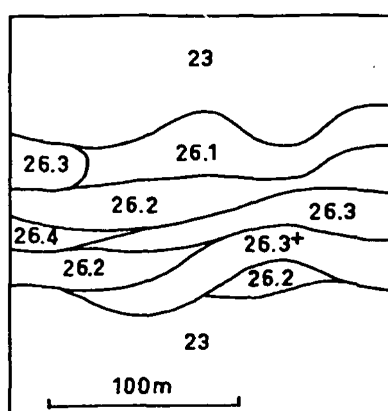


FIG. 128. Very detailed soil map of a sample area in the Sungassar valley. The map shows units 23 and 26 of the soil map in Fig. 125. Subdivisions have been made of soil mapping unit No. 26: 26.1 Cobbly clay; 26.2. medium cobbly clay; 26.3. very cobbly clay; 26.4 stony and cobbly creek bed. A study of soils starts with a very detailed soil survey in sample areas similar to this one. This is followed by a semidetailed soil survey, an example of which is given in Fig. 125. For studies of large areas in a short period, this information can be combined and generalised as has been done in Fig. 127. The soils of the whole valley are finally combined in one unit for an exploratory soil map of Iraq (see map 1).

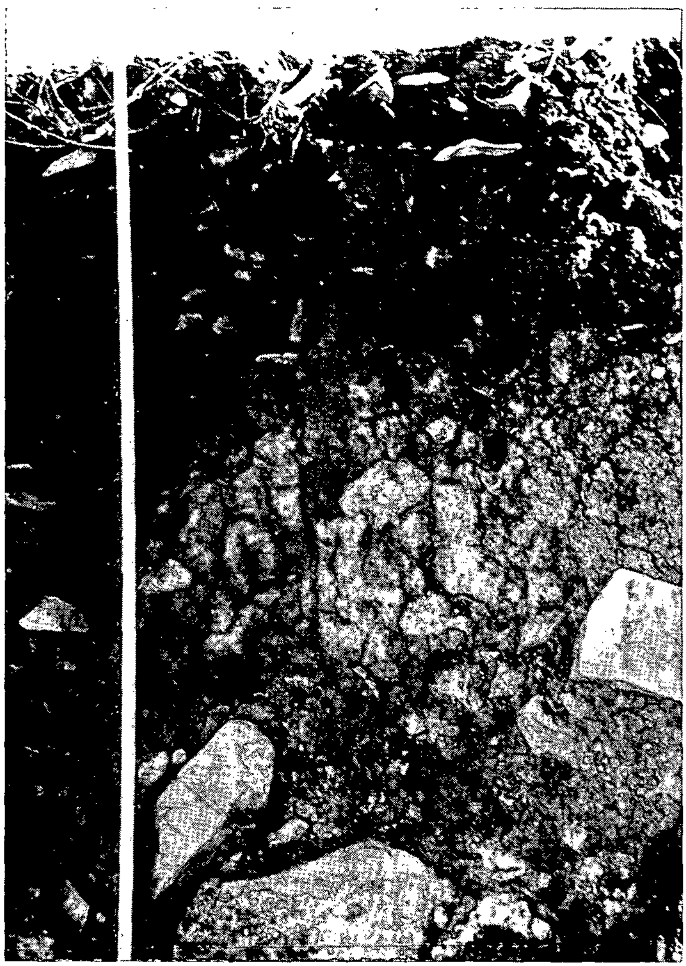


FIG. 129. Soil profile in Dokan clay, a soil series of the Chestnut great soil group. A description of the typical characteristics is given in the text.

silty clay, grading into brown and finally into yellowish-brown friable soil material. There is a continuous mixing of soil material in the upper section of the soil profile. The homogenization process has a favourable influence on soil structure, permeability and fertility. There is a never decreasing soil fertility and the lime content of the surface soil remains at a relatively high level (see Table 28). The organic matter content of the surface soil is relatively low. The smooth upper boundary of the horizon of lime accumulation indicates the approximate depth of soil homogenization. As cracking is sometimes deeper than 60 cm., the lime accumulation is not intensive. It does not exceed 17 %. Soils similar to the Sungassar series have been cultivated for thousands of years without any decrease in fertility. The typical fact is, that 'ploughing' the soil (Fig. 130) and sowing the seed (Fig. 132), is done by nature. Therefore it is not surprising that the oldest agriculture of the world has developed in this area. Man has learned farming practices from nature (Buringh, 1956).

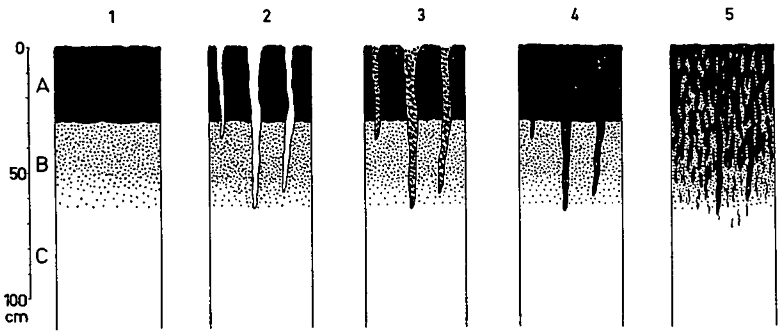


FIG. 130. Diagram demonstrating the churning process in deep Chestnut soils (Sungassar clay). The explanation is given in the text.

Cracking and swelling of these soils is the result of the presence of montmorillonite clay. The process of homogenization in the upper part of the soils of Iraq is limited to the cultivated land, particularly fallow land, of the mountain valleys. Here the soils are self-mulching in the surface (Fig. 133), whereas all other soils in Iraq form a slight or even very hard crust as soon as they dry up. Although there are wide deep cracks in those soils, they are not filled up. The structure of the surface layer is a determining factor.

In the grasslands of the mountain valleys, cracking is less intensive and the grass roots fix the soil. Consequently the soil profiles in natural grasslands have more of the

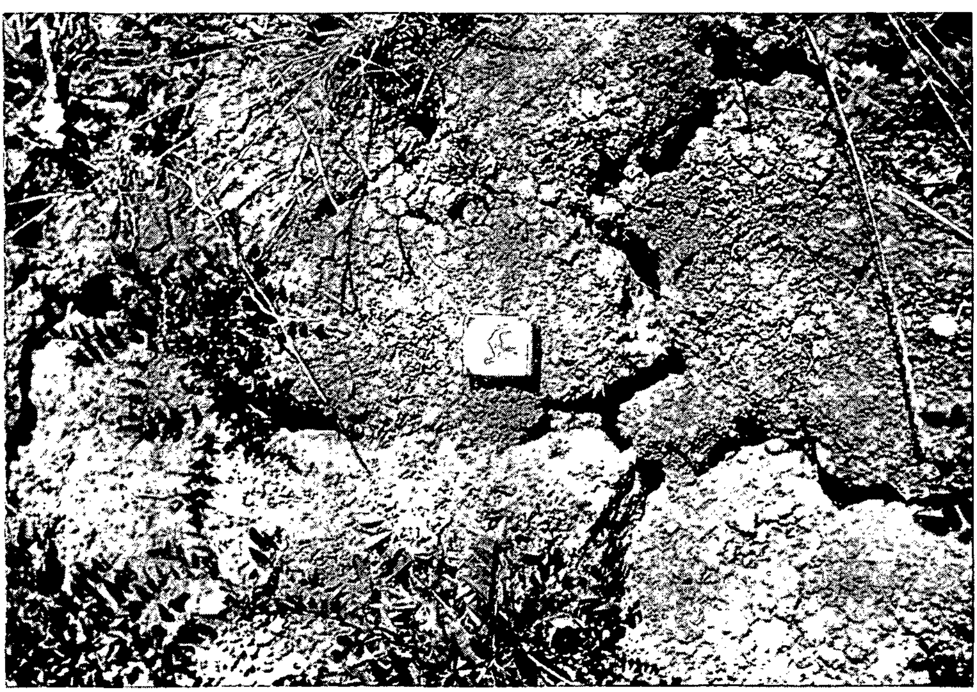


FIG. 131. Surface of a Sungassar silty clay soil in June. Deep wide cracks have just been formed. The surface is mulched. Within a few weeks the cracks are filled up with mulched soil from the surface.

FIG. 132a. Surface of a Sungassar silty clay soil in January. The cracks were filled up with soil material and some wheat grains. The young wheat plants mark the position of last year's cracks.

typical characteristics of Chestnut soils, with a distinct darker coloured (Chernozemic) A-horizon, a more prismatic and browner B-horizon and more abundant lime accumulation (even up to 30%). In soils which contain gravel, the cracking process and consequently, the homogenization process, is also less intensive.

A description of a Chestnut soil in natural grassland is given below for comparison (Fig. 129).

Soil type: *Dokan clay loam;*
Great Soil Group: Chestnut soils;
Natural grassland of tall grass.
Parent material: colluvial weathering products of limestone, mixed with chert.

A 0–28 cm. Dark brown clay loam; medium moderately well formed subangular blocky structure; friable.

B 28–63 cm. Brown clay loam, with a medium moderately well formed prismatic structure.

C_{ca} 63–79 cm. Yellowish-brown clay loam; fine angular blocky structure, many medium and coarse prominent pinkish coloured spots of lime accumulation.

D 79 cm. and below Limestone in blocks of about 30–40 cm.

FIG. 132b. A similar phenomenon as shown in Fig. 132a, although less intensive and deep, was observed in some deep Brown soils. (Photographed some 15 km. east of Tel Kotchek.)

The results of the soil analyses are given in Table 29.

TABLE 29. *Analytical data of a dokan clay loam soil.*

Horizon (cm.)	Mechanical Analysis Sand %	Silt %	Clay %	Lime %	pH	Organic Matter
0–28	30	39	30	3.0	7.6	2.7
28–63	29	34	36	32.8	7.5	0.7
63–79	30	39	31	32.6	7.6	0.5

The differences from the Sungassar soil are evident. In the Dokan clay loam the A, B, C profile horizon development is much more pronounced, the lime content in the A-horizon is relatively low, the B-horizon has a true prismatic structure, colour differences are clear, there is a real lime accumulation and even some clay eluviation. This is all a result of the absence of deep cracks and the presence of a fairly dense grass vegetation. There is hardly any physical homogenization.

Gravel crusts and conglomerate layers occur in the Bakhtiari formation. On the higher terrace, gravel crusts are often at the surface, particularly on the higher parts of the slopes and the rounded hill tops (Fig. 135). On the almost horizontal terraces, the gravels have been cemented by lime at a depth of 1 or 2 metres below the gravel surface, which is about 2–3 metres below the land surface. The cemented gravel layer can be seen everywhere in the terrace and deep gully walls. It is one or two metres thick and is in a horizontal position.

Guest (1953) has published results of the analysis of some soil samples collected east of Dohuk. 'A very heavy soil of dark brown colour, with much organic matter', which is probably a Chestnut soil, showed the following characteristics: (Table 30).

TABLE 30. *Analytical data of a soil sample from Dohuk.*

Particles	Size (mm.)	Per cent	of which are carbonates
Coarse sand	2.0–0.2	3.3	0.7
Fine sand	0.2–0.02	16.8	10.3
Silt and clay	< 0.02	73.2	3.2
Moisture (105 °C.)	–	6.2	–

This analysis, and also those of other samples, indicates that most of the carbonate is present in the 'fine sand' fraction. Approximately 60–100 % of the fine sand particles consist of carbonates. Similar results may be expected for many soils in Iraq, particularly those of the uplands and the Lower Mesopotamian plain, that have extremely high lime contents (generally 20–30 %). A regular distribution of lime over all size fractions, as was predicted by the Hunting Group (1956), cannot be expected.

Something is also known about the soils of the Bakrajo Experimental Station west of Sulaimaniya. There are Chestnut soils with lime accumulation beginning at 50 cm. The land is undulating to rolling; shallow soils occur on the slopes. Rendzina soils are present, too. Recent fertiliser experiments with ammonium sulphate and superphosphate clearly demonstrated the good effect of both, particularly of phosphates.

There is some soil erosion in the mountain valleys. Occasionally rain showers are so heavy that surface runoff becomes important even on almost level and slightly sloping land. It is hardly possible to protect land from such heavy rains. However, there is also much cultivation on sloping land which is unsuitable for it. Most soil management practices are adapted to conservation. As the mountain valleys have been cultivated for at least several thousand years, soil erosion is no problem in this

FIG. 133. Close-up of the soil surface of the Sungassar clay near Qala Dizeh. Medium, moderate crumb structure.

region. One even wonders why the land has not been ruined, and one of the conclusions should be that the farmers of northern Iraq have preserved their land well during quite many centuries. In recent years, farm machinery has been introduced and cultivation of unsuitable land has been started. Both will accelerate the erosion process.

The mountain valleys have been inhabited for thousands of years. Cave men were living in this region during the Neolithic period. Later on the valley bottoms and the soils on the terraces, where numerous tels can be found, were cultivated. Nearly all the archaeological excavations in this region date from the last decade. A better idea about the civilizations in this region can be obtained when more investigations have been made. In Assyrian times the valleys were inhabited and large areas of the mountains were under forest.

The agricultural potentialities of the mountain valley soils are high. Large areas of terrace land could be irrigated in the future. Then more crops could be grown and the fallow system could be abandoned. Fertilisers have to be used, particularly phosphates. Crop rotation could be expanded and livestock could be improved. Better farm management including weed control could be important, too. Introduction of more fruit and various fruit varieties seems feasible if the number of frost-free nights in relation to the growing cycle of the fruits is favourable. A meteorological

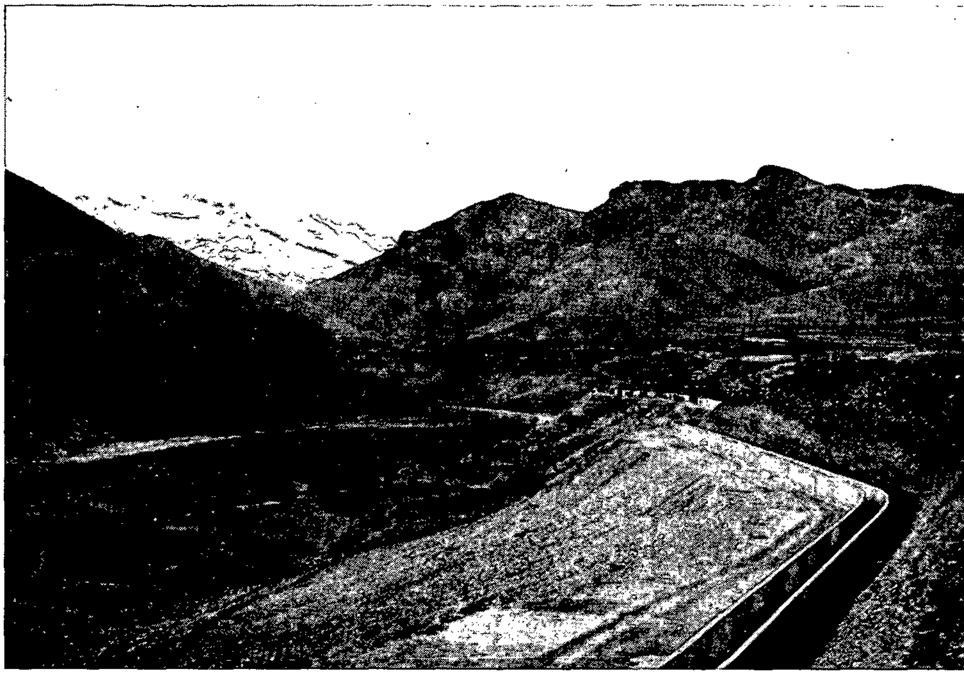


FIG. 134. A concrete flume is being constructed. It will carry water from a small dam, built in a tributary of the Lesser Zab in the mountain valley in the background. Deep Chestnut soils on the terraces of the Sungassar valley will be irrigated in the future.

investigation should not be neglected in a development programme for the mountain valleys.

It may be expected that large parts of the mountain valleys of Kurdistan could be transformed into prosperous agricultural areas, serving the whole country with fruit and vegetables, particularly during the hot season. The transportation problem will be solved when the main roads through the country and those to the valleys are ready and when some secondary roads have also been built. A complex of various measurements must be taken.

From a pedological point of view the potentialities are high. Projects on unsuitable land always end in failure; as may be learned later on from the Sjarkurna project, south-west of Rania.

6.8. FORMATION OF TERRACES

Terraces have been studied in Iraq in the northern part of the Lower Mesopotamian Plain (Chapter 4.2.), as islands in the flood plain (Chapter 4.3.), in the deserts (Chapter 5), and particularly in the uplands and mountain regions (Chapter 6). At least three terraces occur; locally some minor terraces have also been found. Their presence is highly significant for agriculture and soils. The best soils of central and northern

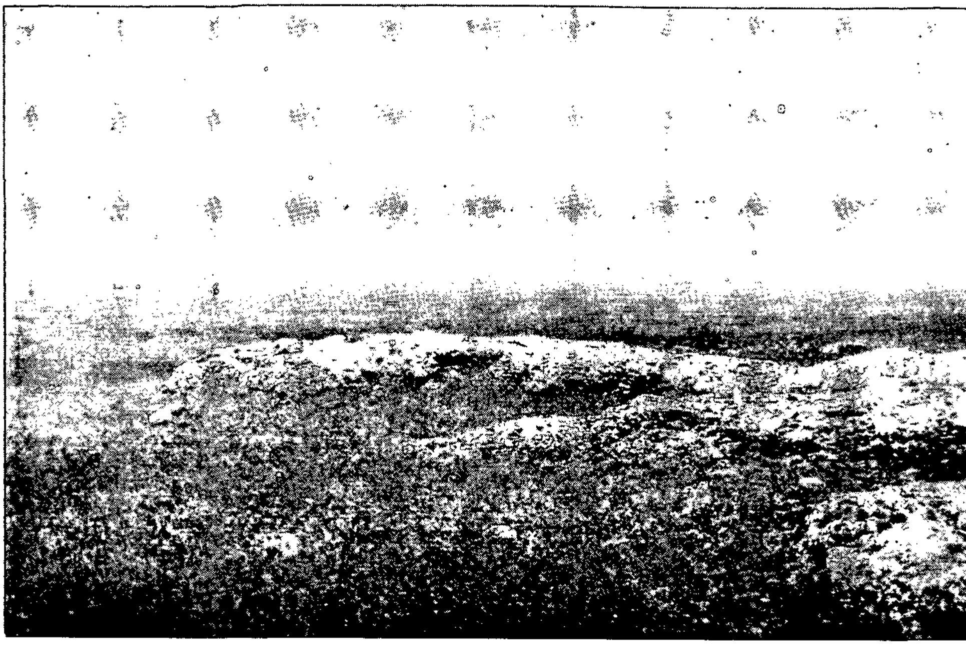


FIG. 135. Shallow soil with gravel crust in the Sungassar valley.

Iraq are located on the terraces. Therefore special attention has to be paid to those terraces, their characteristics and formation. Much can be learned from recent studies made on the same subject in other Middle Eastern countries and North Africa. Reviews of the literature are given by Voûte (1957) and Butzer (1957).

It is generally accepted that the formation of these terraces is the result of an alternation of pluvial (humid) and interpluvial (dry) phases in the climate of the Pleistocene period. These phases probably have to be correlated with the glacial and interglacial phases which are well-known from studies made in Europe and North America. During the pluvial phases of the Pleistocene, the climate in the Middle East was more humid than at the present time and the higher parts of the Zagros mountains were more permanently covered by snow and glaciers. At least two glacial stages have been distinguished in the Iraq mountains (Wright, 1954). During the inter-pluvial phases the climate was drier and warmer. Such phases are comparable with the present-day climate of Iraq.

In Europe and America, the four glacial phases are characterised by a regression, and the interglacial periods by a transgression of the sea. In the glacial periods the sea level was 50–100 metres lower than in the interglacial periods. The various transgressions and regressions of the sea are taken as a basis to explain the formation of coastal and river terraces. This information is also important as regards the southern part of the Lower Mesopotamian Plain and the presence of former cultivated areas on the bottom of the Persian Gulf, as mentioned by Dennis (1953). However, in the mountain valleys of Iraq at an elevation of approximately 500–550 metres above sea level, the explanation using marine transgressions and regressions is erroneous. This has already been pointed out by Choubert (1946) for North Africa. Now the theory of terrace building at high elevations is always considered to be a consequence of changes in climate. The terrace formation is a result of deposition and erosion of soil material by water, characterised by periods with much runoff and periods with less runoff, indicating alternations in the climate.

The chief difficulty found so far is to combine and to correlate all observations (which still have a local character) in order to get a general picture over large areas. The incidental observations made in Iraq during recent years do not even allow of a geographical correlation for this country.

Another problem is how to explain the terrace formation in relation to changing climatic conditions. As regards this problem, Wright (1954) has given his ideas on the terraces near Chemchemal and Jarmo. In my opinion, this theory must be altered a little and some new factors which have not been considered up to now, must be taken into account. After co-operation with my colleague Hoeksema, who studied the formation of river terraces in the Netherlands, it seems to me that a new working hypothesis could be developed.

There are three important facts:

a. The terraces of the mountain valleys are formed in coarse textured, gravelly material, which has been deposited on the valley bottom in fast-flowing water, which came down in large quantities from the mountains.

b. This material has been partly eroded. The non-eroded gravel material in situ finally forms the terrace, and in the eroded part a new, lower lying valley bottom has been formed.

c. A layer of fine textured material covers the erosional surface of the terrace; it is a younger deposit and is being deposited in relatively slow-running water during high floods.

Changes in climate are fundamentally changes in precipitation and temperature. This affects the degree of runoff and erosion, the quantity of water percolating through the soils and the discharge of the rivers accordingly.

During the pluvial phases a relatively dense vegetation has been developed, which is almost absent when the climate is arid. The vegetation affords protection to the soil, decreases runoff and erosion and regulates the discharge of the rivers. If the soil is not protected, the loose material, particularly on slopes, is eroded. The suspended material gives a heavy load to the river water.

Considering the various processes, the figures for extremes of climate should be selected rather than the average data. Most of the precipitation was in the winter months during which the majority of the mountain region was covered by snow and ice. Rainfall was not continuous but there were often very heavy rainstorms. Frequently these rainstorms coincide with the thawing period as a result of which immense quantities of water must be transported by the rivers in a short period.

Taking these basis facts into account, the conditions in a pluvial and interpluvial phase can be described as shown in Table 31. Besides these conditions, those prevailing in an early-pluvial and an early-interpluvial period have to be mentioned in order to point out the extreme conditions which are of paramount importance.

TABLE 31. *Conditions and factors determining terrace formation in the mountains valleys of Iraq.*

Factor/Condition	Pleni-Interpluvial	Early Pluvial	Pleni-Pluvial	Early Interpluvial
Climate	Arid or semi-arid	More humid	Humid	More arid
Precipitation	Low	Increasing	High	Decreasing
Vegetation on Mountains	Sparse	Increasing	Permanent cover	Full cover, decreasing
Soil erosion	Medium	Severe	Slight	Slight, increasing
Runoff	Incidental	Much	Little	Little
Discharge of rivers	Torrential in spring	Very high	Regular	Rather regular
Load in suspension	Great, fine particles	Very great, coarse particles	Relatively little	Little, increasing
River system	Braided	Braided	Meandering	Meandering
Stream erosion	No	No	Yes	Little
Deposition of gravel (valley bottom)	Little	Much	No	No
Deposition of Silt (on terrace)	Almost nil	Almost nil	Yes, during floods	Little, during occasional floods
Final result	Valley is covered with some gravel	Valley is filled with gravel	New valley is eroded; old surface becomes terrace	Deposition on the bottom of the new valley begins

A schematic picture of the situation in the various stages is given in Fig. 136.

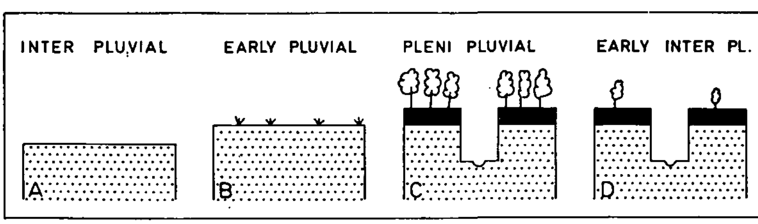


FIG. 136. Schematic diagram of terrace formation in a mountain valley. Explanation in the text.

A. shows the gravelly erosional surface in the valley of a braided river during an interpluvial phase.

B. shows more gravel deposited on the valley bottom during an early pluvial phase, when a large quantity of coarse material is eroded from the mountains; most of this material has been transported to the foothills and uplands. Erosion on the mountains is progressing since the vegetation cover has not yet been fully developed.

C. demonstrates the situation in the pleni-pluvial period (everything has been changed). A vegetation cover has been developed; only fine-textured material is eroded from the mountains. The discharge of the rivers is more regular; the river system has been changed into a meandering river which is eroding the gravelly erosional surface, forming a deep new river valley. The former erosional surface is becoming a high terrace; on top of it fine textured material is deposited during floods.

D. demonstrates the situation at the beginning of an interpluvial period. There is still a vegetation cover and there is no great difference from a pluvial phase.

The whole cycle now starts again on a lower level.

As there are three terraces in the Sungassar valley, there are three cycles of climatic changes. In Africa (Cole, 1954) there is evidence of four major pluvial periods. In applying the above-developed hypothesis to the formation of terraces in the mountain valleys, the following explanation can be given. The pluvials are tentatively correlated with the glacial phases and indicated by the names which are used in Africa (Cole, 1954):

TABLE 32. *Correlation of glacial and pluvial stages in the pleistocene.*

Glacial Stages in Europe	Pluvial stages in Africa and the Middle East
Atlanticum	Makalian
Würm 3 and 4	Gamblian 3
Würm 2	Gamblian 2
Würm 1	Gamblian 1
Riss	Kanjeran
Mindel	Kamasian
Günz	Kageran (?)

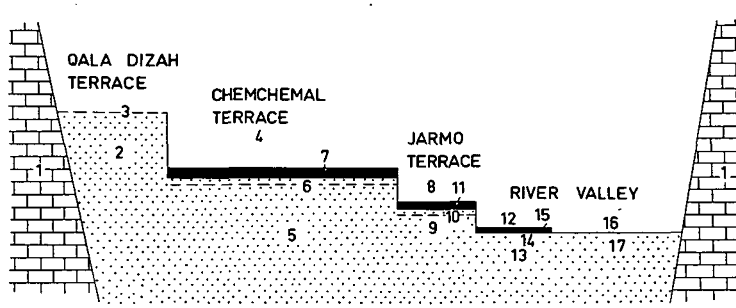


FIG. 137. Schematic cross-section of the Sungassar valley. The explanation is given in the text.

Explanation of the schematic cross-section of the Sungassar valley (see Fig. 137):

Material	Formed in:
1. Limestone mountains	Tertiary period
2. Bakhtiari gravel	Pliocene, Kageran pl.
3. Gravel crust	Kamasian-Kanjeran interpluvial
4. Valley	Kamasian pleni-pluvial
5. Bakhtiari gravel	Valley bottom in late Kamasian pluvial
6. Gravel with crust	Kamasian-Kanjeran interpluvial and early Kanjeran pluvial; crust in Kanjeran-Gamblian interpluvial
7. Silt layer	Kanjeran pleni-pluvial
8. Valley	Kanjeran pleni-pluvial

Material	Formed in:
9. Bakhtiari gravel	Valley bottom in late Kanjeran pluvial
10. Gravel with crust	Kanjeran-Gamblian interpluvial and early Gamblian pluvial; crust in Holocene
11. Silt layer	Gamblian pleni-pluvial
12. Valley	Gamblian pleni-pluvial
13. Bakhtiari gravel	Valley bottom in late Gamblian pluvial
14. Gravel	Early Holocene
15. Silt layer	Floods in Holocene
16. Present river bed	Recent
17. Gravel of river bottom	Recent

The middle and lowest terraces have been named by Wright (1952, 1954) the 'Chemchemal' and 'Jarmo' terrace respectively. I have given the name 'Qala Dizah' terrace to the highest one. A summary of the terrace formation is given in Table 33.

TABLE 33. *Terraces in the Sungassar plain:*

Terrace	Material	Deposited in	Terrace since
Quala Dizah	Gravel	Kageran pluvial	Kamasian pluvial
Chemchemal	Clayey layer	Kangeran pluvial	Kanjeran pluvial
Jarmo	Clayey layer	Gamblian pluvial	Gamblian pluvial
Valley bottom . . .	flooded	Holocene	–

The explanation of the terrace formation in the uplands and the Lower Mesopotamian Plain is different from that of the mountain valley terraces.

Terraces in the plain have been built up by the rivers during periods of great discharge and a large suspended load. The gravel material of the upper terrace consists of the products of stream erosion of the Bakhtiari material in the mountain valleys and foothills. This material has been transported over a great distance and then deposited in the plain along the rivers in a pleni-pluvial phase. Lower-lying stream beds have been eroded in the early interpluvial and pleni-interpluvial, forming at the same time the deposited material of the foregoing pluvial which is left behind as a terrace. Consequently the terrace formation in the uplands and in the Lower Mesopotamian Plain is about a quarter or a half cycle behind. The soil cover on top of these terraces was formed in an early pluvial phase during high floods. Accordingly the following scheme (Table 34) has been put forward for the Tigris terraces (see Chapter 4.2.).

TABLE 34. *Terraces of the Tigris river in the uplands and the Lower Mesopotamian Plain.*

Terrace	Material	Deposited in	Terrace since
Mutawakkil	Gravel	Kamasian pluvial	Kamasian-Kanjeran interpluvial
Muthasim	Gravelly clay	Kanjeran pluvial	Kanjeran-Gamblian interpluvial
Mahdy	Clayey layer	Gamblian pluvial	Holocene
Flood plain	Flooded	Holocene	–

Comparing tables 32 and 33, it is clear that there is an essential difference in age between similar terraces of the mountain valleys and those of the uplands and Lower Mesopotamian Plain. The material has also been eroded and deposited under different environmental conditions. Therefore the terraces have been given different names.

The former bed of the Tigris river, which is situated in the desert on the Mutawakkil terrace south of Samarra (see Fig. 49) therefore indicates the position of the Tigris river during the Kamasian pluvial. The approximate age of the various terraces and soil layers on top of these terraces, which have been mentioned in chapters 4, 5, and 6, can tentatively be determined using the tables in this chapter.

The terraces which can be seen in the deserts of Iraq (Fig. 101) were formed during pluvial phases of the Pleistocene when some heavy showers had produced torrential streams which eroded the desert plains (Chapter 5.3.). Some large desert depressions are dried up lakes of Kanjeran or Gamblian age.

Besides the three main terraces, one, or possible a few, minor terraces occur locally in Kurdistan. One has been mentioned by Wright (1952), which may correspond with a relatively colder post Würm phase in Europe. A minor terrace also occurs near Balad and Samarra (van der Kloes, 1956).

More evidence of former arid stages is provided by the wind-blown sand areas. Some of these sand dune complexes are recent, others (e.g. in the Western Desert) are probably of Kanjeran-Gamblian age.

So far no attention has been paid to tectonic uplifts. According to Wright (1954), no great influences on terrace formation may be expected from tectonic movements in the second half of the Pleistocene and the Holocene. Slight movements have been observed by Lees and Falcon (1952), Voûte (1956) and van der Kloes (1956). Local differences, such as combinations and separations of river drainage systems may also contribute towards explaining the formation of minor terraces.

Another complication is evident from the fact that some of the high valleys were lakes during the pluvial phases, particularly during the first one. As soon as a gorge was formed, the water could drain away. High valley lakes also occurred in Iran (Ghirshman, 1954). Small remnants of gravel crust many metres above the present Sungassar gorge, probably indicate that this valley was once a mountain lake. A landslide in one of the deep gorges may also have given rise to the formation of mountain lakes, and finally to terraces.

The working hypothesis, as explained in this chapter, helps to understand the morphological and soil conditions of large regions of Iraq. This however does not imply that the hypothesis is correct. It may have to be altered when more information is available.

CHAPTER 7

AGRICULTURAL DEVELOPMENT AND SOILS

7.1. AGRICULTURE ON SALINE SOILS

The brief description in Chapter 2.8. gives a general idea about agricultural in Iraq. An extensive description is beyond the scope of this book but some facts on farming on saline land must be discussed.

Irrigation-agriculture in a kind of fallow system of farming is a very old method in the Lower Mesopotamian Plain. The oldest written document on agriculture is a 3,000 years old clay tablet with cuneiform script found at Nippur (Jacobson, 1951); it gives instructions on sowing and irrigation. The present system of farming is based on centuries of practical experience under specific Mesopotamian conditions. Fifty per cent of the cultivated land has a winter cereal crop (shitwi crop, mainly barley, sometimes wheat) from October to April, followed by an eighteen month fallow without irrigation and ploughing for two summers, and with a very scanty rainfall during one winter. According to Turcan (1946) the soil moisture content drops from 34% at the end of the growing season to 10% at the beginning of the new crop season. Summer or saifi crops (mainly cotton and some vegetables) are grown on a very limited area (see Table 15).

The common irrigation method of shitwi crops is the border method, consisting of plots of approximately 15 × 30 metres on both sides of the irrigation ditch. Cotton and most vegetables are grown by applying the furrow method. Water is applied every two or three weeks, to shitwi crops, sometimes once a month. The irrigation system is rather primitive and often there are major water losses.

The wheat and barley varieties are adapted to the Mesopotamian conditions, including soil salinity. Nothing is done to control the weeds; shok *(Prosopis Stephe-*

FIG. 138. Ploughing land in the Lower Mesopotamian Plain.

niana) and agul or camelthorn *(Alhagi maurorum)* being the principal weeds. No fertilisers or manure are being applied. Yields are low (see Table 20).

The tillage practices are rather primitive (Figs. 138 and 139). An animal-drawn wooden plough, a parting plough, is still generally used throughout Iraq. Russel (1957) has described two types: the arrow pointed plough used in the uplands, and the shovel pointed plough used in the Lower Mesopotamian Plain. His conclusion is that both types of plough and the tillage practices are well adapted to the prevailing conditions. Modern ploughs are less suitable.

During the six months of the growing period of shitwi crops, some leguminous weeds (particularly shok and agul) also grow. These deep rooted perennials are rather salt tolerant and grow rapidly after the crop yield. These weeds use the water left in the soil; they lower the perched groundwater table and dry out the soil and substratum. At the end of the eighteen months idle period, the soil is dry to a depth of at least 2–3 metres. As a consequence there is no salt accumulation in the solum. The legumes accumulate nitrogen and are used for fuel at the end of the idle period. During the next periods of irrigation, salts in the surface soil go into solution and are washed down to the subsoil and substratum, particularly when some extra irrigation water is applied. Over-irrigation, a practice which is often criticised, helps to leach the soil.

This system, which is based on the principle of lowering the perched groundwater table during the idle period, only works if a special section of an irrigation unit is irrigated, and another section is left idle. If there is a mixture of irrigated and non-irrigated plots all over the area, the groundwater table will be too high.

Floods, which occur on the flood plain once in a few years, have a similar effect. Flood water leaches the upper part of the dry soil and 'pushes' the salts down to deeper layers.

Russel (1957) has calculated that the idle system with shok and agul enables farmers to use land for about 450 or 500 years. Then the salt accumulation will become dangerous and the farmers will have to abandon the land for a long period, during which the groundwater level will fall to a depth of 5 or 7 metres, and from that time it will be possible to wash the salts out of the upper 2–3 metres down to a depth of 5–6 metres and the land will become suitable for a new cycle of farming.

This type of farming with weeds during the idle period is applied in those parts of Mesopotamia where groundwater under natural conditions is at least some metres below the land surface. It is therefore limited to the northern section of the Lower Mesopotamian Plain, particularly the fluviatile terrace region and the flood plain.

In the delta and marsh region where the groundwater is always high, a different method, which could be called 'the method of isolated salt areas', is applied. Special sections of a cultivated area are left idle. They are surrounded by irrigated fields with shitwi crops. In giving some extra irrigation water to the cultivated plots, salts are leached from the surface soil, and as there is a hydraulic gradient, the saline water is 'pushed' to the idle fields, where salts are accumulated at the surface. Slightly or medium saline land and strongly saline land occur in the area a rather short distance apart. This explains why farmers consider only those soils which have a real white salt crust as being saline. As salts of the sabakh soils are easily washed, such soils are not considered as being unsuitable for crop production.

FIG. 139. Before ploughing the land, barley seed is broad-casted.

The extremely high salt content of uncultivated, older irrigation levee soils is also a result of this system of farming on saline land.

Rice cultivation is based on similar principles. Mostly farmers try to drain some surface water after a few days of heavy irrigation, when this water has become saline due to diffusion.

Another method is applied to vegetables, particularly tomatoes, on small plots during the summer. Farmers dig irrigation furrows about two metres apart, about 30 cm. deep and 30 cm. wide with a flat bottom and erect sides. Tomatoes grow on a small shelf, half way up the northern side of such a furrow, by filling these furrows with water up to the level of the tomatoes. Salts in the soil near the tomato plants are pushed to the upper part of the furrow wall and to the strip in between two furrows. Later on the salt free strip of soil half way up the southern side of the furrow is added to the plants on the northern side.

These methods of farming on saline land are of fundamental importance for Iraq. I do not think any better methods could be developed at the present time.

All measures to be taken in order to improve agriculture in this country are useless if they do not fit into these systems. It will pay to study the various farming methods in more detail in order to profit from them when farming on non-saline, well-drained land is introduced.

At present the farmers do not like weed control, new types of crops, fertilisers, other methods of irrigation, more saifi crops etc. If it is understood why, and under what economic and social conditions the farmer and his family must live, one can at least realise how difficult and complicated it will be to improve the irrigation-agriculture of Iraq. The first step to be taken is the leaching of salts from the soils and drainage of the land.

7.2. Soil fertility

The concepts 'fertile' and 'non-fertile' soil have been used in the past to indicate favourable and unfavourable chemical characteristics of soils under natural conditions in relation to high and low crop production respectively. Improvement of natural fertility can be made by applying chemical fertilisers. But, even with chemical fertilisers, many soils can only produce low yields because the physical soil conditions are poor (structure, consistence, porosity, density, permeability etc.). In modern soil science the concepts 'good' and 'poor' soils, or 'productive' and 'unproductive' soils have therefore been introduced. They refer to the general soil conditions under normal farm management practices, including the addition of fertilisers.

The natural fertility of nearly all soils in Iraq is low. There are many potentially good soils. The effect of commercial fertilisers on the potentially good soils of central and southern Iraq is nil as long as these soils are saline. If applied to the potentially good soils in the non-saline regions of northern Iraq, fertilisers might give a good response.

So far very few chemical fertilisers are used in Iraq (Table 35).

Table 35. *Commercial fertilisers imported into Iraq* (data from the Directorate of Customs).

Year	Kind of Fertiliser	Tons
1951	All	100
1952	All	59
1953	All	32
1954	All	379
1955	All	515
1955	Ammonium sulphate (21 %)	450
	Mixed Fertilisers (13, 13, 18 %)	20
	Superphosphate (16–18 %)	35
	Superphosphate (44–46 %)	10

Approximately 90 % of these quantities are used on vegetables grown for sale in the vicinity of cities.

Manure and town refuse are used in some gardens, particularly near Kerbala. Some tobacco fields in northern Iraq also get some manure. Nearly all manure, particularly in central and southern Iraq, is used as fuel. The fresh or moistened manure is mixed with straw and dried in the sun (Fig. 140). It is often a commercial product.

The centuries-old practice of burning manure is often criticised because the opinion is that the manure should be applied to the soils in order to increase the organic

FIG. 140. Fuel making from dung. 1. dung, mixed with straw; this is wetted, kneaded and dried in the sun (2); 3. the sun-dried product, which is sold in Baghdad and used for cooking and baking local bread. This centuries-old practice is probably better than bringing the dung to the fields.

matter content, and the micro-biological activity, as well as to improve soil structure, as may be learned from all textbooks on soils. I agree with Keen (1946), who states that in arid and hot regions the organic manure disappears in a short time, due to rapid oxidation, and therefore the soils obtain no benefit from it. This is particularly true if the soils are saline.

The organic matter content of Desert soils, Sierozem soils, Reddish brown soils, Brown soils and arid Alluvial soils is extremely low. It is impossible to increase the organic matter content in such soils on a permanent basis to the level of even a few per cent. Even after a few years of pasture, or leguminous fodder crops, the apparently increased organic matter content drops rapidly to the former low level, which is adapted to environmental conditions.

The first information on soil fertility dates from a study by Webster (1921) on the soils of the Diyala region. All studies made so far (see Chapters 4, 5 and 6) have given similar results. There is a shortage of nitrogen and phosphorus. The potassium content generally seems to be sufficient. Although the nitrogen content is relatively low in most arid soils, there is more nitrogen available at the end of the idle period than at the beginning, mostly due to accumulation by leguminous weeds. Keen (1946) points out that nitrogen in these soils is mainly ammoniacal nitrogen, not nitrate, and that there is a rapid biological conversion to nitrate, when remoistening of the soil by irrigation water takes place. It may be noticed that nitrogen is leached during heavy rains, because crops generally suffer from nitrogen shortage after such rains. Shortage of phosphate can be observed in almost all gypsiferous soils. Various deficiency diseases occur in date and citrus trees. A shortage of some minor elements (boron, cobalt and zinc) might be expected.

The number of field trials with chemical fertilisers is very limited. A significant increase in wheat production was found on plots in Abu Ghraib in 1953, but the costs of the fertilisers exceeded the value of the extra yield. For cotton, only phosphate has given any response; here, too, it did not pay. In Bakrajo an important increase in rice production was reached by applying superphosphate. It seems that some positive results were achieved using N- and P- fertilisers on vegetables, particularly tomatoes. Demonstration fields in some newly reclaimed land development projects have given positive indications of response to nitrogen and phosphorus (Ali, 1955). Unfortunately no results of any experiments have been published. Most experiments terminated after one season. It may be expected that the effect of chemical fertilisers would also be important in the second year because hardly any fertilisers are leached. As long as soils in central and southern Iraq are saline, hardly any results may be expected from chemical fertilisers. The Dujaila experiments on leaching of saline soils (Boumans, 1957) have clearly indicated that during leaching, all nitrogen is washed out. After leaching, nitrogen fertilisers have to be applied. In the future nitrogen and probably also phosphorus will be needed on all well drained, non-saline soils. An increase in crop production depends on a series of measures being taken as no important response would be expected from only one, e.g. fertilisers, if the others are neglected. Weed control, insect and disease control, better and proper irrigation practices, new crops, crop rotation and new crop varieties are just a few of them.

The general idea is that for nearly all crops (except tobacco), and for all soils, the present potassium content is sufficient. If in the future crops are grown in an intensive system of farming on a relatively high level, a shortage of potassium will be evident.

So far no chemical fertilisers are advised for saline soils. Investigations could be carried out to at least determine the level and type of salinity in slightly saline soils above which nitrogen and phosphates will definitely give no response.

As soon as leached and well-drained, non-saline areas are available on various types of soil, trials in combination with soil analyses must be made in order to collect basic data on the evaluation of the laboratory analyses, on quantities and kinds of fertilisers to be applied, and on time of application. This information cannot be taken from trials in other countries because soil conditions are different. For the upland and mountain soils this work could be started on a systematic basis.

The commercial fertilisers needed in the future agriculture of Iraq should not contain chloride and magnesium. Lime fertilisers will never be required. Ammonium-sulphate and superphosphate are required in large quantities. In the future ammonium-sulphate will be produced in Iraq by using the oil gases. Superphosphate will probably be sent from Jordan which has natural phosphate resources. The annual requirements of chemical fertilisers in Iraq after 15 or 25 years is estimated by a special committee to be: 17,000 tons pure nitrogen, equivalent to 83,000 tons of ammonium sulphate (20.5%), and 19,000 tons pure P_2O_5 equivalent to 117,000 tons of superphosphate (16%). This estimation depends on the agricultural development, the costs of production and the market price of these fertilisers.

7.3. Irrigation and drainage

7.3.1. *Irrigation*

Irrigation in Iraq dates from prehistoric times, when small earth dams were built in mountain streams in order to direct water to adjacent land which was probably grazing land (Frankfurt, 1951). Some water might have been used for primitive cultivated land. From the time these mountain people came down to the Mesopotamian plain, more than 6,000 years ago, cultivation depending on irrigation started in the plain. The living conditions in the various physiographic regions have been described by Buringh (1957). Under natural conditions, settlement was possible only on the border of the river terraces (Samarra) and on the river banks in the estuary region. Later on settlement became possible in the basins of the delta plain which were irrigated by natural floods. A very primitive system of irrigation consisting of a short cut in the river banks was probably the first step. This system has gradually been developed into a canal system and finally into a controlled canal irrigation system on the delta and flood plain.

Cultivation of land in artificially flooded or irrigated river basins implies a co-operation, organisation and administration of all people depending on the same irrigation unit. Big irrigation schemes like that of the Nahrwan could only be constructed by a central government. In the history of Iraq reference is often made to years in which important canals were dug because the construction of such a canal was regarded as being equal in importance to a victory (Contenau, 1954).

During wars and periods of internal troubles, canals were neglected, silted up and sometimes destroyed. Some areas became too saline for cultivation. The present irrigation system is almost the same as it was centuries ago.

From the time that motor pumps were made available some 30 years ago, irrigation of the higher lands on the river banks became possible. The lift irrigation has created new possibilities for agriculture. It would also have been possible to start land drainage since pumps were available. But the problems related to this subject were not generally understood up to a few years ago, although Willcocks (1911) and the first soil scientists in this country (Webster, 1921) have given good advice.

The physiography of the Lower Mesopotamian Plain is such that drainage and leaching of salt in large areas is almost impossible without motor pumps. Some areas may have a 'free flow' drainage. Modernising the irrigation system has no effect if no drainage system is made at the same time. Since the engineering problems related to land drainage are solved, the agriculture of Iraq is entering a completely new phase. New possibilities are created to improve and expand the agricultural production, which will change the whole country. In the history of six millenia of irrigation agriculture, this will be a real revolution. Under the new conditions a modern irrigation system will also be needed. Some aspects of present-day modern irrigation in Iraq, with an example of the primitive and of a modern system (Greater Mussayib project) have been described by Nugteren (1955).

The costs of the modern irrigation-drainage systems are high and a large number of engineers and technicians are required for construction and later on also for running and maintenance. The total costs of new irrigation works, including drainage, road construction and land levelling are estimated at ID. 335,000,000 (Nelson, 1956). All work has to be based on a central overall planning which requires a strong central government.

Such technical development, which has already been started, has many economic, social and even political consequences. It influences almost all phases of human life. The few decades in which the transition from old to new has to be performed are extremely difficult, particularly for the Government.

From a technical point of view, two basic facts have to be mentioned about soils:

1. Soils which can be drained should only be irrigated. Soils which cannot be sufficiently drained will remain saline or even increase in salinity or alkalinity and consequently they are unsuitable for future agricultural production. A classification of soils according to their drainability therefore has to be made before starting a project.

2. Only land with good and excellent agricultural potentialities should be included in the new projects, because economic agriculture can only be developed on good soils. The population of Iraq is thin; there is enough good land and therefore there is no reason to develop areas with potentially poor soil conditions.

Soil conditions in the Lower Mesopotamian Plain, the most important region for irrigation-agriculture, vary widely, even over short distances. Potentially good and poor soils occur together in an intricate pattern. There are no large areas of uniform, potentially good land. The irrigation-drainage planning should be adapted to this pattern.

In a primitive system of irrigation without drainage, the costs of the irrigation works made to supply land with water, are approximately ID. 1/500 per donum. A modern irrigation-drainage system will cost at least ID. 25 to 35 per donum, not including the costs of the flood protection works, barrages, dams, etc. In some areas the costs are estimated at ID. 50–60 per donum. It is economical to spend this money, if indeed the agricultural production will be increased, which first of all depends on the quality of the soils under the new conditions. Neglecting this basic principle will lead to a failure of the projects, disappointment of the people and the waste of money and natural resources.

Whether land, water or drainage taxes should be paid or not is another problem. Recently the Government has tried to introduce land taxes, but without success; new proposals are in preparation. Product taxes or income taxes, levied in a proper way, might have a similar effect. Water taxes could probably stop cultivation on poor land. Land taxes should be related to the potential agricultural productivity.

The consumption of water will increase and shortage of water may become a problem. More water is required for:

FIG. 133. Close-up of the soil surface of the Sungassar clay near Qala Dizeh. Medium, moderate crumb structure.

region. One even wonders why the land has not been ruined, and one of the conclusions should be that the farmers of northern Iraq have preserved their land well during quite many centuries. In recent years, farm machinery has been introduced and cultivation of unsuitable land has been started. Both will accelerate the erosion process.

The mountain valleys have been inhabited for thousands of years. Cave men were living in this region during the Neolithic period. Later on the valley bottoms and the soils on the terraces, where numerous tels can be found, were cultivated. Nearly all the archaeological excavations in this region date from the last decade. A better idea about the civilizations in this region can be obtained when more investigations have been made. In Assyrian times the valleys were inhabited and large areas of the mountains were under forest.

The agricultural potentialities of the mountain valley soils are high. Large areas of terrace land could be irrigated in the future. Then more crops could be grown and the fallow system could be abandoned. Fertilisers have to be used, particularly phosphates. Crop rotation could be expanded and livestock could be improved. Better farm management including weed control could be important, too. Introduction of more fruit and various fruit varieties seems feasible if the number of frost-free nights in relation to the growing cycle of the fruits is favourable. A meteorological

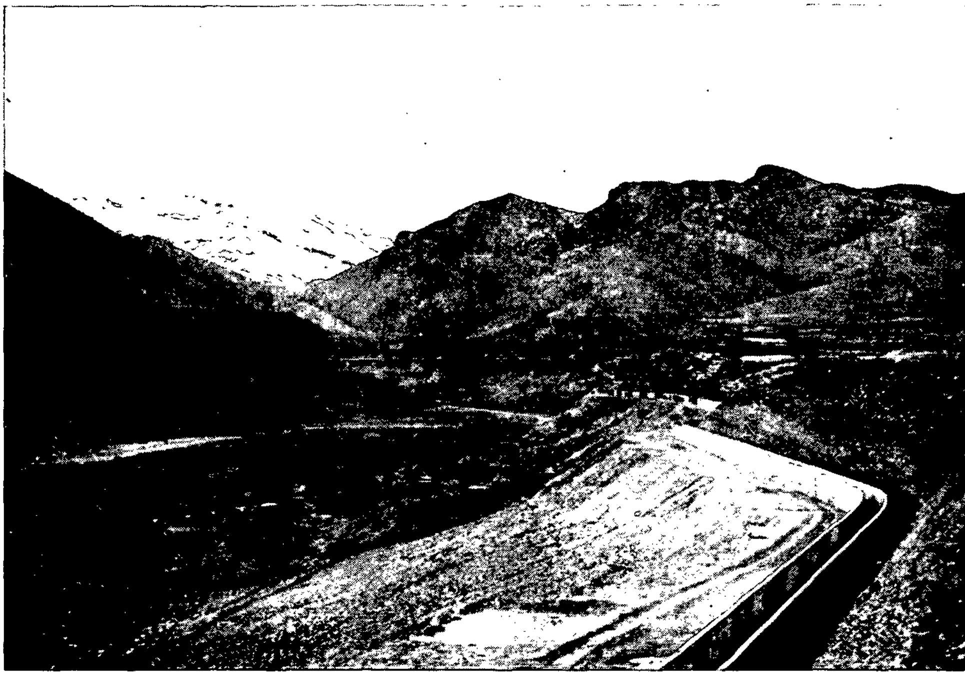


FIG. 134. A concrete flume is being constructed. It will carry water from a small dam, built in a tributary of the Lesser Zab in the mountain valley in the background. Deep Chestnut soils on the terraces of the Sungassar valley will be irrigated in the future.

investigation should not be neglected in a development programme for the mountain valleys.

It may be expected that large parts of the mountain valleys of Kurdistan could be transformed into prosperous agricultural areas, serving the whole country with fruit and vegetables, particularly during the hot season. The transportation problem will be solved when the main roads through the country and those to the valleys are ready and when some secondary roads have also been built. A complex of various measurements must be taken.

From a pedological point of view the potentialities are high. Projects on unsuitable land always end in failure; as may be learned later on from the Sjarkurna project, south-west of Rania.

6.8. Formation of terraces

Terraces have been studied in Iraq in the northern part of the Lower Mesopotamian Plain (Chapter 4.2.), as islands in the flood plain (Chapter 4.3.), in the deserts (Chapter 5), and particularly in the uplands and mountain regions (Chapter 6). At least three terraces occur; locally some minor terraces have also been found. Their presence is highly significant for agriculture and soils. The best soils of central and northern

FIG. 135. Shallow soil with gravel crust in the Sungassar valley.

Iraq are located on the terraces. Therefore special attention has to be paid to those terraces, their characteristics and formation. Much can be learned from recent studies made on the same subject in other Middle Eastern countries and North Africa. Reviews of the literature are given by Voûte (1957) and Butzer (1957).

It is generally accepted that the formation of these terraces is the result of an alternation of pluvial (humid) and interpluvial (dry) phases in the climate of the Pleistocene period. These phases probably have to be correlated with the glacial and interglacial phases which are well-known from studies made in Europe and North America. During the pluvial phases of the Pleistocene, the climate in the Middle East was more humid than at the present time and the higher parts of the Zagros mountains were more permanently covered by snow and glaciers. At least two glacial stages have been distinguished in the Iraq mountains (Wright, 1954). During the inter-pluvial phases the climate was drier and warmer. Such phases are comparable with the present-day climate of Iraq.

In Europe and America, the four glacial phases are characterised by a regression, and the interglacial periods by a transgression of the sea. In the glacial periods the sea level was 50–100 metres lower than in the interglacial periods. The various transgressions and regressions of the sea are taken as a basis to explain the formation of coastal and river terraces. This information is also important as regards the southern part of the Lower Mesopotamian Plain and the presence of former cultivated areas on the bottom of the Persian Gulf, as mentioned by Dennis (1953). However, in the mountain valleys of Iraq at an elevation of approximately 500–550 metres above sea level, the explanation using marine transgressions and regressions is erroneous. This has already been pointed out by Choubert (1946) for North Africa. Now the theory of terrace building at high elevations is always considered to be a consequence of changes in climate. The terrace formation is a result of deposition and erosion of soil material by water, characterised by periods with much runoff and periods with less runoff, indicating alternations in the climate.

The chief difficulty found so far is to combine and to correlate all observations (which still have a local character) in order to get a general picture over large areas. The incidental observations made in Iraq during recent years do not even allow of a geographical correlation for this country.

Another problem is how to explain the terrace formation in relation to changing climatic conditions. As regards this problem, Wright (1954) has given his ideas on the terraces near Chemchemal and Jarmo. In my opinion, this theory must be altered a little and some new factors which have not been considered up to now, must be taken into account. After co-operation with my colleague Hoeksema, who studied the formation of river terraces in the Netherlands, it seems to me that a new working hypothesis could be developed.

There are three important facts:

a. The terraces of the mountain valleys are formed in coarse textured, gravelly material, which has been deposited on the valley bottom in fast-flowing water, which came down in large quantities from the mountains.

b. This material has been partly eroded. The non-eroded gravel material in situ finally forms the terrace, and in the eroded part a new, lower lying valley bottom has been formed.

c. A layer of fine textured material covers the erosional surface of the terrace; it is a younger deposit and is being deposited in relatively slow-running water during high floods.

Changes in climate are fundamentally changes in precipitation and temperature. This affects the degree of runoff and erosion, the quantity of water percolating through the soils and the discharge of the rivers accordingly.

During the pluvial phases a relatively dense vegetation has been developed, which is almost absent when the climate is arid. The vegetation affords protection to the soil, decreases runoff and erosion and regulates the discharge of the rivers. If the soil is not protected, the loose material, particularly on slopes, is eroded. The suspended material gives a heavy load to the river water.

Considering the various processes, the figures for extremes of climate should be selected rather than the average data. Most of the precipitation was in the winter months during which the majority of the mountain region was covered by snow and ice. Rainfall was not continuous but there were often very heavy rainstorms. Frequently these rainstorms coincide with the thawing period as a result of which immense quantities of water must be transported by the rivers in a short period.

Taking these basis facts into account, the conditions in a pluvial and interpluvial phase can be described as shown in Table 31. Besides these conditions, those prevailing in an early-pluvial and an early-interpluvial period have to be mentioned in order to point out the extreme conditions which are of paramount importance.

TABLE 31. *Conditions and factors determining terrace formation in the mountains valleys of Iraq.*

Factor/Condition	Pleni-Interpluvial	Early Pluvial	Pleni-Pluvial	Early Interpluvial
Climate	Arid or semi-arid	More humid	Humid	More arid
Precipitation	Low	Increasing	High	Decreasing
Vegetation on Mountains	Sparse	Increasing	Permanent cover	Full cover, decreasing
Soil erosion	Medium	Severe	Slight	Slight, increasing
Runoff	Incidental	Much	Little	Little
Discharge of rivers	Torrential in spring	Very high	Regular	Rather regular
Load in suspension	Great, fine particles	Very great, coarse particles	Relatively little	Little, increasing
River system	Braided	Braided	Meandering	Meandering
Stream erosion	No	No	Yes	Little
Deposition of gravel (valley bottom)	Little	Much	No	No
Deposition of Silt (on terrace)	Almost nil	Almost nil	Yes, during floods	Little, during occasional floods
Final result	Valley is covered with some gravel	Valley is filled with gravel	New valley is eroded; old surface becomes terrace	Deposition on the bottom of the new valley begins

A schematic picture of the situation in the various stages is given in Fig. 136.

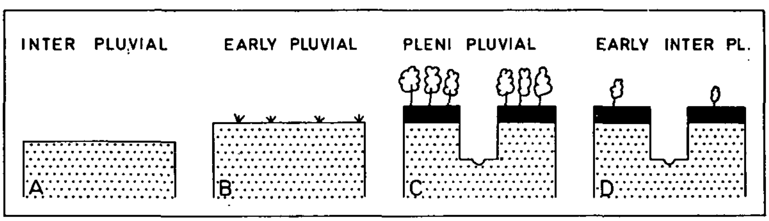


FIG. 136. Schematic diagram of terrace formation in a mountain valley. Explanation in the text.

A. shows the gravelly erosional surface in the valley of a braided river during an interpluvial phase.

B. shows more gravel deposited on the valley bottom during an early pluvial phase, when a large quantity of coarse material is eroded from the mountains; most of this material has been transported to the foothills and uplands. Erosion on the mountains is progressing since the vegetation cover has not yet been fully developed.

C. demonstrates the situation in the pleni-pluvial period (everything has been changed). A vegetation cover has been developed; only fine-textured material is eroded from the mountains. The discharge of the rivers is more regular; the river system has been changed into a meandering river which is eroding the gravelly erosional surface, forming a deep new river valley. The former erosional surface is becoming a high terrace; on top of it fine textured material is deposited during floods.

D. demonstrates the situation at the beginning of an interpluvial period. There is still a vegetation cover and there is no great difference from a pluvial phase.

The whole cycle now starts again on a lower level.

As there are three terraces in the Sungassar valley, there are three cycles of climatic changes. In Africa (Cole, 1954) there is evidence of four major pluvial periods. In applying the above-developed hypothesis to the formation of terraces in the mountain valleys, the following explanation can be given. The pluvials are tentatively correlated with the glacial phases and indicated by the names which are used in Africa (Cole, 1954):

TABLE 32. *Correlation of glacial and pluvial stages in the pleistocene.*

Glacial Stages in Europe	Pluvial stages in Africa and the Middle East
Atlanticum	Makalian
Würm 3 and 4	Gamblian 3
Würm 2	Gamblian 2
Würm 1	Gamblian 1
Riss	Kanjeran
Mindel	Kamasian
Günz	Kageran (?)

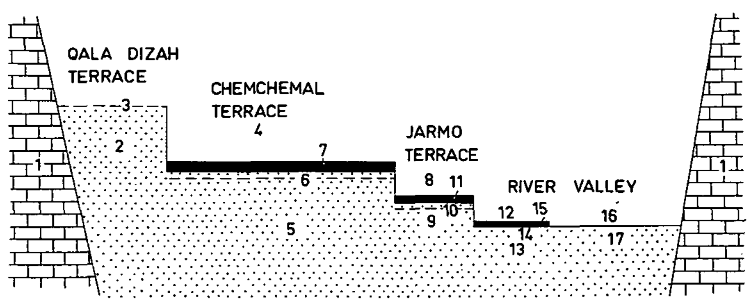


FIG. 137. Schematic cross-section of the Sungassar valley. The explanation is given in the text.

Explanation of the schematic cross-section of the Sungassar valley (see Fig. 137):

Material	Formed in:
1. Limestone mountains	Tertiary period
2. Bakhtiari gravel	Pliocene, Kageran pl.
3. Gravel crust	Kamasian-Kanjeran interpluvial
4. Valley	Kamasian pleni-pluvial
5. Bakhtiari gravel	Valley bottom in late Kamasian pluvial
6. Gravel with crust	Kamasian-Kanjeran interpluvial and early Kanjeran pluvial; crust in Kanjeran-Gamblian interpluvial
7. Silt layer	Kanjeran pleni-pluvial
8. Valley	Kanjeran pleni-pluvial

Material	Formed in:
9. Bakhtiari gravel	Valley bottom in late Kanjeran pluvial
10. Gravel with crust	Kanjeran-Gamblian interpluvial and early Gamblian pluvial; crust in Holocene
11. Silt layer	Gamblian pleni-pluvial
12. Valley	Gamblian pleni-pluvial
13. Bakhtiari gravel	Valley bottom in late Gamblian pluvial
14. Gravel	Early Holocene
15. Silt layer	Floods in Holocene
16. Present river bed	Recent
17. Gravel of river bottom	Recent

The middle and lowest terraces have been named by Wright (1952, 1954) the 'Chemchemal' and 'Jarmo' terrace respectively. I have given the name 'Qala Dizah' terrace to the highest one. A summary of the terrace formation is given in Table 33.

TABLE 33. *Terraces in the Sungassar plain.*

Terrace	Material	Deposited in	Terrace since
Quala Dizah	Gravel	Kageran pluvial	Kamasian pluvial
Chemchemal	Clayey layer	Kangeran pluvial	Kanjeran pluvial
Jarmo	Clayey layer	Gamblian pluvial	Gamblian pluvial
Valley bottom . . .	flooded	Holocene	–

The explanation of the terrace formation in the uplands and the Lower Mesopotamian Plain is different from that of the mountain valley terraces.

Terraces in the plain have been built up by the rivers during periods of great discharge and a large suspended load. The gravel material of the upper terrace consists of the products of stream erosion of the Bakhtiari material in the mountain valleys and foothills. This material has been transported over a great distance and then deposited in the plain along the rivers in a pleni-pluvial phase. Lower-lying stream beds have been eroded in the early interpluvial and pleni-interpluvial, forming at the same time the deposited material of the foregoing pluvial which is left behind as a terrace. Consequently the terrace formation in the uplands and in the Lower Mesopotamian Plain is about a quarter or a half cycle behind. The soil cover on top of these terraces was formed in an early pluvial phase during high floods. Accordingly the following scheme (Table 34) has been put forward for the Tigris terraces (see Chapter 4.2.).

TABLE 34. *Terraces of the Tigris river in the uplands and the Lower Mesopotamian Plain.*

Terrace	Material	Deposited in	Terrace since
Mutawakkil	Gravel	Kamasian pluvial	Kamasian-Kanjeran interpluvial
Muthasim	Gravelly clay	Kanjeran pluvial	Kanjeran-Gamblian interpluvial
Mahdy	Clayey layer	Gamblian pluvial	Holocene
Flood plain	Flooded	Holocene	–

Comparing tables 32 and 33, it is clear that there is an essential difference in age between similar terraces of the mountain valleys and those of the uplands and Lower Mesopotamian Plain. The material has also been eroded and deposited under different environmental conditions. Therefore the terraces have been given different names.

The former bed of the Tigris river, which is situated in the desert on the Mutawakkil terrace south of Samarra (see Fig. 49) therefore indicates the position of the Tigris river during the Kamasian pluvial. The approximate age of the various terraces and soil layers on top of these terraces, which have been mentioned in chapters 4, 5, and 6, can tentatively be determined using the tables in this chapter.

The terraces which can be seen in the deserts of Iraq (Fig. 101) were formed during pluvial phases of the Pleistocene when some heavy showers had produced torrential streams which eroded the desert plains (Chapter 5.3.). Some large desert depressions are dried up lakes of Kanjeran or Gamblian age.

Besides the three main terraces, one, or possible a few, minor terraces occur locally in Kurdistan. One has been mentioned by Wright (1952), which may correspond with a relatively colder post Würm phase in Europe. A minor terrace also occurs near Balad and Samarra (van der Kloes, 1956).

More evidence of former arid stages is provided by the wind-blown sand areas. Some of these sand dune complexes are recent, others (e.g. in the Western Desert) are probably of Kanjeran-Gamblian age.

So far no attention has been paid to tectonic uplifts. According to Wright (1954), no great influences on terrace formation may be expected from tectonic movements in the second half of the Pleistocene and the Holocene. Slight movements have been observed by Lees and Falcon (1952), Voûte (1956) and van der Kloes (1956). Local differences, such as combinations and separations of river drainage systems may also contribute towards explaining the formation of minor terraces.

Another complication is evident from the fact that some of the high valleys were lakes during the pluvial phases, particularly during the first one. As soon as a gorge was formed, the water could drain away. High valley lakes also occurred in Iran (Ghirshman, 1954). Small remnants of gravel crust many metres above the present Sungassar gorge, probably indicate that this valley was once a mountain lake. A landslide in one of the deep gorges may also have given rise to the formation of mountain lakes, and finally to terraces.

The working hypothesis, as explained in this chapter, helps to understand the morphological and soil conditions of large regions of Iraq. This however does not imply that the hypothesis is correct. It may have to be altered when more information is available.

CHAPTER 7

AGRICULTURAL DEVELOPMENT AND SOILS

7.1. AGRICULTURE ON SALINE SOILS

The brief description in Chapter 2.8. gives a general idea about agricultural in Iraq. An extensive description is beyond the scope of this book but some facts on farming on saline land must be discussed.

Irrigation-agriculture in a kind of fallow system of farming is a very old method in the Lower Mesopotamian Plain. The oldest written document on agriculture is a 3,000 years old clay tablet with cuneiform script found at Nippur (Jacobson, 1951); it gives instructions on sowing and irrigation. The present system of farming is based on centuries of practical experience under specific Mesopotamian conditions. Fifty per cent of the cultivated land has a winter cereal crop (shitwi crop, mainly barley, sometimes wheat) from October to April, followed by an eighteen month fallow without irrigation and ploughing for two summers, and with a very scanty rainfall during one winter. According to Turcan (1946) the soil moisture content drops from 34% at the end of the growing season to 10% at the beginning of the new crop season. Summer or saifi crops (mainly cotton and some vegetables) are grown on a very limited area (see Table 15).

The common irrigation method of shitwi crops is the border method, consisting of plots of approximately 15 × 30 metres on both sides of the irrigation ditch. Cotton and most vegetables are grown by applying the furrow method. Water is applied every two or three weeks, to shitwi crops, sometimes once a month. The irrigation system is rather primitive and often there are major water losses.

The wheat and barley varieties are adapted to the Mesopotamian conditions, including soil salinity. Nothing is done to control the weeds; shok *(Prosopis Stephe-*

FIG. 138. Ploughing land in the Lower Mesopotamian Plain.

niana) and agul or camelthorn *(Alhagi maurorum)* being the principal weeds. No fertilisers or manure are being applied. Yields are low (see Table 20).

The tillage practices are rather primitive (Figs. 138 and 139). An animal-drawn wooden plough, a parting plough, is still generally used throughout Iraq. Russel (1957) has described two types: the arrow pointed plough used in the uplands, and the shovel pointed plough used in the Lower Mesopotamian Plain. His conclusion is that both types of plough and the tillage practices are well adapted to the prevailing conditions. Modern ploughs are less suitable.

During the six months of the growing period of shitwi crops, some leguminous weeds (particularly shok and agul) also grow. These deep rooted perennials are rather salt tolerant and grow rapidly after the crop yield. These weeds use the water left in the soil; they lower the perched groundwater table and dry out the soil and substratum. At the end of the eighteen months idle period, the soil is dry to a depth of at least 2–3 metres. As a consequence there is no salt accumulation in the solum. The legumes accumulate nitrogen and are used for fuel at the end of the idle period. During the next periods of irrigation, salts in the surface soil go into solution and are washed down to the subsoil and substratum, particularly when some extra irrigation water is applied. Over-irrigation, a practice which is often criticised, helps to leach the soil.

This system, which is based on the principle of lowering the perched groundwater table during the idle period, only works if a special section of an irrigation unit is irrigated, and another section is left idle. If there is a mixture of irrigated and non-irrigated plots all over the area, the groundwater table will be too high.

Floods, which occur on the flood plain once in a few years, have a similar effect. Flood water leaches the upper part of the dry soil and 'pushes' the salts down to deeper layers.

Russel (1957) has calculated that the idle system with shok and agul enables farmers to use land for about 450 or 500 years. Then the salt accumulation will become dangerous and the farmers will have to abandon the land for a long period, during which the groundwater level will fall to a depth of 5 or 7 metres, and from that time it will be possible to wash the salts out of the upper 2–3 metres down to a depth of 5–6 metres and the land will become suitable for a new cycle of farming.

This type of farming with weeds during the idle period is applied in those parts of Mesopotamia where groundwater under natural conditions is at least some metres below the land surface. It is therefore limited to the northern section of the Lower Mesopotamian Plain, particularly the fluviatile terrace region and the flood plain.

In the delta and marsh region where the groundwater is always high, a different method, which could be called 'the method of isolated salt areas', is applied. Special sections of a cultivated area are left idle. They are surrounded by irrigated fields with shitwi crops. In giving some extra irrigation water to the cultivated plots, salts are leached from the surface soil, and as there is a hydraulic gradient, the saline water is 'pushed' to the idle fields, where salts are accumulated at the surface. Slightly or medium saline land and strongly saline land occur in the area a rather short distance apart. This explains why farmers consider only those soils which have a real white salt crust as being saline. As salts of the sabakh soils are easily washed, such soils are not considered as being unsuitable for crop production.

FIG. 139. Before ploughing the land, barley seed is broad-casted.

The extremely high salt content of uncultivated, older irrigation levee soils is also a result of this system of farming on saline land.

Rice cultivation is based on similar principles. Mostly farmers try to drain some surface water after a few days of heavy irrigation, when this water has become saline due to diffusion.

Another method is applied to vegetables, particularly tomatoes, on small plots during the summer. Farmers dig irrigation furrows about two metres apart, about 30 cm. deep and 30 cm. wide with a flat bottom and erect sides. Tomatoes grow on a small shelf, half way up the northern side of such a furrow, by filling these furrows with water up to the level of the tomatoes. Salts in the soil near the tomato plants are pushed to the upper part of the furrow wall and to the strip in between two furrows. Later on the salt free strip of soil half way up the southern side of the furrow is added to the plants on the northern side.

These methods of farming on saline land are of fundamental importance for Iraq. I do not think any better methods could be developed at the present time.

All measures to be taken in order to improve agriculture in this country are useless if they do not fit into these systems. It will pay to study the various farming methods in more detail in order to profit from them when farming on non-saline, well-drained land is introduced.

At present the farmers do not like weed control, new types of crops, fertilisers, other methods of irrigation, more saifi crops etc. If it is understood why, and under what economic and social conditions the farmer and his family must live, one can at least realise how difficult and complicated it will be to improve the irrigation-agriculture of Iraq. The first step to be taken is the leaching of salts from the soils and drainage of the land.

7.2. Soil fertility

The concepts 'fertile' and 'non-fertile' soil have been used in the past to indicate favourable and unfavourable chemical characteristics of soils under natural conditions in relation to high and low crop production respectively. Improvement of natural fertility can be made by applying chemical fertilisers. But, even with chemical fertilisers, many soils can only produce low yields because the physical soil conditions are poor (structure, consistence, porosity, density, permeability etc.). In modern soil science the concepts 'good' and 'poor' soils, or 'productive' and 'unproductive' soils have therefore been introduced. They refer to the general soil conditions under normal farm management practices, including the addition of fertilisers.

The natural fertility of nearly all soils in Iraq is low. There are many potentially good soils. The effect of commercial fertilisers on the potentially good soils of central and southern Iraq is nil as long as these soils are saline. If applied to the potentially good soils in the non-saline regions of northern Iraq, fertilisers might give a good response.

So far very few chemical fertilisers are used in Iraq (Table 35).

Table 35. *Commercial fertilisers imported into Iraq* (data from the Directorate of Customs).

Year	Kind of Fertiliser	Tons
1951	All	100
1952	All	59
1953	All	32
1954	All	379
1955	All	515
1955	Ammonium sulphate (21 %)	450
	Mixed Fertilisers (13, 13, 18 %)	20
	Superphosphate (16–18 %)	35
	Superphosphate (44–46 %)	10

Approximately 90 % of these quantities are used on vegetables grown for sale in the vicinity of cities.

Manure and town refuse are used in some gardens, particularly near Kerbala. Some tobacco fields in northern Iraq also get some manure. Nearly all manure, particularly in central and southern Iraq, is used as fuel. The fresh or moistened manure is mixed with straw and dried in the sun (Fig. 140). It is often a commercial product.

The centuries-old practice of burning manure is often criticised because the opinion is that the manure should be applied to the soils in order to increase the organic

FIG. 140. Fuel making from dung. 1. dung, mixed with straw; this is wetted, kneaded and dried in the sun (2); 3. the sun-dried product, which is sold in Baghdad and used for cooking and baking local bread. This centuries-old practice is probably better than bringing the dung to the fields.

matter content, and the micro-biological activity, as well as to improve soil structure, as may be learned from all textbooks on soils. I agree with Keen (1946), who states that in arid and hot regions the organic manure disappears in a short time, due to rapid oxidation, and therefore the soils obtain no benefit from it. This is particularly true if the soils are saline.

The organic matter content of Desert soils, Sierozem soils, Reddish brown soils, Brown soils and arid Alluvial soils is extremely low. It is impossible to increase the organic matter content in such soils on a permanent basis to the level of even a few per cent. Even after a few years of pasture, or leguminous fodder crops, the apparently increased organic matter content drops rapidly to the former low level, which is adapted to environmental conditions.

The first information on soil fertility dates from a study by Webster (1921) on the soils of the Diyala region. All studies made so far (see Chapters 4, 5 and 6) have given similar results. There is a shortage of nitrogen and phosphorus. The potassium content generally seems to be sufficient. Although the nitrogen content is relatively low in most arid soils, there is more nitrogen available at the end of the idle period than at the beginning, mostly due to accumulation by leguminous weeds. Keen (1946) points out that nitrogen in these soils is mainly ammoniacal nitrogen, not nitrate, and that there is a rapid biological conversion to nitrate, when remoistening of the soil by irrigation water takes place. It may be noticed that nitrogen is leached during heavy rains, because crops generally suffer from nitrogen shortage after such rains. Shortage of phosphate can be observed in almost all gypsiferous soils. Various deficiency diseases occur in date and citrus trees. A shortage of some minor elements (boron, cobalt and zinc) might be expected.

The number of field trials with chemical fertilisers is very limited. A significant increase in wheat production was found on plots in Abu Ghraib in 1953, but the costs of the fertilisers exceeded the value of the extra yield. For cotton, only phosphate has given any response; here, too, it did not pay. In Bakrajo an important increase in rice production was reached by applying superphosphate. It seems that some positive results were achieved using N- and P- fertilisers on vegetables, particularly tomatoes. Demonstration fields in some newly reclaimed land development projects have given positive indications of response to nitrogen and phosphorus (Ali, 1955). Unfortunately no results of any experiments have been published. Most experiments terminated after one season. It may be expected that the effect of chemical fertilisers would also be important in the second year because hardly any fertilisers are leached. As long as soils in central and southern Iraq are saline, hardly any results may be expected from chemical fertilisers. The Dujaila experiments on leaching of saline soils (Boumans, 1957) have clearly indicated that during leaching, all nitrogen is washed out. After leaching, nitrogen fertilisers have to be applied. In the future nitrogen and probably also phosphorus will be needed on all well drained, non-saline soils. An increase in crop production depends on a series of measures being taken as no important response would be expected from only one, e.g. fertilisers, if the others are neglected. Weed control, insect and disease control, better and proper irrigation practices, new crops, crop rotation and new crop varieties are just a few of them.

The general idea is that for nearly all crops (except tobacco), and for all soils, the present potassium content is sufficient. If in the future crops are grown in an intensive system of farming on a relatively high level, a shortage of potassium will be evident.

So far no chemical fertilisers are advised for saline soils. Investigations could be carried out to at least determine the level and type of salinity in slightly saline soils above which nitrogen and phosphates will definitely give no response.

As soon as leached and well-drained, non-saline areas are available on various types of soil, trials in combination with soil analyses must be made in order to collect basic data on the evaluation of the laboratory analyses, on quantities and kinds of fertilisers to be applied, and on time of application. This information cannot be taken from trials in other countries because soil conditions are different. For the upland and mountain soils this work could be started on a systematic basis.

The commercial fertilisers needed in the future agriculture of Iraq should not contain chloride and magnesium. Lime fertilisers will never be required. Ammonium-sulphate and superphosphate are required in large quantities. In the future ammonium-sulphate will be produced in Iraq by using the oil gases. Superphosphate will probably be sent from Jordan which has natural phosphate resources. The annual requirements of chemical fertilisers in Iraq after 15 or 25 years is estimated by a special committee to be: 17,000 tons pure nitrogen, equivalent to 83,000 tons of ammonium sulphate (20.5%), and 19,000 tons pure P_2O_5 equivalent to 117,000 tons of superphosphate (16%). This estimation depends on the agricultural development, the costs of production and the market price of these fertilisers.

7.3. Irrigation and drainage

7.3.1. *Irrigation*

Irrigation in Iraq dates from prehistoric times, when small earth dams were built in mountain streams in order to direct water to adjacent land which was probably grazing land (Frankfurt, 1951). Some water might have been used for primitive cultivated land. From the time these mountain people came down to the Mesopotamian plain, more than 6,000 years ago, cultivation depending on irrigation started in the plain. The living conditions in the various physiographic regions have been described by Buringh (1957). Under natural conditions, settlement was possible only on the border of the river terraces (Samarra) and on the river banks in the estuary region. Later on settlement became possible in the basins of the delta plain which were irrigated by natural floods. A very primitive system of irrigation consisting of a short cut in the river banks was probably the first step. This system has gradually been developed into a canal system and finally into a controlled canal irrigation system on the delta and flood plain.

Cultivation of land in artificially flooded or irrigated river basins implies a co-operation, organisation and administration of all people depending on the same irrigation unit. Big irrigation schemes like that of the Nahrwan could only be constructed by a central government. In the history of Iraq reference is often made to years in which important canals were dug because the construction of such a canal was regarded as being equal in importance to a victory (Contenau, 1954).

During wars and periods of internal troubles, canals were neglected, silted up and sometimes destroyed. Some areas became too saline for cultivation. The present irrigation system is almost the same as it was centuries ago.

From the time that motor pumps were made available some 30 years ago, irrigation of the higher lands on the river banks became possible. The lift irrigation has created new possibilities for agriculture. It would also have been possible to start land drainage since pumps were available. But the problems related to this subject were not generally understood up to a few years ago, although Willcocks (1911) and the first soil scientists in this country (Webster, 1921) have given good advice.

The physiography of the Lower Mesopotamian Plain is such that drainage and leaching of salt in large areas is almost impossible without motor pumps. Some areas may have a 'free flow' drainage. Modernising the irrigation system has no effect if no drainage system is made at the same time. Since the engineering problems related to land drainage are solved, the agriculture of Iraq is entering a completely new phase. New possibilities are created to improve and expand the agricultural production, which will change the whole country. In the history of six millenia of irrigation agriculture, this will be a real revolution. Under the new conditions a modern irrigation system will also be needed. Some aspects of present-day modern irrigation in Iraq, with an example of the primitive and of a modern system (Greater Mussayib project) have been described by Nugteren (1955).

The costs of the modern irrigation-drainage systems are high and a large number of engineers and technicians are required for construction and later on also for running and maintenance. The total costs of new irrigation works, including drainage, road construction and land levelling are estimated at ID. 335,000,000 (Nelson, 1956). All work has to be based on a central overall planning which requires a strong central government.

Such technical development, which has already been started, has many economic, social and even political consequences. It influences almost all phases of human life. The few decades in which the transition from old to new has to be performed are extremely difficult, particularly for the Government.

From a technical point of view, two basic facts have to be mentioned about soils:

1. Soils which can be drained should only be irrigated. Soils which cannot be sufficiently drained will remain saline or even increase in salinity or alkalinity and consequently they are unsuitable for future agricultural production. A classification of soils according to their drainability therefore has to be made before starting a project.

2. Only land with good and excellent agricultural potentialities should be included in the new projects, because economic agriculture can only be developed on good soils. The population of Iraq is thin; there is enough good land and therefore there is no reason to develop areas with potentially poor soil conditions.

Soil conditions in the Lower Mesopotamian Plain, the most important region for irrigation-agriculture, vary widely, even over short distances. Potentially good and poor soils occur together in an intricate pattern. There are no large areas of uniform, potentially good land. The irrigation-drainage planning should be adapted to this pattern.

In a primitive system of irrigation without drainage, the costs of the irrigation works made to supply land with water, are approximately ID. 1/500 per donum. A modern irrigation-drainage system will cost at least ID. 25 to 35 per donum, not including the costs of the flood protection works, barrages, dams, etc. In some areas the costs are estimated at ID. 50–60 per donum. It is economical to spend this money, if indeed the agricultural production will be increased, which first of all depends on the quality of the soils under the new conditions. Neglecting this basic principle will lead to a failure of the projects, disappointment of the people and the waste of money and natural resources.

Whether land, water or drainage taxes should be paid or not is another problem. Recently the Government has tried to introduce land taxes, but without success; new proposals are in preparation. Product taxes or income taxes, levied in a proper way, might have a similar effect. Water taxes could probably stop cultivation on poor land. Land taxes should be related to the potential agricultural productivity.

The consumption of water will increase and shortage of water may become a problem. More water is required for:

a. Human and domestic consumption;
b. Irrigation of land in new projects;
c. A more intensive agriculture on present irrigated land;
d. Washing of salt from the soils;
e. For the production of higher yields on crop land.

The quantity of water carried by the Euphrates river may decrease considerably when new projects along that river and the Khabour river in Syria are developed. In ancient times an area of 30,000 ha near the Khabour river was once irrigated and almost all the water from that river was used for the irrigation (van Liere and Lauffray, 1955). If such areas and similar areas in the Euphrates valley are irrigated in the future, as is planned, there will be a considerable decrease in the quantity of Euphrates water in Iraq.

It is calculated by Nelson (1956) that the irrigation works on the Twin rivers will provide water supplies to: 13,000,000 mesharas of old land (now irrigated), so that 70% of the area will have water for all-the-year-round irrigation in place of the present irrigation during the high water season. 9,000,000 mesharas of new land which are not yet irrigated can be supplied with water for all-the-year-round cultivation.

Nelson has calculated the water requirements at 26.1 and 12.1 milliard cubic metres per year for the Tigris and Euphrates basins respectively.

It may be learned from Chapter 6 that many good possibilities for irrigation-drainage projects are available in the mountain valleys and particularly in the uplands. Some new projects are planned there.

A broad survey of potential irrigable land in the Mesopotamian plains has been made by K.T.A.M. (1952, see also Powers, 1954). This survey is already out of date. A new survey, including northern Iraq, and based on present knowledge and experience, could be made.

7.3.2. *Drainage*

Drainage is a concept covering several items, e.g. drainage of marshes, drainage of surplus rainfall or irrigation water, drainage of groundwater and soil drainage.

The drainage of marshes is old-established in Iraq. Some marshes were drained and reclaimed in Archeamenian times (Ghirshman, 1954).

The drainage of surplus rainfall, excess irrigation water and groundwater tends to improve the growing conditions of crop plants that suffer from excess of water. Drains are dug to carry off excess water either by gravity or pumps. Since motor pumps can be made available, the excess water can be pumped out easily.

In Iraq drainage must be carried out in order to remove:

a. Excess irrigation water;

b. The upper part of the groundwater, which causes accumulation of salt in the soils, if the groundwater level is too high;

c. The irrigation water, which is used to percolate through the soil and to leach all harmful salts out of the soil.

The drainage of excess irrigation water and groundwater is identical with drainage of land with high groundwater in low lying countries like Holland. It is attained by the construction of a major drainage system, consisting of main drains, various branches and pumping stations. The water may be pumped into the sea, a river or a main outfall. The planning and construction of the major drainage system is largely an engineering subject. The engineer needs, besides other information, to know which areas have to be drained, which will be the required drainage depth and the level of the water in the branch drains in the various sections of the project, what the system of farming is to be and how much water will be used for regular leaching of the soils. The purpose is to provide each farm with at least one second or third order drain. Each farmer will have the opportunity to carry off excess water. Major drainage systems are constructed by the Government because the area to be drained is always a large one, including the land of numerous farmers. The water pumped from one area often influences the hydrological conditions of other areas; in addition, the constructional costs are high.

As soon as the major drainage system is ready, the farm drainage can start. It consists of the digging of some field drains (open ditches or closed tile drains) on each farm. These drains will lower the groundwater table and carry the excess water to one of the branches of the major drainage system. The quantity of the water to be carried off during a certain period determines the depth, width and spacing of the field drains. It depends on:

a. The soil-drainage conditions, which refer to the frequency and duration of periods when the soil is free from saturation or partial saturation.

b. The quantity of irrigation water to be used to wash the excess salts during a certain period, which depends on the soil salinity type, the salt content, the horizontal and vertical permeability, etc.

c. The time and method of washing the soil.

At present the construction of main drains and pumping stations for some project areas in Iraq is under way. So far, no land in Iraq has been drained and only a few small-scale drainage experiments have been made. The first one was by Webster and Viswanath (1921) near Hilla, the second by Tiwary near the Hindiya Barrage in 1926/27. He has washed a Sabakh soil with a sodium chloride content of 2.3 %. After washing it was 0.3 %. On non-drained land, no crop could be grown; on drained land 144 kg. wheat and 192 kg. barley per donum was produced. This was followed by an experiment in the Beni Hassan area, west of Hilla. It was an experiment with open drains 50 metres apart. On non-leached soils, 20–30 kg./donum of rice was grown; on leached soils 150–300 kg. (Report, 1926). The 1927/29 experiment in Saqlawiyah was a failure which has been commented upon by Turcan (1946, Aqar Quf report). The 1945/46 Saqlawiyah experiment was a success (Turcan, 1946), so was the Dujaila project which was started in 1955 (Boumans, 1954/57).

It is astonishing that the problem of soil drainage has not been understood, and that the first development projects have been carried out without drainage; consequently these projects were doomed to fail. Recently a twenty-year drainage programme has been set up consisting of a major drainage system of approximately 15,000 km. in length, many pumping stations and additional works. The cost is estimated at ID. 12 per meshara (van der Sluis, 1956). Three pumping stations (Dujaila, Saqlawihah and Tuwarij) are now working.

The success of a drainage project depends on the drainage on the farms, provided that the major drainage system has been made correctly. The experiments therefore are on farm drainage.

The quantity of water to be used for soil leaching depends on the salinity status and kinds of salts occurring in the soil as well as on the depth to which salts will be leached out. De Gruyter (1953) indicates that a column of 1.15 metres of water is needed. In the Dujaila experiments (Boumans, 1955) one metre of water was needed to leach salts below 60 cm. It was expected that an additional 1.0 to 1.5 metres would have been required to leach most soils below 1.5 to 2.0 metres. Later on Boumans (1957) used 1.61 metres of irrigation water, of which 80 cm. or 50% evaporated and 0.81 cm. was used for leaching; but the salts were not washed out completely; in the upper 0.3 metres of the soil the salt percentage dropped from 6.4 to 0.24% and in the upper 1.0 metre from 3.7 to 0.32%. It probably takes 2–4 years before all salts are leached to a convenient depth. In this experiment, evaporation was 10.5 mm. per 24 hours in April and 20 mm. in May 1956. The water losses due to evaporation are roughly calculated at 50–60% of the applied irrigation water in summer and 10–30% in winter. The movement of salts in the soil during leaching was studied, too. Leaching was more effective at some distance from the drain than nearer the drain, which is explained by the actual flow of the water through the soil to the drain.

An interesting laboratory experiment by Russel (1957) shows that most of the water used for leaching is required for wetting the soil, and a small part of additional water is enough to wash out the salts. In this experiment a column of 0.5 metre saline (1.7%) soil (silty clay loam) was leached with pure water. The first 22.5 cm. water were required to saturate the soil. An additional 5.5 cm. has leached 98% of the total harmful salts. The salt concentration of the leached water was 20%, of the soil 0.03%. It was calculated that 90 cm. of water were required to saturate a soil to a depth of 2 metres; an additional 22 cm. would be enough to remove the salt in a 2 metre column.

In practice the salts should be removed to such a depth that they will not influence crop production. As there is always a capillary rise of the groundwater, this should be taken into account. Turcan (1946) found that drains with a depth of 90 cm. and a spacing of 50 metres were 40 to 100% more effective than similar drains with 100 metre spacing. In the Dujaila experiments (Boumans, 1957), the drains were 1.8 metres deep and 100 metres apart and the leaching was not complete. Van der Sluis (1957) states that the groundwater level should be at 1.5 to 2.0 metres below the land surface, with a drain spacing of 100 to 200 metres. Boumans' (1957) conclusion is that in Dujaila, drains of a depth of 1.8 metres every 100 metres would be sufficient. The required depth of the farm drains determines the depth of the main drainage system in a project. In Mussayib, 2 metre deep drains and 2.5 metre deep collective drains, one km. apart will be put in the main drainage system. This area is planned for intensive cultivation without a fallow or idle period. (Ali, 1955). Early experiments and practices in the Nile valley have demonstrated that a water level in a drain 1.25 metres below the land surface in the lowest spot, plus 20 cm. for every kilometre away from the drain, was not sufficient. Later on a depth of 2.5 metres was adopted throughout the valley (Khairy, 1944). It became a common practice in Egypt to have open field drains 80 cm. deep, spaced 25 metres apart, 100 metres long, discharging into a collector 95 cm. deep, with main collectors 1.25 metres deep. After a few years alternate field drains were filled and permanent drains were left every 50 metres (Khairy, 1944). Hilmy (1944) reports a distance of 20–40 metres between third class drains for the northern part of the Nile delta.

Turcan (1946) obtained on a Saqlawiyah plot an average of 482 kg./donum wheat and 725 kg./donum barley (614 and 880 kg./donum respectively on the best plots). In a K.T.A.M. report (1952), an increase of about 140% in the agricultural production was recorded. De Gruyter (1953) reports a rice production of 20–30 kg./ha. before and of 150–300 kg./ha. after leaching. The yield of barley and wheat is expected to rise from 150–200 kg./meshara before to 375–500 kg./meshara after drainage (van der Sluis, 1956, 1957). This means that the cost of the drainage could be paid off in 4 or 5 years.

It has been learnt from the Dujaila experiments (Boumans, 1955/1957) that nearly all the nitrogen is leached from the soil during the washing of the salts. Consequently nitrogen has to be added to the crops. After leaching, many other factors influencing crop production may become limiting factors, e.g. weeds, diseases, insects, etc. Boumans (1957) also reports that for measurement of the soil permeability with respect to drainage studies, the field test using the Hooghoudt-Ernst method is a reliable test. So far, other field tests and permeability measurements in the laboratory have not given results in accordance with the field work. Another important preliminary finding was that renewed accumulation of salt occurs near the irrigation canals and ditches due to seepage of water, particularly in light-textured soils.

Important practical drainage advice is given by Turcan (1946), who states that the washing of salts can best be done in winter. It should be done continuously. High winds imperil the safety of small bunds along the drains during periods of irrigation. Washing of small blocks of plots was difficult. Inside drains were 3.5 times as effective as outer drains. Washing of large blocks at the same time will be more economical. In Egypt rice is grown during the early stages of reclamation, then cotton is planted for 2–3 years, afterwards the land is fit for maize cultivation (Khairy, 1944). A suitable crop rotation has to be found for Iraq, when drainage must be performed on a large scale.

The soils leached in the Dujaila experiments (Boumans, 1957), originally had a high sodium-exchange percentage (E.S.P.) During the leaching process the E.S.P. dropped quickly and finally it was low in the surface soil, but still high in the subsoil and substrata (Table 36). Similar results were reported from the same experiments in 1955. The conclusion from these tests is that with respect to the high E.S.P., no problems are expected either during or after leaching. The Dujaila experiments were carried out on silty irrigation levee soils, 4.5 metres thick, overlying a heavy, dense, almost impermeable river basin clay. The conclusion therefore should not be assumed to apply to all saline-alkali soils of Iraq. With respect to the decrease of exchangeable sodium during washing, some doubt may be expressed as to the analytical results of the experiment. I personally doubt whether these soils really had a high E.S.P. before leaching. Probably analytical errors have been made. Here, and in many other cases, it is clearly demonstrated that basic research work should be done. I am convinced that the leaching of true saline-alkali soils, which have clear alkali characteristics, will be quite difficult.

TABLE 36. *Salt content and E.S.P. in a soil in the Dujaila drainage experiment before and after leaching* (after Boumans, 1957).

Depth in cm.	Before leaching		After leaching (84 cm. in 69 days)	
	$E.C._e\ 10^3$	E.S.P.	$E.C._e\ 10^3$	E.S.P.
0–30	106	34	2.6	7
30–60	37	38	2.2	21
60–100	34	44	7.5	38
100–150	36	44	2.4	43
150–200	45	42	3.6	42

Unfortunately no soil has been completely washed to a depth of at least 2 metres; this will take a few years.

The results obtained so far clearly indicate that leaching and drainage are extremely important for improving and reclaiming saline soils in Iraq. It may be expected that salts can be washed from the major part of the soils of the Lower Mesopotamian Plain. More investigations have to be made in the near future and very important information will be obtained as soon as practical farm drainage on a project-wide scale has been carried out.

There is no doubt that in the end the salts in the soils will have to be leached to a depth of about 3 metres and that the groundwater level should be kept at a low level. Leaching has to be continued until that condition is reached on a permanent basis. If the upper part of the full capillary zones reaches the solum, salts will accumulate again and they will decrease the yields of the crops. The critical depth of the groundwater in the Lower Mesopotamian Plain is, if calculated according to Polynov's formula (see Chapter 3.5.2.), approximately 3.5 metres. In order to lower the groundwater table to that depth, the farm drains, and consequently all drains of the main drainage system, should be made much deeper than is planned for Iraq. Even though one might consider this groundwater depth to be exaggerated, a depth of 1.8 or 2.0 metres does not appear to be enough for Iraq. This can also be learnt from the drainage practiced in Egypt.

Comparing the drainage of land with too high a groundwater level in hot arid regions with such land in temperate and humid regions, there is one fundamental difference. In the temperate humid regions, a drainage system which lowers the groundwater level by a few decimetres will prove to be a great improvement. A similar fall in the groundwater level of a saline-arid region has hardly any effect, because harmful salts can still accumulate in the solum and no important improvement in crop production can be expected, except when there is a continuous leaching, downward movement of water, and consequently of salts. This however implies continuous care of the farmlands, which can only be given in a system of intensive, high level farming. It cannot be expected that the farmers of this and of the next generation will be able to practice high-level farming. In practice, not enough care can be given to regular washing of the soils. It was learnt from the Saklawiyah drainage experiments that within one year the soils were as salty as before, because the drainage system was neglected and even used for irrigation by the local farmers (Boumans, 1957). If the salts are not leached to a great depth, and if the groundwater level is not below the critical depth, the soils will soon become saline again and it will be extremely difficult, even for very good farmers, to achieve the results which might have been expected. Farming on well-drained, non-saline land will be much easier, particularly for the farmers of Iraq.

The complete washing of salts and the establishment of a good farm drainage system needs at least a few years. Therefore it might be useful to follow the Egyptian procedure by starting the farm drainage with relatively shallow open drains a short distance apart in order to leach the upper few decimetres of the soil in a few months, after which crops could then be grown. This could be followed by filling alternate field drains, deepening the other field drains and continued washing of salts. Finally the field drains could be dug to the required depth; if necessary some could be replaced by tile drains, particularly in present cultivated areas. The salts will be washed out from the deeper layers and land will then be suitable for normal non-saline farming.

Boumans (1957) has suggested washing down the salts of the upper 30 cm. of the soil with approximately 60 cm. of irrigation water in a short time. This seems to be sufficient to start cultivation. Further leaching could be done during and in between the cultivation periods. It is the opinion of Boumans that this method of leaching and drainage will have many advantages in Iraq and some experiments have been started.

Copying what has been done on land newly reclaimed from the sea in the Netherlands, the Government could carry out the whole washing and farm drainage programme and also the additional work to be done to make the farms ready for normal non-saline farming. This takes a few years, but in the meantime the farmers, who will be settled in the new project area, could be employed on the work and trained in farming methods adapted to the new environmental conditions. This also has the advantage that only those families who are really interested will work and stay in the project until they can start working on their own farm.

The general idea is that on non-saline newly reclaimed land, an intensive system of farming should be followed. This implies a complete washing and farm drainage, and also a regular and adequate supply of irrigation water the whole year round. This requires modern farm management methods using chemical fertilisers, good seeds, insect and disease control, weed control and crop rotations for relatively large areas of pastures and fodder crops. The barley-wheat farming during the winter has to be abandoned; new crops should be introduced. The capital for investment could be supplied by the Government, but a farmer's family can only handle a small area in an intensive farming system. Evidently the present settlement units are too large; they also often include areas with soils which are unsuitable for intensive farming. If the modern irrigation drainage systems as well as the intensive farm drainage systems were to be concentrated on potentially really good and excellent land, the farm units could be much smaller. The work to be done by the Government would be more simple and better results might be expected. The introduction of new crops, particularly fodder crops, means that livestock has to be expanded. The farm system will be a system of mixed farming, with milk, meat, dairy products and cash-crops for sale. The less productive land in the vicinity of the areas with intensive farming could be used for extensive low level farming and natural pasture land. It will not be necessary to make this land completely salt-free, as this will be almost impossible.

It can be learnt from the general pedological and hydrological descriptions of the physiographic regions in the Lower Mesopotamian Plain (see Chapter 4) that these regions need a different approach for major and minor drainage.

So far, well-drainage has not been mentioned. This system of drainage means digging deep wells and pumping the water from the wells into drains or direct to the river. Groundwater in a large area around such a well is drained through the substratum to the well. The system can be applied in areas with coarse textured, gravelly substrata. In Iraq these conditions occur on the highest and middle fluviatile terraces of the Tigris river north of Balad, particularly on soils of the Muthasim terrace. It is expected that well-drainage outside these terraces will not have good results, because no gravelly substrata exist. As the groundwater in central and southern Iraq is saline, it cannot be used for irrigation purposes. Well-drainage sometimes relies on using the groundwater for irrigation; this, however, cannot be done in Iraq and therefore it is expected that well-drainage will be too expensive.

The 'biological' method of drainage, as proposed by Russel (1957), will have no practical value because no crop plants similar to shok and agul are available. Besides that, it does not fit into an intensive system of farming.

A well-drained, non-saline soil with a deep ground water table should be the result of land improvement by levelling, washing and drainage. This is in particular true for new agricultural projects in waste land areas. In drainage projects of present cultivated areas it is not always feasible to make or to maintain a non-saline soil condition over the whole project area. Some or probably many farmers will have to live with salinity. They have to apply a different system of farming, with methods adapted to saline conditions. Therefore it is important to study the present methods of agriculture in Central and Southern Iraq. It is easy to understand that the possibilities for agriculture on improved, however still somewhat saline, soils are limited, and soil potentialities therefore are much lower than on non-saline soils. The evaluation of soils for potential agricultural use in reclamation projects on waste land therefore is different from the evaluation of soils in present cultivated areas.

7.4. Soils investigations for land development projects

Various kinds of investigations, including those concerning soils and soil conditions, have to be carried out prior to planning a development project. Many projects all over the world have failed, due to neglecting this principle. The total cost of all the investigations to be made is only a few per cent. of the cost of a project. The cost of a semidetailed

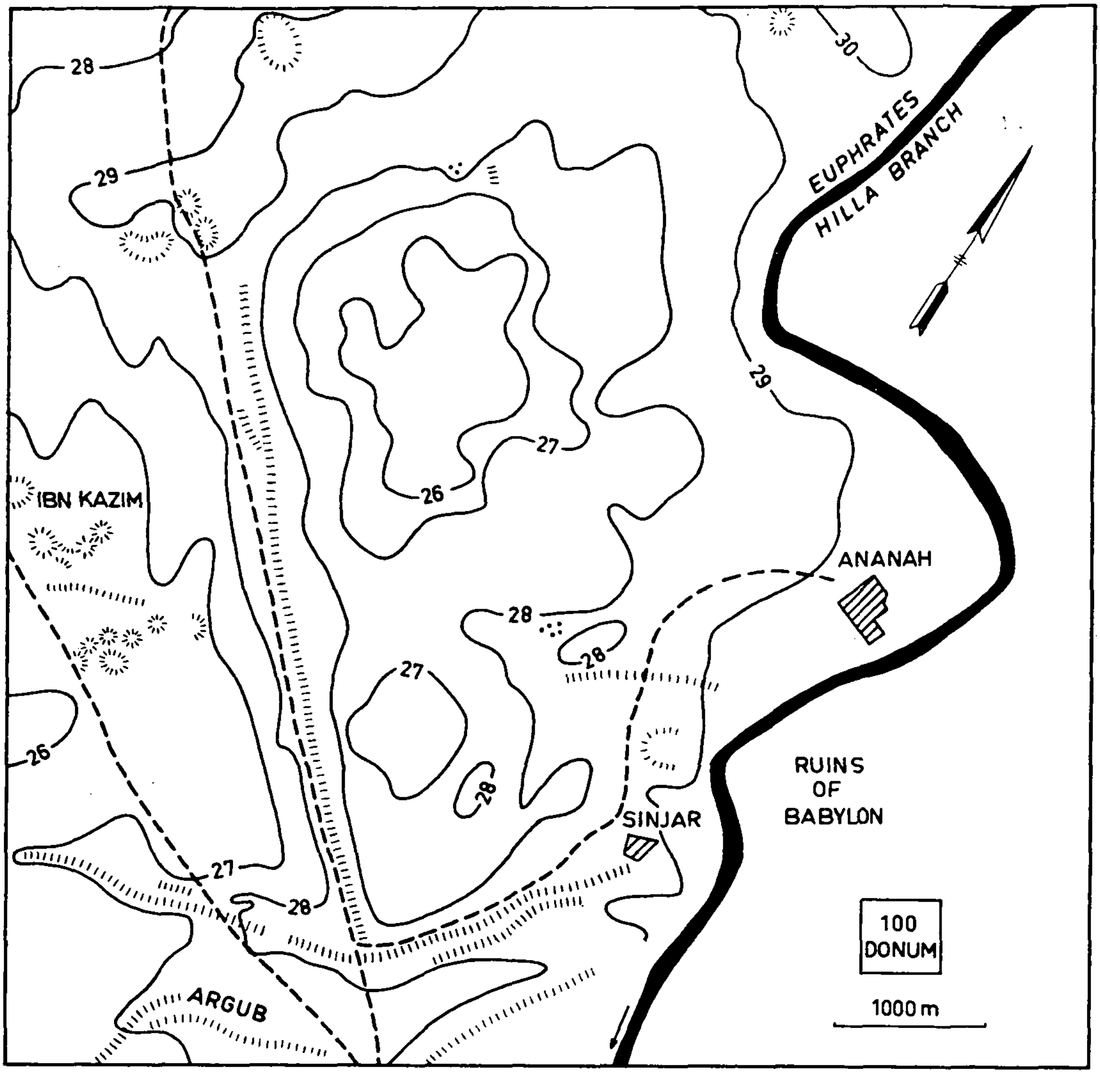


FIG. 141. Section of the contour map of the Hilla-Kifl project. (taken from a map of the Irrigation Department, Baghdad). Contour lines with 1 metre interval, indicating the elevation above average sea level near Fao. The scale of the map is 1:50,000, or 2 cm. on the map = 1000 metres in the field. The following maps (figures 142–149) are of the same area, on the same scale.

soil survey, performed according to the specifications laid down by the Iraq Government is less than ID. 0.100 per donum, if carried out by the Division of Soils, and probably somewhat higher if carried out by soil consultants. The cost of the other investigations is expected to be of the same order, making a total of about ID. 0.500–1.000 per donum. At a project cost of ID. 25/– per donum, the total cost of basic investigations is approximately 2–4%.

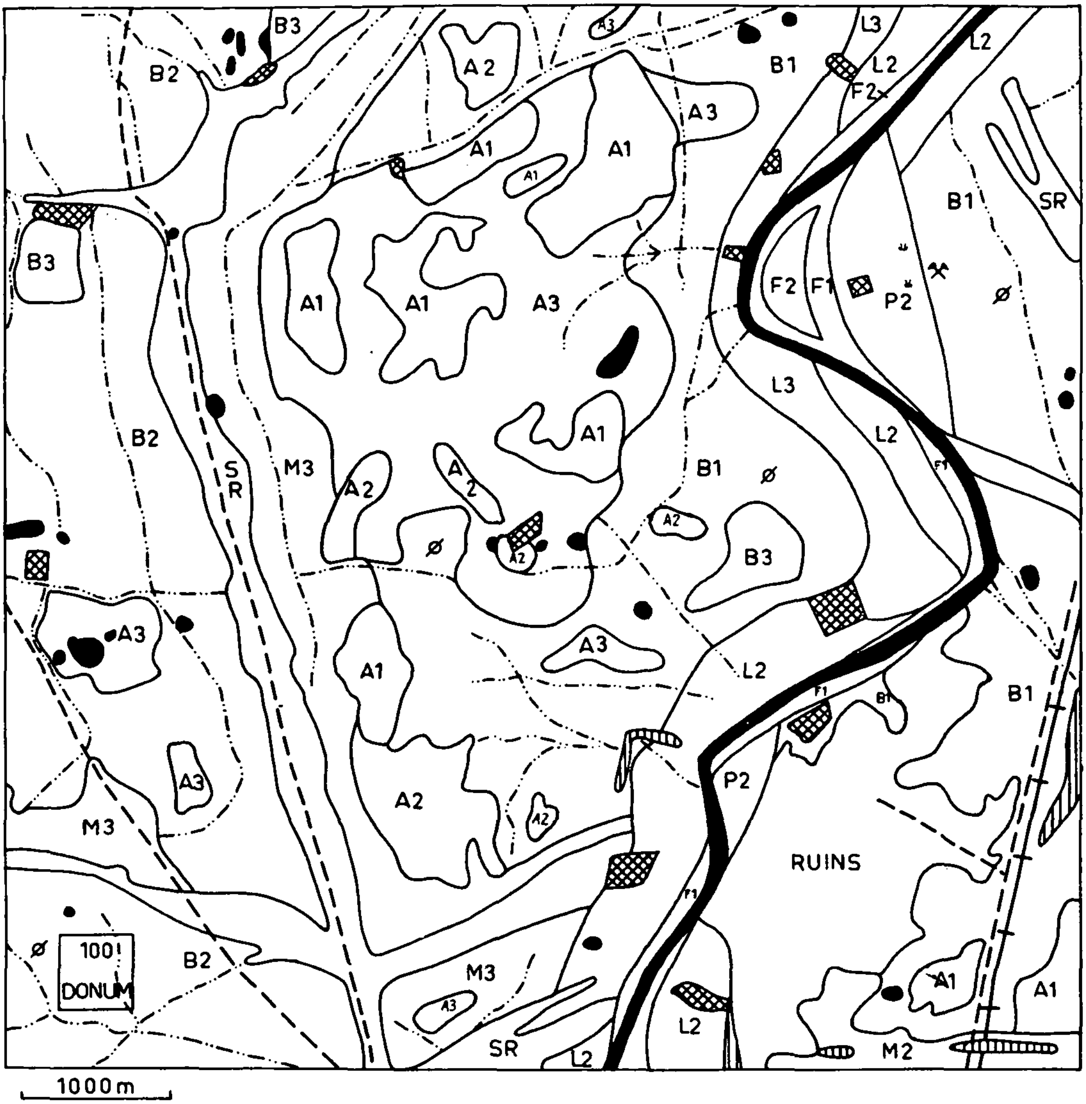


FIG. 142. Section of the semidetailed soil map of the Hilla-Kifl project. This soil map is based on a detailed study of some sample areas. One of them is given as Fig. 76. It covers the area in the upper, right hand corner of this map. L_2 Hillah silt loam, moderately well drained phase; L_3 Hillah silt loam, imperfectly drained phase; B_1 Babylon silt loam, (Fig. 75); B_2 Babylon silty clay loam; B_3 Abu Gharaq clay; M_2 Tahmaziyah silt loam, (Fig. 77); M_3 Tahmaziyah silt loam over clay; A_1 Ananah clay, severely gullied phase; A_2 Ananah clay, moderately gullied phase, (Fig. 79); A_3 Ananah clay, slightly gullied phase; F_1 Euphrates foreland, medium high phase; F_2 Euphrates foreland, low phase; P_2 Barnun silty clay loam; SR Argub (high walls along ancient irrigation canals); –· ·–· ·– Former or present irrigation canal with irrigation levees; ø Scabby spots;

A full description of the soil mapping units is given in the soil survey report of the Hilla-Kifl project (Buringh, 1958). L2 and 3 represent a river levee along the Euphrates (Hilla Branch); Bl, 2, and 3 represent silted river basins; M2 and 3 represent irrigation levees; A1, 2, and 3 represent irrigation depressions; F1 and 2 represent low foreland near the river; P2 represents a silted meander belt.

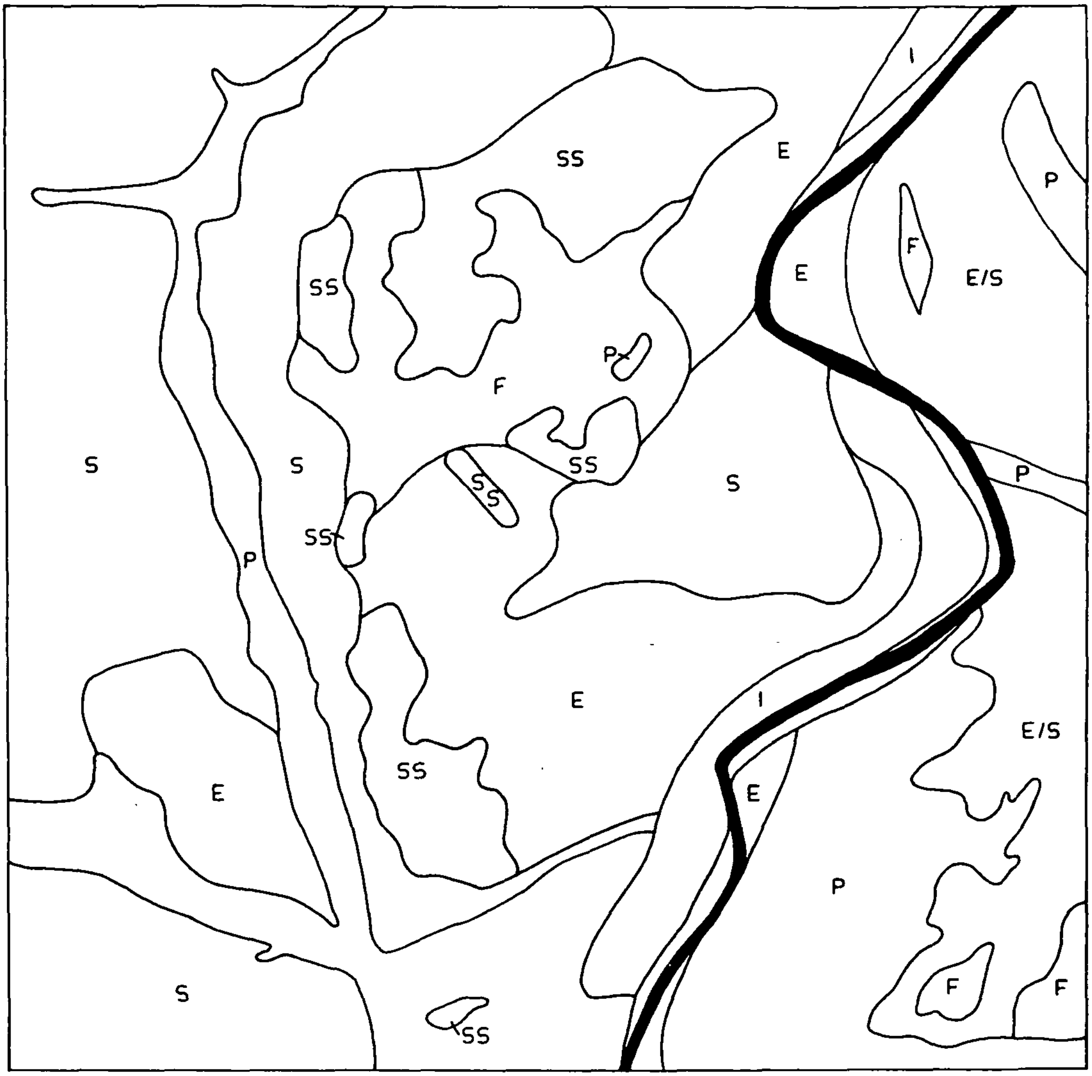


FIG. 143. Section of the map of pedogenetic soil salinity types of the Hilla-Kifl project. All soils are saline or even strongly saline. I. Internal solonchak soils (partly also P and S); E. External solonchak soils (partly also P and S); F. Flooded solonchak soils; P. Puffed solonchak soils (partly also S); S. Sabakh soils (partly also P); SS. Solonetz soils.

It is important to know which kinds of soil occur in a development project, what their characteristics are, where they are located and what their use capabilities are (crops or series of crops to be grown, yields to be expected under specific conditions of irrigation, drainage and farm management). In addition to an intensive study of the major soil series and types in the field and in the laboratory, a systematic regional study has to be made to find out and to map the exact location of each soil. The results

FIG. 144. Section of the map of present soil drainage conditions of the Hilla-Kifl project. 1. moderately well drained soils; 2. moderately to imperfectly drained soils; 3. imperfectly drained soils; 4. poorly drained soils; 5. very poorly drained soils; black: tel, argub, ruins.

are shown on a soil map and described in a report. An example is given in Fig. 142.

Development schemes, particularly those including drainage, should be based on detailed soil surveys. At present it is technically impossible to carry out detailed soil surveys; therefore semidetailed soil surveys are made which are based on detailed soil studies in some sample areas within the project area (Fig. 76).

The soil map (Fig. 142) and the soil salinity map (Fig. 143) also give information

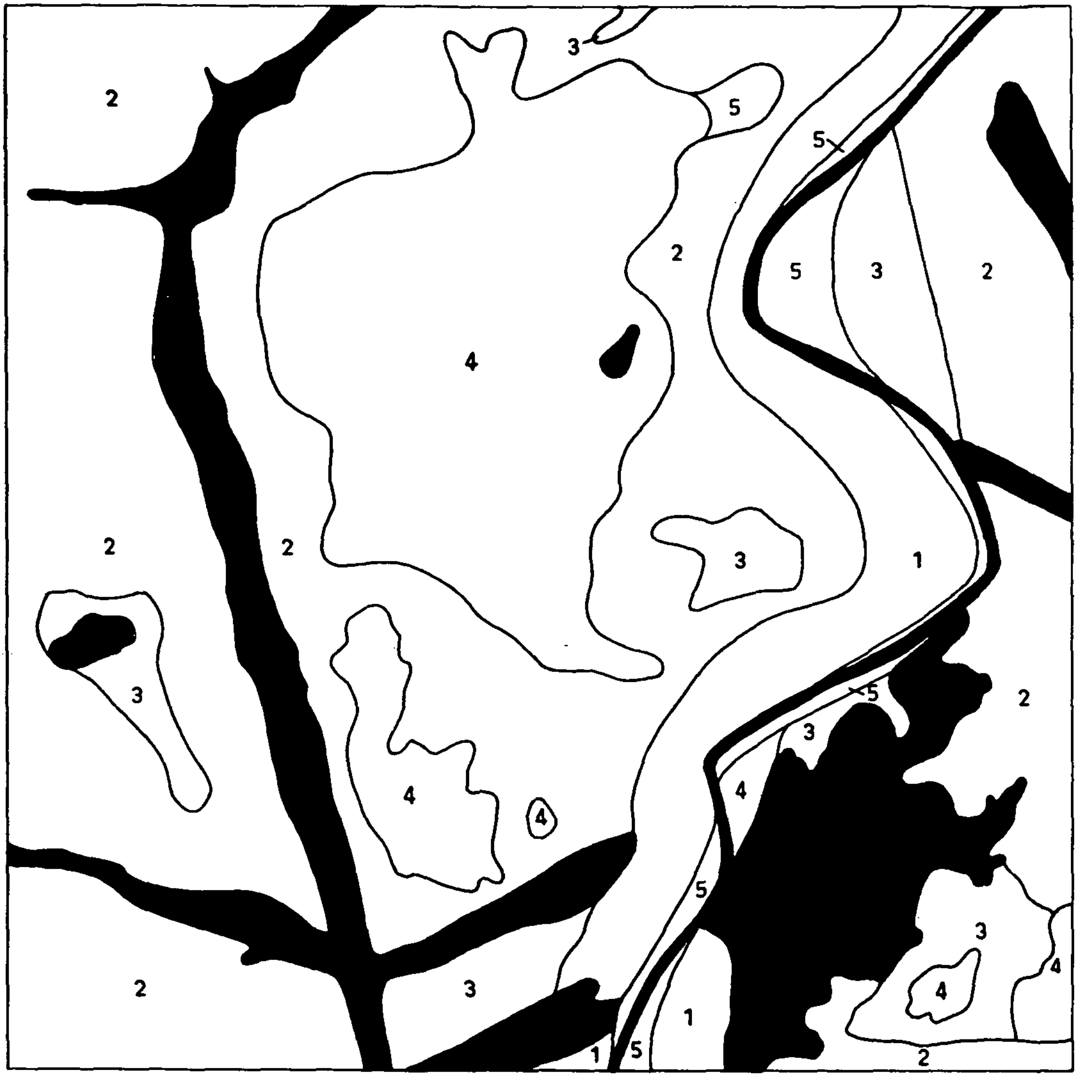


FIG. 145. Section of the soil suitability map for improvement by levelling, drainage and washing (Hilla-Kifl-project). 1. excellent soils; 2. good soils; 3. fair soils; 4. poor soils; 5. very poor soils; black: tel, argub, ruins.

on the present soil drainage conditions and internal soil drainage, as well as on soil permeability and other characteristics. If necessary the present soil drainage classes (Soil Survey Manual, 1951) can be given on a separate map (Fig. 144). Detailed drainage investigations can be carried out in the sample areas by drainage experts who will also study the drainage and movement of underground water in the whole project area. By using and combining the various data on drainage and soils, a drainability map (Fig. 145) and report can be made.

FIG. 146. Section of the soil suitability map for present agricultural use of the Hilla-Kifl project. The evaluation is made on a relative basis. C2. good soils; C3. fair soils; C4. poor soils; C5. very poor soils.

This soils investigation is followed by an agricultural investigation in co-operation with agricultural specialists in order to prepare soil suitability maps, predicting the use suitability of the various soils for agricultural purposes under specific conditions (Fig. 146/149). These maps clearly indicate the location of the areas suitable for certain purposes. Some areas may even be unsuitable for agricultural production due to poor physical characteristics.

It has now to be decided which parts of the project area will be developed, what

FIG. 147. Section of the potential soil suitability map for agricultural use of the Hilla-Kifl project. C1. excellent soils; C2. good soils; C3. fair soils; C4. poor soils; C5. very poor soils.

It can be learned from a comparison of the maps in Fig. 146 and 147 that the soil suitability has been increased considerably after the reclamation works (washing of salt, drainage, proper irrigation, land levelling and good farm management) have been put into effect.

system of farming will suit the various areas in the project best, the size of each farm, etc. Those decisions have to be taken by the Government, with assistance from the various specialists. Economic, social and even political factors may influence the final decision. Then, the final plans on all aspects of the project have to be drawn up before the project can be started.

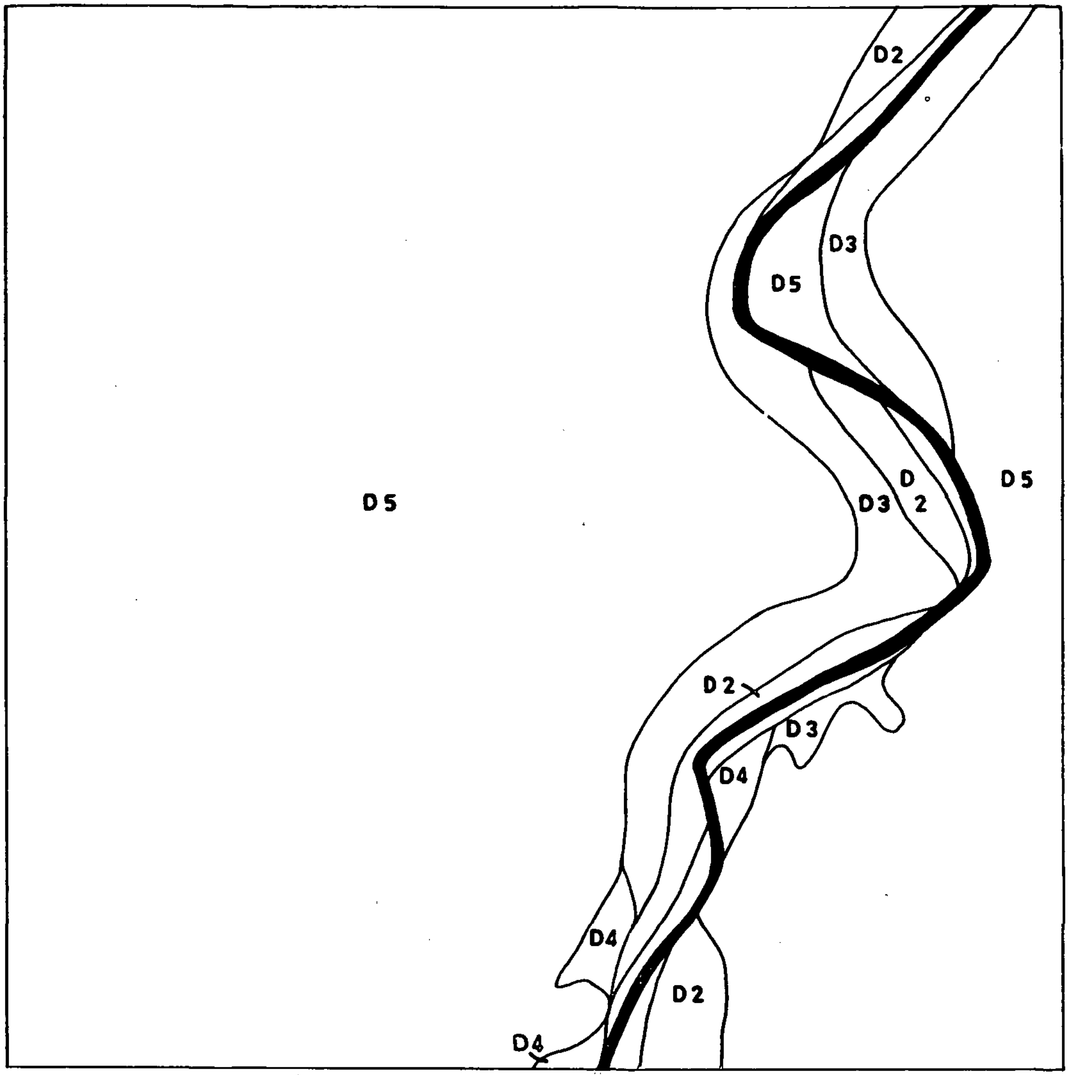


FIG. 148. Sections of the soil suitability map for date and fruit gardens under present conditions of the Hilla-Kifl project. D2. good soils (see Fig. 151); D3. fair soils (see Fig. 152); D4. and D5. poor soils (see Figs. 153–156).

The major drainage and irrigation plan also depends on the results of the abovementioned investigations, although many other factors have to be studied for those plans.

More information on the subject of land development is published by the Food and Agricultural Organization of the United Nations (Lewis, 1952; Stephens, 1953).

Making soil maps for drainage projects in Iraq requires special attention for those soil characteristics influencing the farm drainage. The soil hydrologists and drainage

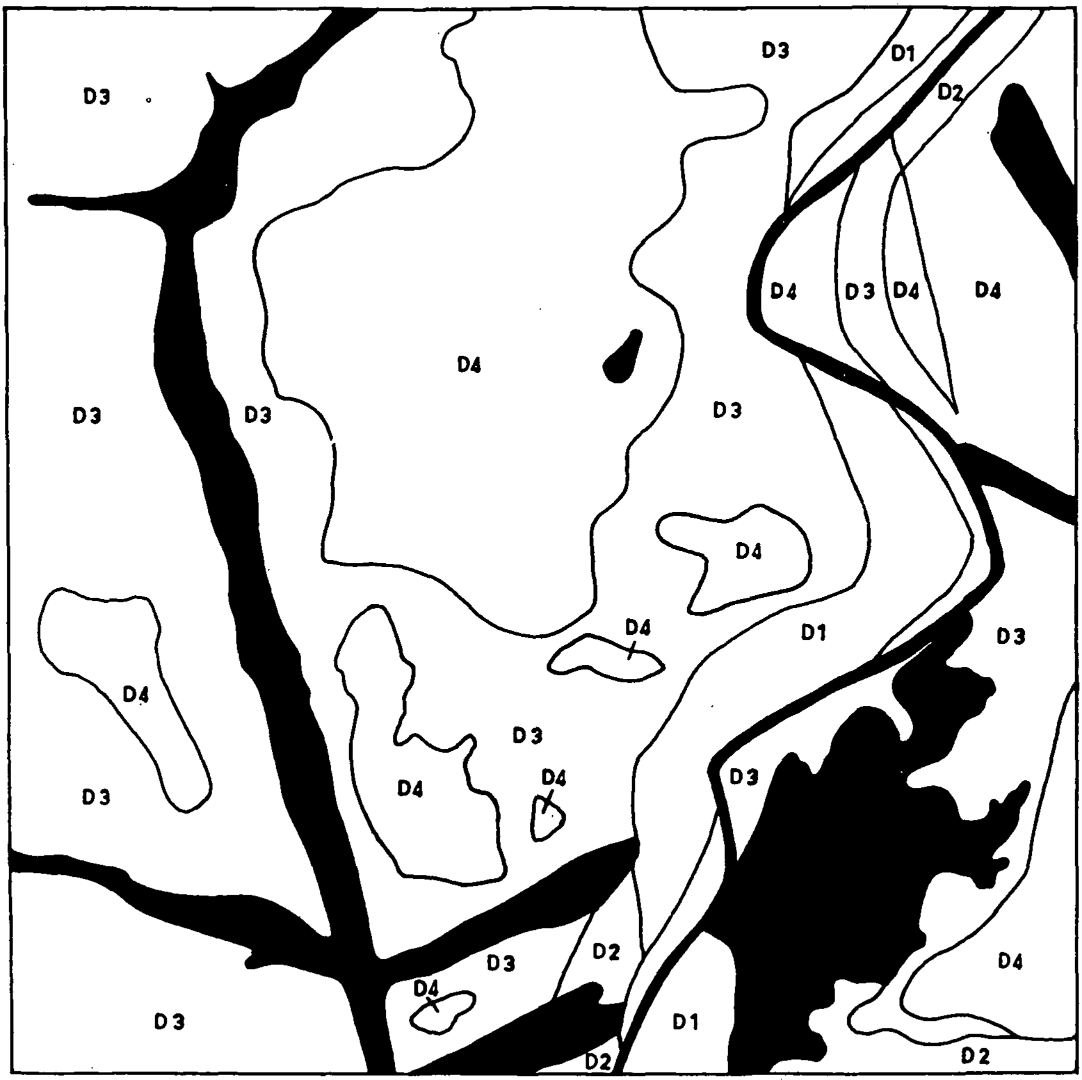


FIG. 149. Section of the potential soil suitability map for date and fruit gardens of the Hilla-Kifl project. D1. excellent soils (see Fig. 150); D2. good soils (see Fig. 151); D3. fair soils (see Fig. 152); D4. poor soils (see Fig. 153–156).

Comparing the maps of Figs. 148 and 149, it is clear that after conditions have been improved (washing of salt, drainage, levelling, better irrigation and farm management practices), the suitability of soils for dates and fruit production have been considerably increased.

specialists have to be provided with special data on soils, which in combination with other data (topography, water table fluctuations, ground water level, underground water flow, vertical and horizontal permeability, etc.) will be used to decide on drain depth and spacing. Besides a soil map and a report, some other maps could be made,

FIG. 150. Date garden on class D1, excellent soils. The garden consists of date palms, (high level crop), citrus, pomegranates, grapes, figs (middle level crops) and various vegetables, water melons etc. (low level crop). The soil is continuously covered by crops, growing in three levels. There are at least three crops annually off the same land. The price of such land is approximately ID. 200 per donum (¼ ha.).

showing one or more soil characteristics. It is important to file the descriptions of soil profiles and borings, and to indicate the location on a special map or photo mosaic. Many soil pits and borings have to be made to at least 3 m., some even to a depth of 5 m. in order to be informed on the statification of the deeper strata. A layer with a high horizontal permeability, even on a depth of a few metre below the surface is of paramount importance.

It is an advantage to study soils intensively in sample areas and to pay special attention to those characteristics, which restrict the internal soil drainage and which therefore dictate the drain depth and spacing.

The examples given in this chapter are taken from the investigations of the Hilla-Kifl project (Buringh, 1958).

An important section of the basic information is the soil suitability classification under specific conditions of irrigation and drainage. This classification is difficult because:

a. Present agriculture is on a low level and adapted to saline conditions. There are no examples in similar regions with which a comparison could be made.

b. The soil and drainage investigations were started a few years ago but many surveys still have to be made.

FIG. 151. Date garden on Class D2, good soils. The garden consists of date palms (high level crop), pomegranates and some citrus (middle level crop), and some vegetables (low level crop). The soil is continuously covered by crops, growing in three levels, but yields are less than on Class D_1 soils and some crops cannot be grown. The price of such land is approximately ID. 100 per donum.

c. Most development projects are situated on fluviatile desert areas without any cultivation.

It is difficult to get an idea of what will be possible for future agriculture. The shortage of knowledge and experience is a real drawback. The only solution is to establish pre-development farms or pilot schemes in the area some years before the final plans are set up. This is done in most countries; examples are given by Vink (1957).

7.5. Land classification

Much work on land classification has been done in Iraq during recent years. Most of these land classifications were carried out by consultants, but some were performed by Government Departments under the direction of foreign specialists. Only one report (West, 1955) has been officially published. The results of almost all land classifications are below the minimum requirements for such work; some are even wrong and misleading. The main reason for it is that the Iraq Government itself did not know exactly what was needed, and what investigations, on which the land classification has to be based, should be carried out in the development projects.

FIG. 152. Date garden on class D3, fair sols. The garden consists of date trees (high level crop) and of some vegetables or alfalfa (low level crops). There is no middle level crop. The price of such land is approximately ID. 50 per donum.

So far the idea has been to carry out two types of land classification for which minimum requirements were set up a few years ago. The idea was to perform 'preliminary land classifications' on a reconnaissance basis or 'semidetailed land classifications'. The field observations had to be made in a grid system of 1 or 0.5 km. respectively. The standards were those of the Bureau of Reclamation of the U.S.A. (see Handbook Vol. V). Due to the characteristic physical conditions of a fluviatile plain, it is rather doubtful whether these standards could be adopted for the Lower Mesopotamian Plain. This can possibly be applied in the uplands and mountain valleys.

If it is supposed possible to adopt the Bureau of Reclamation methods and standards, then it is doubtful whether the work could be done correctly, and whether the results would form a real basis for economic land use planning for irrigation drainage agriculture in Iraq.

There are many factors determining the final classification. All those factors have to be studied, combined and finally evaluated by the land classifiers. This work can only be done by well-trained, experienced and competent land classifiers. Even a highly qualified foreign land classifier needs a few years before he understands at least something about agriculture, hydrology, soils, salinity, drainability, economy, sociology, etc. in Iraq. All these and some other factors, forming the basis of a land

FIG. 153. Date garden on Class D4, poor soils. The garden consists of date trees of a rather poor quality (high level crop) and sometimes there is alfalfa (low level crop). The price of such land is always less than ID. 25 per donum.

classification for irrigability agriculture, have to be studied before the final classification can be set up. There are hardly any basic studies, covering the main factors of land classification, performed in Iraq. The fixed methods and standards of the United States have been applied in Iraq. The physical and other conditions have been evaluated according to similar principles which has led to a misuse of land classification.

Besides this the so-called 'land classification' carried out in Iraq is nothing more than a collection of data on soils, which are put into a formula, giving the final 'land class'. In fact these 'land classes' are nothing more than units of land having a few soil characteristics in common. They are not real soil classes, soil taxonomic or mapping units; they only refer to something far less complete and less accurate than a soil survey.[1] These so-called 'land classifications' of project areas in Iraq are certainly not carried out according to the U.S. Bureau of Reclamation standards; therefore they also discredit those standards.

If the U.S. Bureau of Reclamation standards and methods could be accepted, if they were applied completely and in the right way, and if they indeed were based on basic studies of the typical conditions in Iraq, even then it is doubtful whether these

[1] An example showing the comparison of results of five methods of soil survey in a sample section of the Mussayeb project is given by Buringh in: 'The application of aerial photographs in Soil Surveys', published in: 'Manual of Photo Interpretation' by the U.S. Society of Photogrammetry (1960).

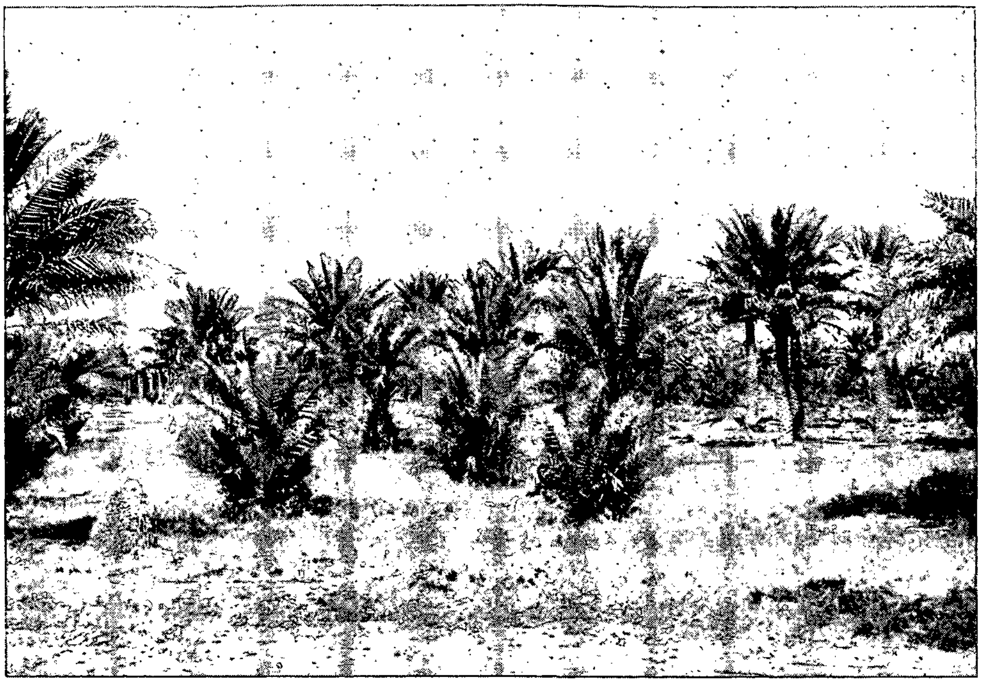


FIG. 154. Date garden on Class D5, very poor soils. The garden consists of poor date trees. There are numerous patches with a white salt crust. The price of the land is approximately ID. 5 per donum.

methods should be adopted for the agricultural development projects. There are three reasons for this:

a. It is necessary to train young Iraqis in land classification; they should take over the work in the future. The system of the Bureau of Reclamation, based on a combination and final evaluation of various quite different factors, requires much knowledge and experience, for which an honours graduate or the equivalent in Europe or America needs several years of post-graduate studies. This therefore cannot apply for Iraq, which has an enormous shortage of graduates.

b. As the results of the land classifications only show the final conclusion of the land classifier, these results cannot be used for any other purpose than that for which they had been formulated. The various information which may have been collected is not available as separate facts. If the appreciation or evaluation of one or more sections of the basic information changes, the classification has to be changed and consequently a large part of the land classification work has to be done again. The basic data may also be needed either as separate facts or in new combinations for other purposes. This is particularly true for Iraq. As those facts are not available now, much work has to be done again, which costs money and manpower.

c. It is extremely difficult to check the results of a complete land classification, as all data leading to the final conclusion of the classification are not available. If

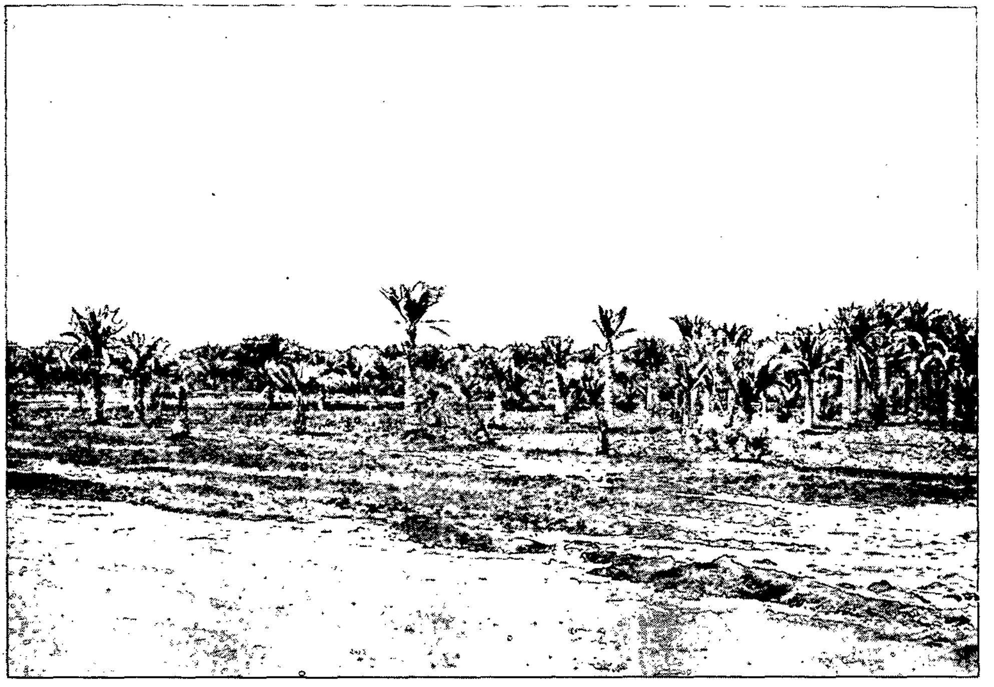


FIG. 155. Date garden on class D6, extremely poor soils. Those soils are completely unsuitable for dates; many soils even have a thick salt crust on the surface. The price of the land is approximately ID. 3 per donum.

during or after the time when the work on the project is carried out, special information is needed, the foreign land classifier has usually already left the country.

These three points become less important in countries with a high level of agriculture where land classifications mostly serve one purpose only and are carried out by qualified classifiers who know the conditions of the country thoroughly and who can easily co-operate with various specialists.

What Iraq needs is basic information on all factors which are important for developing the project. This information is the result of studying, classifying, collecting and evaluating the various factors to be performed by specialists, acting as one group. An example is given in Figs. 141–149. The results of the technical investigations on hydrology, topography, soils, irrigation, drainage, crop production, (see Figs. 150–156) farming, present land use etc. and the results of the economic, social and agronomic investigations will form the basis for the discussions and final decisions on how to develop a project. The specialists will then draw the final technical plans and work can be started.

The excuse of having no time for these investigations is, after a period of five years of development work in Iraq, no excuse at all. Having no time can never be an excuse for the failure of a project.

The contribution of soil specialists consists of providing basic information on soils

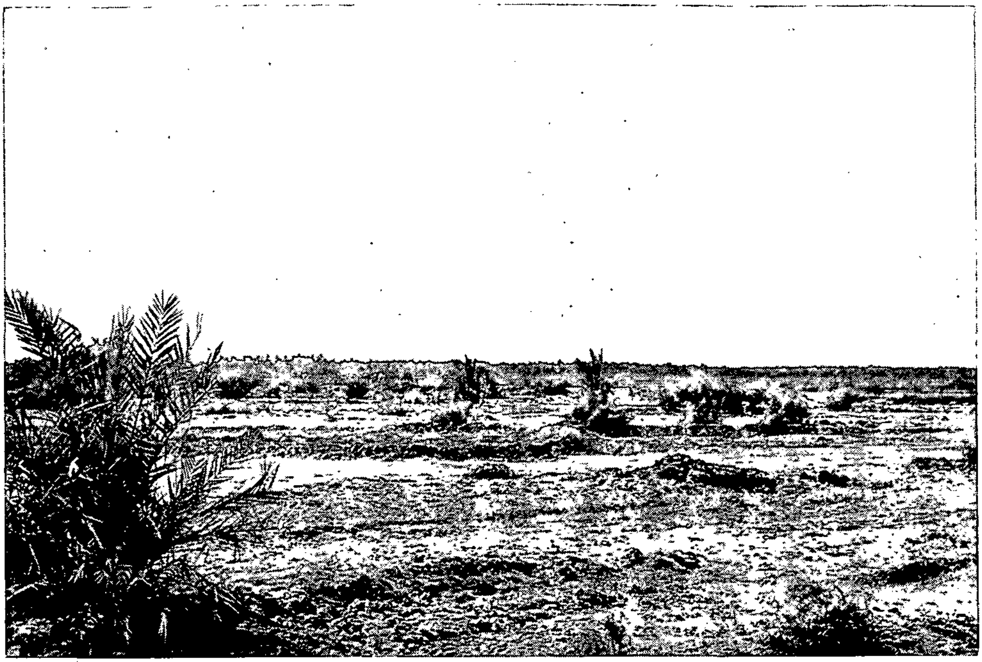


FIG. 156. Date garden on Class D7, extremely poor soils. Soil conditions are so bad that date trees do not grow at all. The price of the land is ID. 2 per donum. Soils of class D5, D6 and D7 may be combined in one class, because they are not suitable for date and fruit gardens.

and soil conditions, at least on a semidetailed basis. Specifications for such investigations have been set up and approved. Furthermore it will be the task of the soil specialists to provide information and a classification on soil suitability. (Lewis, 1952; Stephens, 1953). For Iraq it will be useful to make three types of soil suitability classifications as proposed by Vink (1956).

These are:

1. The suitability for present use (Figs. 146, 148);
2. The suitability for soil improvement (Fig. 145);
3. The degree of suitability for use which will be reached if the classification for improvement is put into practice (Figs. 147, 149).

The examples are from the Hilla-Kifl project (Buringh, 1958).

CHAPTER 8

SOIL EROSION AND MISMANAGEMENT OF LAND

8.1. Introduction

Up to the present hardly any attention has been paid to soil erosion and soil conservation in Iraq. The problem was brought to the attention of the Government during a Conference of Middle East Agricultural Development, which was held in Cairo in 1944 (Radhi, 1944). The only study on soil conservation was made by Gibbs (1954), a F.A.O. soil conservation specialist. He made a general soil conservation survey (1:2,000,000) of the whole country and a more detailed survey of an area near Chemchemal, east of Kirkuk.

The problem of water and wind erosion is a rather important one as 21,028,000 donums have serious water erosion, 31,557,600 donums have serious wind erosion and the rest of Iraq has slight to moderate water or wind erosion (Gibbs, 1954).

In studying the soil erosion problem in Iraq, two facts are of importance:

a. Not all erosion is accelerated soil erosion resulting from human mis-management of natural resources. Much erosion, particularly wind erosion in the deserts, is normal or geological erosion, a natural process, which cannot be stopped by soil conservation practices.

b. Soil erosion which can be observed in many parts of the country is the result of the action of wind or water during a period of many thousands of years. Not all erosion is recent.

Consequently the degree of soil erosion is not as serious as is sometimes concluded from what can be seen and from what is told or written about it. However, it is evident that soil erosion has to be stopped and that soil conservation measures have to be put into effect. Professor J. C. Russel once stated that the farmers in Iraq have preserved their land quite well. If it is taken into account that most areas in the uplands and mountains have already been in use for at least 5,000–6,000 years, little damage has been done by soil erosion. Similar areas in the United States were completely damaged after about 80 years of cultivation!

The forests in Iraq do not seem to be very good forests at all. However, they are, according to Chapman (1957) 'perfectly effective for water and soil conservation'. The trees, even if they are poor, the subsidiary vegetation of grasses and shrubs and the litter of dead leaves protect the soil from being eroded. There is no excessive surface runoff of water, and there is a maximum infiltration of water into the soil. A good grass cover is as effective as a forest. It is necessary to maintain a vegetation cover on mountain and hill slopes; this is the most effective and cheapest method of soil conservation.

Soil erosion in the mountains and uplands is a result of: (according to Chapman, 1949, 1957)

1. Shifting cultivation, which has been practiced since time immemorial. It is the most serious menace to the forests and it is probably the origin of a great deal of the badly eroded lands.

2. Overgrazing, especially by browsing animals such as goats and camels. It is mostly found in the vicinity of the villages.

3. Forest fires; about 300 km.^{2} get burnt every summer. Very few forests do not show signs of having been burned within the last twenty years. Nearly all forest species fortunately are fairly resistant to fire and regenerate in the following spring. During the winter after the fire, soil is exposed to erosion forces, and much damage can be done during that time.

4. Over-cutting for charcoal and firewood production. The value of charcoal and firewood was estimated at ID. 165,000 for 1948/49 and ID. 153,750 for 1949/50 (Statistical Abstracts, 1950). Most cutting is done in the vicinity of the villages.

Soil erosion is most evident in the uplands and in the southern part of the rainfed zone at the transition between the arid and irrigated zones.

Most of the sediment is carried by the rivers, especially by the Adhaim river, and deposited on the irrigated lands of the Mesopotamian plain or in the marshes of southern Iraq. The silt cover on the irrigated land does not improve the soil condition. Another effect is the sedimentation in irrigation canals and ditches, the clearing of which is very expensive.

The study and recommendations made by Gibbs (1954) provide a basis for an effective soil conservation programme. In practice, however, it was rather difficult to introduce soil conservation practices, due to the former economic and social conditions. For the new Republic here is a big task.

If nothing is done, it may be expected that soil erosion in Iraq will increase as a result of the development of the country, because the agricultural production will increase, health conditions will improve, the population will increase and the standard of living will become higher; consequently cultivation and grazing will expand and become more intensive. This process has already been started.

8.2. Overgrazing and shifting cultivation

There are about 4,500,000 sheep and 1,600,000 goats in Iraq, forming the most important part of the livestock. There is much overgrazing, especially near villages and water wells. According to Schwan (1957) plants are grazed far beyond their capacity to remain vigorous. It is a nearly universal practice to start grazing when the plants are barely above the ground. Mostly the perennial grasses, which protect the soils best, are destroyed and replaced by annual grasses which dry up earlier and produce less forage; also their roots do not protect the soil. Generally, lands are grazed too easily, too much and too late in the season. In some areas the surface soil becomes more compact as a result of trampling by livestock; as a consequence the infiltration rate decreases and water moves over the soil rather than penetrating into it.

In saline areas with puffed solonchak soils the thin surface crust is broken when the livestock wander over the land, thus exposing the loose puffed soil layer to the wind (see Fig. 81).

In the driest part of the rainfed zone and at the transition to the arid zone much of the land is cultivated. Some nomadic tribes and farmers plough some land in one place, some in another area. The success of cultivation depends on the rainfall, which is very variable. Rain is an uncertain factor every year. The success of the crop depends entirely on one or two showers in early spring. In order to decrease the farming risks, each tribe cultivates a few plots distributed all over the area, a long distance apart, and if possible in slight depressions. Most land is cropped only once in three or more years. This practice of shifting cultivation is adapted to the characteristic climatic conditions of the region. Nearly all the land has once been cultivated; the natural grass cover has been entirely destroyed, and even the annual grasses are not doing well under these conditions.

It is evident that farming has penetrated much too far into the arid zone of Iraq. As happens all over the world, the farmers are taking too many risks by trying to cultivate the land beyond its land use capability.

In Iraq the zone between the 150 and 400 mm. rainfall lines has been transformed into a barren area of shifting cultivation and overgrazing. This destructive process has been intensified in recent years by introducing modern farm machinery such as tractors and combines by the big landowners and by similar people who rent large areas of land for modern extensive farming on too commercial a basis. It is demonstrated by the facts shown in Fig. 157.

The over-grazing in the desert areas is also a problem. Rainfall is low and very variable. A few years of increased aridity weakens the scanty surface cover, and the soils are more prone to erosion. On the other hand, the vegetation increases during a few years of rather more abundant rain. Then more livestock is grazed, which also

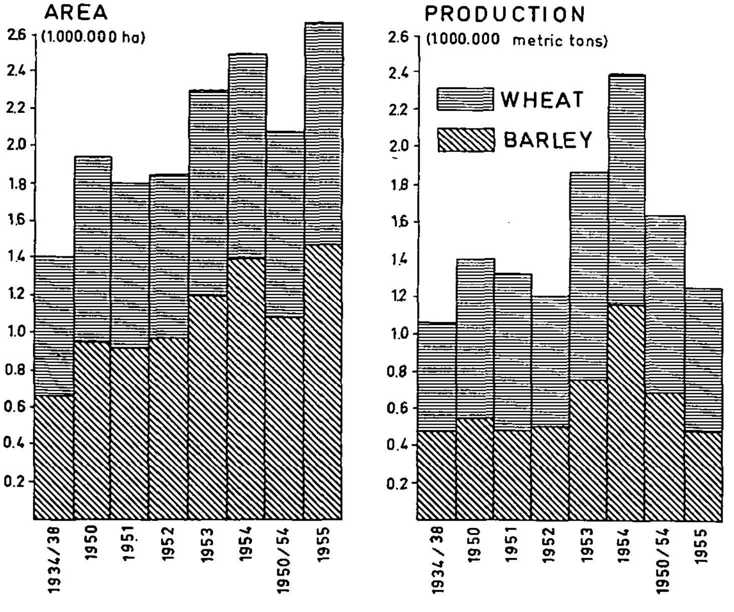


FIG. 157. Variations in area and production of the main crops in Iraq during recent years (source: Statistical Abstracts, Min. of Economics). 1955 was a very dry year.

leads to overgrazing and accelerated wind erosion as soon as normal conditions or a few relatively arid years follow.

Originally the vegetation in the steppes was much thicker. Since World War I, the number of livestock has been increased considerably (Springfield, 1954). Much steppe land has been cultivated, particularly in the last decade, since mechanised farming has been practiced. Consequently overgrazing has been increased. The common practice of shifting cultivation was in the past adapted to environmental conditions. However, at present it is responsible for the destruction of many of the best natural grazing lands.

8.3. Water erosion

Water erosion is rather important on cultivated hill and mountain slopes and even on the more undulating and flat areas. Ploughing of hill slopes is increasing. At many places even steep slopes have been cultivated in recent years, which has given rise to destruction of the land. Here, too, the increasing population, the improvement of communication systems and agriculture, as well as the increasing standard of living, forces the farmer to cultivate land which often is unsuitable, unless effective protective practices (terracing) are employed. Mostly, the only means of conservation is

FIG. 158. Water erosion of soils is a problem in the southern part of the rainfed zone at the transition between deserts and the irrigated Lower Mesopotamian Plain. Near the Adhaim river some 100 km. north of Baghdad, erosion starts during heavy showers. There is much runoff water, even on almost flat land, and erosion starts as indicated on this photograph.

FIG. 159a. Soil erosion, a gully has been formed. Most of the silt load of the Tigris river is material eroded from the transitional zone between the real rainfed and irrigation regions of Iraq.

to establish a permanent grass-cover or forest. It is characteristic that hardly any trace of ancient terracing is found in Iraq; whereas this occurs in many neighbouring countries. This probably indicates the absence of over-population in the past. At present terracing is practiced only on irrigated tobacco lands in small mountain valleys.

In the flatter lands south of the uplands, severe gully erosion occurs locally. As an example, attention can be drawn to the deeply gullied banks along the Adhaim river (Chapter 4.2.3.). This erosion is a result of occasional heavy showers, low infiltration rates of the encrusted surface layer of the saline soils, over-irrigation of adjacent land and poor soil management. In the soil survey report of the Hunting Group (1956), recommendations are given for soil conservation practices in order to stop this active erosion process. The Government seems to be improvident in spending large sums of money on land reclamation, partly on rather poor land, whereas no attention is being paid to the destruction of potentially productive land in the Adhaim area.

Rill erosion can be observed all over the hilly areas. Although this type of soil erosion does not intensively destroy land, a continuous process of rill erosion can cause much damage.

Sheet erosion is rather important in the Lower Mesopotamian plain, particularly on the silty irrigation levees sloping to the basin depressions.

Water erosion in the desert areas is often related to over-grazing and low water

FIG. 159b. Gully erosion in irrigation sediment along the Adhaim river.

intake of the surface soils; nearly all the water runs over the surface to depressions and wadis, especially when surface crusts occur. Although the annual rainfall is very low, occasionally catastrophic rainstorms occur, the desert may look like a huge lake and wadis are transformed into torrential streams for a short time.

The Jabal Hamrin, south of Kirkuk, is one of the most intensively eroded areas in Iraq. This erosion is, for the most part, normal erosion. The weakly cemented sandy layers are very liable to erosion and vegetation is very sparse or absent. In addition to water erosion, wind erosion is also active.

Other extensive and severely eroded areas are found west of Tuz, north of Mosul and west of the Tigris in Upper Jezirah near the Syrian-Turkish border. The first one is in the zone of Reddish-brown soils, the other two in the zone of Brown soils. Water erosion in the mountains is mainly limited to bare, steep areas with relatively impervious layers, crust and sparse vegetation, where runoff is high.

Most of the erosional products, which reach the Mesopotamian plain as silt, suspended in the water of the Tigris river, come from the upland and foothill zone.

8.4. Wind erosion

Wind erosion in Iraq is for the most part normal. Accelerated wind erosion is mainly a result of over-grazing and shifting cultivation. The surface soil is removed and the material is accumulated either a short or long distance away, depending on the

FIG. 160. In the rainfed zone and the mountain region, real soil erosion is limited to the smooth valleys. During heavy showers some water runs over the surface, forming small streams which at once form deep erosion gullies, which in turn gradually form small valley streams.

particle size of the material which has been blown away. In the field it is hardly possible to separate areas of accumulation and removal, as the material is intermixed and shifting all the time. As the fine material is blown away, more of the sandy material remains, forming the surface soil in extensive areas of active wind erosion. In those areas dune formation is active; many of such areas are indicated on the Exploratory Soil Map of Iraq (map 1).

In saline areas with loose surface layers (puffed solonchak soils) wind erosion is rather destructive, particularly on the silty irrigation levees. Here the fine soil particles, which are flocculated, act like sandy material, sometimes forming dunes or sheets. Such material is called 'pseudo sand' (Buringh and Edelman, 1956). The transportation and accumulation of salt-flocculated soil material, a process which was previously unknown in soil science, has been rather important in Africa and Australia in the Pleistocene (Butler, 1956). See also Figs. 82 and 83, and Chapter 4.3.2.

FIG. 161. Small stream photographed half an hour after a heavy shower in Sulaimaniya. The stream suddenly forms a deep gully in a deep Chestnut soil. The same stream can be seen in Fig. 160.

In the barren non-cultivated areas, which have been irrigated in the past, wind erosion is very active and dunes have been formed.

In the river valleys of the north and along the river beds in central and southern Iraq, soil material is blown out during heavy storms and sometimes small dunes are formed along the river beds. As wind erosion is rather active in the Adhaim area south of the Jabal Hamrin, particularly on the terrace bordering the Adhaim valley, much productive land in the valley is covered by a thick sand layer.

In the gypsum areas of Iraq (see Fig. 105a), wind erosion is very active, the rather sandy surface material is easily removed and large parts of the areas have a hummocky surface consisting of small fine sand dunes, as described in Chapter 5.2.

The large areas in the deserts which are covered with a gravelly desert pavement indicate severe wind erosion in the past. At present the gravelly layer protects the soil

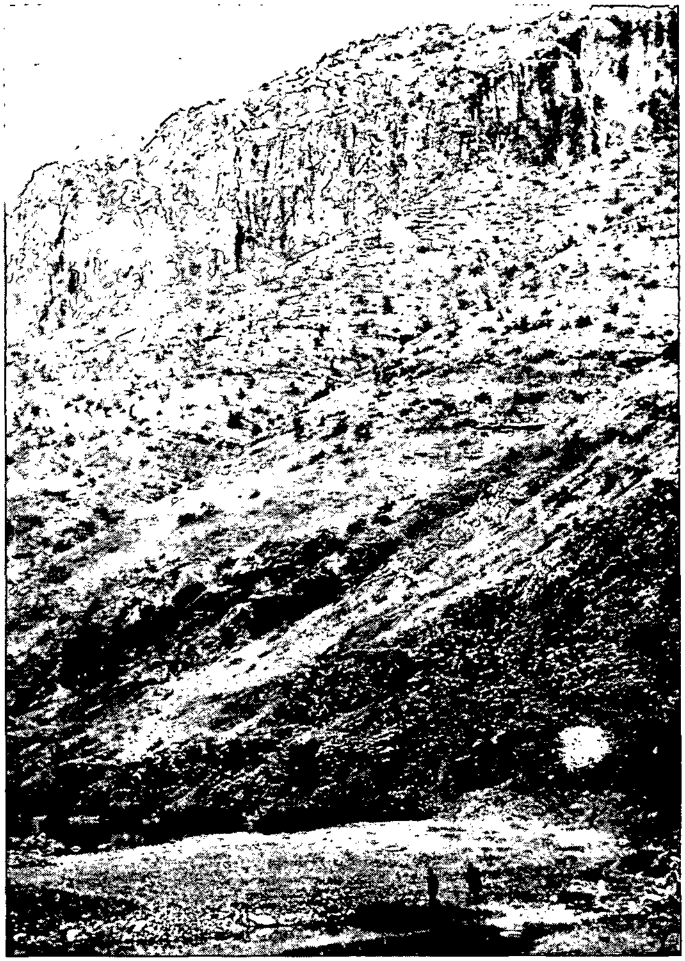


FIG. 162. Soil erosion in the mountains is limited. Most slopes are covered by grasses or by low oak trees.

from being eroded. Near centres of ancient civilization in the plain, a layer of potsheards and bricks at the surface acts like a desert pavement.

There are two kinds of wind transported material, as can be observed during heavy dust storms:

a. The fine dust, consisting of fine particles (maximum 100–200 microns) in suspension in the air, often up to a height of one kilometre.

b. The coarse dust, consisting of the coarser particles (150–250 microns and larger), which are transported along the earth's surface in an air layer up to 3 metres thick; most of this material is transported in the layer nearest the ground (0–0.5 metre).

The fine dust is transported over great distances and the coarse material over short distances, mostly forming dunes. Lees and Falcon (1952) estimate that due to duststorms, approximately 2.5 mm. of soil material is deposited in the Lower Mesopotamian Plain of Iraq each year. This estimate seems to be too high because most of the

APPENDIX 1

THE EXPLORATORY SOIL MAP OF IRAQ

Scale 1:1,000,000

INTRODUCTION

The purpose of this soil map of Iraq is to show the broad geographical relationships between soils and the contrast in soil conditions in the various regions. The map is based on the present knowledge of soils of this country. It is called an 'exploratory soil map' in order to point out that the soils shown on the map are identified mainly by original field observations, whereas the boundaries are largely compiled from various sources. A liberal use has been made of various data concerning soils, land classification, topography, vegetation, climate, hydrology and geology, which are available in various reports.

The main sources of information were:

The topographical map of Iraq, quarter of an inch to 1 mile;
The provisional geological map of Iraq, 1:2,000,000, 1937;
The soil conservation map of Iraq, 1:2,000,000 (Gibbs, 1953);
The forest map of North-eastern Iraq, 1:850,000;
Some aerial photo-mosaics;
Some soil and land classification maps of project areas.

The soil mapping units indicated on the map by a symbol and a colour are mentioned in the legend. They represent soil associations and miscellaneous land types, which are briefly described below. More details concerning these soils can be found in this book.

It should be understood that the areas shown on the map by the same symbol and colour do not represent areas of uniform soil conditions; on the contrary, they may consist of very different kinds of soils, combined in one soil unit on the exploratory soil map, which only gives a simplified idea of the general soil conditions.

The soil map is printed at a scale of 1:1,000,000; one centimetre on the map represents ten kilometres in the field. Areas smaller than approximately 40 sq. km. are not shown on the map, except in a few cases where attention is drawn to special soils.

Most of the names of the soils are descriptive names. The specific soil terminology is in accordance with the Soil Survey Manual (1951), of the U.S. Soil Survey Staff.

An attempt has been made to show the main soil forming processes prevailing in various parts of Iraq. In addition, some special soil characteristics of specific agricultural importance are shown, e.g. soil depth, soil erosion, etc.

In order to get at least some idea of the soils shown on the exploratory soil map, a number of general soil characteristics have been described below. This information also refers to the general soil conditions and not to local details. In addition there is some information on:

a. The present relative soil suitability for general agriculture, indicating the agricultural purpose for which the soils are most suitable in the prevailing physical environment.

b. The total area in donums of each mapping unit, measured on the map (1 donum = $\frac{1}{4}$ ha.). This figure is an approximation; it is not accurate due to the type of map and survey.

c. The potential productivity, which means the agricultural productivity under ideal conditions of farm management, including several measures like drainage, land levelling, irrigation, terracing, etc.

d. The potential productive area as a percentage of the total area of that unit. This indicates that not the whole area of the unit will have the potential productivity described, but only a part of it. The reason is that some soils of a much lower potential productivity are included in the total area.

Data on climate and vegetation can be found in Chapter 2.

Some parts of the map are more reliable than others, owing to the fact that rather detailed and accurate data were available from some areas, whereas from other areas (deserts) little information could be collected. The relative reliability of the soil map has been indicated on a special small scale map. The reliability refers more to the location of the boundaries than to the occurrence of the specific soil units.

The geodetic accuracy of the soil boundaries is fair, because the original data were drawn on the sheets of the topographical map of Iraq, scale quarter of an inch to one mile. No reproduction or scale reduction facilities were available;consequently all data had to be reduced to the 1:1,000,000 scale by hand, following a simple grid system method. Finally the 'Illustrated map of Iraq for development projects', scale 1:1,000,000 was used as a base map for the position of the various sheets on a reduced scale. The local accuracy is good.

Physiographic units

When considering the soil conditions of the whole country, Iraq has to be divided into:

A. *The lower Mesopotamian Plain* – the broad plain of the Tigris and Euphrates rivers, mainly formed by sedimentation of fluviatile material. It consists of units 1–16 on the soil map, which will be explained below. The plain begins near Samarra and Ramadi and ends near the Basra Gulf. It is approximately 600 km. long and 200 km. wide. Most soils are Arid-Alluvial soils. As a consequence of the typical arid climate they are in the process of salinization and also partial alkalinization. This plain is one of the most important parts of Iraq, due to its irrigation agriculture. It has been sub-divided into physiographic units which are regions with completely different soil conditions, mainly as a consequence of different soil forming and sedimentation processes, and of different hydrological conditions (chapter 4).

1. *The Older Fluviatile Terraces* – (Units 1, 2 and 3 on the soil map). These terraces are situated approximately 15 to 20 metres above the present river plain. They are therefore never flooded and the groundwater level is very deep. Soils are much

older than in the rest of the plain; they are classified as Sierozem and Reddish-Brown soils. At present they are extensive desert areas (chapter 4.2.).

2. *The Flood Plain* – the section of the meandering Tigris and Euphrates rivers around Baghdad, characterised by river levees and basins and by occasional floods in spring. The groundwater level is relatively deep for the greater part of the year (units 4, 5, 6 and 7 on the map). See chapter 4.3.

3. *The Delta Plain* – the Twin rivers are here splitting up into many branches. It is an extensive wide area which is sometimes flooded. The groundwater level is high to very high; the deepest parts of the basins are marshy or even Haurs (depressions filled with water during the greater part of the year), and some of them are being silted up, mainly during rice cultivation. The units 5′, 8 and 9 are the most important (chapter 4.4).

4. *The Marsh Region* – a very wide area in which the rivers and their branches are losing almost all their water and sediment. Each year the whole area is flooded. Groundwater is near or above the land surface. Almost the whole area is covered by reeds and rushes. In some parts rice and millet is grown. There is hardly a distinction between water and land (units 10 and parts of 8 and 9). See chapter 4.5.

5. *The Estuary Region* – an area which is influenced by the tidal effects of the Basra Gulf. The water level in the Shatt-Al-Arab rises and falls twice a day, thus irrigating and draining the land near the river naturally (unit 13). The extensive tidal flats some distance from the river form waste land (unit 14). See chapter 4.6.

6. *The Coastal Region* – a relatively small strip of land near the Basra Gulf, often submerged by the sea and mainly consisting of marine sediments. The soils are wet, weak and muddy and of no use for agriculture (units 15 and 16). See chapter 4.7.

7. *The Eastern Section* of the Lower Mesopotamian Plain a flat, featureless plain formed by the Tigris sediments and erosion products of the Iranian mountains. The soils are mainly marshy basin soils (unit 5″) including some Haurs (chapter 4.8).

B. *The Desert Regions* – the extensive western part of the country, indicated by units 17–26 on the soil map. The region consists of:

a. The Jezira Desert – (mainly No. 25 on the map); this is a gypsum desert, forming part of the wide Jezira area extending into Northern Syria (chapter 5.2).

b. The Northern Desert – (units 19 and 24 and the northern half of 17 and 20), mainly a limestone desert, extending into Syria, Jordan and Saudi Arabia (chapter 5.3).

c. The Southern Desert – (southern half of units 17 and 20 and unit 23 on the map), mainly a limestone and partly a sandy and pebbly desert, extending into Saudi Arabia and Kuwait (chapter 5.4).

The subdivisions made in these deserts are mainly based on their physiography and soil parent material. There are many marshy depressions (unit 22) and two large lacustrine areas of former lakes (unit 21); they are all strongly saline. In the south-eastern section of the deserts, extensive sand dune areas occur (unit 18).

C. *The Uplands and Hilly Region* – extending from the Jezira desert and the Lower Mesopotamian Plain up to the mountains of North-eastern Iraq. There is a gradual transition from Reddish-Brown soils to Brown soils (27, 28, 33 and 35 on the map), due to an increase in precipitation. Large parts of the uplands and hills consist of shallow soils, overlying gypsum, mud and sandstone, limestone and gravel. Some areas are deeply eroded, partly by normal erosion (units 30 and 34′), particularly the Jabal Hamrin (unit 29). The area of Kirkuk, Erbil and Mosul is an important area with deep Brown soils (unit 35). See chapter 6.

D. *The Mountain Region* – which is a part of the Zagros mountains, consisting of many parallel mountain ranges, separated by valleys, a few of them being important for agriculture, owing to their deep Chestnut soils (unit 37). Most of the mountain region is Rough Broken and Stony Land (unit 38) with Lithosols, Rendzina soils and shallow Brown and Chestnut soils. At some specific places deep Chernozem soils occur as intrazonal soils. The highest part of the mountains is above the oak forest zone; it is almost Rough Mountainous Land (units 39 and 40) in limestone and partly in metamorphic rock material. The mountains higher than 9,000 feet belong to the Alpine phase (chapter 6).

Characteristics of the soil mapping units

Map symbol	1	3
Soil mapping unit	Gypsiferous gravel soils	Older river plain soils, silted phase
Main great soil group	Sierozem soils	Minimum Reddish-Brown-Solonchak
Minor great soil group(s)	Regosols	Regosols
Land form	Undulating	Level, irrigation meso-relief
Parent material	Fluviatile, gravel, pebbles and secondary gypsum	Fluviatile, silt loam to clay, covered by irrigation sediment
Soil depth	Shallow	Deep
Soil erosion	Medium wind erosion	Some wind and sheet erosion, severe gully erosion along rivers
Soil salinity	Free or slightly affected, some saline depressions	Moderately to strongly saline, external and puffed solonchak
Present land use	Poor grazing land	Idle and some crop land
Relative soil suitability for present use	Fair, winter grazing only	Fair crop land in some areas
Total area in donums	2,312,000 (1.3 %)	888,000 (0.5 %)
Potential soil suitability	Very low	high
Potential productive area as a percentage of the total area	2 %	50 %
Soil description in Chapter	4.2.1.	4.2.3.

Map symbol	2	4
Soil mapping unit	Gravelly, older river plain soils	River levee soils
Main great soil group	Minimum Reddish-Brown-Solonchak	Arid-Alluvial soils
Minor great soil group(s)	–	Arid-Alluvial-Solonchak soils
Land form	Level	Level
Parent material	Fluviatile, loam to clay, with some gravel of mixed origin	Fluviatile, fine sandy loam to silty clay loam
Soil depth	Deep	Deep
Soil erosion	Some wind and sheet erosion	No
Soil salinity	Strongly saline, external and puffed solonchak	Free to moderately saline in deeper subsoils
Present land use	Idle, and some crop land	Date and fruit gardens, vegetables
Relative soil suitability for present use	Fair crop land in some areas	Good for dates and fruit gardens, vegetables
Total area in donums	356,000 (0.2 %)	2,140,000 (1.2 %)
Potential soil suitability	Medium to high	High to very high
Potential productive area as a percentage of the total area	30 %	80 %
Soil description in Chapter	4.2.2.	4.3.1.

Map symbol	5	5″
Soil mapping unit	River basin soils, poorly drained phase	River basin soils, marsh phase
Main great soil group	Arid-Alluvial-Solonchak soils	Arid-Alluvial-Solonchak soils
Minor great soil group(s)	–	–
Land form	Level, irrigation meso-relief	Level
Parent material	Fluviatile, silty clay loam to clay with irrigation sediment on top	Fluviatile silty clay loam to clay with influence of Iranian mountains
Soil depth	Deep, with relatively high groundwater table	Deep, with high groundwater table
Soil erosion	Some sheet erosion and severe wind erosion on non-cultivated land	No
Soil salinity	Moderately to strongly saline, external solonchak and sabakh	Moderately to strongly saline, often sabakh
Present land use	Barley and some wheat in fallow system	Waste land
Relative soil suitability for present use	Fair to good	Poor grazing land
Total area in donums	5,360,000 (3.1 %)	5,640,000 (3.2 %)
Potential soil suitability	Medium to high for half the area	Unknown (very low?)
Potential productive area as a percentage of the total area	50 %	0 %
Soil description in Chapter	4.3.2.	4.8.

Map symbol	5′	6
Soil mapping unit	River basin soils, poorly drained phase	Basin depression soils
Main great soil group	Arid-Alluvial-Solonchak soils	Arid-Alluvial-Solonchak and Solonetz soils
Minor great soil group(s)	–	Solonetz-Solonchak soils
Land form	Level, irrigation meso-relief	Level, with gilgai relief
Parent material	Fluviatile, silty clay loam to clay with irrigation sediment on top	Fluviatile, silty clay loam to clay often with irrigation sediment
Soil depth	Deep, with high groundwater table	Deep, high groundwater table or flooded
Soil erosion	Some sheet erosion	Some sheet erosion
Soil salinity	Moderately to strongly saline, often sabakh	Strongly saline or solonetzic, often flooded solonchak
Present land use	Barley in fallow system	Waste land or poor grazing land
Relative soil suitability for present use	Fair	Very poor
Total area in donums	10,480,000 (5.9 %)	532,000 (0.3 %)
Potential soil suitability	Medium	Very low
Potential productive area as a percentage of the total area	30 %	0 %
Soil description in Chapter	4.3.2.	4.3.2.

7	9	11
Periodically flooded soils	Silted Haur and Marsh soils	Active dune land
Arid-Alluvial-Solonchak soils	Arid-Alluvial-Solonchak soils	Regosols
–	–	–
Level, in depressions	Level	Hummocky or dunes
Fluviatile, silty clay loam or clay	Fluviatile, silt loam to clay, with irrigation sediment	Aeolian, pseudo-sand (flocculated fine textured material)
Deep, waterlogged	Deep, high groundwater table	Loose material
No	No	Severe wind erosion
Strongly saline, external and flooded solonchak, sabakh	Moderately saline solonchak and sabakh soils	Saline to strongly saline
Waste land	Crop land (rice, millet), idle	Waste land
Poor to fair	Fair to good	Very poor
532,000 (0.3 %)	2,676,000 (1.5 %)	532,000 (0.3 %)
Fair to low	Medium	Very low
20 %	30 %	0 %
4.3.2.	4.4.	4.3.2.

8	10	12
Haur soils	Marsh soils	Fan soils
Hydromorphic soils	Hydromorphic soils	Arid-Alluvial soils
–	Organic soils	–
Level, in depresions, gilgai	Level	Sloping
Fluviatile and lacustrine, clay	Fluviatile, often with organic cover	Gravelly material of mixed origin
Often flooded	Deep, with very high groundwater table	Shallow
No	No	Some water erosion
Strongly saline	Moderately to strongly saline	Moderately saline
Waste land	Reed land, some rice and millet	Grazing land
Very poor	About 10 % is good for rice and millet	Poor
2,500,000 (1.4 %)	2,852,000 (1.6 %)	888,000 (0.5 %)
Very low	Very low, good for rice and millet	Low
0 %	10 %	2 %
4.3.2.	4.5.	4.8.

Map symbol	13	15
Soil mapping unit	Estuary levee soils	Coastal flats
Main great soil group	Arid-Alluvial soils	Arid-Alluvial-Solonchak and Solonetz soils
Minor great soil group(s)	Arid-Alluvial-Solonchak soils	–
Land form	Level	Level, with creeks
Parent material	Fluviatile, silt loam to silty clay loam	Marine silt loam to heavy clay
Soil depth	Deep	Deep, with very high groundwater, submerged
Soil erosion	No	No
Soil salinity	Free or slightly saline	Moderately to strongly saline and alkali
Present land use	Date and fruit gardens	Waste land
Relative soil suitability for present use	Good to excellent	Poor
Total area in donums	356,000 (0.2 %)	356,000 (0.2 %)
Potential soil suitability	High to very high	Low
Potential productive area as a percentage of the total area	80 %	0 %
Soil description in Chapter	4.6.	4.7.

Map symbol	14	16
Soil mapping unit	Tidal flats	Coastal beach
Main great soil group	Arid-Alluvial-Solonchak soils	Arid-Alluvial-Solonchak and Solonetz soils
Minor great soil group(s)	–	–
Land form	Level, with creeks	Level with creeks
Parent material	Fluviatile silty clay loam to clay	Marine fine sand to clay, with some gravels
Soil depth	Deep, very high groundwater table	Deep, with high groundwater, submerged
Soil erosion	No	No
Soil salinity	Moderately to strongly saline and alkali	Moderately to strongly saline and alkali
Present land use	Waste land	Waste land
Relative soil suitability for present use	Poor	Poor
Total area in donums	1,068,000 (0.6 %)	52,000 (0.0 %)
Potential soil suitability	Low to fair	Low
Potential productive area as a percentage of the total area	10 %	0%
Soil description in Chapter	4.6.	4.7.

17	19	21
Mixed gypsiferous desert land	Gravelly desert and stony waste land, deeply eroded phase	Saline lake bottom land
Sierozem soils	Desert and Sierozem soils	Solonchak soils
Regosols, Lithosols	Regosols, Lithosols	–
Undulating	Undulating, with deep wadis	Level
Gypsum, limestone, sandstone	Limestone	Lacustrine loam to silty clay loam
Shallow	Shallow	Deep, with high groundwater table
Moderate to severe wind erosion	Slight to moderate wind and gully erosion	No
Moderately to strongly saline	Slightly saline	Strongly saline, sabakh
Winter grazing land	Winter grazing and waste land	Waste and grazing land
Poor	Poor	Poor
15,680,000 (8.8 %)	19,400,000 (10.9 %)	888,000 (0.5 %)
Very low	Very low	Low
0 %	0 %	1 %
5.	5.3.	5.

18	20	22
Sand dune land	Stony desert land	Saline desert marshes
Regosols	Desert and Sierozem soils	Solonchak soils
–	Regosols and Lithosols	Hydromorphic soils
Hilly	Undulating	Depressions
Sand, mainly quartz	Limestone, aeolian sand	Colluvial, fluviatile and lacustrine
Loose material	Shallow	Deep, with high groundwater table
Severe wind erosion	Slight to moderate wind erosion	No
Free to slightly saline	Free to slightly saline	Strongly saline
Waste land	Winter grazing land	Waste and grazing land
Poor	Poor	Poor
2,676,000 (1.5 %)	29,000,000 (16.3 %)	1,960,000 (1.1 %)
Very low	Very low	Low
0 %	0 %	1 %
5.3.	5.3 and 5.4.	5.

Map symbol	23	25
Soil mapping unit	Pebbly and sandy desert land	Gypsum desert land
Main great soil group	Desert soils	Sierozem soils
Minor great soil group(s)	Red desert soils(?)	Lithosols and Regosols
Land form	Undulating	Undulating
Parent material	Sand, limestone, pebbles	Gypsum and some limestone and sandstone
Soil depth	Shallow	Shallow
Soil erosion	Moderate to severe wind erosion	Moderate to severe wind erosion, moderate water erosion
Soil salinity	Moderately to strongly saline	Moderately to strongly saline
Present land use	Winter grazing, waste land	Winter grazing
Relative soil suitability for present use	Poor to fair	Fair
Total area in donums	9,040,000 (5.1 %)	14,200,000 (8.0 %)
Potential soil suitability	Low	Low
Potential productive area as a percentage of the total area	0 %	0 %
Soil description in Chapter	5.4.	5.2.

Map symbol	24	26
Soil mapping unit	Limestone desert land	Valley bottom soils
Main great soil group	Desert and Sierozem soils	Alluvial soils (semi-humid region)
Minor great soil group(s)	Lithosols	–
Land form	Undulating	Level
Parent material	Limestone	Young, fluviatile
Soil depth	Shallow	Deep
Soil erosion	Moderate wind and water erosion	Sometimes flooded
Soil salinity	Free to slightly saline	Free in Northern Iraq
Present land use	Waste land, some grazing	Summer crop land and vegetables
Relative soil suitability for present use	Poor	Excellent under irrigation
Total area in donums	5,840,000 (3.3 %)	712,000 (0.4 %)
Potential soil suitability	Low	High
Potential productive area as a percentage of the total area	0 %	70 %
Soil description in Chapter	5.3.	6 and 7

27	29	31
Reddish-Brown soils, medium and shallow phase	Bad-land	Lithosolic soils in sandstone and gypsum
Reddish-brown soils	Reddish-brown soils	Lithosols
Lithosols	Lithosols	Reddish-brown and Brown soils
Undulating to rolling	Hilly to steep	Hilly and steep
Older fluviatile, colluvium. No 27 over gypsum, sandstone and mudstone no 27′ over gravel	Sand, mudstone, gypsum	Sand and mudstone, gypsum locally limestone
Shallow and moderately shallow	Very shallow	Very shallow
Locally gully erosion	Severe, active gully erosion	Moderate gully erosion
Locally some saline depressions	Some salinity	No
Grazing and dry farming land	Waste land	Waste and grazing land
Fair for grazing and dry farming	Very poor grazing land	Poor
3,212,000 (1.8 %)	1,420,000 (0.8 %)	888,000 (0.9 %)
High, with irrigation and drainage	Very low	Very low
10 % and 30 % for grazing	0 %	0 %
6.1.	6.3.	6.2 and 6.3.

28	30	32
Reddish-brown soils, deep phase	Gullied land	Lithosolic soils in limestone
Reddish-brown soils	Reddish-brown and Brown soils	Lithosols
–	–	Brown soils
Level to undulating	Level to undulating	Hilly and steep
Older fluviatile and weathering product of gypsum, limestone and mudstone	Older fluviatile and aeolian deposits	Limestone
Deep	Deep	Very shallow
Locally severe, active gully erosion	Severe, active gully erosion	Locally rill erosion
Locally some saline depressions	Locally slightly saline	No
Dry farming (barley)	Waste and poor grazing land	Grazing and poor forest
Good in wet winters	Poor	Fair for grazing
3,568,000 (2.0 %)	1,600,000 (0.9 %)	532,000 (0.3 %)
High if irrigated and drained	Very low	Low
60 %	2 %	0 %
6.1.	6.3.	6.5.

Map symbol	33	34′
Soil mapping unit	Brown soils, medium and shallow phase over Bakhtiari gravel	Brown soils, shallow and medium phase, deeply eroded
Main great soil group	Brown soils	Brown soils
Minor great soil group(s)	Lithosols	Lithosols
Land form	Undulating and rolling	Hilly and steep
Parent material	Limestone and Bakhtiari gravel	gypsum and limestone, aeolian
Soil depth	Shallow and moderate	Shallow to moderately deep
Soil erosion	Rill erosion (locally)	Severe gully erosion
Soil salinity	No	No
Present land use	Grazing land	Waste and poor grazing land
Relative soil suitability for present use	Good grazing land	Poor grazing land
Total area in donums	4,280,000 (2.4 %)	532,000 (0.3 %)
Potential soil suitability	Low to fair	Low
Potential productive area as a percentage of the total area	5 %	0 %
Soil description in Chapter	6.5.	6.2. and 6.4.

Map symbol	34	35
Soil mapping unit	Brown soils, medium and shallow phase over gypsum	Brown soils, deep phase
Main great soil group	Brown soils	Brown soils
Minor great soil group(s)	Lithosols	Lithosols
Land form	Undulating and rolling	Level to undulating
Parent material	Gypsum and locally limestone	Old fluviatile and aeolian
Soil depth	Shallow and moderately shallow	Deep and moderately deep
Soil erosion	Sheet and rill erosion	Some rill and gully erosion
Soil salinity	No	No
Present land use	Grazing land, locally crop land	Dry farming crop land, wheat
Relative soil suitability for present use	Fair to good grazing land	good winter crop land, if rainfall is sufficient
Total area in donums	1,600,000 (0.9 %)	6,200,000 (3.4 %)
Potential soil suitability	Low to fair	Excellent crop land under irrigation
Potential productive area as a percentage of the total area	5 %	70 %
Soil description in Chapter	6.2 and 6.3.	6.4.

36	38	40
Chestnut soils, shallow, strong and sloping phases	Rough broken and stony land	Rough mountainous land, Alpine phase
Chestnut soils	Lithosols and Rendzina soils	Lithosols
Reddish Chestnut, Rendzina soils and Lithosols	Brown and Chestnut soils	Podsolic soils(?)
Hilly and steep	Steep, mountainous	Very steep, high mountain tops
Limestone	Limestone	Metamorphic rocks, limestone
Shallow to moderately shallow	Shallow, minor areas deep	Shallow
Locally some sheet and rill erosion	Some erosion (locally)	Some erosion
No	No	No
Mostly grazing land	Oak forest, bushes, grazing land	?, above forest region
Good grazing land	Fair to good forests and grazing land	Low
888,000 (0.5 %)	6,760,000 (3.8 %)	36,000 (0.0 %)
Good grazing land	3 % for crops, 50 % for grazing	Low
10 % as crop land, 50 % as grazing land	3 %	0 %
6.6 and 6.7.	6.6.	6.6.

37	39
Chestnut soils, deep phase	Rough mountainous land
Chestnut soils	Lithosols
Reddish Chestnut and Chernozem soils	Brown and Rendzina soils
Level	Steep to very steep, high mountains
Fluviatile and limestone	Metamorphic rocks, limestone
Moderately deep to deep	Shallow
No	Some erosion
No	No
Winter crop land (wheat)	Oak forest and grazing land
Good for winter crops	Fair to good forest land
1,068,000 (0.6 %)	1,068,000 (0.6 %)
Excellent under irrigation	Only minor areas suitable for crops
70 %	2 %
6.7.	6.6.

General relative classification of soil suitability for present agricultural use

The general relative suitability of the various soil units for agriculture under the present conditions has been indicated on a map (Fig. 163). The classification is relative; it is based on the information in the exploratory soil map and on a general knowledge of the agriculture of Iraq. These are 10 classes on the map and for each class the gross area (in km.^{2} and in percentages of the total area of Iraq) has been determined. It has been pointed out before that each unit on the map includes soils with a much lower quality as has been described in the explanation to the exploratory soil map. It has therefore also been tried to calculate the net areas in km.^{2}; the result is given in Table 37.

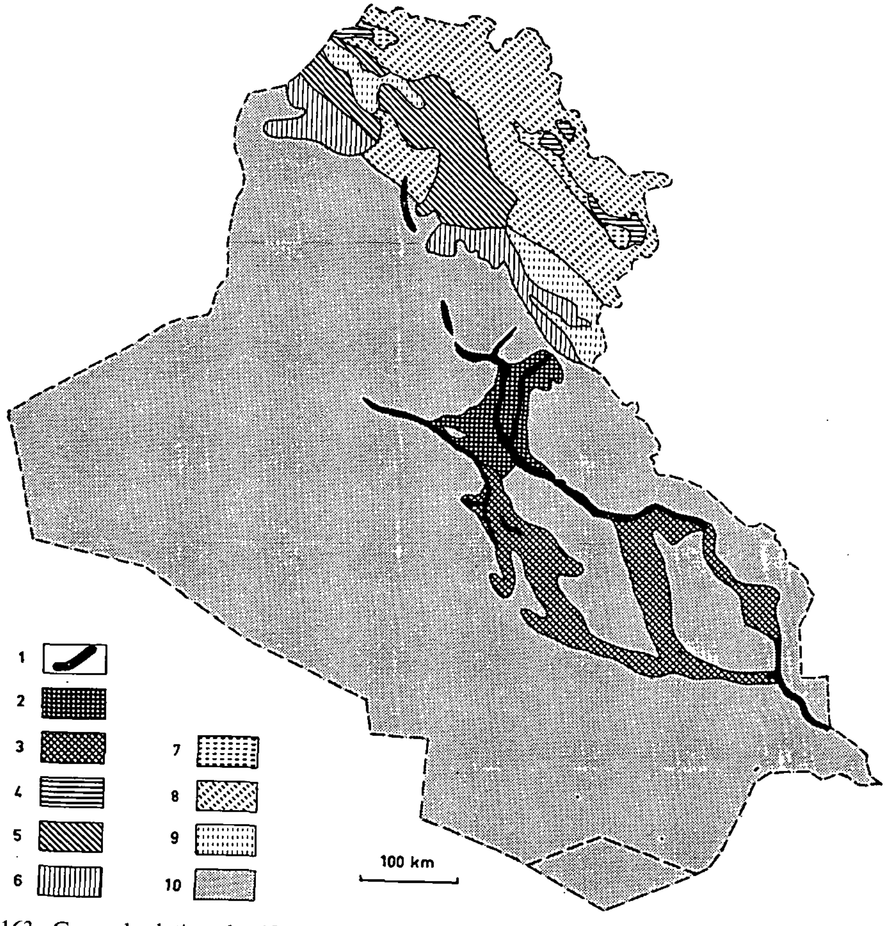


Fig. 163. General relative classification of soil suitability for present agricultural use. Explanation in the text and in Table 37. The map is an approximation; in addition to the statistical data of Table 37, the location of the various areas are shown. (unit 1 is black on the map).

TABLE 37. *Soil Suitability for present agricultural use.*

Map Unit	Soil Class	Gross area × 1000 km²	Gross % Total area	Net area × 1000 km²
1.	Very good for irrigation farming	12.0	2.7	9.6
2.	Good for irrigation farming	6.4	1.4	2.6
3.	Fair for irrigation farming	21.5	4.8	6.5
4.	Very good for dry farming	3.2	0.7	2.2
5.	Good for dry farming	16.0	3.6	9.6
6.	Fair for dry farming	10.7	2.4	6.4
7.	Very good for grazing	2.1	0.5	1.1
8.	Good for grazing	35.4	7.9	17.7
9.	Fair for grazing	8.3	1.8	2.5
10.	Sub-marginal soils	328.4	74.2	rest

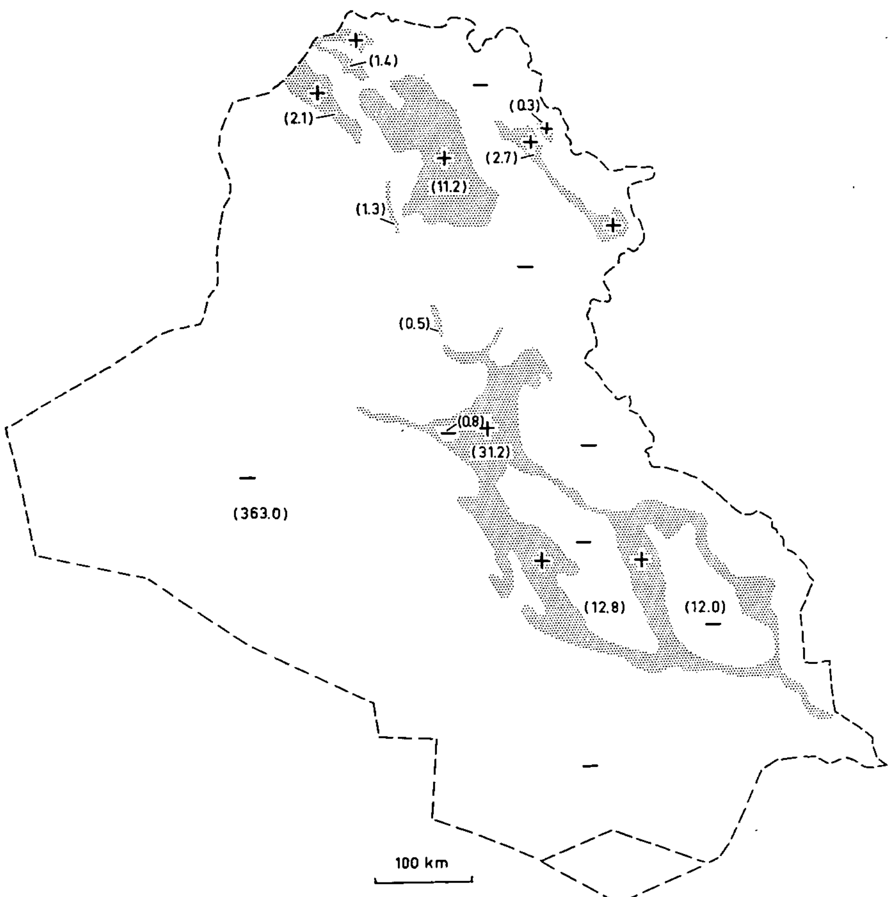


FIG. 164. Areas of surplus (+) and subsistence (–) farming in Iraq. (31.2) = area in 1000 km.². The total area of surplus farming covers 11.5% of Iraq; the area of subsistence farming, including nomadic farming is 88.5%. As only half of the area of subsistence farming is cultivated each year, the real area is about 6% of Iraq.

These figures are approximations only. More accurate data can be given when more detailed soil studies are available.

Areas of Surplus and Subsistence Farming

The map in Fig. 164 gives a general idea about those areas in which the agricultural production is supposed to be larger than the local consumption by the farmers and their families. Therefore in these areas there is a surplus in the agricultural production, which is used for consumption by the non farming people in the towns and in the

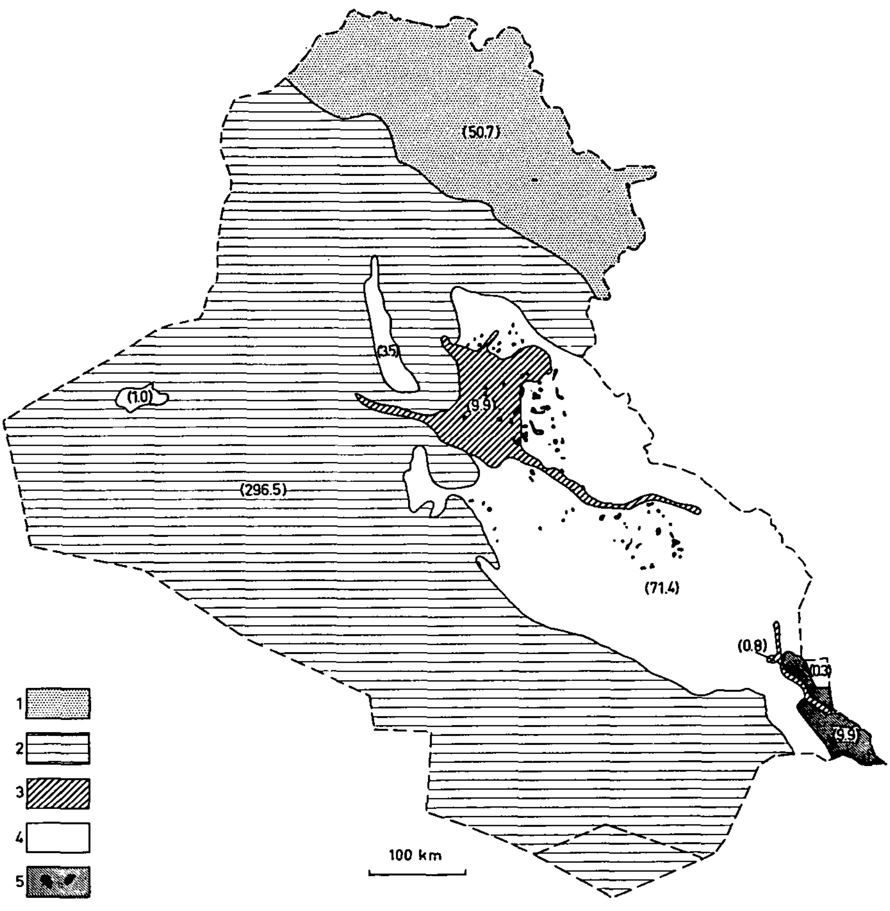


FIG. 165. Schematic map of salinization in soils of Iraq. 1. soils without salinization; 2. deserts and soils with some salinization locally; 3. soils with moderate salinization; 4. soils with severe salinization; 5. (and black dots) soils with salinization and solonization. (9.9)-area in 1000 km.[2].
Solodization processes have only been noticed in some small areas on Tigris terraces east of Samarra.

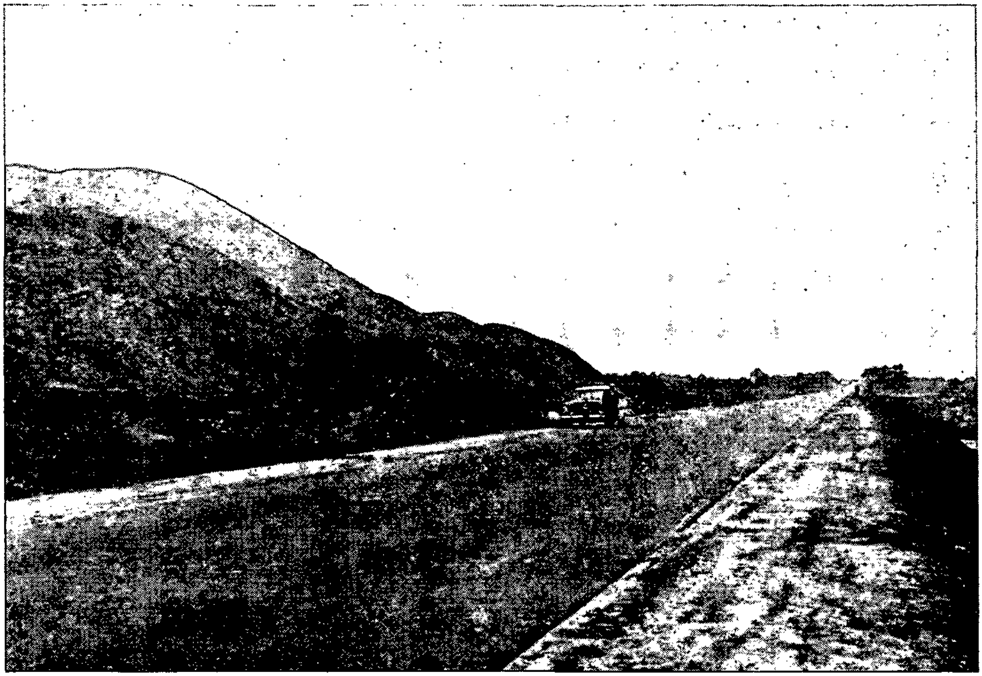


FIG. 167. The new Hilla-Bahdad road near the ruins of Babylon, symbolising the famous past, the decline, and the reconstruction of the country, in shâ Allâh.

LITERATURE CITED

ADAMS, DORIS, G. (1956), Current Population Trends in Iraq. Middle East Journ. 10, (2), 151–165.
ADDISON, A. (1955), Land, Water and Food. London.
ADMIRALTY WAR STAFF, (1916), A Handbook of Mesopotamia, 4 vol. London.
ADMIRALTY NAVAL STAFF, (1918), Geology of Mesopotamia and its Borderlands. London.
ALGHITA, B. K. (1956), Farm Irrigation Methods used at present in Iraq. Lecture, Iraqi Agr. Soc. Dec. 1956.
ALI, HASSAN MOHAMMED, (1955), Land Reclamation and Settlement in Iraq. Baghdad.
AUBERT, G. (1937), Les sols à croûte calcaire. C. R. des Conf. Péd. Méditerrannéenne, Montpellier, Alger, 330–337.
BAGNOLD, R. A. (1952), The Surface Movement of Blown Sand in Relation to Meteorology. Proc. Intern. Symp. Desert Res.
BAGNOLD, R. A. (1954), The Physics of Blown Sand and Desert Dunes. 2nd. ed.
BAILEY, G. L. (1944), Some Difficulties in Land Reclamation. An Example from Southern Persia. Proc. Middle East Agr. Development, Cairo, 51–61.
BAKIR, ABDUL JABBAR AL-, (1955), Scientific Research and Extension in Agriculture. Majallatu-'Zzira'atil-'Iraqiyah, 10, (1).
BEEK, M. A. (1955), Aan Babylons stromen. Derde Druk. Amsterdam.
BEEK, M. A., and BURINGH, P., (1955), Statement Concerning Archaeology and Soil Survey in Mesopotamia. Sumer, 11, (2), 143–144.
BELL, H. S. (1940), Armored Mud-balls, Their Origin, Properties and Role in Sedimentation. Journ. Geol. 48, 1–31.
BENNET, H. H. (1939), Soil Conservation.
BIBLIOGRAPHY (1954), A selected and annotated bibliography of economic literature on the Arabic speaking countries in the Middle East, 1938–1952.
BINNS, B. O. (1953), Cadastral Surveys and Records of Rights in Land; a F.A.O. Land Tenure Study. Rome F.A.O. Studies, No. 18.
BLANK, E. (1929), Handbuch der Bodenlehre, Berlin.
BLANK, E., PASSARGE, S., and RIESER, A. (1926), Ueber Krustenböden und Krustenbildung wie auch Roterden, insbesondere ein Beitrag zur Kenntnis der Bodenbildung Palästinas. Chemie der Erde, 2, 348–395.
BLANCKENHORN, M. (1914), Syrien, Arabien und Mesopotamien, Handbuch der Regionalen Geologie, Bd. V, Abt. 4.
BLANCKENHORN, M. (1918). Der Böden Palästinas. Berlin.
BLANCKENHORN, M. (1928), Der Böden Palästinas, seine Entstehung, Beschaffenheit, Bearbeitung und Ertragsfähigkeit. Berlin.
BOBEK, H. (1951), Die natürlichen Wälder und Geholzfluren Irans. Bonner Geogr. Abh. (8).
BOESCH, H. (1949), Beiträge zur Morphologie des nahen Ostens. Ecologae Geologicae Helvetiae, 42 (1).
BOLTON, (1954), in: Mineral Survey of Iraq – Preliminary Report on the Mineral Occurrence in Iraq by Site Investigation Co. Ltd. and Dr. G. L. Paver, Baghdad.
BONNÉ, A. (1934), Conditions and Problems in the Agriculture of Iraq. Bull. Agr. Econ. and Soc. Rome.
BOOYA, HANNA, A. (1956), The Nature of the Saline (Sabakh) Soils of Iraq and their Desalinization. Thesis M. Sc., Univ. of Arizona.
BOULAINE, J. (1956), Quelques données numériques sur l'hétrogénété des sols salin. Algérie.
BOULAINE, J. (1957), Principles et Méthodes de la Pédologie. Bull. Soc. Hist. Naturelle d'Afrique du Nord. 21–48.

Boumans, J. H. (1954/7), Report on Drainage Experiments in Dujaila 8. Area. Development Board, Baghdad. Report I (1954); Report II (1955); Report III (1957); Report IV (1957).

Boumans, J. H. (1956), Drainage and Land Reclamation Experiments in Dujaila. Mim. paper, Development Board, Baghdad.

Boumans, J. H. (1956), Drainage and Land Reclamation Experiments in Dujaila. Majallatu-'Zzira'-ati'l-Iraqiyan. Min. of Agr. Baghdad, XI, (2–3), 189–196 (Arabic).

Braidwood, L. (1953), Digging Beyond the Tigris. New York.

Braidwood, R. J. (1951), A Preliminary Note on Prehistoric Excavations in Iraqi-Kurdistan. Sumer, VII, 99 etc.

Braidwood, R. J. (1952), From Cave to Village. Scientific American, 62–66.

Braidwood, R. J. (1952), Early Food Producers: Excavations in Iraqi Kurdistan. Archaeology, 157–164.

Braidwood, R. J. (1952), The Near-East and the Foundations for Civilization. Oregon.

Braidwood, R. J. (1954), The Iraq-Jarmo Project. Sumer, X, (2), 120–138.

Braidwood, R. J. and L. (1953), The Earliest Village Communities in South-western Asia. Journ. of World History, I, 278–310.

Bureau of Reclamation Manual, Vol. V. Irrigated Land Use. U.S. Dept. Interior.

Buringh, P. (1953), The role of Aerial Photography when Drafting Schemes for Under-developed Countries. Netherl. Journ. Agr. Sc. 1, 251–255.

Buringh, P. (1954), The Analysis and Interpretation of Aerial Photographs in Soil Survey and Land Classification. Netherl. Journ. Agr. Sc. 2, 16–26.

Buringh, P. (1955), Some Problems Concerning Aerial Photographs in Soil Survey. Netherl. Journ. Agr. Sc. 3, (2), 100–105.

Buringh, P. (1955), Soil Survey of the Sungassar Valley, Iraq. Min. of Agr. Baghdad. (in press).

Buringh, P. (1956), Some Results of Recent Soil Investigations in Iraq. Majallatu-'Zzira'ati'l-Iraqiyan. Min. of Agr. Baghdad, XI, (2 + 3), 173–188 (in Arabic).

Buringh, P. (1956), Land Classification in Iraq, a Memorandum to the Government of Iraq. Min. of Agr. Baghdad.

Buringh, P. (1956), Pluvial phases in the Pleistocene and their Influence on Present Soil Conditions in Iraq. Proc. Six Intern. Congress of Soil Sc. Paris V, 14, 87–88.

Buringh, P. (1956), Soils of the Oldest Cultivated Area of the World. Proc. Six Intern. Congress of Soil Sc., Paris, V, 14, 89–91.

Buringh, P. (1957), Living Conditions in the Lower Mesopotamian Plain in Ancient Times, Sumer, XIII, (1 + 2), 30–57.

Buringh, P. (1958), Soil Survey of the Hilla-Kifl Project (Iraq). Min. of Agr. Baghdad. (in press).

Buringh, P. and Edelman, C. H., (1955), Some Remarks about Soils of the Alluvial Plain of Iraq, south of Baghdad. Netherl. Journ. Agr. Sc. 3, (1), 40–49.

Buringh, P. and Kadry, L. T., (1956), Soil Survey and Classification in Iraq. Proc. Six Intern. Congress of Soil Sc. Paris, V, 14, 83–84.

Buringh, P. and Kadry, L. T. (1956), The Study of Great Soil Groups in Iraq. Proc. Six Intern. Congress of Soil Sc. Paris, V, 14, 85–86.

Buringh, P. and Kadry, L. T. (1956), Specifications for Semidetailed Soil Surveys. Min. of Agr. Baghdad. (see Appendix 2).

Buringh, P. and van Liere, W. J., (1954), Example of a Reconnaissance Soil Map produced by Pedological analysis of Aerial Photographs followed by the study of Soils in the Field. Proc. Fifth Intern. Congress of Soil Sc. Leopoldville, II, V, 55.

Butler, B. E. (1956), Parna-An Aeolian Clay. Australian Journ. of Sc. 18, (5), 145–151.

Butzer, K. W. (1957), Late Glacial and Post-glacial Climate Variations in the Near East. Erdkunde, XI, 21–35.

Caponera, D. A. (1954), Waterlaws in Moslem Countries, F.A.O. Rome.

Ceram, C. W. (1953), Goden, graven en geleerden. Geschiedenis der Archaeologie, 5 dr. Amsterdam.

Chapman, G. W. (1949), Forestry in Iraq. Unasylva II, 5, 251–253.

Chapman, G. W. (1950), Notes on Forestry in Iraq. Empire Forest. Rev. 29, 132–135.

Chapman, G. W. (1957), Forestry in Relation to Watershed Protection in Iraq. Lecture Iraq Soc. Agr. Baghdad.

CHAPMAN, G. W. (1957), Forest and Forestry in Iraq. Baghdad, Min. of Agr.
CHOUBERT, G. (1946), Sur l'influence des pluvieaux sur le creusement et le comblement fluviatiles pendant le Quaternaire. C. R. de l'Acad. Sc. T. 223, 810–812.
COLE, S. (1954), The Pre-History of East Africa. London. Pelican Book A 316.
COMMITTEE OF OFFICIALS (1946), Kingdom of Iraq. Baghdad.
CONTENAU, G. (1954), Everyday life in Babylon and Assyria. London.
CRAWFORD, O. G. S. (1929), Air Photographs of the Middle East. The Geogr. Journ. LXXIII, (6), 497–512.
DAPPER, O. (1680), Nauwkeurige beschrijving van Asië, behelsende de gewesten van Mesopotamië, Assyrië, Anatolia, Klein-Asië, Arabië, Amsterdam.
DEICHA, G. (1943), Génèse et facies dy Gypse, Bull. Sté, Franc. de Minéralogie, LXVI, (16), 153–160.
DENNIS, P. E. (1953), Report to the Government of Iraq on the Investigations and Development of Groundwater Resources. Rep. No. 189, F.A.O. Rome.
DEVELOPMENT BOARD (1951–1956), Annual reports on the operation of the Development Board, 1951, 1952/53, 1953/54, 1954/55, 1955/56. Baghdad.
DEVELOPMENT BOARD (1954), Invitation to Qualified Consultants to perform Land Classifications in Iraq. Baghdad.
DIRECTORATE OF ANTIQUITIES (1940), Excavations at Samarra, 1936–39, 2 vol. Baghdad.
DOST, H. (1953), Bibliography on Land and Water Utilisation in the Middle East, Wageningen.
DOUGLAS, W. O. (1951), Strange Lands and Friendly People.
DOWSON, E. (1932), An Inquiry into Land Tenure (Iraq). Baghdad.
DOWSON, V. R. W. (1921–23), Dates and Date Cultivation in Iraq. Agr. Directorate, Baghdad.
DOWSON, V. R. W. (?), Provisional list of the Date Palms of Iraq. Trop. Agr. 16, (7), 164–168.
DUBERTRET, L. (1942), Carte Géologique du Moyen Orient, 1:2,000,000.
DURAND, J. (1949), Essai de Nomenclature des Croûtes. Bull. Sté. des Sc. Nat. de Tunesie, II, 141–142.
DURAND, J. (1949), Formation de la Croûte Gypseuse du Souf (Sahara). C. R. Somm. Sté. Géol. de France, 304–305.
DURAND, J. H. (1952), Etude géologique, hydrologique et pédologique des croûtes en Algérie. Serv. Etudes Sc. pédologie. No. 1.
DURAND, J. (1952), Le vent et sa conséquence, l'érosion éolienne, facteur de formation des sols au Sahara.
DURAND, J. H. (1954), Les sols d'Algérie. Serv. des Etudes Sc. pédologie No. 2.
EATON, F. M. (1949), Irrigation Agriculture along the Nile and Euphrates. Sci. No. 69, 34–42.
EATON, F. M. (1950), Significance of Carbonates in Irrigation Waters. Soil Sc. 69, 123–133.
EDELMAN, C. H. (1950), Soils of the Netherlands, Amsterdam.
EDELMAN, C. H. (1952), Verslag van een reis naar Syrië, Iraq en Pakistan. Landbk. Tijdschr. 331–335.
EDELMAN, C. H. (1954), L'importance de la Pédologie pour la production agricole. Proc. Fifth Intern. Congress Soil Sc. Leopoldville, C.G.I.
ELGABALY, M. M. (1950), Preliminary Survey of the Saline and Alkali Soils of Egypt. Proc. Fourth Intern. Congress of Soil Sc. Amsterdam. Vol. II, 247–250.
F.A.O. (1953), Agriculture in the Near East, Development and Outlook, Rome.
F.A.O. (1953), Centre on Land Problems in the Near East, Salahuddin, Iraq. Country Information Report of Iraq.
FERGUSON, C. E. and KADRY, L. T. (1956), Forage Crops and the Salinity Problem. Lecture Iraq Soc. Agr. Baghdad.
FERTILISER COMMITTEE OF IRAQ (1955), Report to the Government of Iraq. (unpublished).
FIELD, H. (1953/56), Bibliography on South-western Asia, Vol. I, II, III, Florida.
FISHER, S. N. (1955), Social Forces in the Middle East. New York.
FISHER, W. B. (1950), The Middle East, a Physical, Social and Regional Geography. London-New York. (ed. 3, 1956).
FISHER, W. B. (1953), The Middle East, Some Recent Studies, Geogr. Rev. 256–259, 570.
FISHER, W. B. and DUBERTRET, L. (1945), Moyen Orient: Carte des pluies 1:2,000,000. Beirut.
FLANDRIN, J., GAUTIER, M. and LAFFITTE, R. (1948), Sur la Formation de la Croûte Calcaire en Algérie. C. R. Acad. Sc., T. 226, 416.
FRANKFORT, H. (1951), The Birth of Civilization in the Near East. Univ. of Indiana, Bloomington.

FRANKFORT, H. e.a. (1954), Before Philosophy, the Intellectual Adventure of Ancient Man. Penguin Book, A. 198.
FROE, A. DE (1955), De gouden beker. Wending 10, (1), 3–9.
FRYE, R. N. (1951), The Near East and the Great Powers. London.
GARBUTT, W. D. (1944), Large Scale Production in the Middle Euphrates Zone. Proc. Conf. Middle East Agr. Dev. Cairo, Middle East Supply Centre, Agr. Rep. No. 6, 61–75.
GAUCHER, G. (1947), The Red Soils and Crusted Soils of Bas-Chélif and the Lower Oran Plains. C.R. 225, 133–135.
GAUDEFROY-DEMOMBYNES, M. (1950), Muslim Institutions. London.
GAUTIER, E. F. (1946), Le Sahara, Paris.
GÈZE, B. (1956), Carte de Reconnaissance de Sols du Liban. Beyrouth. Min. of Agr.
GHIRSHMAN, R. (1954), Iran. Pelican Book, A. 239.
GIBBS, G. I. (1954), Soil Conservation in Iraq. F.A.O. Rep. 242, Rome.
GOETZE, A. (1955), Archaeological Survey of Ancient Canals (in Iraq). Sumer, XI, (2), 127–129.
GOUVERNEMENT GÉNÉRAL DE L'ALGÉRIE (1954/55). Notice explicative de la carte de reconnaissance des sols d'Algérie. Feuille 9, 21, 30. Alger.
GOVERNMENT OF IRAQ, (1953), Iraq To-day. Baghdad.
GOVERNMENT OF IRAQ (1954), Statistical Abstracts 1953, Baghdad.
GOVERNMENT OF IRAQ (1957), Statistical Abstracts 1956, Baghdad.
GOVERNMENT OF IRAQ (1954), Climatological Means for Iraq. Publ. No. 10. Baghdad.
GOVERNMENT OF IRAQ (1954), Dokan Dam Project. Development Board, Baghdad.
GOVERNMENT OF IRAQ (1955), Law No. 43 for the Year 1955 for the general programme of the projects of the Development Board and the Ministry of Development, Baghdad.
GOVERNMENT OF IRAQ, (1956), A Graphic Summary of Agriculture in Iraq. Baghdad. Min. of Agr. (data 1952/53 Agricultural census).
GOVERNMENT OF IRAQ (1956), Development of Iraq. Baghdad.
GRAÇANIN, U. (1950), To the Problem of Evaluating Soil Structure. Proc. Fourth Intern. Congr. Soil Sc. Amsterdam, I, 40–43.
GRANT, C. P. (1937), The Syrian Desert. Caravan, Travel and Exploration. London.
GREENE, H. (1948), Using Salty Land. F.A.O. Agr. Lt. 3. Rome.
GRUYTER, P. DE (1953), Drainage in Iraq. De Ingenieur, 62, (2), B 1–17. (in Dutch).
GRUYTER, P. DE (1955), Over de aanleg van grote openbare werken in Iraq. Weg en Waterbouw, 15, (3–4), 39–57.
GUEST, E. (1929), Names of Plants in Iraq. Dept. of Agr. Leaflet No. 4. Baghdad.
GUEST, E. (1932), Notes on Trees and Shrubs for Lower Iraq. Dept. of Agr. Bull. 26, Baghdad.
GUEST, E. (1933), Notes on Plants and Plant Products with Colloquial Names in Iraq. Dept. of Agr. Bull. 27, Baghdad.
GUEST, E. (1953), The Rustam Herbarium, Iraq. Part VI. Kew Bull. No. 3, 383–403.
HAIDARI, DARWISH AL (1948), The Improvement of Tobacco in Iraq. Iraqian Agr. Rev. 3, 280–282. Baghdad.
HAIDER, S. (1942), Land Problems of Iraq. (Ph. D. thesis, London).
HAIGH, F. F. (1949), Report on the Control of the Rivers of Iraq and the Utilisation of their Waters. Irr. Dev. Comm.
HALLSWORTH, E. G., ROBERTSON, G. K., and GIBBONS, F. R. (1955), Studies in Pedogenesis in New South Wales VII. The 'Gilgai' soils, Journ. Soil Sc. 6, 1–34.
HANNA, A. B. (1956), The Nature of the Saline (sabakh) Soils of Iraq and their Desalinisation. Master's thesis. Univ. of Arizona.
HARE, H. H. (?), Report to Iraq Government on Farm Management. F.A.O. publ. No. 192, Rome.
HARRIS, S. A. (1958), The Gilgaied and Bad Structured Soils of Central Iraq. Journ. of Soil Sc. 9, (2), 169–185.
HARRIS, S. A., and ADAMS, R. (1957), A note on Canal and Marsh Stratification near Zubediyah. Sumer XIII, (1 + 2), 157–163.
HARRISON, P. W. (1924), The Arab at Home. New York.
HAUSER, G. F. (1953), Afghan Alkali Soil and its Improvement. Soil Sc. 76, 367–375.

HAYWARD, H. E. and WADLEIGH, C. H. (1949), Plant Growth on Saline and Alkali Soils. Advances in Agron. 1, 1–38.
HERON, A. U. (1943), The Zones of Nappes in Iraq Kurdistan (report).
HERWIJER, S. (1954), Report on the Rehabilitation and Reconstruction of Flooded Areas in Iraq. F.A.O. Report.
HERZFELD, E. (1909), Über die Historische Geographie von Mesopotamien, ein Programm. Petermanns Mitt. 55, 345–349.
HERZFELD, E. (1923–30), Die Ausgrabungen von Samarra, 5 vol. Berlin.
HILMY BEY, U. (1944), Reclamation of Waste Lands in the Northern Part of the Delta (Egypt). Proc. Conf. M. E. Agr. Dev. Cairo. M. E. Supply Centre, Agr. Rep. No. 6.
HITCHEN, C. S. (1948), Geology of the Tharthar Depression, Iraq (report).
HITTI, P. K. (1953), The Arabs, a short history, sec. ed. London.
HOOKER, D. (1937), Useful Plants and Drugs of Iran and Iraq. Publ. of the Field Mus. of Nat. Hist. Bot. Sec. Vol. 11, No. 3.
HOURANI, A. H. (1947), Minorities in the Arab World. Oxford.
HUNTING AEROSURVEYS Ltd. (1956), Soil Survey and Land Classification, Nahrwan, Adhaim and Ishaqi areas. Report Dev. Board, Iraq.
HUNTING AEROSURVEYS Ltd. (1956), Makhmour area, Iraq. Irrigation, Soil Survey, Land Classification and Agricultural reports. Dev. Board, Iraq.
HUXLEY, J. (1954), From an Antique Land. London.
INTERN. BANK FOR RECONSTRUCTION (1952), The Economic Development of Iraq, Baltimore.
IONIDES, M. G. (1937), The regime of the Rivers Euphrates and Tigris, London.
IRELAND, P. W. (1937), Iraq, a Study in Political Development. London.
JACOBSEN, T. (1951), An Agricultural Document from Nipur. Sumer VII, (1), 77–78.
JAMALI, M. F. (1934), The New Iraq: its problems of Bedouin Education. Columbia Univ.
JANITZKY, P. (1957), Salz- und Alkaliböden und Wege zu ihrer Verbesserung. Ein vergleich russischer und amerikanischer Forschungsergebnisse, Gieszen.
JENNY, H. (1941), Factors of Soil Formation. New York.
JOFFE, J. S. (1949), Pedology. New Brunswick.
KADDAH, M. T. (1948), The Soils of Egypt. Soil Sc. 65, (5), 357–365.
KADRY, L. T. (1957), The Soil Projects (Arabic with Eng. summ.) Majallatu-'Zzira'ati'l-Iraqiyah. Vol. XII, (1), 91–100.
KADRY, L. T. (1957), The Role of Soil Factors in Agricultural Production. Majallatu-'Zzira'ati'l-Iraqiyah, Vol XII, 223 (Arabic with Eng. summ.).
KAREEM, H. A. (1956), Some Physical Properties of Soil and its Importance in Agriculture. Majallatu-'Zzira'ati'l-Iraquyan. Min. of Agr. Baghdad. 11, (2 + 3), 228–232.
KAREEM, M. Z. A. (1954), A Beehive of Construction, Development Board, Baghdad.
KEEN, B. A. (1946), The Agricultural Development of the Middle East. London.
KELLY, W. P. (1937), The Reclamation of Alkali Soils. Univ. California, Bull. 617.
KELLY, W. P. (1951), Alkali Soils, their Formation, Properties and Reclamation. New York.
KELLOG, C. E. (1952), Potentialities and Problems of Arid Soils. Proc. Intern. Symp. on Desert Res. Jerusalem.
KELLOG, C. E. (1954), Soil Conservation. Proc. Fifth Intern. Congr. of Soil Sc. Leopoldville. Vol. 1, C.G. 2.
KETTANEH, M. S. (1957), Introduction to Watershed Protection. Lecture Iraq Soc. Eng. Baghdad.
KHAIRY BEY, A. (1944), Control of Irrigation and Drainage in the Nile Valley, and Recent Development in Covered Drainage. Proc. Confer. M. E. Agr. Dev. Cairo, M. E. Supply Centre, Agr. Rep. 6.
KHOLY, F. AL (1952), Hydrology of the River Tigris.
KHOLY, F. AL (1956), Suspended Sediment in River Tigris for the Year 1953. Baghdad.
KLOES, L. J. J. VAN DER (1956), Soil Survey of the Naifa Project near Samarra, Iraq. Min. of Agr. Baghdad (in press).
KNAPPEN-TIPPETTS-ABBETT-MCCARTY (1952), Report on the Development of the Tigris and Euphrates River Systems. New York–Baghdad.
KNAPPEN-TIPPETTS-ABBETT-MCCARTY (1953), Irrigability Land Classification of the Babil Extension Area. Dev. Board, Iraq.

KNAPPEN-TIPPETTS-ABBETT-McCARTY (1953), Report on the Gharraf Project, Iraq. Development Board.
KNAPPEN-TIPPETTS-ABBETT-McCARTY (1954), Development of the Tigris-Euphrates Valley. Baghdad. (Abridged version of K.T.A.M., 1952).
KNAPPEN-TIPPETTS-ABBETT-McCARTY (1954), Report on the Basra Vicinity, Iraq. Development Board.
KNAPPEN-TIPPETTS-ABBETT-McCARTY (1955), Preliminary Land Classification Report on the Diwaniyah-Dagharrah Extension (Iraq). Development Board.
KNETCH, G. (1955), Lebendige Tectonik im Irak. Geol. Rundschau, 43, 227–232.
KOVDA, V. A. (1944), Soils of Iran. Pocvovedenie, No. 9, Moskwa (Russian).
KOVDA, V. A. (1946–47), Formation and Conditions of Saline Soils, Vol. I and II (Russian).
KOVDA, V. A. (1954), La géochimie des déserts de l'U.R.S.S. Comm. Ve Congr. Intern. de la Sc. du Sol. Moskwa.
KRAMER, P. J. (1949), Plant and Water Relationships.
KREEB, K. (1957), Hydratur und Ertrag. Ber. der Deutschen Bot. Gesell. LXX, (3), 121–136.
KUBIËNA, W. L. (1953), The Soils of Europe. Madrid-London.
KUIPERS, S. F. (1950), Gley phenomena in marine clay soils with a salty subsoil. Trans. Fourth Int. Congr. Soil Sc. Amsterdam, II, 245–247.
KULJAN, (1957) Corporation, Eski Mosul irrigation project, reconnaissance report, Aug. 1957 (Dev. Board).
KURON, H. and JANITZKY, P. (1957), Zum Probleme der Takyre. Gieszener Abh. zur Agrar- und Wirtschaftsforschung des Europäischen Ostens, Bd. 3.
LAHEE, F. H. (1952), Field Geology. New York, 5th Ed.
LAPHAN, U. H. (1932), Genesis and Morphology of Desert Soils. Amer. Soc. Ass. Bull. 13, 34–52.
LAUDERMILK, D. J. (1931), On the Origin of Desert Varnish. Am. Journ. Sc. 21, 51–66.
LEBON, J. H. G. (1953), Population Distribution and the Agricultural Region of Iraq. Geogr. Rev., 223–228.
LEES, G. M. (1950), Some Structural and Stratigraphical Aspects of the Oilfields of the Middle East. Proc. Intern. Geol. Congress, 1948, Vol. VI, London.
LEES, G. M. and FALCON, N. L. (1952), The Geographical History of the Mesopotamian Plain, Geogr. Journ. CXVIII, I, 24–39.
LEWIS, A. B. (1952), Land Classification for Agricultural Development. F.A.O., Rome, Agr. Dev. paper No. 18.
LIBBY, W. F. (1955). Radio Carbon Dating. Sec. ed. Chicago.
LIERE, W. VAN (1953), Etude générale des grandes groupes de sols de la Syrie. Prél. report. F.A.O. Rome.
LIERE, W. J. and LAUFFRAY, J., (1955), Nouvelle prospection archéologique dans la Haute Jezireh Syrienne. Ann. Archéol. de Syrie, (4 et 5), 129–148.
LLOYD, S. (1945), Ruined Cities of Iraq. Ed. 3. Oxford.
LLOYD, S. (1947), Twin Rivers, – a brief history of Iraq from the earliest times to the present day. 2nd ed. Oxford.
LLOYD, S. (1947), Foundations in the Dust. A story of Mesopotamian Exploration. London.
LLOYD, S. (1956), Early Anatolia. The Archaeology of Asia Minor before the Greeks. Pelican Book A 354.
LOBOVA, H. V. (1956), Géographie des sols de la zone désertique de l'U.R.S.S. Sixth Intern. Congress Soil Sc. Paris, V, 213–219.
LONGRIGG, S. H. (1925), Four centuries of Modern Iraq. Oxford.
LONGRIGG, S. H. (1953), Iraq, 1900 to 1955, a Political, Social and Economic History. London.
MACDONALD, M. and Partners (1957), Report No. 1. Diyala and Middle Tigris Projects. Development Board, Iraq.
MACFAYDEN, W. A. e.a. (1931–48), The Natural Building Materials, Report. Iraq. Geol. dept.
MACFAYDEN, W. A. (1938), Water Supplies in Iraq. Iraq Geol. Dept. Publ. 1. Baghdad.
MAGISTAD, O. C. (1945), Plant Growth Relations on Saline and Alkali Soils. The Bot. Rev. 11, (4), 181–215.
MAJALLATU-'ZZIRA'ATI'L-IRAQIYAH (Iraq Agr. Rev.), a quarterly magazine of Iraqi Agriculture, publ. by the Min. of Agr. Baghdad since 1945.

MALIEPAARD, C. H. J. (1953), Zwervend tussen Arabieren en Koerden.
MARBUT, C. F. (1951), Soils, their Genesis and Classification. Soil Sc. Soc. of America.
MARGULUS, H. (1956), Les théories pédologiques et agronomiques de l'académicien Willams. Toulouse.
MARSHALL, T. J. and GURR, C. G. (1954), Movement of Water and Chloride in Relatively Dry Soil. Soil Sc. 77, (2), 147–153.
METEOROLOGICAL DEPT. (1940), Rainfall in Iraq 1936–1939, Baghdad.
METEOROLOGICAL DEPT. IRAQ (1954), Climatological means for Iraq. Publ. No. 10. Baghdad.
MIDDLE EAST INSTITUTE (1955). Current Research on the Middle East. Washington.
MITCHELL, R. C. (1956), Aspects géologiques du désert occidental de l'Irak. Bull. Soc. Géol. de France, 6, 391–406.
MORTESEN, H. (1930), Die Wüstenböden, Handbuch der Bodenlehre, Blanck, Bd. 3, Berlin.
MUIR, A. (1951), Notes on Soils of Syria. Journ. Soil Sc. I (2), 163–183.
NAJI AL-ASIL (1951), The Growth of Human Civilization in Mesopotamia from Hassuna to Eridu and to Hatra. Ill. London News, 10 Nov. 1951.
NASHAT, T. H. (1956), Soil Analysis and its Practical Application in Agriculture. Majallatu-'Zzira'ati'l-Iraqiyan. Min. of Agr. Baghdad, 216–227.
NEDECO (1956), Study of the Abu Dibbis Depression, Iraq. Report to Development Board, Baghdad.
NELSON, W. R. (1956), Control and Use of the Waters of the Tigris and Euphrates Rivers. Lecture Baghdad, March 1956.
NEOLDEKE, A. (1945), Zur hydrographic des Euphrat im Schwemmlande.
NOBLE, A. H. (1927), Subsurface Water Resources of Iraq. Baghdad.
NORTON, E. A. (1939), Soil Conservation Handbook. U.S. Dept. Agr. Washington.
NUGTEREN, J. (1955). Enige aspecten van de irrigatie praktijk in Iraq. De Ingenieur (33 en 34), 1–14.
OBERMEYER, J. (1927), Die Landschaft Babylonien, Geographie und Geschichte, Frankfurt a/M.
PALLIS, S. A. (1956), The Antiquity of Iraq. Copenhagen.
PARROT, A. (1946). Archéologie mésopotamiènne. Paris.
PARSONS, R. M. COMP. (1955). Groundwater Resources of Iraq. Vol. 3, Baiji-Samarra Area; Vol. 5. Jezira Desert; Vol 7, Southern Desert; Vol. 8, Northern Desert. Development Board, Baghdad.
PASSARGE, S. (1904), Die Kalahari, Berlin, 2 Bd.
PASSARGE, S. (1908), Südafrika, eine Landes-, Volks- und Wirtschaftskunde. Leipzig.
PAVER, G. L. SITE INVEST. Co. Ltd. (1954). Mineral Survey of Iraq. Preliminary report on the Mineral Occurrence in Iraq. Development Board, Baghdad.
PEAKE, H. J. E. (1928), The Origin of Agriculture. London.
PETROV, M. P. (1955), Iran. Moscow. (Russian).
PETTIJOHN, F. J. (1948), Sedimentary Rocks. New York.
POLYNOV, B. B. (1956), Izbrannye trudy (Selected articles), Moscow, (Russian).
POWERS, W. L. (1946), Reclamation and Use of Alkali Soils. Techn. Bull. 10, Oregon State College.
POWERS, W. L. (1954), Soil and Land Use Capabilities in Iraq, a Preliminary Report. Geogr. Rev. 373–380.
RADI, M. S. (1944), The Training of Agricultural Personnel in Iraq. Proc. Conf. M. E. Agr. Dev., Cairo, M. E. Supply Centre, Agr. Rep. No. 6.
RAMANN, E. (1918), Bodenbildung und Bodeneinteilung, Berlin.
RAVIKOVITCH (1944), in Proc. Conf. M. E. Agr. Dev., Cairo, M. E. Supply Centre, Agr. Rep. No. 6.
RAWLINSON, G. (1949), The History of Herodotus. Vol. I. London.
RAYCHAUDHURI, S. P. and BISWAS, N.R.D., (1954), Saline and Alkali Soils of Asia, with particular Reference to India.
REGEL, C. VON (1954), Phytogeography of Iraq. Eighth Intern. Bot. Congr. Paris, Sections 7–8, 51–52.
REGIONAL SALINITY LABORATORY (1947), Diagnosis and Improvement of Saline and Alkali Soils. U.S. Dept. of Agr. Handbook 60.
REIFENBERG, A. (1952), The soils of Syria and the Lebanon. Journ. Soil Sc. 3, (1), 68–88.
REPORT (1926), by the Executive Engineer, Irr. Euphrates Division, Hindiya Barrage. Notes on Land Washing Experiments.
ROBINSON, G. W. (1950), Soils, Their Origin, Constitution and Classification. Ed. 3, London.
ROUX, G. (1956), The Story of Ancient Iraq. III. From Cave to Farm. Iraq Petroleum, 6, (4), 33–37.

RUSSEL, E. J. (1950), Soil Conditions and Plant Growth, ed. 8, London and New York.
RUSSEL, J. C. (1956), Historical Aspects of Soil Salinity in Iraq. Majallatu-'Zzira'ati'l Iraqiyan. Min. of Agr. Baghdad, XI, 2 and 3, 204–215 (Arabic.).
RUSSEL, J. C. (1957), Soil Salinity in Iraq. Lecture. Baghdad.
RUSSEL, J. C. (1957), Iraq lives with Soil Salinity. Lecture, Baghdad.
RUSSEL, J. C. (1957), Tillage Practices in Iraq. Mimeographed paper, College of Agr. Abu Ghraib.
SALIM, S. A. (1955). Economic and Political Organization of Echchabaysh, a Marsh Village in Southern Iraq. Thesis London, (Printed in Arabic).
SALTER, LORD (1955), The Development of Iraq, a Plan of Action. Development Board, Baghdad.
SCHALKERS, K. H. (1957), Socio-Economic Survey of Iraq. Min. of Agr., the Hague, Netherlands.
SCHILSTRA, J. and ADTHARI, M. (1957), Report of a Detailed Soil Survey of a part of Abu Ghraib. Div. of Soils, Baghdad (not published).
SCHWENG, L. D. (1953), Agricultural Problems in the Middle East. Journ. Farm Econ. 35, (4). 582–594.
SCHOKALSKAJA, S. JU. (1953), Die Böden Afrikas, Berlin.
SCHULLER, C. W. (1951), De Sociaal- en economisch-geographische structuur van Irak. 30e vacantie census voor geografen. Amsterdam.
SCHWAN, H. E. (1957), Watershed Protection in Relation to Range Management. Lecture, Iraqi Soc. Agr. Baghdad.
SIGMOND, A. (1930), Salzböden. In Handbuch der Bodenlehre, Bd. 3, Berlin.
SIGMOND, A. A. J. DE (1938), The Principles of Soil Science. London.
SLUIS, P. M. VAN DER (1956), Drainage in Iraq. Lecture, Baghdad.
SLUIS, P. M. VAN DER (1957), In het land van de Euphraat en de Tigris Tijdschr. Ned. Heide Mij. Febr. Maart, 39–50, 66–71.
SMITH, J. (1944), Report on Forests and Forestry in the Northern Liwas of Iraq. Baghdad.
SMITH, R. (1950), Solonetz Soils of the Subhumid Zone of South-western Australia. Proc. Fourth Intern. Congress. Soil Sc. Amsterdam I, 386–389.
SMITH, R. (1957), The Relationship between Water Quality and Drainage Characteristics of some Iraq Soils. Proc. Third Intern. Comm. Irr. and Drainage, San Francisco, 10 RI 1–26.
SMITH, R. and ROBERTSON, V. C. (1956), A Classification of the Saline Soils of the Old Irrigation Lands of the Middle Tigris Valley, Sixth Intern. Congr. Soil Sc. VI, 33, 693–698.
SOLECKI, R. S. (1954), Dokan Cave, an Occupation Station on the Lesser Zab River in Northern Iraq. Sumer, X (1), 69–79.
SOILS AND MEN (1938), U.S. Dept. Agr. Handbook.
SOIL SURVEY MANUAL (1951), by U.S. Soil Survey Staff. U.S. Dept. Agr. Handbook No. 18.
SOUSSA, A. (1945), Irrigation in Iraq, its History and Development.
SOUSSA, A. (1945), The Hindiya Barrage. Baghdad.
SOUSSA, A. (1947), An Engineer's Episode, or the Lost Canal, Baghdad.
SOUSSA, A. (1953), Atlas of Iraq, Baghdad.
SOUSSA, A. and ATKINSON, J. D. (1944/46), Iraq Irrigation Handbook.
SPEISER, E. A. (1951), Ancient Mesopotamia, a Light that did not fail. Nat. Geogr. Mag. 49 (1), 41–105.
SPRINGFIELD, H. W. (1954), Natural Vegetation in Iraq, Techn. Bull. Min. Agr., Baghdad.
STEBUTT, A. (1930), Lehrbuch der algemeinen Bodenkunde. Berlin.
STEPHES, H. (1954), Oil in the Middle East, its Discovery and Development.
STEPHENS, C. G. (1953), Soil Surveys for Land Development, F.A.O., Agr. Stud. No. 20. Rome.
LE STRANGE, G., (1905), The Lands of the Eastern Caliphate, Mesopotamia, Persia and Central Asia from the Moslem Conquest to the time of Timur, Cambridge.
SULEYMAN, H. S. (1956), Oil in Iraq. Baghdad.
SYMPOSIUM (1954), on the Protection and Conservation of Nature in the Near East. Beyrouth.
THORNE, D. W. and PETERSON, H. P. (1949), Irrigated Soils. New York.
THORNTON, H. G. (1952), Some Problems Presented by the Microbiology of Arid Soils. Proc. Intern. Symp. on Desert Res. Jerusalem.
TIPPETTS-ABBETT-MCCARTY-STRATTON (1957), Report on the Zubair Irrigation Project, Basra Vicinity. Development Board, Baghdad.

TIWARIJ, S. (1927), Unpublished Report on Soil Samples of a Drainage Experiment near Hindiya Barrage, Baghdad.
TIWARIJ, S. (1930), Soil Survey of the Abu Ghraib Area. Dept. Res. Farm Rustam. Baghdad.
TURCAN, J. S. (1946), Report on Aqar-Quf Drainage Project, Irrig. Dept. Baghdad.
TURCAN, J. S. (1946), Saqlawiyah Experimental Plots, note on Shitwi Crops, Grown 1945/46. Irrig. Dept. Baghdad.
TURCAN, J. S. (1952), Report on Drainage Investigations, Dujaila, No. 8 area. Development Board, Baghdad.
ULLIG, C. (1917), Mesopotamien, Ztschr. Gesell. Erdkunde zu Berlin. 333–358; 397–430; 530–546.
UNESCO, (1953), Review on Research on Arid Zone Hydrology.
UNITED STATES DEPARTMENT OF AGRICULTURE (1948), Agricultural Geography of Europe and the Near East. Misc. Publ. 665, Washington.
UNITED STATES SALINITY LAB. (1946), The Salt Problem in Irrigated agriculture, Washington. Misc. Publ. 607, Washington.
UNITED STATES SALINITY LAB. STAFF, (1954), Diagnosis and Improvement of Saline and Alkali soils. Agr. handbook 60, Washinghton.
VAJDA, A. DE (1952), Some aspects of Survace Water Development in Arid Regions. F.A.O. Dev. Pap. 21, Rome.
VALKENBURG, S. VAN (1954), Focus by the American Geogr. Soc. 4 (5), 1–5.
VAUMAS, E. DE (1955), Etudes Irakiennes, prem. Série. Bull. Soc. Geogr. d'Egypte, 28, 125–194.
VEENENBOS, J. S. (1955/56), Aerial Photointerpretation for Soil Survey and Land Classification Purposes. Photogrammetria, 12 (4).
VEENENBOS, J. S. (1956), Small-scale Pedological Photo-analysis and Map Compilation. Proc. Sixth Intern. Congress. Soil Sc. Paris, V, 40, 251–255.
VILLAR, E. H. (1947), Types de sol d'Afrique du Nord. Rabat.
VINK, A. P. A. (1957), Principles and Objectives of Land Classification. Proc. Intern. Seminar on Land Dev. for Agr. uses. Wageningen, Netherlands.
VOÛTE, C. (1955), Climate or Tectonics. Geol. en Mijnb. 17 (8), 197-206.
VOÛTE, C. (1956), Study of the Abu Dibbis Depression, Iraq, Geol. Report, Nedeco, (1956).
VOÛTE, C. (1957), A Prehistoric Find near Razzaza (Kerbal Liwa, Iraq). Sumer XIII, (1 and 2), 135–155.
WALLACE, T. (1951), The Diagnosis of Mineral Deficiencies in Plants by Visual Symptoms. London.
WALTER, H. (1956): See Gouvernment of Iraq, 1956.
WALTER, H. (1956/57), Klima-Diagramme als Grundlage zur Feststellung von Dürrezeiten. Wasser und Nahrung 1, (1).
WALTER, H. (1957), Klima-Diagramme des Irak-Stuttgart-Hohenheim.
WARRINER, D. (1948), Land and Poverty in the Middle East. London-New York.
WARRINER, D. (1957), Land Reform and Development in the Middle East. London.
WEBSTER, J. F. (1921), Alkali Lands in Iraq, a Preliminary Investigation. Agr. Dept. of Mesopotamia. Mem. No. 1. Bombay.
WEBSTER, J. F. (1921), Report on the Soil Survey of the Diahlah Area, Right Bank. Mem. No. 2, Agr. Dept. Mesopotamia, Bombay.
WEBSTER, J. F. (1924), Note on Mesopotamian Bricks. (unpubl. rep.). Agr. Directorate, Baghdad.
WEBSTER, J. F. and VISWANATH, B. (1921), Further Studies of Alkali Soils in Iraq. Agr. Dept. Iraq. Mem. No. 5, Bombay.
WEST, B. (1955), Report of the Soil Survey and Soil Classification, Dujaila Project, Min of Agr. Baghdad.
WEST, B. G. (1955), Interim Report to the Government of Iraq on a Programme for Soil Survey and Classification. F.A.O. Rome.
WILCOX, L. V. (1955), Classification and Use of Irrigation Waters. U.S. Dept. Agr. circ. No. 969.
WILLCOCKS, W. (1917), Irrigation in Mesopotamia.
WILLIAMS, S. R. and BEKHOR, S. D. (1950), Minerals of Kerbala Liwa. Rep. Geol. Dept. Baghdad.
WOOLLEY, L. (1938), Ur of the Chaldees.
WRIGHT, H. E. (1951), Physiographic Reconnaissance in Iraq Kurdistan. Bull. Geol. Soc. America. 62, 1492/3.

WRIGHT, H. E. (1952), The Geological Setting of Four Prehistoric Sites in Northern Iraq. Bull. Amer. Sch. Orient. Res. 128, 11–24.
WRIGHT, H. E. (1954), Part of article of Braidwood (1954), in Sumer X, (2), 120–138.
WRIGHT, H. E. (1955), Geological Aspects of the Archaeology of Iraq. Sumer, XI, (2), 83–91.
WRIGHT, H. E. and HOVE, B. (1951), Preliminary Report on Soundings at Barda Balka. Sumer, VII, (2), 107–117.
ZEKI, M. (1954), Iraq Year Book, 1953. First Ed. Baghdad.
ZEKI, M. (1957), Shatt-Al-Arab. Baghdad.
ZOHARY, M. (1940), Geobotanical Analysis of the Syrian Desert, Palest. Journ. Bot. Ser. J. 46.
ZOHARY, M. (1944), The Flora of Iraq and its Plants with Geographical Affinities. Dept. of Agr. Baghdad.
ZOHARY, M. (1941), The Flora of the Desert to the South and West of Basra, Mesopotamia. Proc. Linn. Soc. 1, 98–107.
ZOHARY, M. (1950), The Flora of Iraq, and its Phytogeographical Subdivision. Iraq Dept. Agr. Bull. No. 31.

LIST OF MAPS OF IRAQ

Provisional geological map of Iraq	1:2,000,000, Iraq Geol. Dept (1938)
Geological maps of deserts	1:6,000,000, Mitchell (1956)
Schematic soil map of Iraq	1:5,000,000, West (1955)
Exploratory soil map of Iraq	1:1,000,000, Buringh (1960)
Physiographical map of deserts	1:6,000,000, Mitchell (1956)
Physiographical map of Lower Mesopotamia	1:3,000,000, Buringh (1960)
Climatic diagrammatic map of Iraq	1:2,000,000, Walter (1957)
Climatological atlas of Iraq	various, Meteorological Dept. (1945)
Rainfall map of Iraq	1:3,000,000, K.T.A.M. (1952)
Hydrological map of Iraq	1:5,000,000, K.T.A.M. (1952)
Topographical map of Iraq	1:1,000,000, International Map of the World
Topographical map of Iraq	1:2,000,000, Survey Dept.
Topographical map of Iraq	1: 253,440, London (1942)
Topographical map of Iraq	1: 500,000, London (1934)
Topographical maps, parts of Iraq	various, Survey Dept.
Cadastral maps, parts of Iraq	various, Survey Dept.
Landforms of the Near East	1″ = 50 miles, Raisz (1951)
Administrative atlas of Iraq	various, Soussa (1953)
Liwa map of Iraq (Arabic)	1:1,500,000, Survey Dept.
Population distribution, Iraq	1:5,000,000, Lebon (1953)
Agricultural atlas (crop distribution)	1:6,000,000, Min. of Agr. (1956)
Development projects (general)	1:1,000,000, Dev. Board (1957)
Development projects (irrigation)	1:6,000,000, Powers (1954)
Land use in Iraq	1:6,000,000, de Gruyter (1953)
Forestry map of Iraq (N. section)	1: 800,000, Forestry Dept. (1954)
Soil conservation map of Iraq	1:2,000,000, Gibbs (1954)
Tourist map of Iraq	1:2,000,000, Survey Dept. (1957)
Map of ancient sites	1:1,000,000, Dept. Antiquities (1954)
Map of ancient sites	1:4,000,000, Roux (1956)
Lands of the Bible to-day	1:2,851,200, Nat. Geogr. Mag. Dec. 1956

Published Soil Maps

Semidetailed s.m. El Sabbaghiyah	1: 50,000, Buringh and Edelman (1955)
Reconnaissance s.m. of a section of the Mussayib project	1: 250,000, Buringh and Edelman (1955)

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أظهرت التنقيبات التى أجريت فى منطقة السهول العالية الواقعة فى الشمال الشرقى من العراق والمحاذية للكهوف الكائنة فى أطراف تلال ووديان جبال الزاخروس، أن تلك البقعة قد شهدت الحقبة الزمنية التى تطور خلالها الانسان التقدم من مرحلة الصيد كوسيلة لتأمين معيشتة الى مرحلة اعتماده على الزراعة، وقد حدث ذلك قبل مائة وخمسين الف سنة وشهدت بلاد الرافدين لأول مرة استثمار الأراضى للأغراض الزراعية فى التاريخ البشرى، وقد قامت خلال التاريخ البعيد والقريب حضارات عريقة اعتمدت شهرتها لحد ما على تقدم وتطور الفنون الزراعية المتبعة آنذاك . ومن الأمثلة البارزة على ذلك قيام حضارة سومر واكد وبابل وآشور.

وقد حقق التقدم الزراعى فى بلادنا ذروته فى زمن الخلفاء العباسيين، وقد اشارت المخطوطات التاريخية لهذه الفترة الى أن الاراضى المزروعة كانت تنتج الكفاية من الغلة لاستهلاك عدد من السكان يفوق عدد سكان العراق فى الوقت الحاضر. هذا وقد شهدت البلاد فى تلك المرحلة من التاريخ تطورا فى مشاريع الارواء، زيادة فى كمية المحاصيل المنتجة.

يتضح مما تقدم بأن لمناطق العراق الزراعية امكانيات وموارد وفيرة اذا ما استخدمت اراضيها بالطرق الفنية الحديثة التى تتلائم وطبيعتها . ولهذا فمن المتطلبات الملحّة للقائمين بالاشراف على انماء وتطور مناطق البلاد الزراعية أن يستندوا الى تقديرات موثوق بها للأرض . وبالاستناد الى المعلومات الأساسية فى وصف الخصائص الفيزيائية والكيميائية والبيولوجيه للترب المختلفه، وأسلوب انتشار وتوزيع هذه الترب فى الحقل، ليتسنى للفنى الزراعى ان يحدد الخطة الواقعية للعمل. تلك الخطة التى تستهدف تنمية وسائل تطبيق الطرق الملائمة لأدارة الأراضى والتى يجب أن تتناسب وأساليب الاستغلال الاقتصادى الناجح، وقد وضع المؤلف الدكتور بيتر بيورنك الخبير فى علم التربة الأهداف الآنفة الذكر كأساس لتقدير المواضيع التى يبحثها الكتاب.

يسرنى بهذا أن اسجل تقديرى للمؤلف لما بذله من جهد مشكور ولتيسيره مرجعا اساسيا لذوى الاختصاصات العلمية والفنية والأجتماعية والأقتصادية والتعليمية فى بلدنا، وأنى واثق بأن هذا الكتاب سيحقق فائدة ايجابية لكل من يستهدف تقدم العلوم الزراعية والفنية فى العراق.

بغداد : نيسان ١٩٦٠

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بغـداد

أراضى العراق واحوال التربـة

وضع

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اخصائى فى مسح و تصنيف التربة

بغـداد ١٩٦٠