COMPARISONS OF THE CHEMICAL PHYSICAL AND MINERALOGICAL PROPERTIES OF SOME IRAQI AND MICHIGAN SOILS

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY

Tariq Harran

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To my wife Suham

COMPARISONS OF THE CHEMICAL PHYSICAL AND MINERALOGICAL PROPERTIES OF SOME IRAQI AND MICHIGAN SOILS

By

Tariq Harran

AN ABSTRACT OF A THESIS

Submitted to
Michigan State University of Agriculture and
Applied Science in
partial fulfillment of the requirements
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MASTER OF SCIENCE

Department of Soil Science

1961

Approved: E.P. Whiteside

ABSTRACT

COMPARISONS OF THE CHEMICAL
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This study is a comparison of the chemical, physical and mineralogical determinations of three pairs of surface and subsoil samples from the Greater Mussayib Project in Iraq with a sandy subsoil (Kalkaska-Bh) from Ottawa County, Michigan and a clayey subsoil (Kent-Bt) sample from Newaygo County, Michigan.

The results of mechanical analyses show that the Kent-Bt is the finest textured sample studied. It contained much more water at the same tension than the coarse textured Kalkaska-Bh. The Iraqi samples ranged from silty clay to loam.

The soils from the arid region (Iraq) are alkaline and the soils from the humid region (Michigan) are acid in reaction. None of the Iraqi soil samples contain as much organic matter as the subsoil samples from Michigan.

There is a great difference in carbonate, gypsum, and chloride contents between soils studied. The Michigan soil samples contained no carbonates and very little gypsum or chloride. Electrical conductivity showed that the Michigan soil samples and the Imam profile from Iraq had negligible salinity. The yield of very sensitive crops on the soils from Kharbana and Rashayid may be restricted by the salt contents.

Tariq Harran

All Iraqi samples are higher in extractable sodium, potassium, calcium, magnesium and phosphorus than the Michigan samples, except the Kent-Bt horizon which showed a higher potassium content than the profile from Rashayid.

A comparison of the X-ray diffraction patterns of all clay samples studied shows that kaolinite, chlorite, illite and montmorillonite are the main clay minerals in the Iraqi samples. Vermiculite, chlorite and kaolinite are present in small amounts in the Kalkaska-Bh horizon but much of the clay in that sample is non-crystalline. Illite, kaolinite and vermiculite are the main clay minerals in the Kent-Bt horizon. The Iraqi samples and the Kent-Bt horizon all contain some inter-stratified clay minerals composed of montmorillonite and chlorite layers.

The results of this study must lead to the conclusion that all three Iraqi soils are fairly well suited for farming purposes. Nitrogen and phosphate fertilizers may be required in large quantities. Their extractable K contents are high. Lime will never be required.

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I. INTRODUCTION

Iraq is basically an agricultural country. Enough arable land and irrigation water are available to support a prosperous farm population, but the actual condition of farmers is far from being satisfactory. The needs are: for improvement in agricultural practices; for better organized marketing services; for irrigation, flood control and drainage projects; and for a more equitable land tenure system. These should be provided for, to raise the standard of living of the rural population and to increase the national income.

The agricultural production in Iraq depends on three quite different kinds of areas: the rainfed zone of the northern hills and mountains, the irrigated plain of the twin rivers Euphrates and Tigris, often referred to as Mesopotamia, and the arid grazing lands of the southwestern plateau.

It is known that the development of agriculture in the Mesopotamian plain is seriously hindered in places by the high salt content of the soil. Consequently crop yields in irrigated areas are sometimes fractions of what are considered as normal. Measures are being studied and programs are being carried out to overcome salinity and salinization by combined irrigation and drainage.

This study is concerned with a study of six samples from three soils on the Lower Mesopotamian plain and comparisons of their physical, chemical and mineralogical properties with those of two soil samples from

Michigan.

A. Historical

The systematic scientific study of soils in Iraq started only a few years ago. The main purpose is to collect basic information on soil conditions in various parts of the country. The results are used in the planning and execution of agricultural development schemes. Since the succwss of these schemes mainly depends on the quality and potential uses of the various kinds of soils, intensive soil studies are being made - both in the field and in the laboratory. In the field the soils are investigated and classified. Their geographical distribution is shown on soil maps. The work itself is termed soil survey and classification.

During the field work, intensive studies are made using the new technique of the systematic analysis of aerial photographs (Buringh, 1960). In addition to the use of the soil survey information in planning and development of agricultural projects, it may also be important for archaeologists and those who are conducting studies of the ancient civilizations in the country.

B. Location and Size of Iraq

Iraq, as shown in Figure 1, covers an area of about 174,688,800 mesharas (about 168,000 square miles). It is roughly triangular in shape, with the base running southwest to northeast and the apex terminating at the Persian Gulf.

Figure 1. Major physiographic features of Iraq (Davies, 1957) and location of Greater Mussayib Project.

I. Arabian massif or western plateau.

II. High fold mountain zone, (Disturbed mesozoic and tertiary sediments: limestone, marls and sandstone.)

III. Alluvium, out-wash and loess deposits:

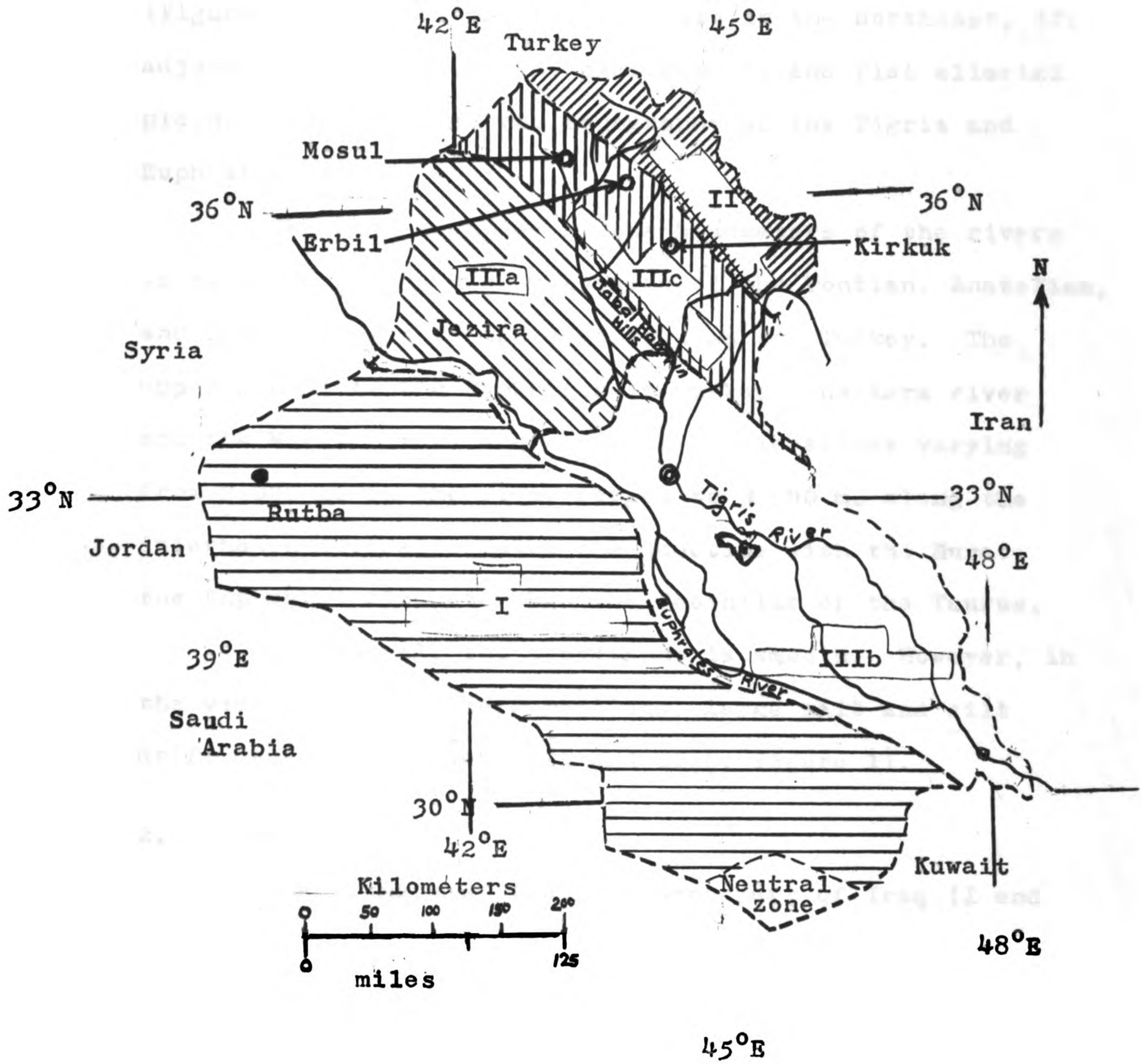
a. Miocene plain of upper Mesopotamia, older deposits and higher level alluvium.

b. Flood plain of lower Mesopotamia, younger deposits and lower level alluvium.

c. Assyr foothills.

Greater Mussayib Project

Rashayid area


42°E
Turkey
45°E
Mosul
36°N
Erbil
II
36°N
Kirkuk
N
IIIa
IIIc
Jezira
Syria
Iran
Rutba
33°N
Tigris River
33°N
Jordan
48°E
I
Euphrates River
39°E
IIIb
Saudi
Arabia
30°N
42°E
Kuwait
Kilometers
0
50
100
150
200
Neutral
zone
0
125
miles
48°E
45°E

C. Soil Formation Factors in Iraq

1. Physiography and Topography

As indicated by the physiographic map of Iraq (Figure 1): rugged mountain terrain in the northeast, II; adjoining foothills, IIIc; plateaus, I; and flat alluvial plains, IIIb; feature the topography of the Tigris and Euphrates basins.

The area occupied by the headwaters of the rivers is composed of the high mountains of the Pontian, Anatolian, and Taurus ranges to the east in Iran and Turkey. The upper basins of the Euphrates in Turkey (the Kara river and the Murat river) are rugged with elevations varying from 2,000 m. in the river gorges to 3,500 m. along the interbasin divides. Below the junction with the Murat, the Euphrates flows through the foothills of the Taurus.

In general, the topography is smooth. However, in the western and southern portions, large salt and silt drift dunes are present, (I and IIIb, Figure 1).

2. Climate

The climate of the sourthern part of Iraq (I and IIIb, Figure 1), is sub-tropical, continental, and arid desert with dry, hot summers and cool winters, Figure 2. Greater rainfall in the foothills of the northern part of the country and adjoining countries supply water to the Tigris and Euphrates rivers.

Due to the fact that Iraq has two big rivers and large flood plains, living in settlements is possible.

While 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 there is very low and a large portion of the rainwater evaporates immediately. In reality the amount of water available there for plant growth and soil formation is thus much smaller than is indicated by precipitation data.

The influence of the Persian Gulf on the climate of Iraq is very limited. However, near the Gulf the relative humidity is higher than in other parts of the country.

3. Geology (primary material and age)

The tectonic and paleographic events in the history of Iraq and the basins of the Tigris and Euphrates rivers can be summarized in broad outline as follows:

a. Marine conditions characterized by deposition of estuarine, and in some places continental sediments, prevailed throughout the Cretaceous and Eocene periods.

b. The upper Eocene and the Oligocene were mainly periods of tectonic movements with erosion. Sedimentation continued only in the central parts of the geosynclinal trough. c. During the early part of the Miocene period the sea became more and more restricted and finally only brackish waters with very small or no connections to the open ocean were left. d. In the second half of the Miocene and in the Pliocene periods the region was above sea level and was covered by broad alluvial fans, which are the deposits of detrital material encountered in the Upper Fars and Bakhtiari formations. e. The end of the Bakhtiari period was a generally turbulent time, with earth movements and subsidence of great parts of the basin, thus allowing the deposition in great thickness of sediments. f. The soils of the Mussayib project have formed in recent sediments. g. The position of the main geosynclinal trough, situated east of the Tigris, was practically unchanged throughout the entire period under consideration. Folding was possible in the unconsolidated sediments of the sedimentation basin in eastern Iraq, while only superficial movements and faulting were possible on the rigid Arabian massif.

The main masses of the mountain ranges in which the Euphrates and Tigris rivers rise are composed of continental sediments which have been structurally altered in varying degrees due to localized tectonic movements or volcanic action. The detailed geology of large portions of the area is not known.

The continental sediments forming the mountain ranges (II, in Figure 1) consist of paleozoic schists, slates and marls. Mesozoic strata of later origin overlie the older rocks in varying positions depending upon the extent of geologic movement and volcanic action which have occurred. The Cretaceous and Eocene sediments consist of limestone, marls, marbles, schists, slates, flysch,*

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*A thick conglomeratic series of rocks in southern Europe, partly of Cretaceous and partly of Eocene age.

sandstones and conglomerates. Sediments of the Oligocene period are characterized by sandstone and marls sometimes associated with deposits of gypsum and rock salt. The Miocene sediments are often lacustrine in nature, consisting of porous limestone and white marls.

The foothills (III, in Figure 1) form a folded tectonic zone of transition between the high mountains rimming the basin and the vast central plains. The foothills are broad and follow the outskirts of the northern mountains in Iran to the Persian Gulf. The foothill zone is a region of anticlines and synclines which are often more intensively folded and faulted near the mountain ranges. The sediments of the foothill zone vary from cretaceous limestones, marls and slates and Eocene limestone and shales to the more recent Miocene sediments such as chalky limestone, gypsum, anhydrite, marly clays and siltstones. In the valley of the Tigris river north of Khabour river, effusive rocks, generally basaltic, cover wide areas.

The broad plains (IIIa and b, Figure 1) occupying the central part of the sedimentation basins are underlain by Miocene formations represented by the sand, sandstones, silts, and silty clays of the Upper Fars formation, and the sand and gravels of the Kuwait series. The Pliocene age is represented by the marls, siltstones and sandstones, gravels and conglomerates of the Bakhtiary formation on top of the Fars formation. The recent geological age is represented by deep alluvial deposits of gravel, sand, silt and clays which are confined to the broad alluvial plain of Mesopotamia and the delta plains of the Tigris and Euphrates rivers on the Persian Gulf.

Table 1 (Buringh, 1960) summarizes the geology of Iraq. Since soils in the Mesopotamian plain are formed only in the recent sediments they are young soils which show little differential profile formation.

4. Vegetation

As a consequence of the arid climate, vegetation is scarce in large parts of Iraq, Figure 2. 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. Nearly everywhere natural vegetation has been destroyed. General studies on the vegetation of Iraq have been published by: Guest (1932, 1933, 1953), Zohary (1950) and Springfield (1954). Guest's work is still in progress; he is preparing a vegetation map of Iraq and its complete flora. Smith (1944) and Chapman (1949) have described the forests in northern Iraq. The books of Hooker (1937) on Iran and of Zohary (1940) on the Syrian desert are also of general interest for Iraq. 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

Table 1. Summary of the geology of Iraq, after Buringh (1960).

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

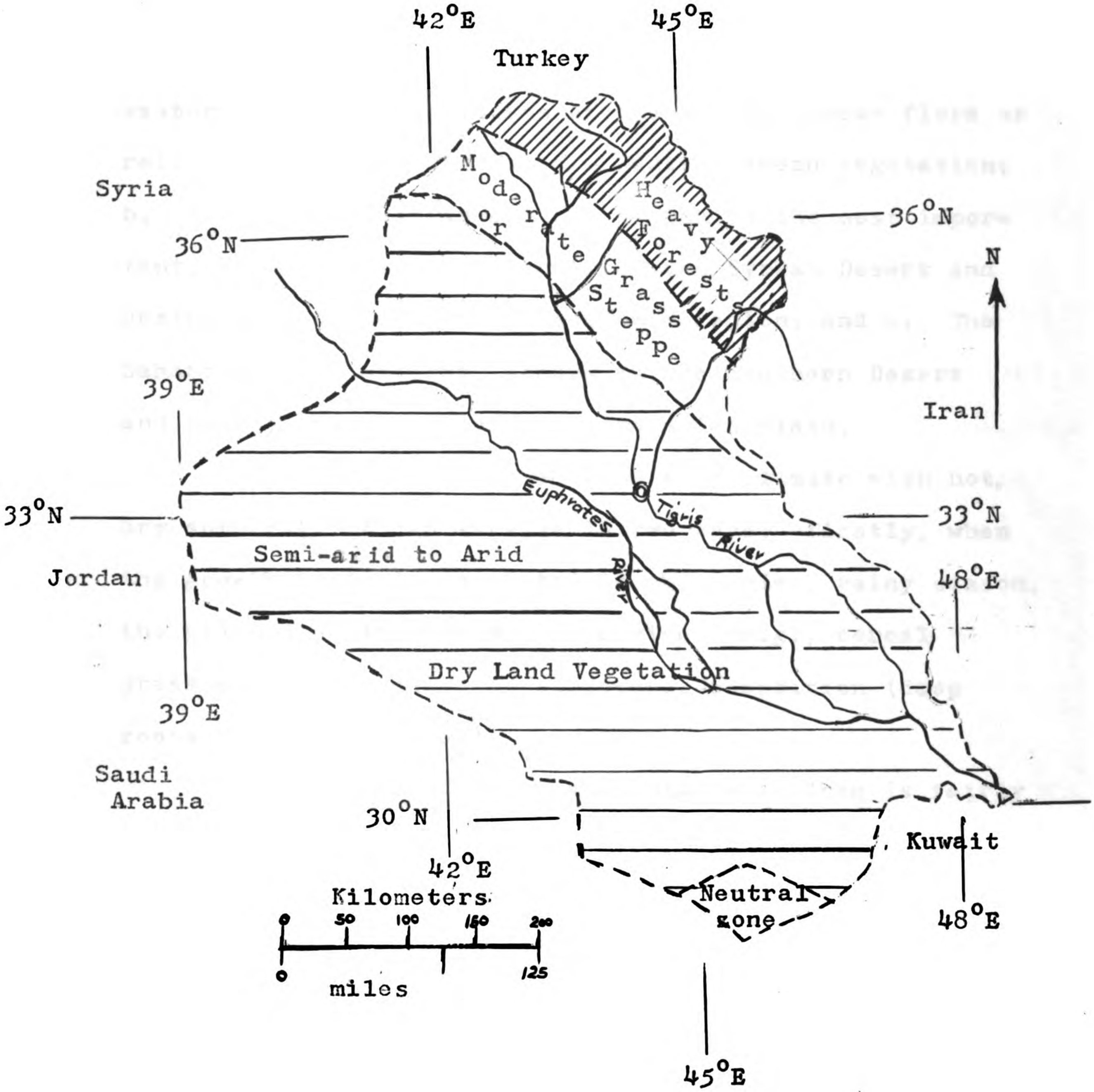

Figure 2. Precipitation (Powers, 1954) and vegetation (Davies, 1957) in Iraq

geographical regions or elements are represented in this country: a. The Mediterranean element is represented by a number of Mediterranean weeds that occur in cultivated fields. It is believed that these weeds are either the easternmost representatives of the Mediterranean flora or relics of the Tertiary Paleo - Mediterranean vegetation; b. The Irano-Turanian element, which is the most important, occurs in the vast areas of the Syrian Desert and Jezira and in the hill and mountain region; and c. The Saharo-Sindian element, occurs in the Southern Desert and nearly the whole lower Mesopotamian plain.

The vegetation is adapted to a climate with hot, dry summers. It can survive in two ways: firstly, when the growth cycle is completed in the cooler, rainy season, the plant dies and the seeds survive, (e.g., cereal grasses); or secondly, 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 natural vegetation in the river plain has largely been destroyed, and the principal vegetation is now hydrophytic, halophytic, and crude (Springfield, 1954).

Leguminous species are exceptionally abundant as weeds on cultivated land. They are significant from the point of view of maintenance of soil fertility and desalinization.

The influence of human activity on the natural vegetation is very important (Buringh, 1957, 1961 and Bennett, 1939). Human activity has caused the deterioation of natural conditions by: a. cultivation of land for many thousands of years; b. shifting cultivation in the stèppe region; c. grazing and overgrazing, particularly in the semi-arid regions; d. using wood for fuel and house construction; e. digging sub-shrubs for fuel; f. irrigation, with resulting salinization and over-silting; and g, as a result of mismanagement, wind and water erosion.

If the natural vegetation is destroyed, it is very difficult and often nearly impossible to restore the natural conditions, particularly in an arid and semi-arid climate or 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 only bare rocks remain.

alternately farmed and abandoned many times.

The present farming practice, in this and the surrounding area, has possibly existed in the area for centuries. Areas irrigated by large ditches from the Tigris and Euphrates rivers are farmed to alternate wheat or barley (planted in the late fall) and fallow, until through salting up of the land or the silting of ditches, they become uneconomical for further cultivation. When this occurs, the people move to another piece of land. There is evidence that in time many of these pieces of worn out land heal themselves and the cycle begins over again.

C. Land Classification

A reconnaissance land classification survey is being conducted in the Tigris and Euphrates basins by the Miri Sirf Land Development Committee under the direction of H. Wautenpaugh. Technicians locate the areas suitable for irrigation, and indicate their relative values for development. Their reports designate which areas are suitable for irrigation under a specific plan of development.

The work started in December, 1953, and is still in progress. To date a broad reconnaissance land classification (and drainage study) has been made over the whole area and a semidetailed classification has been completed for the Rashayid area which covers 40,000 mesharas,* Figure 1.

1. Reconnaissance Survey

In making the reconnaissance survey, one step

*Meshara equals 0.6 acre.

II. THE GREATER MUSSAYIB PROJECT

A. General Character of the Area

The Greater Mussayib Project, Figure 1, is situated between the Euphrates and Tigris rivers. This can be called an alluvial desert area. The main part of the project area is very dry.

One of the special features of this area is the high amount of sand and especially pseudosand (clayey aggregates with the "grainsize" of sand) which move with every rather strong wind. In many places these materials form complexes of many crescent-shaped dunes. This creates a terrific problem in the establishment and maintenance of irrigation or drainage canals and ditches.

Some of the pseudosand is deposited around Shnan* plants in smaller or bigger hummocks. These hummocks can vary in height from 10-100 cm. The higher they are the more they will create difficulties when leveling for irrigation is attempted.

B. Past Land Use

Ruins of ancient and recent irrigation ditches, widely scattered broken pottery, trodden paths that wind erosion has been unable to destroy, abandoned villages and historic tales, give evidence that the area at one time or another, over the centuries has all been farmed. It is doubtful if all the area or even a majority of it was ever farmed at any one time. Perhaps portions of it have been

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*Shnan is a kind of *Chenopodiaceae*.

was to open 18 pits, 2 meters deep. These pits were located 5 kilometers apart throughout the project. In digging the pits, a shelf was made on each soil horizon, and percolation was studied on each bench.

An examination of the physical characteristics of the horizons in the pit sampled in relation to their percolation rates showed the following:

Rapid percolation -- Soils with >20.0 centimeters percolation per hour were: loose to slightly compact, light brown to grey in color, slightly granular in structure, and fine sands to coarser in texture.

Moderately rapid percolation -- Soils with 6.0 to 20.0 centimeters percolation per hour were: loose to compact, and loamy sands to silt loam in texture. These soils were frequently full of shells.

Moderate percolation -- Soils with 2.0 to 6.0 centimeters percolation per hour were: loose to compact, light-brown to coffee-brown to grey in color, very thin platy or slightly vesicular (full of tiny holes) in structure and sandy loam to silty loam textures.

Moderately slow percolation -- Soils with 0.8 to 2.0 centimeters percolation per hour were: very compact, slightly rusty mottled or light brown to grey in color, massive to nutty in structure, usually somewhat sticky when wet and were slightly vesicular in structure. They ranged from silt loam to clay loam in texture.

Slow percolation -- Soils with 0.4 to 0.8 centimeter percolation per hour were: compact, reddish brown in color, massive in structure and clay loam to clay in texture; or were soft, brown to grey brown in color, very vesicular in structure, and silt loam to clay in texture.

Very slow percolation -- Soils with 0.1 to 0.4 centimeter percolation per hour were: very compact, often bluish-grey mottled, and steely grey to grey, but more often brownish red in color. They were not vesicular in structure, and silty clay loams to clays in texture.

Extremely slow percolation -- Soils with less than 0.1 centimeter percolation per hour were: very compact, distinctly reddish brown in color and usually massive, but sometimes platy in structure. They were silty clay or clay in texture.

The profiles were described, and soil samples were taken of each horizon in the field. Analyses of the salt content, and pH of the samples from each horizon, of each hole have been made in the laboratory. Samples of each horizon have also been sent to the Irrigation and Drainage Laboratory for further analyses.

In addition to the above, at each location or pit sample a deep boring was made to 21 feet. The soil was described by horizons, from 2 meters to this depth and determinations of salt and pH were made in the laboratory. These samples have also been sent to the Irrigation and Drainage Laboratory for further analyses. In each deep hole a 1 1/8 inch pipe has been installed to serve as an observation well.

In analyzing the (deep holes) for permeability in accordance with the above findings it was found that, except for two holes, extremely slowly permeable layers were present in each case. Sometimes there were as many as three separate horizons with this characteristic. At some locations very permeable layers were found above the impermeable layers, but these location were not contiguous.

In two cases holes were dug in areas in which irrigation has been practiced longer than one year. Perched water tables were found in these soils. No water tables were found on the unirrigated lands.

In the Latifiyah Project, which adjoins the Mussayib to the north and which was inundated by a flood 6 or 7 years before, 18 deep holes revealed that perched water tables were higher than on the presently unirrigated land. The height of water table was greater with the number of years under irrigation. Many of the lands bordering the project, after irrigation for a number of years, have a high water table and have gone out of production.

An analysis of the pit samples and the deep holes indicates that 10 of the locations now have sufficient salt to seriously affect plant growth. Three more of the locations, upon a rise of water table to within 1 meter of the surface, will soon be effected with salt accumulation. Only 5 of the 18 locations were free enough of salt that salinity control would not be a serious consideration. Tests of the pH, on the pastes at 1-5 dilution, showed no indication that high alkalinity will be a serious problem.

From the above facts it is seen that: under a "full water supply without drainage" a water table will soon be a problem to crop production; project drainage will not fully solve the drainage problem, and farm drainage also will be necessary in places; drainage is not feasible in some areas; salt accumulation is already a problem, and strict salinity control is necessary if continued farming is to be experienced in the area.

2. Grouping of Soils into Land Classes for Semidetailed Mapping

The soils have been grouped into the following land classes for mapping purposes:

Class 1 These lands have no limitation, and are adapted to intensive farming. No crop failure could be expected. They contain no salinity and need no drainage. The land is easily prepared for farming, irrigation and management.

Class 2 Land in this class has some deficiencies and is of less value for farming purposes than Class 1. The deficiencies may be the soil (s), salinity (a), topography (t), or farm drainage (d).
2s land is either very sandy and needs irrigation frequently, or requires fertilization, and therefore increases cost of farming; or is very heavy soil increasing cost of farming or decreasing yields due to difficulty of obtaining good water percolation; or it may be shallow soil incapable of high production without much fertilization and requiring labor for frequent irrigation and cultivation.

2a is land on which salinity, white alkali or sabach, will be a problem. The amount of the salts cuts down the production and limits crop adaptability and increases cost of farming practices.

2t land has a topographic deficiency which if not corrected by leveling, will lower yields and increase farming costs, or if corrected will involve considerable expense and labor.

2d is land on which care must be exercised in cropping practices and use of water so as not to raise the water table to a dangerous height and/or where some additional farm drainage ditches must be constructed to remove excess water.

Land classes with two deficiencies as 2sd or 2as are slightly affected by these factors, but the combination of the two are economically as detrimental as land with only one deficiency.

Class 3 This is the lowest class of land that can be farmed successfully for a long period of time under normal project management and farming practices. Its limitations are more serious than those for Class 2 for each subclass, e.g. 3s, 3sd, 3std, 3satd, etc. In general, water control to prevent high water tables and farm drainage, while relatively costly, though not prohibitive, will have to be rigidly observed in most cases.

Class 4 This land is so alkali or has such great drainage problems that it cannot be economically maintained under permanent irrigation. It will at present, however, produce some crops for a limited number of years under low water application and a fallow system of farming. Family farms located on this land are not expected to be permanent.

Class 5 These are lands that cannot be farmed at present because of some limitation (usually high salinity) but are believed good enough to be economically reclaimed.

Class 6 These lands are characterized by such adverse soil conditions (high salinity, irregularity of topography, or poor drainage) as to make them definitely uneconomical to reclaim. They are too unproductive to support a farm family even with excessive irrigation.

3. Specification or Standards for Semidetailed Mapping

This classification is best designated, according to U. S. Bureau of Reclamation Standards, as semidetailed. The land classes, outlined above, are shown on semidetailed maps. They are made according to the following standards:
a. Delineations are made on a map 1:20,000 in size.
b. The accuracy of the delineation shows different classes of land with at least 80 percent accuracy. c. Each area of Class 6 lands of 20 mesharas or larger in size is shown. d. Each delineation of arable land does not contain more than 40 mesharas of another class within the delineation. e. Each delineation has recorded for it not only the land class but also at least one typical

soil profile, the topography, the drainage, and the alkali conditions. The procedure for recording this data is similar to that used by the U. S. Bureau of Reclamation. f. The land is examined to the depth of 2 meters. One sample is taken for salt content determination, at a minimum of each one-half kilometer or in each delineation, whichever is smallest. g. At each kilometer distance, a 3 meters hole is recorded and the samples are sent to the Irrigation and Drainage Laboratory for analyses.

D. Development of the Area

1. The Project Layout and Subdivision into Farms

The project area was divided into townships of one hundred square kilometers each. These townships were further subdivided into 25 sections of 1,600 mesharas each. Each section consists of 24 rectangular farm units, 500 by 333.5 meters dimensions (66.33 mesharas in area).

The project subroads, laterals and farm ditches were laid out along the sections lines, all the project subroads are connected to the main road running along the Mussayib canal east to the Baghdad-Hilla highway.

Village sites have also been located in different parts of the project as will be seen a little later.

2. The Project Irrigation

The completion of the Warrar inlet and the Dhiban outlet canals connecting the Euphrates with the Habbaniyah Lake, will make it possible to utilize the stored flood water to augment the supply of the Euphrates with sufficient amount of water during late summer when the river is low.

The Mussayib area is one of the projects that will make use of this additional flow by bringing the water down through the Mussayib canal. The canal, completed in 1954, is almost 50 kilometers long and runs southwest from the left bank of the Euphrates 10 kilometers below the Hindiyah Barrage.

3. The Project Drainage

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 percent of the reclaimed land will be abandoned after some years of cultivation.

E. Resettlement

1. Proposed Land Use and Farmers Experiences

The Greater Mussayib Project is one of the concrete efforts of the Government to help the small farmers of Iraq to become land owners. It is a noble experiment and will have the blessing of thoughtful people all over the world.

The capacity of this project is about 3,000 families. Each family lives on its own land. Some of them are using new methods of farming such as crop rotations, treated seeds, and machinery, but most of them are using primitive methods. Nothing is done to control the weeds. No fertilizers or manure are being applied. Yields are low. Fifty percent of the cultivated land has a winter cereal crop (mainly barley, sometimes wheat). Water is applied every week to ten days during winter, and two times a week during summer.

2. Problems and Solutions

a. Saline and alkali* soils

The principal soil formation process in the soils of central and southern Iraq is salinization (Russel, 1957). This is the accumulation of salts in the soil.

Iraqi farmers classify the saline soils into two groups of soils that are salty. These are Sabach soils and Shura soils.

Sabach soil generally implies a saline soil of calcium chloride variety, or one which becomes wet at high humidity (Booya, 1956). It is then much darker colored than the dry non-sabach soils. The soils have a high content of $CaCl_2$ and $MgCl_2$ which are deliquescent. Even in the dry hot summers of Iraq these soils remain moist.

Shura soils are saline soils with white salt crusts. The soils have a high content of Na_2SO_4 or mixed Na_2SO_4 and NaCl. They correspond to white alkali soils of the United States.

b. Principles of reclamation

Crop rotation may be defined as a system of growing

*The word alkali in English comes from Arabic, al kali. The arabic etymology of it seems to be Kawi = to burn or specifically the caustic derived from wood ashes. Compare to the German, Kalium = potassium which occurs in wood ashes.

different kinds of crops in recurrent succession on the same land. A rotation may be good or bad as measured by its effects on soil productivity or on the economic returns. A good rotation provides for maintenance or improvement of soil productivity. It usually includes a legume crop to promote fixation of nitrogen, a grass or legume sod crop for maintenance of humus and for soil structure, a cultivated or intertilled crop for weed control and a suitable sequence to avoid plant diseases or insect pests. A good rotation permits diversification of crops which helps to promote a more reliable income for farmers and a greater variety of food for their families. It furnishes feed for livestock which brings added income to the farmer. If the animal manure is returned to the land it decreases the role of fertility depletion.

It has long been known that legume crops are necessary in the rotation if yields are to be maintained without nitrogen fertilization, and that the practices which maintain a high content of soil organic matter will also maintain high yields of clean tilled crops. If it is more economical to grow alfalfa as a source of nitrogen than to buy nitrogen, then alfalfa (which is the most successful legume crop in this area) should be grown in the rotation. Farmers in Iraq harvest alfalfa two or three times a year, then turn under the residues and find that alfalfa is a profitable crop. The cotton or wheat crop following the alfalfa is very favorably affected by the legume residues.

In Greater Mussayib Project there has been little effort to establish a crop rotation of any kind. Crop rotations adapted to the economy of the project, and of the country need to be introduced and taught to the farmers.

In the Greater Mussayib Project, as in many other places in Iraq (Burnell, 1955), it is the common practice to fallow the land in alternate years. There are many advantages in this system. It helps to control weeds. Only deep rooted perennials and fast growing annuals are able to survive in the fallow year. The deep rooted perennials like shok (Prosopis Stephaniana) and agul (Alhagi Maurorum) offer little competition to the winter crops, since most of their growth is made in the summer. Most of the annuals offer little competition to the winter crops. The grain is usually mature enough in the spring by the time the seeds of annuals germinate so that the seedlings are shaded out until after the crop matures. Both annual and perennial weeds are a serious problem in the summer crops, even under the fallow system. However, the deep rooted perennials dry out the substratum since most of their growth is made on stored moisture. This permits the salts to be washed down into the substratum during the irrigation of the fallowing winter crops. Shok, one of these deep rooted perennials, is a legume so it may contribute some nitrogen to the soil which is an additional advantage. There appears to be enough build up of nitrogen with a one-year fallow to produce a moderate yield without addition of fertilizers. But any effort to increase yields must be accompanied by a fertility program. Soil borne diseases are partially controlled by fallowing. It is probable that some insect pests are either partially or adequately controlled by fallowing.

There are also some disadvantages of the fallow system. It is difficult to reclaim salty land where the fallow system is used. A much more extensive canal system is required, (however, the main canal would need to be larger if it were to carry water for all the land every year). The canal and ditch system usually supplies water to 50 percent of the land in the winter and about 15 percent in the summer. The principal winter crops are barley, wheat, and broad beans. The principal summer crops are sesame and green grass. Attempts made to grow cotton when the project was first started were largely unsuccessful. A more extensive road system is required for a given amount of production.

III. EXPERIMENTAL WORK

A. Description of the Soil Samples

The six Iraqi samples studied have been brought from three locations in Greater Mussayib Project. A surface and a subsoil sample from each profile was collected by A. S. Harran at the request of the author. These samples were sterilized in the United States before the author started any experimental work on them. Two soil samples from Michigan were also studied for comparisons of all chemical, physical and mineralogical properties. The locations, depth, texture, pH (by Soil Tex indicator solution), and color of each of these samples are shown in Table 2.

The classification of the soils from Iraq as judged by their position on the general land classification map of the project area, made under the direction of Watempaugh is discussed below.

The soil from the Imam district was placed in land class 4ad. This class is so saline (a) and has such great drainage (d) problems that it cannot be economically maintained under permanent irrigation. It will at present, however, produce some crops for a limited number of years under low water application and a fallow system of farming. Family farms located on this land are not expected to be permanent. If these lands are given to farmers who have little or no resources, they will need more than the usual financial backing until these farms can be made productive.

The soil from the Kharbana district was classified

Table 2. Description of the soil samples from Iraq and Michigan.

Location or soil series name	Depth in cm. or hori-zon	Tex-ture	pH Soil-Tex	Munsell Color Notations		ISCC-NBS Color Names	
				Dry	Moist	Dry	Moist
Imam, Iraq	0-20	silty clay	8.0	10YR7/1	10YR5/2	yellowish gray	grayish yellowish brown
	20-50	silty clay	8.5	10YR7/2	10YR5/2	yellowish gray to light grayish yellowish brown	grayish yellowish brown
Kharbana, Iraq	0-20	silty clay	8.5	10YR6/3	10YR5/3	light grayish yellowish brown to light yellowish brown	grayish yellowish brown to moderate yellowish brown
	20-50	silty clay	8.0	10YR7/3	10YR6/3	light grayish yellowish brown to light yellowish brown	light grayish yellowish brown to light yellowish brown
Rashayid, Iraq	0-20	silty clay loam	7.5	10YR7/2	10YR6/2	yellowish grayish to light grayish yellowish brown	light grayish yellowish brown
	20-50	loam	8.0	2.5Y6/2	2.5Y5/2	light olive brown	light olive brown
Kalkaska (Ottawa co., Mich.)	Bh	sand	5.0	7.5YR3/2	5YR3/2	grayish brown	grayish brown
Kent (Newaygo co., Mich.)	Bt	clay	6.0	5YR5/3-5/4	7.5YR4/4	light brown	moderate brown

as class 6ad. These lands are so affected by high salinity, and poor drainage as to make them definitely uneconomical to reclaim. They are too poor to support a farm family even with irrigation.

The soil from the Rashayid district was classified as class 3ad. This is the lowest class of land that can be farmed successfully for a long period of time under normal project management and farming practices. The limitation of class 3 soils are more serious than those for class 2 for each subclass e.g. 3s, 3sd, 3std, 3satd, etc. In general, water control to prevent high water tables and farm drainage are relatively costly but not prohibitive. These limitations will have to be, in most cases, rigidly observed.

Buringh (1960) has mentioned that the irrigation depression soils in the Hilla-Kifl project are mapped in the Ananah series. The author believes that the Iraqi soils which were studied in this thesis are very closely related to that soil series. The following is a description of the Ananah silty clay, severely gullied phase, cited by Buringh. (The color names have been changed to correspond to the ISCC-NBS system (Kelley and Judd, 1955) and the terms have been rearranged to give a more consistent arrangement.)

0-25 cm. Light grayish yellowish brown to grayish yellowish brown (10YR5.5/2); silty 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. Grayish yellowish brown (10YR5/2); silty clay; moderate, medium, prismatic structure; some wider pores; very firm; some shall fragments.

35-50 cm. Grayish yellowish brown (10YR5/2); silty clay; moderate, medium, angular blocky to prismatic structure; very firm; no macro pores; shell fragments.

50-100 cm. Similar to above, very firm or sticky, some rust like mottling.

100-120 cm. Grayish yellowish brown to moderate yellowish brown (10YR5/3); clay; sticky; some rust like mottling.

120-130 cm. Light grayish yellowish brown to light yellowish brown (10YR6/3); clay; sticky; rust and gley.

130-150 cm. Grayish yellowish brown to moderate yellowish brown (10YR5/3); clay; sticky; rust and more gley.

150-170 cm. Grayish yellowish brown (10YR4/2); silty clay loam; rust and gley, more gley.

170-200 cm. Grayish yellowish brown (10YR5/2) clay, more gley.

200-260 cm. Grayish yellowish brown to moderate yellowish brown (10YR4/2.5); clay; with abundant reduction (gley) spots.

Groundwater was found at 130 cm.; capillary water occurred about 50 cm. above groundwater level. The soil below 150 cm. represents an ancient soil, covered by clay during floods and irrigation. When the Ananah silty clay occurs in irrigation and basin depressions, which are often submerged by water, shell fragments occur indicating lacustrine conditions during deposition. Soil texture analyses of Ananah soils are shown in Figure 3 and Table 3.

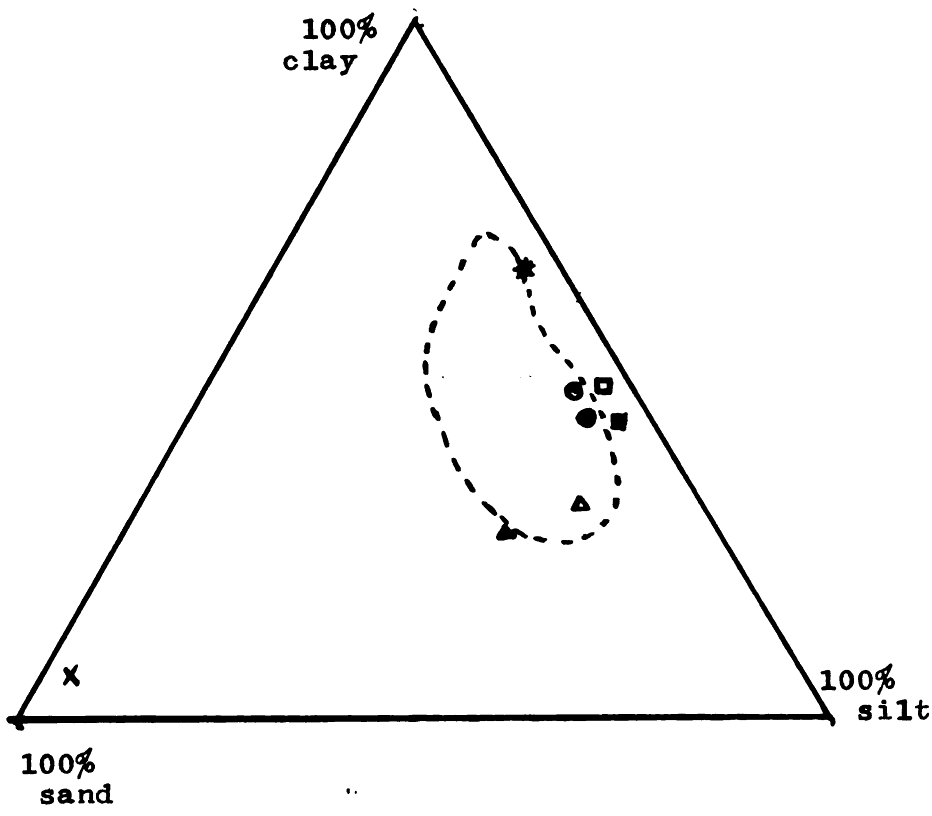


Figure 3. Diagram comparing the textures of soils of the Ananah series ( ), with soils of this study:

◎=	Imam	0-20 cm.,	●=	Imam	20-50 cm.;
■=	Kharbana	0-20 cm.,	■=	Kharbana	20-50 cm.;
▲=	Rashayid	0-20 cm.,	▲=	Rashayid	20-50 cm.'
X=	Kalkaska	Bh hor. ;	✱=	Kent	Bt hor.

Table 3. Analyses of Ananah series*, after Buringh (1960)

Depth cm.	Texture			Lime %	pH	Total soluble salt %	Gypsum me/100 gms.
	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 is less than 0.8%.

The Michigan soils from which samples were taken by K. Pregitzer for this study were subsoils. One was from a coarse textured soil series, Kalkaska, located in Ottawa County, and the other was from a fine textured soil series, Kent, located in Newaygo County, one mile west of Brohman. The Kalkaska series includes well-drained Podzols developed in sand glacial drift that contained little or no calcareous material. The Kent series includes weakly developed, well to moderately well-drained, Gray Wooded soils developed in light brown calcareous clay or silty clay till. Profiles of these soil series are currently described by the National Cooperative Soil Survey in the United States as follows: (The color names have been changed to correspond to the ISCC-NBS system (Kelley and Judd, 1955).)

Soil Profile: Kalkaska series.

A0	2-0"	Partially decomposed leaves, and raw organic matter. One to 3 inches thick.
A1	0-2"	Brownish gray (10YR3/1) humus, mixed with light brownish gray (10YR6/1); sand; numerous fine roots; medium acid; abrupt smooth boundary. One to 3 inches thick.
A2	2-8"	Brownish pink (7.5YR7/2) or light grayish yellowish brown (10YR6/2); loamy sand or sand; single grain; loose; medium to strongly acid; abrupt wavy boundary. Three to 12 inches thick.
B21h	8-14"	Grayish brown - moderate brown (7.5YR3/2-4/4) or grayish brown (5YR3/2); loamy sand or sand; very weak medium granular structure; loose to very friable; medium to strongly acid; gradual irregular boundary. Four to 8 inches thick.
B22ir	14-20"	Moderate brown (7.5YR4/4); sand; very weak medium subangular blocky structure to single grain; very friable to loose; strongly to slightly acid; gradual irregular boundary. Six to 12 inches thick.
B23ir	20-30"	Light brown to strong yellowish brown (7.5YR5/6) or moderate brown (7.5YR4/4);

sand; single grain; loose; medium to slightly acid; gradual irregular boundary. Eight to 12 inches thick.

B3	30-40"	Light yellowish brown to dark orange yellow (10YR6/6) or moderate yellowish brown (10YR5/4); sand; single grain; loose; medium to slightly acid; gradual wavy boundary. Eight to 12 inches thick.
C	40"+	Light grayish yellowish brown to light yellowish brown (10YR6/3) or light yellowish brown (10YR6/4); sand; single grain; loose; slightly acid to mildly alkaline.

<u>Soil Profile</u>: Kent series.

Ap	0-6"	Grayish yellowish brown (10YR4/2) or dark grayish yellowish brown (10YR3/2); silt loam; moderate, fine to medium, granular structure; friable; slightly acid to mildly alkaline; abrupt smooth boundary. Five to 8 inches thick.
A2	6-8"	Grayish yellowish brown (10YR5/2), light grayish yellowish brown to light yellowish brown (10YR7/3-7/4), or yellowish gray to light grayish yellowish brown (10YR7/2); silt loam; weak medium platy, or weak fine subangular blocky structure; friable to slightly firm; slightly acid to mildly

alkaline; clear wavy boundary. One to 4 inches thick.

A2B1 8-11" Grayish yellowish brown (10YR5/2) or light grayish yellowish brown to light yellowish brown (10YR7/3-7/4); silt loam, representing the A2 horizon; and light grayish brown to light brown (5YR5/3) or moderate brown (7.5YR4/4); silty clay or clay, representing the B1 horizon; A2 occurs as coatings on peds and along cracks; B1 occasionally occurs as isolated peds, surrounded or nearly surrounded by A2; massive to weak coarse granular (A2), and moderate fine angular blocky structure; friable (A2) to very firm (B1); slightly to medium acid; gradual wavy boundary. Two to 4 inches thick.

B21t 11-20" Light grayish brown to light brown (5YR5/3-5/4) or moderate brown (7.5YR4/4); silty clay or clay; thin coatings and crack fillings of yellowish gray to light grayish yellowish brown (10YR7/2) and grayish yellowish brown (10YR5/2); a few thin clay coatings of grayish brown (5YR4/2) and moderate brown (5YR4/4) on some peds; moderate to strong, fine and medium, angular blocky structure; very firm; medium acid to neutral; clear wavy boundary. Seven to 20 inches thick.

C	20"+	Moderate brown to light brown (7.5YR4/4-5/4), or light brown (5YR6/4); silty clay or clay till; weak, medium to fine, angular blocky structure; very firm; calcareous.

B. Laboratory Studies

In the laboratory the samples described in Table 2 were crushed by a wooden rolling pin to pass through a 2mm sieve. All the laboratory studies were conducted on subsamples from these crushed bulk samples.

1. Physical Properties

a. Mechanical analyses

The mechanical analyses were done according to the method of Kilmer and Alexander (1949). Hydrogen peroxide was used to destroy organic matter and sodium hexametaphosphate was used as a dispersion agent. A 270-mesh sieve was used to separate the sands from the silt and clay.

The results of the mechanical analyses were calculated on an oven dry, organic matter free basis. These analyses are recorded in Table 4.

The content of total clay is higher in the Iraqi surface samples of all three profiles than in their subsoils, but the content of total silt is higher in the subsoils than in the surface. The clay contents of the samples studied are lowest in the Kalkaska-Bh horizon and greatest in the Kent-Bt horizon.

The results of mechanical analyses suggested that no downward movement of clay has taken place in the three

Table 4. Mechanical analyses of the soil samples from Iraq and Michigan.

Location or soil series name	Depth in cm. or horizon	2.0-1.0 mm.	1.0-.5 mm.	.5-.25 mm.	.25-.1 mm.	.1-.053 mm.	.053-.02 mm.	.02-.002 mm.	$<$.002 mm.
Imam	0-20	0.02	0.08	0.07	0.84	4.8	8.0	37.6	48.6
Imam	20-50	0.10	0.08	0.05	0.73	4.8	10.3	38.0	46.0
Kharbana	0-20	0.01	0.05	0.02	0.22	1.7	5.9	43.4	48.6
Kharbana	20-50	0.02	0.03	0.02	0.20	2.0	11.2	42.6	44.0
Rashayid	0-20	0.14	0.10	0.08	1.92	13.1	17.8	32.7	34.2
Rashayid	20-50	0.07	0.21	0.16	2.70	24.6	24.6	23.4	25.2
Kalkaska	Bh	2.60	10.90	38.20	37.97	2.1	0.0	2.2	7.1
Kent	Bt	0.00	0.33	0.88	1.81	0.9	2.9	30.7	62.5

Iraqi profiles. The Kent-Bt horizon is an horizon of maximum clay accumulation in the Kent soil profile (t = finer textured layer or ton for clay in German). The Kalkaska-Bh horizon is a subsoil horizon in which humus has accumulated and it contains little more clay than the overlying or underlying horizons.

b. Bulk densities

The bulk densities of disturbed samples were measured in this study by pouring the crushed fine earth into a cylinder 1-inch high and 3 inches in diameter. The surface was then leveled with a spatula. The bulk density was determined by dividing the oven dry weight of the soil sample by the volume of the core. The results of these measurements are shown in Table 5.

The bulk density of the subsoils of all Iraqi samples are slightly lower than the bulk density of the surface layers. The Kent-Bt horizon shows a lower bulk density, and the Kalkaska-Bh horizon shows a greater bulk density than do the Iraqi soils. The Kent-Bt horizon sample has the highest clay content and the Kalkaska-Bh horizon has the highest sand content of the samples studied. This observed relationship between mechanical composition and bulk density is in agreement with the observation of Baver (1948). The undisturbed bulk densities will usually exceed those measured on crushed samples.

c. Percent total pore space

The percent total pore space was calculated in two

Table 5. Other physical properties of the soil samples from Iraq and Michigan

Location or soil series name	Depth in cm. or horizon	Bulk density	% total pore space		% air dry moisture content by weight
			Based on bulk density and specific gravity	Based on water saturation	
Imam	0-20	1.30	50.5	73.6	4.39
"	20-50	1.28	51.0	71.1	4.73
Kharbana	0-20	1.31	50.0	71.8	4.41
"	20-50	1.23	53.0	68.1	4.00
Rashayid	0-20	1.30	50.5	64.8	3.82
"	20-50	1.25	52.0	66.4	3.23
Kalkaska	Bh	1.63	36.6	51.6	0.60
Kent	Bt	1.21	54.0	70.4	4.20

ways as shown in Table 5 (Richards, 1954). They are based on bulk density and assumed specific gravity, or water content at saturation.

The results indicate that the percent pore space based on water saturation is higher than that determined by the other method. This is due at least in part to the swelling on wetting which gave a high amount of water held by the particles and an actual volume when wet that is greater than when dry.

The profile from Rashayid contains very much gypsum which has a specific gravity 2.32. Use of an actual specific gravity of this sample would give a lower porosity than that calculated assuming a density of 2.60.

Generally speaking the method based on bulk density and specific gravity is probably the more desirable method for determining the percent pore space of disturbed samples.

A medium textured mineral soil that is in good condition for plant growth will contain about 50 percent total pore space on the basis of volume. This pore space is important for gas exchange (O_2 and CO_2) between the soil and atmosphere, water movement and water storage.

d. Air dry moisture

The results in Table 5 show that the coarse textured Kalkaska-Bh horizon has a low air dry moisture content. The fine textured Kent-Bt horizon and the moderately fine textured Iraqi soil samples retain much more moisture when air dry.

e. Moisture retention studies

A modified method proposed by Richards (1954) for moisture retention studies was used in this study. Tension tables were used for 0.01, 0.03, and 0.1 atmosphere measurements; pressure cookers were used for 0.3, and one atmosphere determinations; and pressure membranes were used at 3, and 6 atmospheres. Cores 1-inch high and 3 inches in diameter were used on the tension table and in the pressure cooker studies.

The results of these measurements are shown in Table 6. Curves showing the results of the moisture determinations at different atmospheric tensions are illustrated in Figure 4. These data show that the coarse textured Kalkaska-Bh horizon has a low moisture content, while the fine textured Kent-Bt horizon and the Iraqi soil samples contain much more water at the same tensions. This is due to the larger number of contact points and the greater surface area in the finer textured horizons. The Kalkaska-Bh horizon had a moisture content of about 9.0 percent at 0.05 atmosphere's tension, while the Kent-Bt had 43.0 percent at the same tension. The maximum water holding capacity (M.W.H.C.) is at about 0.01 atmosphere and the field capactiy (F.C.) is at about 0.05 atmosphere tension, (Stolzy, 1954), when these measurements are made on undisturbed samples. The permanent wilting percentage (P.W.P.), as indicated in the review by Veihmeyer and Hendrickson (1948), is generally accepted as being the lower limit of water available for plant growth in non-saline

Table 6. Moisture retained at various tensions by the soil samples from Iraq and Michigan

Location or soil series name	Depth in cm. or horizon	Percent moisture (by weight) retained at following tensions						
		.01 atm.	.03 atm.	.1 atm.	.3 atm.	1.0 atm.	3.0 atm.	6.0 atm.
Imam	0-20	52.5	49.4	44.0	42.5	40.4	21.3	20.0
Imam	20-50	49.3	46.0	40.8	39.0	37.4	19.7	18.3
Kharbana	0-20	51.3	47.7	41.7	41.1	40.2	22.4	20.7
Kharbana	20-50	51.8	48.2	42.4	41.5	41.0	21.8	20.4
Rashayid	0-20	42.3	38.7	34.0	32.9	31.9	14.6	14.0
Rashayid	20-50	43.4	39.7	34.5	34.0	31.7	12.6	11.7
Kalkaska	Bh	28.4	11.6	6.8	5.5	4.8	2.8	2.4
Kent	Bt	56.7	46.8	39.8	38.1	35.2	21.4	20.4

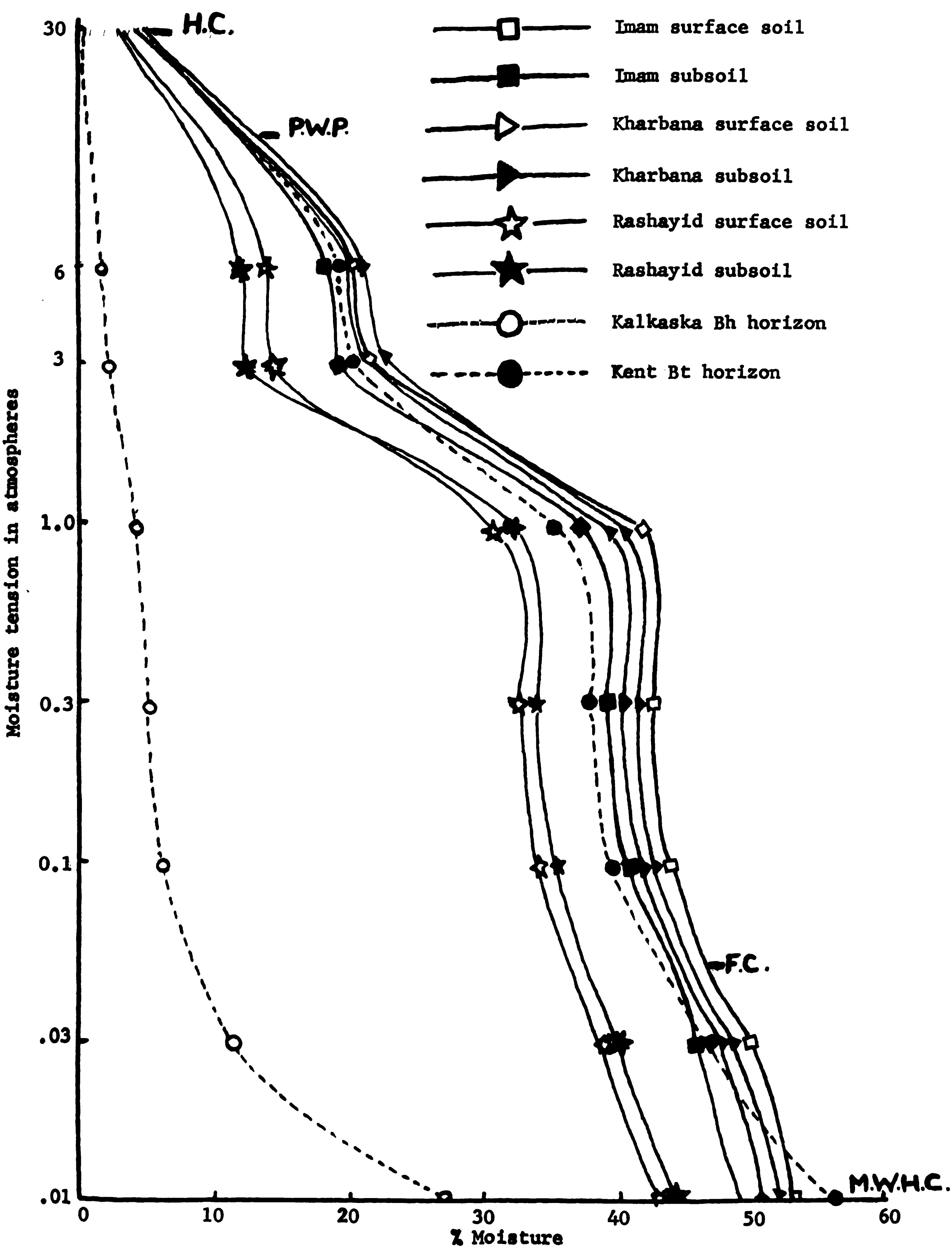


Figure 4. Soil moisture retention curves

soils. This corresponds to about 15 atmospheres tension on disturbed soil samples. Moisture commonly becomes a limiting factor in the rate of plant growth before the 15 atmospheres percentage is reached (Shaw et.al., 1952). One third (1/3) atmosphere's tension has commonly been assumed to approximate field capactiy on disturbed samples (Richards, 1954). One third (1/3) atmosphere values are commonly below field capacities on sandy soils (Russells, 1950). The results of available moisture estimates made in different ways are shown in Table 7.

The availability of soil moisture to the growing plant has most commonly been assumed to be the water held between 1/3 atmosphere and 15 atmospheres tension when the measurements are made on disturbed samples. These values are shown as the last column in Table 7 for the soil samples in this study. For the sample of sand, the 1/3 atmosphere tension probably underestimates the field capacity as the Russells have indicated. The amount of water held at 0.05-15 atmospheres is probably a much better estimate of the available water holding capacity of this sample. These values are probably the best estimates of available moisture under dry land conditions.

Since plant growth is usually inhibited before the 15 atmospheres percent is reached the 1/3 atmosphere to 6 atmosphere percentages in the next to the last column of Table 7 may be better estimates of the available moisture in the Iraqi and the Kent samples for irrigated conditions. The values for the available water in the

Table 7. Available moisture estimates for the soil samples from Iraq and Michigan, in percent moisture by weight.

Location or series names	Depth in cm. or horizon	.05-6.0 atm.	.05-15 atm.	0.3-6 atm.	0.3-15 atm.
Imam	0-20	26.5	33.0	22.5	29.6
"	20-50	24.8	33.0	20.7	28.0
Kharbana	0-20	23.5	30.5	20.4	27.7
"	20-50	24.0	32.0	21.1	28.3
Rashayid	0-20	22.0	25.2	18.9	22.8
"	20-50	26.0	29.5	22.3	25.8
Kalkaska	Bh	6.5	8.0	3.1	4.6
Kent	Bt	23.0	31.5	17.7	25.5

Kalkaska-Bh horizon are probably too low in this column and those in the third column .05-15 atmospheres are probably too high. For this sample the value in the first column (.05-6 atmospheres) is probably the best estimate of the available water in this sample for irrigated conditions.

The effect of soil salinity on crops is also related to the range over which the moisture content of the soil varies. The concentration of the soil solution depends both on the amount of soluble salt and the amount of water present.

2. Chemical Properties

The results of chemical studies of the soil samples from Iraq and Michigan are shown in Tables 8 and 9.

a. pH measurements

pH measurements were made on 10 gm. of air dry soil mixed with 20 cc. of distilled water in a 50 ml. beaker and allowed to equilibrate for half an hour. Measurements were made using a Beckman Zeromatic pH-meter.

Except with two soil samples, the results obtained with the pH-meter in Table 8 were about the same as those obtained with the Soil-Tex indicator as reported in Table 2. The Soil-Tex indicator is not as accurate over the full range of pH values.

The pH values in Table 8 show that the soils from Iraq are all mildly to moderately alkaline except

Table 8. Potentiometric pH measurements plus H_2O_2 loss, organic matter, nitrogen, and carbonate contents of samples.

Location or soil series name	Depth in cm. or horizon	pH	H_2O_2 loss(-) or gain(+) %	O.M %	Total N %	C/N	$CaCO_3$ %
Imam	0-20	7.9	0.00	0.54	0.018	17.4	14.1
Imam	20-50	8.5	0.05	0.44	0.025	10.2	15.2
Kharbana	0-20	8.3	+0.06	0.38	0.018	12.3	14.5
Kharbana	20-50	8.2	+0.05	0.36	0.019	11.1	14.1
Rashayid	0-20	7.4	0.10	0.41	0.017	14.0	14.9
Rashayid	20-50	7.4	0.14	0.38	0.013	17.0	14.3
Kalkaska	Bh	4.7	0.08	0.69	0.017	23.6	0.0
Kent	Bt	6.2	0.01	0.64	0.043	8.7	0.0

the subsoil from Imam which is strongly alkaline.

The two soil samples from Michigan are acid in reaction. The Kalkaska-Bh horizon has a medium acid reaction and Kent-Bt horizon has a slightly acid reaction.

There is a distinct difference in reaction between the soils from the arid (Iraq) and humid (Michigan) regions.

b. Organic matter content

The wet combustion method of Walkley (Richards, 1954) was used to determine organic carbon. The results were calculated as percent of organic matter by multiplying the organic carbon content by 1.72.

As shown in Table 8 the organic matter content of all the samples is very low. The surface horizons of the soils from Iraq contain slightly more organic matter than their subsoils, but none of the Iraqi soil samples contain as much organic matter as the subsoil samples from Michigan.

The H_2O_2 losses in Table 8 are less than the organic matter in the samples. Indeed the profile from Kharbana showed a gain on H_2O_2 treatment. These gains are probably due to either higher oxidation or hydration. Impurities in the H_2O_2 might also add a small amount to the sample. Particularly in the Iraqi samples the gain if due to oxidation, might indicate that these samples were deficient in drainage as was indicated in the land classification of the areas sampled.

The smaller loss than anticipated from the organic matter contents may be due either to some of the above gains as well as some losses of organic matter or perhaps the organic matter was not completely oxidized with H_2O_2. The profile from Rashayid showed greater loss than any other of the Iraqi samples. This was probably due to the abundance of gypsum, some of which was probably dissolved in the H_2O_2 treatments.

c. Total nitrogen determination

The modified Kjeldahl method was followed as described by Jackson (1958), for total nitrogen determinations. In general all the samples had a low total nitrogen content, Table 8. The Kent-Bt horizon had a higher N content than the other samples. The subsoils of the Imam and Kharbana samples have higher N content than the surface horizons. This may be due to the denitrification in a hot climate reducing the amount of nitrogen in the surface. However, it may be due to the leaching process carrying the nitrogen as NO_3^- from the surface to the subsoils and their accumulation deeper in the profile. The relative NO_3^- contents of the samples in these profiles are in agreement with this idea, Tables 8 and 9. However, the amount of nitrate is not enough to explain all the differences in nitrogen.

In the Rashayid profile the total nitrogen percent in the surface is higher than in the subsoil as would commonly be expected. The NO_3^- content of the surface here is also higher than in the subsoil.

d. Carbonate content (lime)

A quantitative determination method of Williams and Schollenberger (Richards, 1954) was used to determine alkaline-earth carbonates in these soils.

The alkaline-earth carbonates that occur in significant amounts in soils consist of calcite, dolemite, and possibly magnesite. Owing to low rainfall and limited leaching, alkaline-earth carbonates are usually constituents of soils of arid regions (Richards, 1954).

Alkaline-earth carbonates influence the texture of the soil when present in appreciable amounts, for the particles commonly occur in the silt size fraction (Richards, 1954). Alkaline-earth carbonates, if present, are important constituents of alkali soils. They constitute a potential source of soluble calcium and magnesium for the replacements of exchangeable sodium.

All the Iraqi samples contained 14-15 percent of carbonates as $CaCO_3$ equivalents, Table 8. There is little variation in carbonate content between layers within one profile or between the three profiles.

There is a great difference in carbonate content between Iraqi soils and Michigan soils, Table 8. The Michigan soil samples contained no carbonates even though they were both formed from materials containing some limestone. This is due to the fact that free carbonates have been removed by leaching in this humid climate as was also indicated by the pH values which are below 7.

e. Nitrate determination

The phenoldisulfonic acid method proposed by Jackson

(1958) was used to determine the NO_3^- content of the soil samples studied. The results of the determinations are given in Table 9.

Valid interpretations of nitrate data in terms of field conditions can only be made when samples are analyzed in a moist condition directly out of the field. Even with rapid drying some increases in nitrate will occur before nitrification is completely suppressed.

There was no correspondence between NO_3^- levels and total N in these soils. The fact that nitrate was found in all soils in detectable quantities does indicate that the appropriate organisms for nitrification were present and active in all soils prior to air drying.

f. Chloride determination

A method proposed by Reitemeier (Richards, 1954) was used to determine the Cl^- content of the soil samples studied by titration with silver nitrate. The results of these determinations are given in Table 9.

Chloride is known to be an essential plant nutrient but its exact function in the plant is not known (Donahue, 1958). It is pertinent, at this point to point out that it has been reported that high levels of chlorides (or sulfate) may interfere with nitrogen, phosphorus, or sulfur nutrition (Richards, 1954). However, the accumulation of the chloride ion in plant tissues may not manifest toxic symptoms. Many plant species are no more sensitive to chloride salts than they are to isosmotic concentrations of sulfate salts. There is good evidence, however, for the specific toxicity

Table 9. Nitrate, chloride, gypsum content, and electrical conductivity of samples studied

Soil	Depth in cm. or horizon	N from NO_3^- me./100 gm. of soil	Cl^- me./100 gm. of soil	Gypsum me./100 gm. of soil	E.C. mmhos/cmX10^3
Imam	0-20	0.032	3.53	0.20	1.7
Imam	20-50	0.039	1.85	5.00	1.5
Kharbana	0-20	0.043	8.94	0.16	2.7
Kharbana	20-50	0.143	5.25	0.16	2.8
Rashayid	0-20	0.071	9.84	44.00	3.2
Rashayid	20-50	0.059	10.50	48.50	3.6
Kalkaska	Bh	0.054	0.17	0.05	0.05
Kent	Bt	0.041	0.44	0.05	0.11

of chloride to some tree and vine crops. Hayward and associates and Brown and co-workers have found chloride salts to be toxic to peaches and other stone fruits. Chloride burn has also been reported for citrus by Reed and Haas.

The results in Table 9 indicate that some chloride is present in all Iraqi samples but there is very little in the Michigan samples. Imam and Kharbana samples show lack of effective leaching of chloride through the profile, since the surfaces contain higher chloride content than the subsoils. While the soil from Rashayid had a higher chloride content in the subsoil than in the surface, both were higher than in the surface of the other Iraqi soils.

g. Gypsum determination (Quantitative)

The gypsum determination was done according to the method of Bower and Huss (1948) which involves its precipitation with acetone.

Although gypsum is a salt which occurs in many Iraqi soils, Table 9, it does not adversely influence plant growth. The reason is that the solubility of gypsum in water is very low (1.8 g gypsum in one liter of water) (Delver, 1960). Therefore, the osmotic pressure of the gypsum solution never increases beyond 0.5 atmospheres. At low total salt concentrations 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 gm/1), the gypsum solubility decreases. The presence of gypsum in saline soils prevents these soils from becoming alkali soils by supplying calcium to the soil solution for replacing exchangeable Na from the soil.

Table 9 shows that soil from Rashayid has a high gypsum content both in the surface and the subsoil. The gypsum content of the subsoil is more than in the surface in the profiles from Rashayid and Imam. The soil from Kharbana has a low gypsum content. Michigan soils contain a very low gypsum content compared with the Iraqi soils.

h. Electrical conductivity (Standard Wheatstone Bridge)

The electrical conductivity of 1:5 soil-water extracts as suggested by Campbell and others (1949), was used in these studies.

It is very important to know when the concentration of soluble salts in a soil is so great as to injure plants or prohibit their germination or growth.

Table 9 shows that Imam, Kalkaska-Bh horizon and Kent-Bt horizon have negligible salinity. In the soils from Kharbana and Rashayid, the yields of very sensitive crops may be restricted by the salt contents. The study in this thesis does not agree with the former land classification stating that these Iraqi samples are strongly saline.

i. Determinations of extractable sodium, potassium, calcium, and magnesium

The methods used for determining the extractable nutrients are these used in the Soil Testing Laboratory in Michigan State University. Extractable sodium, potassium, calcium and magnesium were obtained by extracting the soil with neutal normal ammonium acetate at a soil to extract ratio of 1:10. The quantitative determination of Na, K and Ca in the soil extract was carried out on a Coleman flame photometer. Magnesium was determined on a Beckman D. U., with a flame attachment, at a wave length of 282.5 mu.

The results of these determinations are shown in Table 10.

(1) <u>Extractable sodium</u>

Sodium in the soil may exert important secondary effects on plant growth through adverse structural modifications of the soil. Thus, if the exchange complex contains appreciable amounts of exchangeable sodium, 10-15 percent saturation, the soil may become dispersed and puddled, thereby causing poor aeration and low water permeability. In general increasing the exchangeable-sodium percentage of the substrate results in a decreased accumulation of calcium, magnesium and potassium in the plants (Richard, 1954).

Laboratory experiments by Bower and Turk have shown that the addition of calcium and sometimes magnesium, to alkali soils can improve plant growth very markedly with an associated increase in the uptake of the nutrients by the plants.

As shown in Table 10, the amounts of sodium in all the Iraqi samples are much greater than in the Michigan

Table 10. Pounds per acre of extractable nutrients in soil samples studied.

Soil	Depth cm.	Na	K	Ca	Mg.	P
Imam	0-20	5,087	960	15,456	1,050	32.5
Imam	20-50	3,285	840	15,792	984	37.5
Kharbana	0-20	10,500	840	12,800	912	41.5
Kharbana	20-50	11,500	816	11,480	896	41.5
Rashayid	0-20	3,368	594	31,800	1,568	53.0
Rashayid	20-50	3,368	478	30,150	1,208	59.0
Kalkaska	Bh	46	35	76	4	28.0
Kent	Bt	280	652	890	307	21.5

samples. The soil from Kharbana seems to contain a higher amount of exchangeable sodium than the other Iraqi samples.

(2) Extractable potassium

All the samples except Kalkaska-Bh horizon contained a very high amount of exchangeable potassium, Tables 10 and 11. The surface layers of the soils from Iraq contain higher amounts than the subsoils. The soil from Rashayid seems to contain a lower amount of exchangeable potassium than the other Iraqi samples. The Kalkaska-Bh horizon is low in exchangeable potassium.

Table 11. Adequacy of potassium soil test levels for mineral soils

Fertility Level	Pounds per acre
Very low	0-50
Low	51-125
Medium	126-200
High	201-400
Very High	401+

Among the soils studied, all Iraqi soils and the Kent-Bt horizon from Michigan had very high levels of extractable potassium. The Kalkaska-Bh horizon showed a very low level of potassium.

(3) Extractable calcium

Calcium like potassium is absorbed by plants as the cation (Ca^{++}). This may take place either from the soil solution or by the process of contact exchange.

The calcium content of the soils from Iraq is high. This is the result of calcium carbonates and/or calcium sulfates in the primary material and a low rainfall with little leaching. Many of the soils of the arid regions actually have within their profile secondary deposits of $CaCO_3$ or $CaSO_4$.

(4) Extractable magnesium

The Kalkaska-Bh horizon is very low in extractable magnesium, Table 10. This might have been anticipated from its acid reaction and sandy texture. Crops on this soil would probably respond to additions of Mg fertilizers such as dolomitic lime.

The Iraqi surface soils contain higher Mg than the subsoils. All of these samples have more than 200 pounds of Mg per acre and the calcium-magnesium ratio is usually smaller than 20 to 1, and their potassium-magnesium ratio is smaller than 3 to 1. Consequently, none of these finer textured samples are considered to need additions of magnesium.

j. Available phosphorus

The available phosphorus was extracted with 0.025 N HCl, containing 0.03 N NH_4F, at a soil to extract ratio of 1:8. The phosphorus was determined by a colorimetric method using the ammonium molybdate, hydrochloric acid solution proposed by Dickman and Bray (1940) and 1-amino, 2-napthol, 4-sulfuric acid reducing agent developed by Tiske and Subbarow (1925).

The results of these analyses in Table 10 indicate that samples from Rashayid contain the highest amounts of available phosphorus. Both Imam and Rashayid subsoils contain more available phosphorus than their surface soils. The content of available phosphorus is higher in Iraqi soils than in Michigan soils. But because crops vary in their responses to phosphorus and also differ greatly in cash value, the adequacy of the amounts present have to be considered in the light of the fertility levels indicated for different crops as shown in Table 12.

Table 12. Fertility levels indicated by the phosphorus soil tests for various crops (those grown in Greater Mussayib Project are underscored.)

	Crops to be grown		
Fertility level	Pasture, Hay, <u>Barley</u>, Oats, Rye, Soy Beans	Corn, <u>Wheat</u>, Field Beans, <u>Alfalfa</u>, Peas	Sugar Beets, Potatoes, <u>Most Vegetables</u>
Very low	0-10	0-15	0-20
Low	11-20	16-30	21-40
Medium	21-35	31-50	41-70
High	36+	51+	71+

From Table 12, the following suggestions can be made: the soil from the Rashayid district has a sufficient amount of phosphorus for growing barley, wheat, and alfalfa, but would require additional P for vegetables; soils from Imam and Kharbana districts, showed a medium to high level of P for only barley but require additional phosphorus for wheat, alfalfa and vegetables. Michigan soils have a medium level of P for barley, pasture, hay, oats, rye, and soybeans but are low in phosphorus for other crops.

3. Mineralogical Composition

a. Mineralogical analyses of the non-clay fractions

The Rashayid sand fractions contained many shiny platy grains. This is due to somewhat more mica in that soil.

In the Imam sand samples black grains were noticed which were probably due to the presence of magnetite.

The Kalkaska-Bh horizon sand fraction showed a reddish color due to coatings on the sand grains.

Carbonate and gypsum: All the Iraqi samples contained free carbonates as shown in Table 8, while the Michigan samples contained no carbonates, even though these soils were probably formed from materials containing limestone. The Michigan samples also contained a very low gypsum content compared with the Iraqi soils. The Rashayid profile has a very high gypsum content. Much of the carbonates and gypsum are probably present in the non-clay fractions.

b. Mineralogical analysis of clays

(1) X-ray determinations of clay minerals

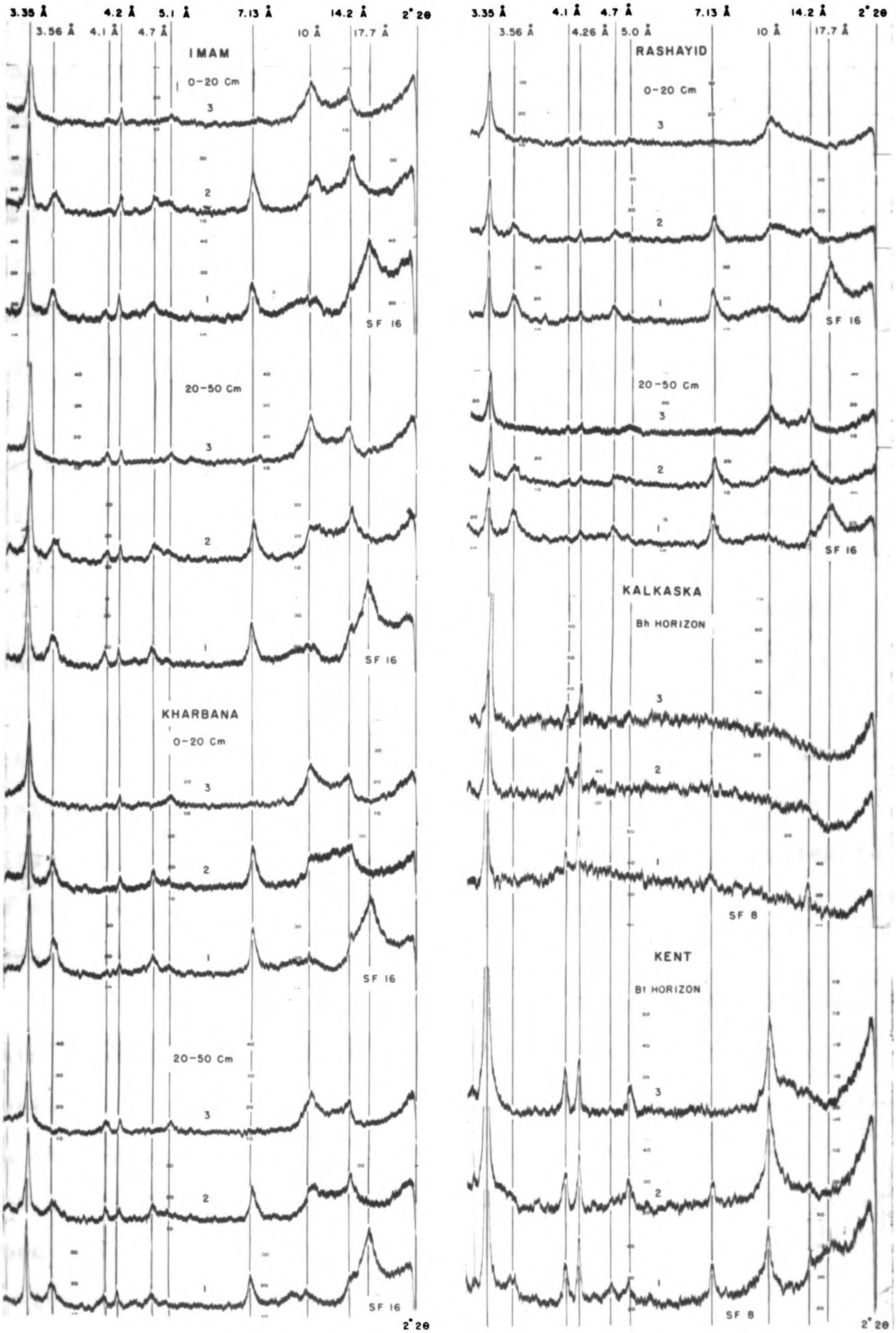
The clay fractions from the mechanical analyses were carefully separated from the silt by repeated decantations. In mineralogical studies of these clay fractions, about five ml. of the suspension, containing 30-40 mg. of clay were transferred to test tubes. Then 5 drops of glycerol were added. The suspension was shaken and let stand overnight. In the morning a porous ceramic plate was placed on a holder and attached to a vacuum. The clay suspension was poured into the well of the holder. When the clay was all deposited on the porous plate it was leached with three increments of 0.1N $CaCl_2$ containing 3 percent glycerol by volume. This was followed by 3 percent, 10 percent and 40 percent glycerol solutions. The plates were then removed and left overnight in a desiccator containing $CaCl_2$. The plates were then mounted on the Norelco X-ray spectrometer, using a 1/4" divergent silt, 0.003" receiving slit and a 1/4" scatter slit in the beam collimating system. The diffraction unit was operated at 20 milliamperes and 35 kilovolts using a copper target tube. The recording unit circuit panel was set at time constant four and multiplier one. A scale factor (SF) of 16 was used for the Iraqi samples and a scale factor of 8 was used for the Michigan samples. The clay samples were scanned from two to thirty degrees 2Θ. These diffraction patterns are shown as curves numbered 1 in Figure 5.

Figure 5. X-ray diffraction patterns of the $< 2\mu$ fractions of the soil samples from Iraq and Michigan.

Patterns No. 1 Correspond to Ca^{++} and glycerol saturated samples.

Patterns No. 2 Correspond to samples which were K^+ saturated and heated to 110°C.

Patterns No. 3 Correspond to samples which were K^+ saturated and heated to 550°C.


3.35 Å
4.2 Å
5.1 Å
7.13 Å
14.2 Å
2° 2θ
3.56 Å
4.1 Å
4.7 Å
10 Å
17.7 Å
IMAM
0-20 Cm
20-50 Cm
KHARBANA
0-20 Cm
20-50 Cm
3
2
1
SF 16
RASHAYID
4.1 Å
4.7 Å
4.26 Å
5.0 Å
0-20 Cm
20-50 Cm
KALKASKA
Bh HORIZON
SF 8
KENT
Bt HORIZON

After irradiation, the ceramic plates were replaced in the holders and the clay was leached three times with 10-15 drops of 0.1N KCl then washed with distilled water, dried for four hours in the desiccator, and then placed in an oven at 110°C for twenty-four hours, and left to cool in the desiccator. The samples were then scanned again in the X-ray diffraction unit. These diffraction patterns are shown as curves numbered 2 in Figure 5.

Finally, these samples were heated to 550°C for twenty-four hours, cooled and scanned for the third time. These diffraction patterns are shown as curves numbered 3 in Figure 5.

The effect of the above treatments on the common clay minerals, quartz, calcite and the ceramic plates are listed in Table 13. The results of the different methods used in the analysis of clay show, Table 14, that kaolinite, chlorite, illite, and vermiculite are the main clay minerals in Kent-Bt horizon. Some montmorillonite is also present in the Kent-Bt horizon but in a very low percentage.

The Iraqi samples and the Kent-Bt horizon all contain some interstratified clay minerals containing montmorillonite and chlorite. Much of the clay in the Kalkaska-Bh sample was apparently amorphous since the intensity of the clay mineral peaks were quite low for that sample. Only about 15 percent of this clay sample was accounted for by the clay minerals present.

(2) Calcite contents

In the X-ray diffraction studies of the clay fractions a 3.03Å spacing appeared in all Iraqi samples. This line disappeared on ignition of the samples. It indicates the presence of calcite (Whiteside, 1948) in the clay fractions of those soil samples. This line is absent in Michigan samples, so there is no calcite present in the clay fraction from those horizons. If we had gone farther, more than 30° 2θ, in the X-ray diffraction studies of Iraqi soils it would have been possible to determine, on the basis of the presence or absence of a diffraction line at 2.89Å, whether or not dolomite is present in those samples.

(3) Colors of clays before and after ignition at $550^{\circ}C$

All the clay samples reddened on ignition, Table 14. The clay from the soil profile near Imam, Iraq, became darker in color on ignition as well as redder. Its color changed on heating from light grayish yellowish brown (10YR6/3) to light grayish brown (7.5YR5/3-5/2). This may be due to the presence of some organic matter that charred on heating but did not decompose because of its combination with the clay. Another possibility might be the presence of some manganese dioxide. The other Iraqi clay samples became brighter on ignition as well as redder. The Kent-Bt horizon became lighter and brighter as well as redder on ignition. The clay from the Kalkaska-Bh horizon became lighter in color as well as redder on ignition. Its grayish reddish orange (10R5/6) color after ignition may be due to a higher content of iron oxide or hydrated oxides than in the other samples.

Table 13. Effect of heating on lattice spacings (in Ångstroms) of clay minerals

Clay minerals	Glycerol $+CaCl_2$	KCl saturation 110°C	KCl saturation 550°C
Kaolinite	7.1, 3.56	7.1, 3.56	Decomposed
Halloysite	10., 5.0	7.1, 3.56	Decomposed
Montmorillonite	17.7,	10.	10.
Illite	10., 5.0, 3.3	10., 5.0, 3.3	10., 5.0, 3.3
Vermiculite	14.2, 7.1, 4.7	10., 5.0, 3.3	10., 5.0, 3.3
Chlorite	14.2, 7.1, 4.7	14.2, 7.1, 4.7	14.2, 7.1, 4.7
Quartz	4.26, 3.35	4.26, 3.35	4.26, 3.35
Calcite	3.03	3.03	Decomposed
Ceramic Plate	5.4, 4.2, 4.1, 3.35		

Table 14. Clay minerals identified in the soil samples from Iraq and Michigan.

Soil	Depth in cm. or horizon	Clay mineral types (arranged in relative order of abundance of minerals)	Color of clay	
			before ignition	after ignition
Imam	0-20	Kaolinite, Chlorite, Illite, Montmorillonite, Vermiculite, (Quartz, Calcite)	10YR6/3	7.5YR5/3
Imam	20-50	Kaolinite, Chlorite, Illite, Montmorillonite, Vermiculite (Quartz, Calcite)	10YR6/3	7.5YR5/2
Kharbana	0-20	Kaolinite, Chlorite, Illite, Montmorillonite, Vermiculite, (Quartz, Calcite)	10YR6/3	5YR6/4
Kharbana	20-50	Kaolinite, Chlorite, Illite, Montmorillonite, Vermiculite (Quartz, Calcite)	10YR6/3	5YR6/4
Rashayid	0-20	Kaolinite, Chlorite, Illite, Montmorillonite, Vermiculite, (Quartz, Calcite)	10YR6/3	5YR6/4
Rashayid	20-50	Kaolinite, Chlorite, Illite Montmorillonite, Vermiculite (Quartz, Calcite)	10YR6/3	5YR6/4
Kalkaska	Bh	Vermiculite, Chlorite, Kaolinite, (Quartz)	2.5YR4/6	10R5/6
Kent	Bt	Illite, Kaolinite, Vermiculite, Chlorite Montmorillonite, (Quartz)	7.5YR5/4	2.5YR6/6

IV. SUMMARY AND CONCLUSIONS

In this study some physical, chemical and mineralogical properties of a sandy subsoil (Kalkaska-Bh) sample from Michigan and a clayey subsoil (Kent-Bt) sample from Michigan were compared with three pairs of surface and subsoil samples from the Greater Mussayib Project Area in Iraq.

Mechanical analysis showed the sandy subsoil from Michigan had a sand and the clayey subsoil had a clay texture, four of the six samples from Iraq had silty clay textures. The samples from the profile near Rashayid, Iraq, had a silty clay loam texture in the surface and a loam texture in the subsoil.

The results of mechanical analysis show that no downward movement of clay has taken place in any of the three Iraqi profiles. In contrast, from field studies the Kent-Bt horizon is known to be an horizon of clay accumulation in the Kent soil profile. The Kalkaska-Bh horizon is a subsoil horizon in which humus has accumulated and it contains little more clay than the overlying or underlying horizons (Bailey, 1957).

The finer textured soil samples contained much more water at the same tension than the coarse textured Kalkaska-Bh. This is due to the larger number of contact points and the larger area of particle surfaces in the finer textured samples as well as differences in the clay minerals present. The availability of soil moisture to the growing plants is usually estimated by the differences in moisture contents at field capacity and at the permanent wilting point. In this study the amount of water held at 1/3 atm. by the crushed finer textured samples is believed to be the best estimate of field capacity. However, for the Kalkaska-Bh sample a 0.05 atmosphere tension was used. The first wilting point, beyond which we would not wish to go when growing irrigated crops, is near 6.0 atmospheres tension as Stolzy (1954) has indicated. The permanent wilting point near 15 atmospheres would be a better measure of the low available water range under dry land conditions. On the basis of these premises the readily available and available water content of these samples were estimated for irrigated and dry land conditions.

The Kalkaska-Bh horizon had a higher bulk density than the fine textured disturbed samples. The finer textured soils contained about 50-55 percent total pore space and this is considered as a good condition for plant growth. Percent pore space based on bulk density and specific gravity is probably the most desirable method among those used for determining the pore space.

The chemical properties show that there is a distinct difference in reaction between the soils from the arid region (Iraq) which are alkaline and the soils from the humid region (Michigan) which are acid. None of the Iraqi soil samples contain as much organic matter as the subsoil samples from Michigan, but in general the organic matter content of all the samples is very low. Two of the Iraqi profiles contained slightly less nitrogen in the surface than in the subsoil. It is suggested that this may be due to denitrification and/or leaching of nitrate and their deposition in the subsoil.

There is a great difference in carbonate, gypsum, and chloride contents between Iraqi samples and Michigan samples. The Michigan soil samples contained no carbonates and very little gypsum and chloride, even though they were probably formed from material containing limestone. This is due to the fact that the free carbonates and more soluble salts have been removed by leaching in this humid climate as was also indicated by the pH values.

Electrical conductivity showed the Michigan soil samples and the Imam profile from Iraq had negligible salinity. On the soils from Kharbana and Rashayid, the yield of very sensitive crops may be restricted by the salt contents.

All Iraqi samples are higher in extractable sodium, potassium, calcium, magnesium and phosphorus than the Michigan samples, except the Kent-Bt horizon which showed higher potassium content than the Rashayid profile. The general idea is that for nearly all crops (except tobacco), and for all Iraqi samples and the Kent-Bt horizon, the present potassium content is sufficient. Lime fertilizers will never be required. Buringh reports (1960) that ammonium-sulfate and superphosphate are required in large quantities. The level of phosphorus in Iraqi samples indicated a level suitable for growing barley but additional P would be needed for vegetables and occasionally also for wheat and alfalfa. The Michigan soil samples have a medium level of phosphorus for barley, pasture, hay, oats, rye, and soy beans but would require additional phosphorus for other crops.

A comparison of the X-ray diffraction patterns of all clay samples studied shows that, kaolinite, chlorite, illite and montmorillonite are the main clay minerals in the Iraqi samples. Vermiculite, chlorite and kaolinite are present in small amounts in the Kalkaska-Bh horizon but much of this clay seems to be amorphous or non-crystalline. Illite, kaolinite and vermiculite are the main clay minerals in the Kent-Bt horizon. The Iraqi samples and the Kent-Bt horizon all contain some interstratified clay minerals containing montmorillonite and chlorite layers.

The combination of all the results of this study must lead to the conclusion that all of Greater Mussayib Project soil samples studied are fairly well suited for farming purposes unless they have some deficiency such as drainage which is affecting the value of the land.

V. BIBLIOGRAPHY

Bailey, H. H., Whiteside, E. P. and Erickson, A. E., 1957. Mineralogical composition of glacial materials as a factor in the morphology and genesis of some Podzol, Gray Wooded, Gray-Brown Podzolic, and Humic-Gley soils in Michigan. Soil Sci. Soc. Amer. Proc. 21: 433-441.

Baver, L. D., 1948. Soil Physics. John Wiley & Sons, Inc., New York. 3rd. ed.

Bennett, H. H., 1939. Soil conservation. McGraw-Hill Book Company, Inc. N.Y.

Booya, H. A., 1956. The nature of the saline (sabach) soils of Iraq and their desalinization. Unpub. M.S. Thesis, University of Arizona, Tuscon.

Bower, C. A., and Huss, R. B., 1948. Rapid conductometric method for estimating gypsum in soils. Soil Sci. 66: 199-204.

Buringh, P., 1957. Living conditions in the lower Mesopotamian plain in ancient times. Dept. of Agr., Baghdad, Iraq.

Buringh, P., 1960. Soils and soil conditions in Iraq. Printed in the Netherlands by H. Veenman & Zonen N. V., Wageingen.

Burnell, G. W., 1955. Report of the soil survey and soil classification Dujaila Project. Ministry of Agriculture. Baghdad, Iraq.

Campbell, R. B., Bower, C. A., and Richards, L. A., 1949. Change of electrical conductivity with temperature and the relation of osmotic pressure to E. C. and ion concentration for soil extracts. Soil Sci. Soc. Amer. Proc. (1948) 13: 66-69.

Chapman, G. W., 1949. Forestry in Iraq. Unasylva II, 5: 251-253.

Davies, D. H., 1957. Observation on land use in Iraq. Economic geography 33: 122-134.

Delver, I. P., 1960. Saline soils in the lower Mesopotamian plain. Minist. of Agri. of Iraq. Div. of Soils & Agri. Chem.

Dickman, S. R. and Bray, R. H., 1940. Colorimetric determination of phosphate. Ind. Eng. Chem. Anal. 12: 665-668.

Donahue, R. L., 1958. Soils an introduction to soils and plant growth. : 119-129. Prentice-Hall Inc., Englewood Cliffs, N.J.

Fisher, W. B., 1950. The Middle East, a physical, social and regional geography. London-New York. ed. 3, 1956.

Guest, E., 1932. Notes on trees and shrubs for lower Iraq. Dept. of Agr., Bul. 26. Baghdad.

Guest, E., 1933. Notes on plants and plant products with colloquial names in Iraq. Dept. of Agr., Bul. 27. Baghdad.

Guest, E., 1953. The Rustam Herbarium, Iraq. Part VI. Kew Bull. No. 3: 383-403.

Hooker, D., 1937. Useful plants and drugs of Iran and Iraq. Publ. of the Field Mus. of Nat. Hist. Bot. Sec. Vol. II, No. 3.

Jackson, M. L., 1958. Soil chemical analysis. Prentice-Hall, Inc., Englewood Cliffs, N. J.

Kelly, K. L. and Judd, D. B., 1955. The ISCC-NBS method of designating colors and a dictionary of color names. National Bureau of Standards, Circular 553.

Kilmer, V. J. and Alexander, L. T., 1949. Methods of making mechanical analysis of soils. Soil Sci. 68: 15-24.

Powers, W. L., 1954. Soil and land capabilities in Iraq, Economic Geography. 44: 373-380.

Richards, L. A. and United States Salinity Laboratory Staff, 1954. Diagnosis and improvement of saline and alkali soils. Agr. Handbook No. 60 U.S.D.A.

Russel, J. C., 1957. Soil salinity in Iraq. (Lecture)

Russell, E. J., and Russell, E. W., 1950. Soil conditions and plant growth. New York, London, Longmans, Green, and Co.

Shaw, B. T., 1952. Soil physical conditions and plant growth. Academic Press Inc., Publisher, New York, N.Y. pp 151-158.

Smith, J., 1944. Report on forests and forestry in the Northern Liwas of Iraq. Baghdad.

Springfield, H. W., 1954. Natural vegetation in Iraq. Ministry of Agr., Tech. Bul. Baghdad.

Stolzy, L. H., 1954. The effect of mechanical composition and clay mineral types on the moisture properties of soils. Unpublished Ph.D. Thesis, Michigan State University, 135 numbered leaves.

Tiske, C. H. and Subbarow, Y., 1925. The colorimetric determination of phosphorus. Jour. Biol. Chem. 66: 375-400.

Veihmeyer, F. J., and Hendrickson, A. H., 1948. The permanent wilting percentage as a reference for the measure of soil moisture. Trans. Am. Geophys. Union, 29: 887-896.

Whiteside, E. P., 1948. Preliminary x-ray study of loess deposits. Soil Sci. Soc. Am. Proc. 12: 415.

Zohary, M., 1940. Geobotanical analysis of the Syrian Desert, Palest. Journ. Bot. Ser. J. 46.

Zohary, M., 1950. The flora of Iraq, and its phytogeographical subdivision. Iraq Dept. Agr. Bull. No. 31.