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THE CHANGING PHYSICAL ENVIRONMENT OF THE HOPI INDIANS OF ARIZONA

BY

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Chapter II

THE INHABITANTS OF THE HOPI COUNTRY

THE HOPI RESERVATION

THE region now referred to as the Hopi Indian Reservation is an area of 780 square miles, surrounded by the Navaho Reservation which is 23,994 square miles in size. Their boundaries are indicated in fig. 1. A few years ago the Hopi Reservation was much larger. It extended northward as far as the northern part of Black Mesa and as far south as the Hopi Buttes. It included the Jeddito Valley and Howell Mesa, (see fig. 2). The Hopi did not occupy this large region, however, and confined their activities to a much smaller area. Accordingly new boundary lines were drawn, and the present Hopi Reservation boundary divides quite closely the spheres of activity of the Navaho and Hopi.

For administrative purposes, the Hopi Reservation as shown in fig. 1 is referred to as Land Management Unit No. 6 by the U. S. Soil Conservation Service. The statistics presented in the following pages refer to the area of this unit and are taken from a land planning report of the U. S. Soil Conservation Service for 1937.

The reservation is easily reached by a well-maintained, graded road from Holbrook, Arizona, about 90 miles to the south. Another road, less well-travelled, runs from Winslow to Polacca and another, farther west from Winslow to Oraibi. The main east-west road of the Navaho Reservation running from Window Rock to Tuba City passes through the Hopi Country.

POPULATION

The inhabitants of the Hopi Reservation number about 3,000. Probably over 100 of them are Navahos. Government officials and white employees, probably number about 100 also. The rest are Hopis.

The Indian Agency is at Keams Canyon, on the eastern edge of the Reservation. It contains a hospital, administrative offices and a boarding school. Day schools are located at Polacca, Toreva, Shimopovi, Oraibi, and Hotevilla, in or near main Hopi villages, and there is a High School at Oraibi.

There are only four trading posts in the reservation, but there are seven or more small stores operated by Hopis.

ECONOMY

The Hopi are primarily an agricultural people. Today they obtain a large income from other sources, which, however, are the result of new industries brought in by the white man or by the influence of the white man's economic world. The U. S. Soil Conservation Service estimates the division of income as follows:

TABLE COMPILED BY THE U. S. SOIL CONSERVATION SERVICE
INCOME (1937)

Item	Commercial		Non-Commercial	Total Income	Percent of Total	Approx. Per Cap. Annual Income
	Amount	Percent	Amount			
Wages	$164,301.84	72.18		$164,301.84	32.47	$53.10
Livestock*	40,275.78	17.69	$ 11,250.00	51,525.78	10.18	16.65
Agriculture	5,369.78	2.36	267,177.69	272,547.47	53.86	88.09
Woodland products	7,361.19	3.23		7,361.19	1.45	2.38
Rugs and blankets	6,056.05	2.66		6,056.05	1.20	1.96
Miscellaneous	4,279.66	1.88		4,279.66	.85	1.38
	$227,644.30	100.00	$278,427.69	$506,071.99	100.00	$163.56

* The non-commercial income from livestock is a round figure estimate.

Wages: The wages are primarily of government employees. $160,609.84 was paid to Hopis or residents of the Hopi country by the government. and $3,692.00 was paid in wages by traders. The wages were paid for various services, teaching and care of schools being the most important. Hospital work, road work, coal mining, sheep dipping etc. are other sources of wages: These activities are entirely foreign to the Hopi and introduced by the government. Thus this large source of income, which is paid out in turn for work which greatly benefits the Indians was completely lacking before the arrival of the Anglo-Americans.

Live stock: The live stock on the Hopi Reservation is divided as follows (1937):

Present Stocking (1937)

Sheep	11,202
Goats	317
Cattle	7,695
Burros and horses	5,085

These animals are grazed on the reservation throughout the year. At present they furnish ten percent of the income of the Hopi. About three fourths of this income is commercial, and derived from the sale of wool, meat, live animals, and pelts and hides.

The Hopi have had some live stock income ever since the introduction of domestic animals by the Spaniards in the sixteenth and seventeenth centuries. Before that time the only domestic animals which they had were turkeys and dogs, so that most of this source of income is of recent development.

Woodland products: Woodland products consist mostly of piñon nuts, gathered by the Hopis outside the Hopi Reservation. Some wood is used for fence posts, firewood, and building. Wood probably always has been used for firewood, and in building construction. Its value as a resource must have increased greatly, however, when the Spaniards introduced iron axes and beasts of burden making the gathering of wood less laborious. Before the arrival of the Spaniards the Hopi heated their houses with coal.[1]

Rugs and miscellaneous: Rugs and blankets and miscellaneous products, which include plaques, jewelry, baskets, and pottery account for about three percent of the income.[2] These items have always been a source of income, both commercial and non-commercial, for the Hopi today manufacture ceremonial garments which are sold to other Pueblo peoples. This relationship is a part of a long standing tradition.

[1] See Hack, 1942.

[2] This figure may include rugs woven by the Navaho Indians living within the Hopi Reservation.

[3] See Jones, 1936.

[4] Gregory, 1915b.

Agriculture: The remaining source of income is agriculture, which constitutes fifty-four percent of the total. Of the whole agricultural income of $272,547.47 only $5,369.00 or about 1 percent is considered commercial, and most of this amount consists of products sold to traders which are resold to Hopis.

Thus the largest source of income today is from agriculture. The remaining income is derived mostly from wages, paid for activities which are of recent introduction. The third largest source is derived from live stock, and introduced since the seventeenth century.

Manufactured goods such as pottery and rugs have always furnished some income but only an insignificant share of the total, and not enough to affect the real wealth of the Hopi. The introduction of live stock and of government activities and improvements, has certainly greatly increased the standard of living, for the commercial income derived from these sources is spent mostly for food and clothing which cannot be grown or made on the reservation. In the prehistoric Hopi economy the important item of clothing was an agricultural product, for the early Spanish explorers report many cotton fields among the Hopi farms.[3]

THE HOPI VILLAGES

There are twelve important Hopi villages. Moenkopi would make a thirteenth but lies outside the reservation and about 100 miles west of Hotevilla. It was settled in the 1870's by a group of emigrants at Oraibi who took advantage of the permanent water available in Moenkopi Canyon for irrigation. Gregory[4] has described the history and geography of this outpost village and it is not discussed here. The other Hopi villages are in the Hopi Reservation. One of them, Old Oraibi, has been inhabited at least since 1100 A.D. and thus claims to be the longest continuously occupied village in the United States. In 1906, Old Oraibi and New Oraibi together were the most important towns of the whole Hopi country, having a population of about 1,200. During 1906 a quarrel ended in the emigration of large numbers of the inhabitants who founded Hotevilla in 1906 and Bacobi in 1907. Hotevilla is now the largest of the Hopi villages, having about 420 inhabitants.

Polacca is also a recent development, having grown up at the foot of First Mesa in the latter part of the nineteenth century. Toreva is really not a Hopi town but contains a school and mission. The remaining six towns are all built on the ends of the projecting spurs of Black Mesa, and have all been founded since 1680.[5] The inhabitants before that time lived in villages below the mesa tops and apparently moved up on top after the Pueblo rebellion, perhaps in fear of the Spaniards. Hano is a village of Tewa Indians, whose ancestors moved over from the Rio Grande region at this same time or shortly thereafter.[6]

The Hopi are village dwellers, who are accustomed to change their ways, or their place of abode more slowly than their neighbors, the Navaho. Their homes are permanent structures, built of sandstone, with wood and mud roofs. The location of their dwellings is largely determined by their agricultural economy and by the water supply. The largest springs of the whole region are located near the mesa ends on the south side of Black Mesa, where the large quantities of sand on the mesa tops make good intake areas for the springs below.

Agriculture and especially flood irrigation leads to central locations for dwellings. The Hopi farms are located in the valleys and on the mesa sides, in every bit of land suitable for farming. Although fields are in many places far apart and some of the largest of them are on the most distant borders of the Hopi Reservation, centrally located permanent dwellings are desirable, for the position of fields change, and several fields are usually cultivated by the same family. Small farmhouses, near fields far from the central towns, are commonly occupied by individual families during small parts of the year.

EARLY HISTORY OF THE HOPI AND THE PEOPLE OF THE JEDDITO VALLEY

The history of the Hopi before the arrival of the Spaniards is known only from archaeological research. Other reports of the Peabody Museum Awatovi series will deal with this subject in detail. Agricultural peoples ancestral to the modern Hopi have occupied the region at least since Basketmaker III time (500–700 A.D.) and probably earlier. Ruins of villages and houses closely resembling those of the Hopi are found all over northeastern Arizona, and it is certain that the Hopi are the cultural descendants of a people who once occupied a much larger area. The cultures of the San Juan and Little Colorado areas are the most closely related.

The excavations of the Peabody Museum Awatovi Expedition were carried on in the Jeddito Valley region which lies on the eastern border of the Hopi Reservation. In addition to many small ruins, ruins of four large and several medium sized villages, which were occupied from about 1100 to 1500 or 1700 A.D., are found on the north side of the valley.

The Jeddito Valley ruins are so similar in construction to the modern towns and their environment is so similar, that although the valley is now occupied by Navahos it should geographically be considered a part of the Hopi country. One Hopi (Sequi) still lives near Jeddito Trading Post. He is a member of the Warrior Clan, and considers himself the guardian of the Hopis' right to the land of the region. His wife is a Navaho.

The history of the Hopi is undoubtedly affected by the relatively recent intrusion of the Navaho. It is not known how important this effect is or when it began to develop. It may be that the Navaho were an unimportant tribe in the Southwest until they obtained horses from the Spaniards. There is no evidence of the time of their arrival or of their importance in prehistoric time. They are first mentioned by Fray Alonzo Benavides, O. F. M., in his Memorial to the King of Spain written in 1630.[7]

CONCLUSION

Hopi economy except for recently introduced activities is primarily agricultural. Before the coming of the white man they must have depended entirely on their own resources for food, clothing and shelter.

Because of their dependence on agriculture, which is certainly practiced under great difficulties in this dry region, the Hopi are very much affected by changes in their environment, and the suitability of a region for habitation depends entirely on conditions of climate and physiography.

[5] Colton and Baxter, 1932.
[6] See Colton and Baxter, 1932, for other details.
[7] Franciscan Fathers, 1910.

Chapter III

THE PHYSICAL BASIS FOR HOPI AGRICULTURE

SEVERAL studies of primitive farming have been made which in a general way point to the conclusions presented here. Gregory[1] describes briefly the most important type of Hopi and Navaho farming, flood irrigation or flood-water farming. Bryan[2] made a more detailed study of flood-water farming and gave examples of its variations as practiced by Pueblos and Spaniards. Studies of the agriculture of the Hopis have been made by Hoover,[3] Clarke[3a] and Forde,[4] the last with emphasis on the sociological problems connected with farming. The reader is referred to these sources for other aspects of Hopi farming.

The present study deals only with the physiographic aspects of farming. Owing to lack of rainfall to produce either good soil or enough water for farming as the Anglo-American practices it, the prime problem of the Hopi farmer is that of watering his crops. The fields may thus be classified on the basis of their water supply which, in turn, depends largely on the physiographic position of the field.

The success of the present study is in large part due to the excellent maps and agronomy surveys of the U. S. Soil Conservation Service. Much data obtained by this bureau was generously loaned to the writer and is used freely in the following pages.

CROPS

The principal food of the Hopi is corn. This is used in many different ways. It is ground into meal and made into bread, mush, or the delicacy, *piki*. It is eaten on the cob, or made into hominy and used in stew. Fruit crops are also important. They may be dried or stored for a long time like corn. They are principally peaches, melons, apricots, and apples. In addition a few grapes are grown. Beans, which are grown in abundance, are also an important crop. There are a few irrigated gardens in which small crops of onions, tomatoes, squash, cabbages, carrots, tobacco, chili, corn, apples, peaches, and other plants are grown. These crops, though of small amount, are probably of importance in Hopi diet and ritual. The table below shows the percentage of total farmland devoted to the production of these various plants.

Percent of Total Area of Farmland Devoted to Various Crops

Crop	Percent
Corn	72.0
Peaches	8.9
Apples	1.5
Apricots	2.8
Melons	2.6
Beans	8.7
Garden	.1
Idle	2.8

Some of the plants now grown, notably peaches, and many garden plants have been introduced since Spanish time.[5] In considering the crops of ancient farmers, cotton must be considered as one of the important plants, even though it is not grown in large quantity today. At the time of the coming of the Spaniards it was probably next to corn in importance, and apparently was planted in the same kind of fields.[6]

RELATION OF AGRICULTURE TO CLIMATE

Problems of Climate

As was shown in Chapter I, the Hopi country has a rainfall of only 10 to 13 inches. Spring is the driest time of the year, and is characterized by strong, sand-moving winds. The growing season is about 130 days, a period short enough to permit considerable damage from frost.

These difficulties are met by the use of crop plants specially adapted to the region, by special crop practices and by the location of fields in physiographic positions which permit the concentration and conservation of water.

Special Plants

Hopi corn is a variety well adapted to the

[1] Gregory, 1916, p. 103.
[2] Bryan, 1929b.
[3] Hoover, 1930.
[3a] Clarke, 1928.
[4] Forde, 1931.
[5] Whiting, 1939.
[6] Jones, 1936.

severity of the climate. It is planted about 10 to 15 inches in the ground to a depth at which moisture is held in the sandy soil. Ordinary corn cannot be planted deeper than 3 to 5 inches. When full grown, Hopi corn reaches a height of only 3 or 4 feet except in exceptional cases.[7] This deep planting allows the plant to gain moisture during the dry spring and helps protect it from very late frosts. Some moisture is stored in the subsoil in the proper locations throughout the dry spring.

In prehistoric time the Hopi made their clothing from cotton, which they raised in the Hopi country.[8] The growing of cotton has now ceased almost entirely except for a small amount for ceremonial purposes, but at one time cotton was grown in flood-water fields in the same position as corn. It is a special variety known as *Gossypium hopii*, which can apparently be grown far outside the normal range of other varieties.

Other crop plants as far as known are similar to varieties grown in other parts of the world. Many varieties of the adaptable bean are found in the Hopi country. Several plants such as peaches, apples, carrots, onions, have been introduced by Europeans, and thrive under the farming practices of the Hopi.

The Problem of Frost

The growing season in the Hopi country has a length of about 130 days. This period might be adequate in wetter regions but in the Hopi country crops are often lost because of damage by frost. This is partly because the water supply is scanty and the crop matures slowly. An unusually long spring drought may require a new planting during the summer, with increased danger of frost damage in the fall. The Hopi usually begin planting corn about the 15th of April.[9] Only a small amount is planted at this time. It is intended to be harvested at the end of July and roasted while still green for use in a festival known as the *Nimankatcina*. The writer has observed that many of the fields in which early corn is grown are located in narrow gullies on steep slopes where the nocturnal radiation of heat from the gully walls protects the plants from frost. About the first of May some watermelon and squash are planted. But the main planting of corn does not take place until the middle of May or about the time of the last killing frost. It lasts until the summer solstice (June 21). Each family will have certain planting dates set aside which cover the whole of this planting period. This spread in planting dates may provide for the loss of early corn due to a late frost in June when the crop may be replanted, or for the loss of late corn due to an early frost in the fall.

The harvesting of the corn planted in April takes place at the end of July, a period of about 100 days from the time of planting. This corn is still green and is roasted as part of the *Nimankatcina* festival. The main harvest begins about the 25th of September, 130 days after the beginning of the main planting. By this time a frost has often already occurred.

The dates of planting and the growing season for a twenty-two year period averaged from the records at Keams Canyon and Jeddito are indicated diagrammatically in fig. 9. The planting dates used are those given by Forde[10] and apply only to First and Second Mesa, whereas the climatic records are taken from points about 15 miles to the east. Planting dates at Third Mesa, in the western portion of the Hopi country may be somewhat different. The diagram is only a rough indicator of the relation of the planting dates to the frost-free season, but it clearly shows that the growing season available is little longer than the season necessary to ripen corn and be assured of good crops.

Rainfall

A mean annual precipitation of only 11 or 12 inches such as characterizes the Hopi country is not sufficient to grow corn without special methods. Flood-water farming is necessary and is the dominant type of agriculture in the region. Small rains, such as are of frequent occurrence, may not even wet the ground and it probably takes a rain of .20 or .30 inch to cause an arroyo to run. It is only these rains which are of value for crop production.

Because the rainfall of each day nearly always occurs in a single storm of short duration, it is possible to use the daily rainfall records as a measure of the amounts of rain which fall in single storms. The analysis of rainfall concentration can be shown in several ways. One of the most obvious is shown in fig. 10. Here are shown

[7] Collins, 1914.
[8] Jones, 1936.
[9] Forde, 1931.
[10] Forde, 1931.

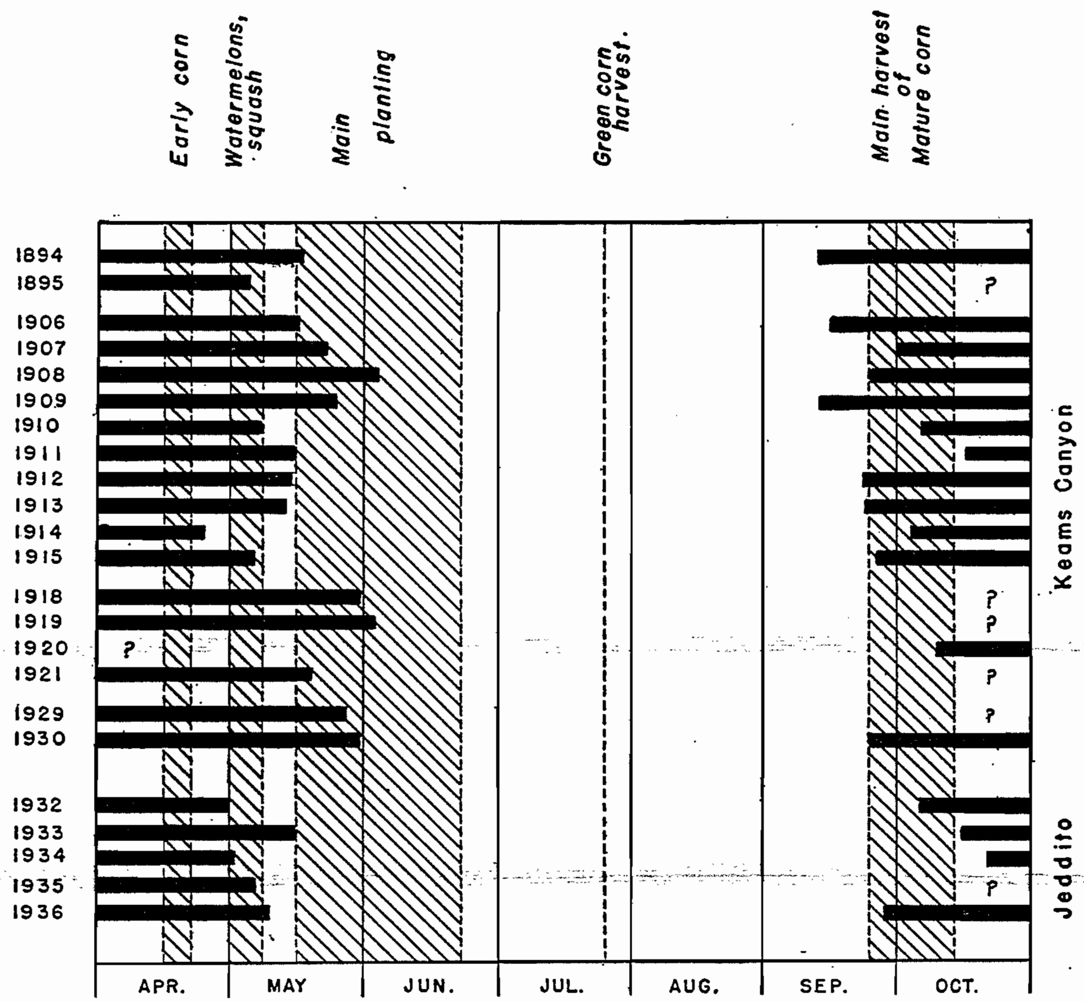

FIG. 9. Relation of planting dates at First Mesa (after Forde, 1931) to the length of the frost-free season at Jeddito and Keams Canyon. The black bars represent periods during which frost occurs. Shaded areas are times of planting and harvest.

the number of days each year on which rain of different amounts fell at Jeddito in the period 1935–1937. There were only four days when more than 1 inch of rain fell and they were all in the summer. On the other hand more light rains occur in winter than in summer. In summer probably only thirty days out of this 3-year interval have had sufficient rain to cause arroyos to run and thus to water the fields. This is an average of ten days a summer. The yearly means from a three year record at Jeddito and a ten year record at Kayenta, of the total amount of rain which falls in storms of over .30 inch during each month are shown in fig. 11. The totals are a measure of the moisture effective for the watering of fields and available each month. This diagram also shows that this effective rainfall is most concentrated in the summer months. Note that there is twice as much effective rainfall at Jeddito as there is at Kayenta.

But flood-water farming does not depend on the absolute amount of precipitation available. It depends on location so that a sufficient frequency of floods occurs. Thus a field might be located in a region where the frequency of heavy rains is very low, but might receive water from a drainage area where the frequency of heavy rains is very high. Most of the fields in the Hopi country

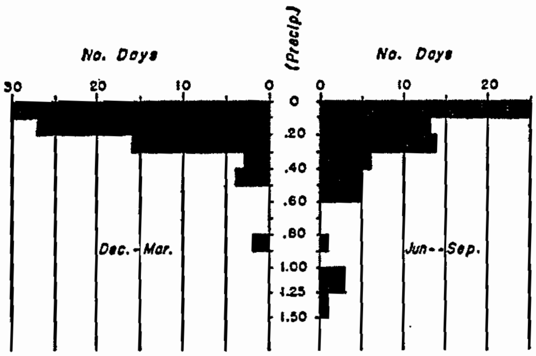

FIG. 10. Diagram showing the sizes of storms in which rain has fallen in the winter and summer seasons, for a period of three years, at Jeddito Trading Post. Each bar represents the number of days on which precipitation of the amount shown in the vertical column has occurred. Note that large rains are not frequent, and are more common in the summer than in the winter.

are now located on very short arroyos, but there are many areas of fields in the Navaho country which are in dry regions or even in desert regions and have a distant source of flood-waters in more humid areas.

CLIMATIC ZONES AND AGRICULTURAL ZONES

One of the reasons why the Hopi country is now inhabited by an agricultural people is because it lies in the local climatic zone which is most suitable for agriculture. It was shown on page 7 that in the Navaho country, which surrounds the smaller Hopi country, the mean precipitation increases with altitude and the length of the growing season decreases with altitude. It is obvious that in regions with very low precipitation agriculture can hardly be practiced at all, and in regions of the highest rainfall, the growing season is too short. The Hopi country lies in the zone which has 10 to 12 inches of precipitation, which, as shown by fig. 3, is the favorite zone for farming. Dense farming areas outside of this zone are located either along very large streams like the Little Colorado River, or where springs are abundant as along the Echo Cliffs. Thus the Navaho country can be divided into zones of agriculture, related to zones of climate.

The Chuska Mountains and portions of the Defiance Plateau rise above the elevation at which the growing season is generally shorter than 120 days. Much of the area of Black Mesa which rises to an elevation of 7,500 feet or more probably has a growing season shorter than that suitable for corn. The length of the growing season is thus a factor limiting the type of agriculture practiced by the Navaho and Hopi Indians. In this connection it might be argued that the corn grows more rapidly in regions of higher precipitation. Although this may be true to some extent, the critical period in the growth of the plant is the

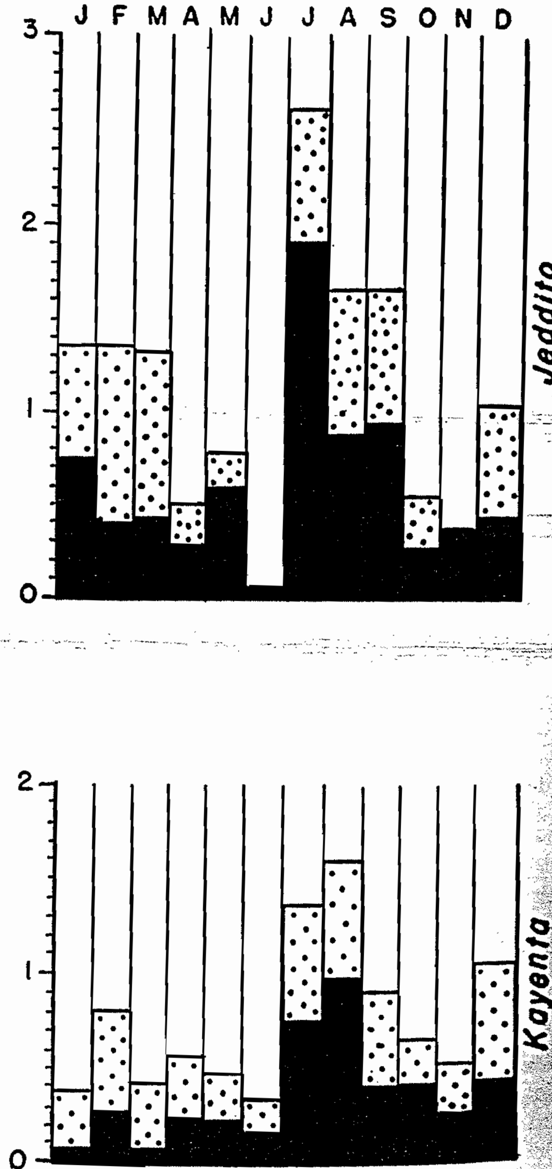

FIG. 11. Average monthly precipitation at Jeddito (3 year period) and Kayenta (10 year period). The black bars represent the average amount of precipitation which falls in storms of over .30 inches.

June dry season. All the stations have a very low precipitation in this month and the average annual frequency of June rain is only one day greater at Flagstaff, the wettest station, than at Keams Canyon.

Thus there must be a zone in the Navaho country in the highest areas, and in the areas of greatest precipitation, in which corn cannot be grown. The lower limit of this zone is probably defined by the 16 or 18 inch rainfall isohyet. Below this isohyet, the growing season is long enough for the growing of corn, although the zone at which corn crops are relatively safe from frost must be considerably below the 16 inch isohyet. Throughout the lower areas, free from danger of frost, the agriculture is limited by lack of rainfall or by the small frequency of rains of sufficient magnitude to flood the fields.

Flood-water farming is practiced throughout the Navaho country, but in the areas with the highest rainfall, the fields are located on smaller arroyos than they are in the areas with lower rainfall. In the driest regions only the largest water courses, like the Little Colorado River, or the Chinle Wash, which head in areas of great rain frequency will support agriculture. Thus in the 10–12 inch rainfall zone (fig. 3) the fields are scattered over the country, between the main water courses, as in the Hopi country. Lower down in the drier regions, the fields, which are few, cluster along the main water courses. The Tuba City area appears to be anomalous. Fields in this very dry region are irrigated by permanent streams or by springs which appear in the Moenkopi Canyon, and along the base of Echo Cliffs.

Thus the farming in the Navaho country may theoretically be divided into four zones which depend entirely on climate.

1) Zone of no corn production and scant farms in which precipitation is over 16–18 inches, and the growing season is shorter than 110 to 120 days.

2) Zone of precarious flood-water farming in which precipitation is over 12 inches and less than 16 to 18 inches, and the growing season is longer than 120 days.

3) Main zone of flood-water farming (on small arroyos) in which precipitation is over 9 to 10 inches and less than 12 to 13 inches, and the growing season is adequate.

4) Lower zone of flood-water farming in desert regions (on main water courses), in which the rainfall is less than 9 inches, and the growing season is adequate. Farming in this zone is precarious because of the difficulty of protecting fields from powerful floods.

This theory of zonal distribution of agricultural practices is derived primarily from analysis of the climate. However it may be checked by consideration of the map in fig. 12 which shows the location of fields of the principal crops. This map is a reduction of the agronomic maps made by the U. S. Soil Conservation Service in their census of 1937. Three administrative districts extending from the northeast end of Black Mesa (Elev. 7,500 feet) to the Little Colorado River (Elev. about 4,150 feet at Leupp) are included. The maps include the entire drainage areas of the two largest Tusayan Washes, the Polacca and the Oraibi. District 5 is the driest of the three districts and is occupied by Navaho Indians (Pop. 1,212–1.0 per square mile). District 6 is occupied mostly by Hopis (Pop. 2,779–3.6 per square mile), and District 4 on Black Mesa is inhabited almost entirely by Navahos (Pop. 2,422–1.6 per square mile).

At the headwaters of the Tusayan Washes there are few fields, and the crops are principally oats, potatoes and alfalfa. No corn is grown in the fields having the highest altitudes. This is the climatic zone in which corn cannot be grown because of the short growing season. Further down toward Piñon, the number of fields increases, and corn, beans, and melons, which are the principal crops of both Hopi and Navaho predominate. In this region the main streams are entrenched in the alluvium of the narrow canyons of Black Mesa and fields are planted mostly on the floors of small tributary canyons at the ends of short gullies or water courses.

In District 6 the fields are relatively dense. Here they are located mostly at the ends of shallow arroyos of somewhat greater length than those utilized in the area to the north. The much greater concentration of fields in this region is of course due in part to the fact that its population has an agricultural economy whereas the inhabitants of District 4 are primarily stock raisers. However this reasoning may be reversed. The Hopi, as the first comers, undoubtedly chose to inhabit District 6 because it is a more favorable place for agriculture than Districts 4 or 5.

In District 5 there are almost no fields. According to the theory of agricultural zones, and according to Gregory's map (see fig. 3) there should be fields scattered along the course of the

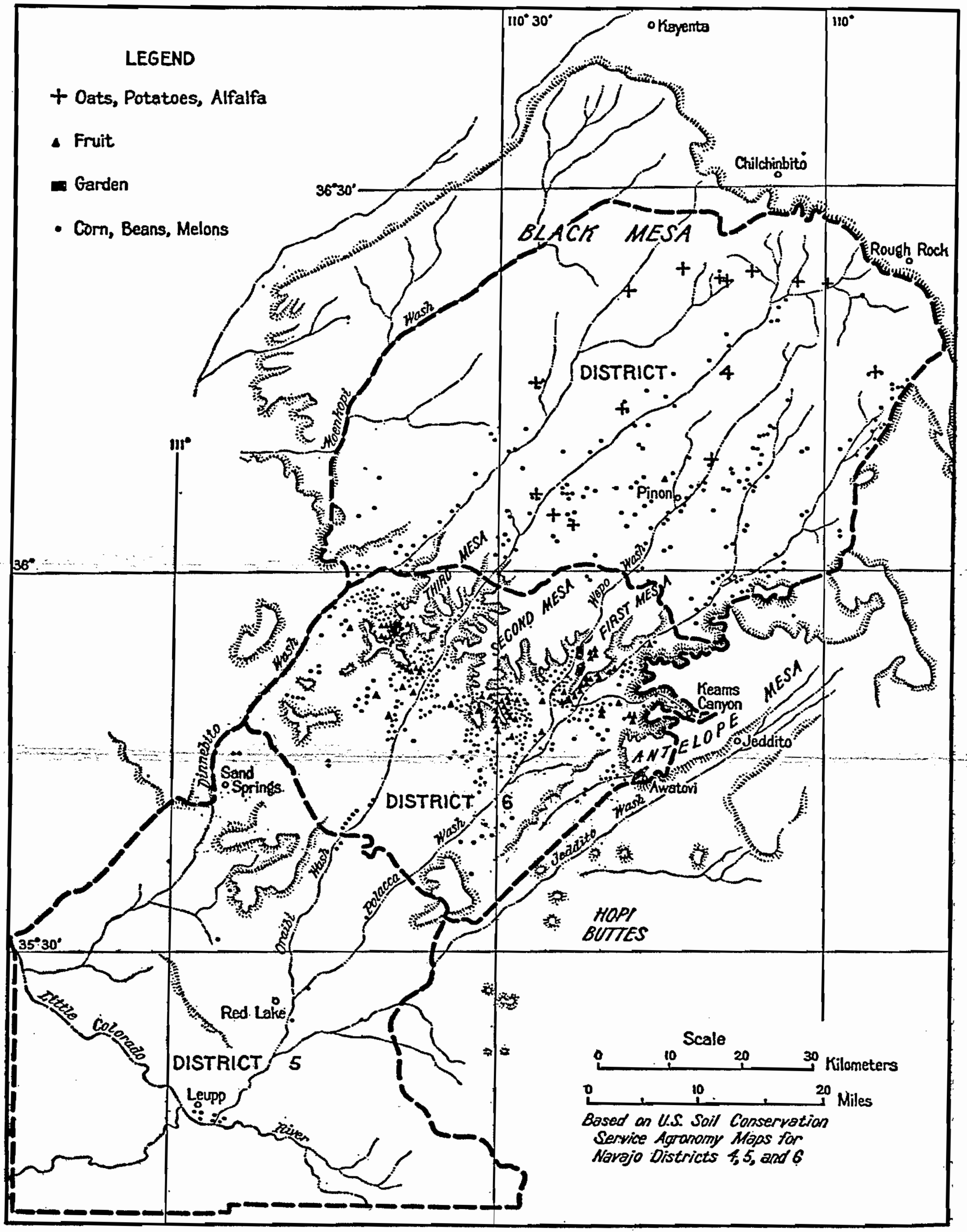

FIG. 12. Map of the drainage basins of the Tusayan Washes, including Navaho Land Management Units 4, 5 and 6. Shows the zoning of agricultural crops from low, warm and dry areas (along the Little Colorado River), to high cold and wet areas, where crops which mature quickly are most common.

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Little Colorado River. Most of the fields in this district are located near Leupp in a government planned irrigation project. Mr. J. W. Bush of Dilkon Trading Post informed the writer that at one time fields were located along the Little Colorado, but were unsatisfactory because of frequent destruction by large floods. Colton[11] has shown that in 1880 the stream bed of the Little Colorado River was much narrower than it is now, and contained a well-regulated perennial stream. Cottonwood grew in abundance on its banks, and pools and stream were inhabited by beavers.

The map of the agriculture in these three districts (fig. 12) bears out the idea of zoning of agriculture in the Navaho country. The Hopi country is in the most favorable zone where the growing season is adequate, and where the rainfall is sufficient to permit the location of fields over a larger portion of the region than in the lower zones. Even in the Hopi country less than 3 percent of the area is actually farmed. Fig. 3 shows that there are many portions of the zone of favorable climate (rainfall 9 to 13 inches) in which there are few fields and in which the population is small. Thus the favorability of the Hopi country is dependent on some factor other than climate. This factor is its physiography, for it is characterized by wide, frequently flooded valleys and the presence of unusually large quantities of wind-blown sand both of which increase the supply of ground-water available both to plants and to man.

SOILS

The agricultural soils of the Hopi country are almost entirely transported. Fields are usually located in areas of soil accumulation so that almost no soils in which crops are grown ever have a chance to develop profiles. The usual classification of soils is thus of little significance for Hopi agriculture. In a general way they are classified as follows:

- I. Soils transported by water (alluvial soils)
  - A. Clayey soils—apt to be alkaline
  - B. Sandy soils—well drained
- II. Soils derived by slope wash on steep mesa sides (colluvial soils)—are gravelly, sandy or clayey
- III. Soils transported by the wind (eolian soils)
  - A. Active dunes
  - B. Ancient dunes, usually containing caliche.

[11] Colton, 1937.

Soils transported by water are the most important class because fields irrigated by flood waters are planted on this type. Such soils may be entirely clayey silt, sand or loam, with all transitions between, depending on the source of the material transported. The more clayey soils are apt to be alkaline because they cannot be well drained in every location, for flood waters are apt to be ponded on them and, not being able to sink into the ground, dry up and deposit salts. There are areas in the Hopi country, otherwise ideally situated for farming, where there are no fields because of a clayey soil and poor drainage. The clay flat at the Naha well in the Jeddito valley may be such an area. The soils in the Oraibi Valley and in the Polacca Valley are generally more clayey than those in the Dinnebito or Jeddito Valleys, probably because the Mancos shale supplies more of the debris of the Polacca and Oraibi Washes. The upper portion of the Jeddito Valley contains only areas of sandy rocks and therefore the soils of the valley are sandy and porous.

A few farms are found on the steep mesa edges or on benches of mesas where soil composed of dune sand, blocks of debris, pottery fragments, trash and weathered shale, has collected by slope wash. These soils are very variable in texture but are relatively porous.

The greater part of the Hopi country is underlain by sandy soils transported by the wind. Wind-blown sand mantles all the interstream divides as well as the mesa edges and mesa tops. The dunes covering the lower plateaus of the southern three quarters of the Hopi Reservation are mostly very ancient and now fixed by vegetation. This is true of the dunes far back on the mesa tops. The sand of these areas has been subjected to weathering for several thousands of years and on this account has developed thin films of caliche around the sand grains. In some places rainwash has altered and subdued the form of the dunes and concentrated the finer material in hollows and low places. But few fields are planted in these areas and the soil type is of minor economic importance.

Close to the mesa edges and around the foot of the mesas fresh dune sand is piled up in many large dunes, either active now or partially fixed. The soils of these dunes contain very little material not classified as sand. Fields are commonly placed on such dune sand because of its great waterholding capacity.

CLASSIFICATION OF FIELDS

The Hopi apparently have an excellent practical knowledge of the action of physiographic processes, for the position of their fields is closely related to the concentration of surface runoff and the flow of ground water. Fields on dunes are located in the proper place so as to take full advantage of the moisture available in them, and the position and construction of the wind breaks attest to the Hopi's knowledge of eolian processes.

Fields are first classified on the basis of their water supply, which in turn depends upon their physiographic position. There are four main classes which may be further subdivided on the basis of position or type of soil:

- I. Fields watered by surface runoff (flood-water farming)
  1. Akchin fields (at arroyo mouth)
  2. On floodplains of large streams
  3. On flood terraces of large arroyos
  4. In bottoms of small arroyos
  5. Trinchera fields (on artificial terraces in drainage ways)
  6. Watered by hillside wash (probably not found in Hopi country)
- II. Fields watered by rainfall
  1. Sand dune agriculture—sandy soil
  2. In alluvial and other soils (in higher parts of Navaho country)
- III. Fields watered by underground seepage (seepage fields)
  1. In dune sand
  2. In colluvial soils
  3. In dune hollows
- IV. Irrigated fields (usually in colluvial and alluvial soils)
  1. Irrigated by diversion of permanent streams (not found in Hopi Reservation but common at Moenkopi)
  2. Irrigated from springs

Of the four main types of water supply, fields watered by surface runoff are most important. Flood-water farming is the main agricultural practice and about 73 percent of the cultivated land is farmed in this way. The remaining 27 percent is mostly farmed by the use of sand dune agriculture, a form of "dry" farming. Seepage fields and irrigated gardens occupy only a small part of the land. Only 11 acres in District 6 (Hopi Reservation) are watered by springs but this small acreage is of very large value both because the crop is somewhat more desirable, and because it is free or almost free of risk of loss.

FLOOD-WATER FARMING

General Statement

On ordinary farms of the eastern United States, crops are watered by the rain that actually falls on the field and by the moisture that is stored in the ground between rains, but the rainfall in the Hopi country is inadequate for such farming. In flood-water farming the crops are watered by the runoff of an area much larger than the area actually cultivated. The moisture is stored in the soil between floods and provides a constant water supply for the plants except during long droughts. Flood-water fields are thus always located in a water course or adjacent to a water course, in such a position that during a flood large quantities of water will pass over the field, but not so rapidly as to wash out the crop. In the Hopi country the water courses are dry arroyos or washes which flow after every large rain in their drainage area, but which are dry between rains. On the watersheds of such streams, light falls of rain or heavy rains sink rapidly into the ground. When after continued rain the upper layers become saturated, runoff begins and the intricate network of runnels, gullies, arroyos, and washes begins to carry more and more water as muddy spates or floods. The peak flood in a large arroyo in the Hopi country occurs some time after the beginning of the rain and water will flow for several hours after the rain ceases because of the excess of water that has seeped into the ground. The larger washes may flow for several days after a heavy rain. A field located so as to catch part of the flood of an arroyo will thus receive a larger quantity of water and be soaked for a much longer time than any piece of ground not in a water course or on a floodplain.

Akchin Fields

The most common location for a flood-water field in the Hopi country is on an arroyo of intermediate size at its so-called mouth or at the place where there ceases to be a channel and the water spreads. An arroyo starts its course on steep slopes, where the quantity of water flowing with great velocity erodes its walls and banks. Further down the stream gradient flattens and the load of silt being carried in the water increases. Finally a point is reached where the stream can no longer erode but must deposit its load. Here the channel ceases rather abuptly and a shallow fan is built up, over which the water spreads. This is the

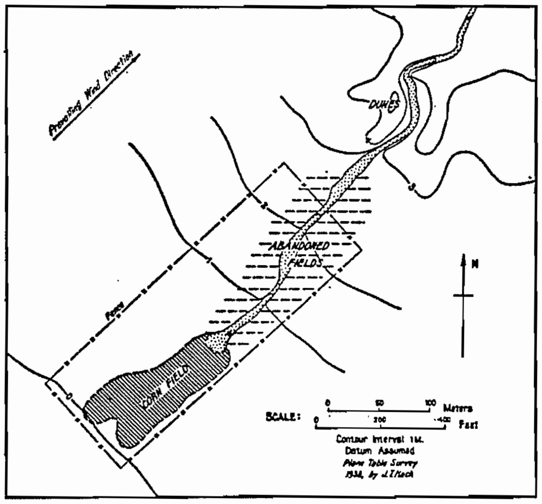

Fig. 14. Cultivated akchin field in the Tallahogan Valley.

arroyo mouth, called the "akchin" by the Papago Indians and accepted as a technical term by Bryan.[12] The akchin is a favored place for the location of a field because the runoff of the entire watershed of the arroyo, which has been concentrated in the stream channel, spreads out naturally over a relatively smooth surface without the aid of artificial spreading.

Many akchin fields are shown on the map, fig. 13. At present this is by far the most common type of field in the Hopi country. Their relative number would be strikingly shown on the map had the minor watercourses been indicated. The akchin of an arroyo is not a fixed location, because its position depends upon the ratio of the velocity of the flowing water to the relative volume of debris carried. In one flood the critical point at which deposition occurs may be downstream from the similar point for another flood. The result is that the alluvial fan produced by one flood may be channelled by the next and a new fan will form below. Thus the akchin is really an elongate area which is subject to channelling and may change its shape from one flood period to the next. Sometimes it may even be that the whole akchin will move upstream or downstream.

Fig. 14 shows an akchin field which has changed its position and which is located on a shallow alluvial fan. The field was formerly higher upstream. The map also shows the effect of the wind. High dunes are located just above the akchin where sand has collected after being blown off the field. Fields are ideal areas for the wind to pick up sand, for in order to farm, the fields must be cleared of shrubs and weeds, and since there is a wide space between plants the wind has a clean sweep. This sand is an important factor in the prevention of channelling of the akchin and also it tends to maintain it in a stable position since it hinders the eroding work of the floods.

Fig. 15 shows a typical Hopi farm. The house in the center of the farm is occupied by the farmer and his family during the growing season, for the location is about 8 miles from Sichomovi where he lives during the largest part of the year. The small arroyo on the left waters a melon patch, where a small earthen dike or spreader is set up at the top part of the akchin artificially to prevent channelling or washing out of the crop during floods. The cornfield on the right of the farm is watered by a much larger arroyo. The course of the floodwater across the field is in part controlled by the labor of the farmer who aids in spreading the water by digging channels to areas that are in danger of being left dry. One can see the Hopi farmers out working in the fields during almost every flood of the growing season. Sometimes water will be diverted to each plant individually if there is danger from drought. A fence now surrounds the field. Vegetation grows along its edge and the wind and water tend to pile up debris along it. The result is a ridge of sand two or three feet high, at the north end of the field. Even without a fence, sand piles up into a ridge at the lower end of the field if the wind blows in the right direction, for this is the limit of the cleared land and the wind is apt to scour out the sandy alluvial soil of the akchin and blow it off the cleared area onto the more thickly overgrown areas just surrounding it. Such a ridge of sand of course helps to stabilize the position of the field and to hold the water for a longer period of time. Such ridges are so common that abandoned fields may be located by them. In airplane photographs they produce a rectilinear criss-cross pattern on the ground where there have been many fields with changing positions. The action of the wind as well as the artificial spreaders of the farmer have the effect of hindering changes in the stream gradient. Thus akchin farming in no way favors the cutting of arroyos but in fact it rather has a tendency to prevent it.

[12] Bryan, 1929b.

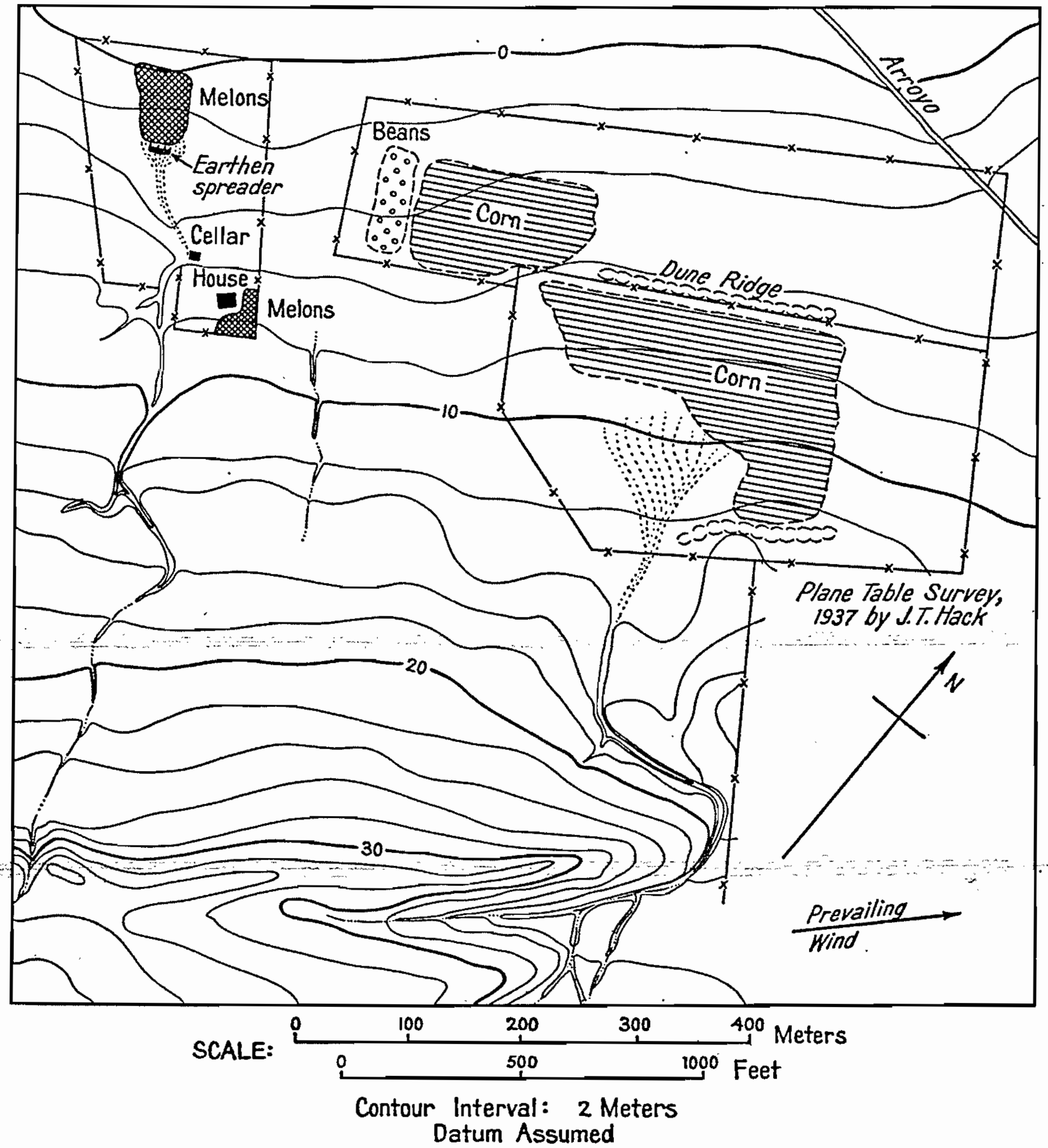

Fig. 15. A typical group of fields of the akchin type, worked by one Hopi, in the Tallahogan Valley.

Fields Located on Floodplains of Streams

Another common location for fields is a position along the course of a shallow arroyo where the water will spread over a wide area during a flood. Shallow arroyos like the Tallahogan Wash vary considerably in depth along their courses and in some places are so shallow that the water can easily be diverted by earthen spreaders. A field located in such a position is in reality an akchin field even though the arroyo on which it is located is a large one and continues as such below the field.

Before the present cycle of arroyo cutting began (in 1900 in the Oraibi Valley and in 1910? in the Polacca Valley) many fields were located along the main streams. The Indians at Oraibi are said to have farmed by the use of the floodwaters of the main stream of the Oraibi Valley and to have had large spreaders and ditches which con-

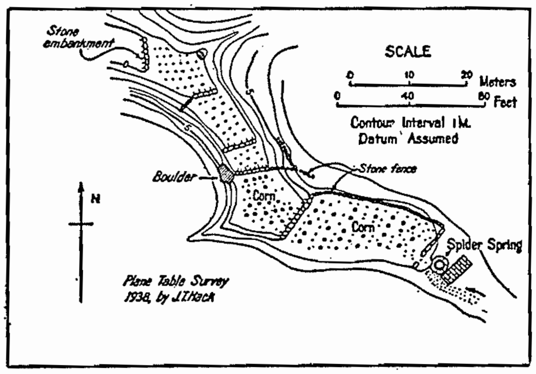

FIG. 16. Trinchera field in an arroyo tributary to the Wepo Wash, below the village of Hano. The gully walls are rock.

trolled the course of the floods. (see page 58). At the present time the Tallahogan Wash is the only wash of large size which is now shallow enough to flood its banks, and it does so only in small portions of its course.

Many farms which are adjacent to the Polacca Wash are visible in fig. 13. These are all akchin fields watered by tributaries of the Polacca which have never cut through the alluvium. Some of these tributaries are quite large and water many fields. If the present cycle of erosion continues and headward cutting proceeds from the main arroyo channels, eventually these akchin fields will be destroyed. In a long enough period of time all the tributary streams will be graded to the main streams and incised.

Fields on Low Flood Terraces of Large Arroyos

Most of the large arroyos of the Hopi country have low but wide terraces in them, which are usually about 10 to 15 feet above the stream bed. These terraces form just below the level of the highest floods, and represent the new floodplains which are beginning to form above the stream beds of the incised arroyos by lateral migration of the streams. These terraces or incipient flood plains are thus overspread during all large floods. In lesser floods they are moistened by underground seepage of water. They are favored locations for cornfields, many of which are seen on the flood terraces of the Oraibi Wash. They have the disadvantage of being subject to destruction by violent floods.

Fields in the Bottoms of Arroyos

Fields are occasionally planted in the bottoms of arroyos. These situations, like fields on terraces in arroyos, are subject to the danger of being washed away during a flood. Accordingly only arroyos which have small drainage areas are suitable.

Trinchera Fields

A field in a small arroyo bottom can be greatly improved and made relatively safe from violent floods by building stone dams across the arroyo, making a series of terraces, called trinchera plots. The term, trinchera, has been used to describe terraces constructed of stone work on hillsides in Mexico.[13] Ordinarily trincheras are thought of as extending around a hillside. In the Hopi country trincheras are located principally in small arroyos on mesa sides and are constructed for the purpose of holding soil and controlling the course of floodwaters. Some trincheras, or terraces built of stone, are found on hillsides in irrigated gardens, and are described on page 37.

Fig. 16 shows a typical trinchera field at Spider Spring below the village of Hano. A rock-walled gully cutting through a steeply inclined landslide block is dammed in several places by small checks made with piles of small sandstone blocks and brush, making several flat, even terraces. Corn is the crop planted in these situations, which is nearly always of "early" type. It is planted in April, long before the date of the last killing frost in Spring, and is harvested in July. These localities in narrow gullies with steep gradients are likely to be frost free on cold nights as there is always a good circulation of air in a gully, and nocturnal radiation from the bare rock gully walls should help warm the plants. It is believed that the Hopi go to a great deal of trouble to make such gullies suitable for planting, because of the value of the early corn crop, which is associated with feasts and celebration.

Fields Watered by Slope Wash

Bryan describes fields watered simply by slope wash at the break in slope on a valley side.[14] Such fields have not been observed in the Hopi country, probably because the valley sides are usually underlain by a very sandy alluvium or by dune sand, which banks up against the sandstone cliffs. There is little runoff from such material. The

[13] Sauer and Brand, 1931.

[14] Bryan, 1929b.

runoff comes principally from the mesa walls themselves and flows in the arroyo courses to the point where it spreads out at the akchins on the valley floor.

Relation of Cultivated Areas to Watersheds

With the exception of the type cited above, all flood-water fields depend on the concentration of the runoff of a much larger area than that of the field itself. This volume of water, having been concentrated, must again be spread out evenly enough and gently enough so as not to wash out the plants. Where the runoff of a large watershed is concentrated a large field can be placed. Where the watershed is small, the field must be small. Actually there seems to be in the Hopi country a fairly constant ratio between the size of fields and the watersheds which supply them. Several fields and watersheds are shown in fig. 17. In these fields the area farmed is between 3 to 6 percent of the area of the whole drainage basin. The ratio varies considerably because of differences in amount of runoff from one watershed to another. Runoff from sandy watersheds is less than from those that are mostly bare shale slopes. In the whole Hopi country the area cultivated by flood-water farming is less than 2 percent of the total area. About one half of the area is either flat mesa top or low plateau surface covered with old dunes and therefore has almost no runoff. Thus actually about 3 to 4 percent of the area on which runoff takes place can be said to be cultivated. This figure is comparable to the percentage arrived at from fig. 17.

The main streams of the Hopi country, whose watersheds are principally on Black Mesa are now deeply incised. Before this dissection occurred the runoff of an area many times larger than the Hopi country was brought into the Hopi country and there spread over the flood plains of its master streams. In other words the farm land of the Hopi country was watered not only by the runoff from land within its own boundaries but also by the runoff from the upper drainage basins of the Tusayan Washes. Thus the area which could be farmed must have been much larger than it is today. The effect of the recent epicycle of erosion has been not only to reduce the amount of flood-water farming, but to shift the position of fields from the floodplains of large streams to the akchins of tributary streams. Inasmuch as the Hopi country is characterized by unusually broad valleys, which contain many streams tributary to the main through-flowing streams or washes, the effect of arroyo cutting is less devastating to its agricultural inhabitants than in other areas where farmers are dependent solely on the flood-water of the main streams.

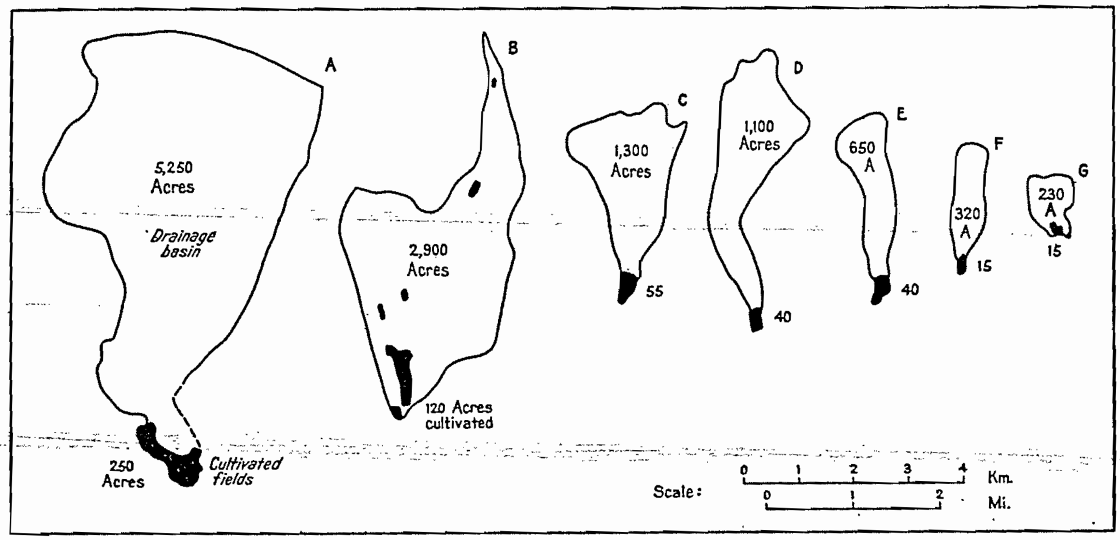

Fig. 17. Relationship between areas of cultivated akchin fields and the areas of the watersheds which supply them with water.

SAND DUNE AGRICULTURE

Principles

Fields on the bare sandy areas of mesa tops and mesa slopes are second in area to flood-water fields. There is no obvious source of moisture for these fields except that which falls as rain. On less porous soils, rainfall alone is inadequate as a source of moisture, but it is apparent that crops can be grown in dune sand, owing to its superiority as a storage reservoir for moisture. There are several sub-types of this sand dune agriculture all of which depend on the ability of the highly porous sand to store and conserve moisture. By far the most common situation of sand dune fields is where a more or less thin cover of dune sand (one half to three feet thick) rests on a less pervious sub soil, which being on a mesa top or mesa side is probably colluvial, derived by rainwash and slope wash. Many Hopi fields are known to be planted on a thin cover of sand. When abandoned the sand is blown away and reveals the thicker colluvial soil or bare rock below.

Colton[15] has compared Indian farming on sand with the well-known "dry farming" as developed and practiced in the Great Plains. In this method of farming penetration of moisture into the soil is promoted and the moisture obtained is conserved. The essential procedure is to treat the top soil differently from the lower layers of the soil. The land is plowed deeply and thus loosened at depth. Plowing is followed by light packing of the surface and then by deep planting. After each rain the top layer of the soil is harrowed to produce a dry mulch which invites penetration of rain and prevents evaporation of the soil moisture below. In Hopi sand dune agriculture, the loose surface of the sand acts as a dry mulch which invites the absorption of rain and which also prevents evaporation. So far as penetration of moisture is concerned the sand is more effective than the dust mulch of the "dry farming" method, as it is well known that there is no runoff from dune sand even in the heaviest rains. Furthermore only a thin layer of the sand dries out and the sand below will remain saturated for a long time by the water held up by the less pervious soil below.

Many sand dune fields are planted on large climbing dunes or steep dune covered slopes of a mesa, where the sand must be thick. A common position for fields is near the base of these climbing dunes. Here water may be supplied by underground seepage from the upper dune slopes, so that some of the fields in these positions may come under the heading of seepage fields.

Some sand dune fields, however, seem to require some other source of moisture to start plant growth. Fields on the lower slopes of the mesa walls, in many places seem to be planted on dune sand which is perhaps much over 10 feet thick. Ground water must be present at depth in these dunes and it can probably be reached by the roots of mature plants. It is doubtful, however, that this ground water is available to young plants. In sand the size of that of the Hopi country, water probably does not rise more than 3 feet above the water table because of capillary action, and it is not likely that the water table is within 3 feet of the surface in all dunes on which crops are planted.

Studies of moisture in dune sand have been made in the Kara-kum desert of Turkestan, an area with a climate similar to the Hopi country, by Doubiansky.[16] His observations show that below a surface of shifting sand where ground water is present at depth there is always a zone of moisture (2 or 3 percent) at a depth of 40 to 120 centimeters. Even though this zone of moisture is underlain by dry sand, it persists throughout the dry season, and is available for use by plants.

Doubiansky calls this the sub-superficial moisture horizon. He believes that moisture is concentrated at this shallow depth because diurnal changes of temperature in the sand cause condensation of the vapor evaporated from the ground water at great depth.

It may be that there is a sub-superficial horizon of moisture in the dunes of the Hopi country which aids the growth of the young plants during the dry spring.

Thus the sand dune fields depend on the conservation of moisture by the superficial layer of dry shifting sand, and the prevention of runoff. There must be some soil moisture in the sand to start plant growth, but even so growth is probably not possible if the depth to the capillary fringe above the water table or to a heavier clayey soil, is too great for the plant roots to reach it.

Crop Practices

Many crops are planted in sand dune fields. The most conspicuous crop near the Hopi towns is peaches, a crop introduced by the Spaniards. Apricots and apples are also found in these fields,

[15] Colton, 1932, p. 588.
[16] Doubiansky, 1928, p. 238.

but the most important sand dune crop is certainly beans. Although corn is the staple Hopi food, in areas where sand dune agriculture is practiced beans seem to be more abundant than corn. Much corn is also grown by this method, however. Melons, an important item in Hopi food supply, are almost entirely confined to flood-water fields.

An explanation may be found for this selection of crops in the root habits of the plants. Melons are conspicuously absent from sand dune fields. This is probably because they have long, branching lateral roots, adapted only to feed on soil moisture and have no deep roots to reach water at depth.[17] Beans have long branching roots and are very efficient in utilizing soil water, more so than corn. They also have deep roots which may go to some depth for ground water.[18] They thus may be better adapted to this type of situation than corn, for they may get their start by utilizing the scant soil moisture, and when grown penetrate the zone of saturation at depth, or the capillary fringe above it. Corn, peaches, and other fruits also have deep roots.

Sand dune fields are the only type which leave clues by which the archaeologist may recognize the places where they once existed, for elaborate stone work is used in these fields, to protect the plants from damage by blowing sand. The principal disadvantage of this type of dry farming is that in order to conserve the moisture in the dunes, a large area around the fields must be cleared of natural vegetation. This leaves the crop plants completely exposed to the wind, which is most violent in the spring when the tender young plants are just coming to the surface. Also the dune sand is looser and easier for the wind to move than the siltier sand of the flood-water fields. Elaborate methods must thus be used to protect the plants from being torn to shreds. In fields not greatly exposed, as on rolling mesa tops, large stones or tin cans are placed around each plant. On exposed slopes more extensive measures must be undertaken. Many of the fields are located on a thin sand mantle resting on less pervious soil or bed rock, and the sand itself is in danger of being swept away, when cleared for planting. To hold it, lines of brush are placed in rows about 2 to 5 meters apart. The brush is held in place by heavy stones which become buried by the sand leaving only the brush projecting from 1 to 3 feet above

[17] Weaver and Bruner, 1927.
[18] Weaver and Bruner, 1927.

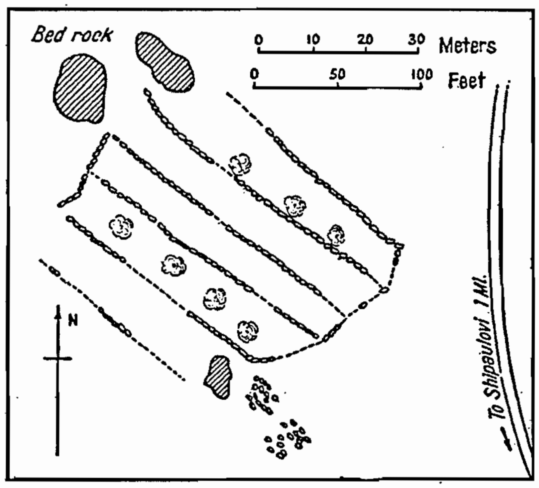

Fig. 18. Abandoned apple orchard of the sand dune type on Second Mesa, near the village of Shipaulovi. This map shows the use of lines of stones to keep the sand from blowing away (see pl. VIa). These stones once held down lines of brush, which are now destroyed.

the sand. When a field thus protected is abandoned, the brush gradually rots or is cut away by moving sand and eventually the whole area is blown clear of sand leaving only the lines of stones as evidence of the former existence of a field. On Second Mesa an abandoned apple orchard was found with most of the sand blown away, but with rotten brush still piled up under the parallel rows of stones (fig. 18, and pl. VIa). Ancient lines of stones were found in abundance in the Jeddito Valley. They are described in Chapter VI.

Favorite Locations

Sand dune fields are probably most common on the mesa walls where the cover of dune sand on colluvial soil is thin, or near the base of great climbing or falling dunes banked up against the mesa sides. Another common location is on ancient dunes on the mesa tops which have been cleared of vegetation and kept from becoming active either by the use of wind breaks, or by leaving large uncleared areas between. Sand dune agriculture is not practiced in areas of active dunes.

The largest development of this kind of agriculture is at the village of Hotevilla where according to U. S. Soil Conservation statistics (1937) over 60 percent of the cultivated land is watered by rainfall only, and thus is farmed by the method of sand dune agriculture. This figure is in great contrast to the figure for the whole Hopi coun-

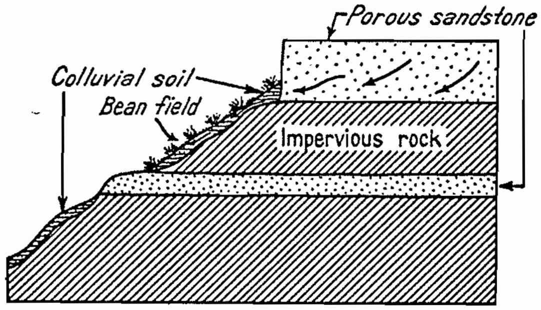

Fig. 19. Cross section of a seepage field below Old Oraibi on the east side of Third Mesa (see pl. VIc).

try, in which less than 27 percent of the land is watered by rainfall only. The inhabitants of Hotevilla are unique in preferring this kind of agriculture. It is a particularly favorable place for it, however, because dune sand has here banked up against the side of the mesa and many good sites for fields are available near the town. At Hotevilla beans equal corn in importance as food, probably due to the fact that this type of farming is better suited to beans. Such variation from the usual practice of Hopi farming may aid in the explanation of the quarrel at Oraibi which ended in the migration of a portion of its inhabitants to Hotevilla and the founding of that town, in the year 1906.[19] In 1893 the inhabitants of Oraibi diverted water from the main Oraibi wash for flood-water farming. By 1902 the wash was 10 or 12 feet deep and 20 to 30 feet wide; by 1905 it was deeply entrenched.[20] In 1906 the quarrel at Oraibi culminated in the migration to Hotevilla, a place where the inhabitants do not depend so much on flood-water farming. It may be that one of the underlying causes for the split at Oraibi was the crowding of farmers, as one field after another was destroyed by the cutting of the wash. Three informants (White, Hubbell, Nequatewa) assured the writer that no quarrel over land holdings was involved but the coincidence in time with the cutting of the wash is circumstantial evidence which should not be ignored. It may have been largely responsible for causing unrest and dissension which led to a quarrel over an entirely different matter.

FIELDS ON COLLUVIAL SOIL WATERED BY RAINFALL ONLY

In regions of higher rainfall it is possible to farm on more clayey alluvial soils, or colluvial soils, without making use of the concentrated runoff of a larger area. Several such "dry" farms have been seen by the writer on the Defiance Plateau in the zone of yellow pine, where the mean annual precipitation is over 16 inches. But these fields suffer from a short growing season. None are found in the Hopi country.

[19] Colton and Baxter, 1932, p. 46.
[20] Communication with Mr. Lorenzo Hubbell.
[21] Brunhes, 1920.

SEEPAGE FIELDS

Seepage fields like the irrigated fields depend for their water supply on reservoirs of ground water. In the Hopi country the principal springs are found close to the mesa tops along the base of the massive sandstone cap rock. Between the few springs water constantly seeps out, and in many places at this level abundant vegetation grows in the moist soil. The base of the massive sandstone is thus a favored place for a field if there is any colluvial soil available under it. A few small fields of this type are found in the Hopi country as illustrated in fig. 19, and pl. VIc, but the occurrence of colluvial soil at this horizon is rare. Dune sand, however, frequently covers the edge of the mesa and is kept moist by the underground seepage of water. Fields in dune sand are very common at this horizon. Naturally such a water supply is more reliable than rainfall alone. It is thought that many of the peach orchards on the steep sandy slopes of First Mesa are watered by ground water issuing from the cap rock of the mesa. Actually it is often impossible to distinguish a field of this type from a "dry" sand dune field.

In the often cited oases of the Sahara Desert, groves of date palms are grown in the underground water supply available in the dune hollows.[21] Farming in dune hollows is done on a smaller scale in the Hopi country, but the principal is the same. Seeps are of common occurrence in dune hollows (see fig. 6), and in the dunes of First Mesa this occurrence of ground water is utilized for agriculture.

IRRIGATION

General

There are two kinds of irrigation practiced by the Hopi. At Moenkopi, which is a distant outpost of the Hopi country, not in the reservation, the Indians irrigate the alluvial floor of Moenkopi canyon by diverting the water of the wash, which

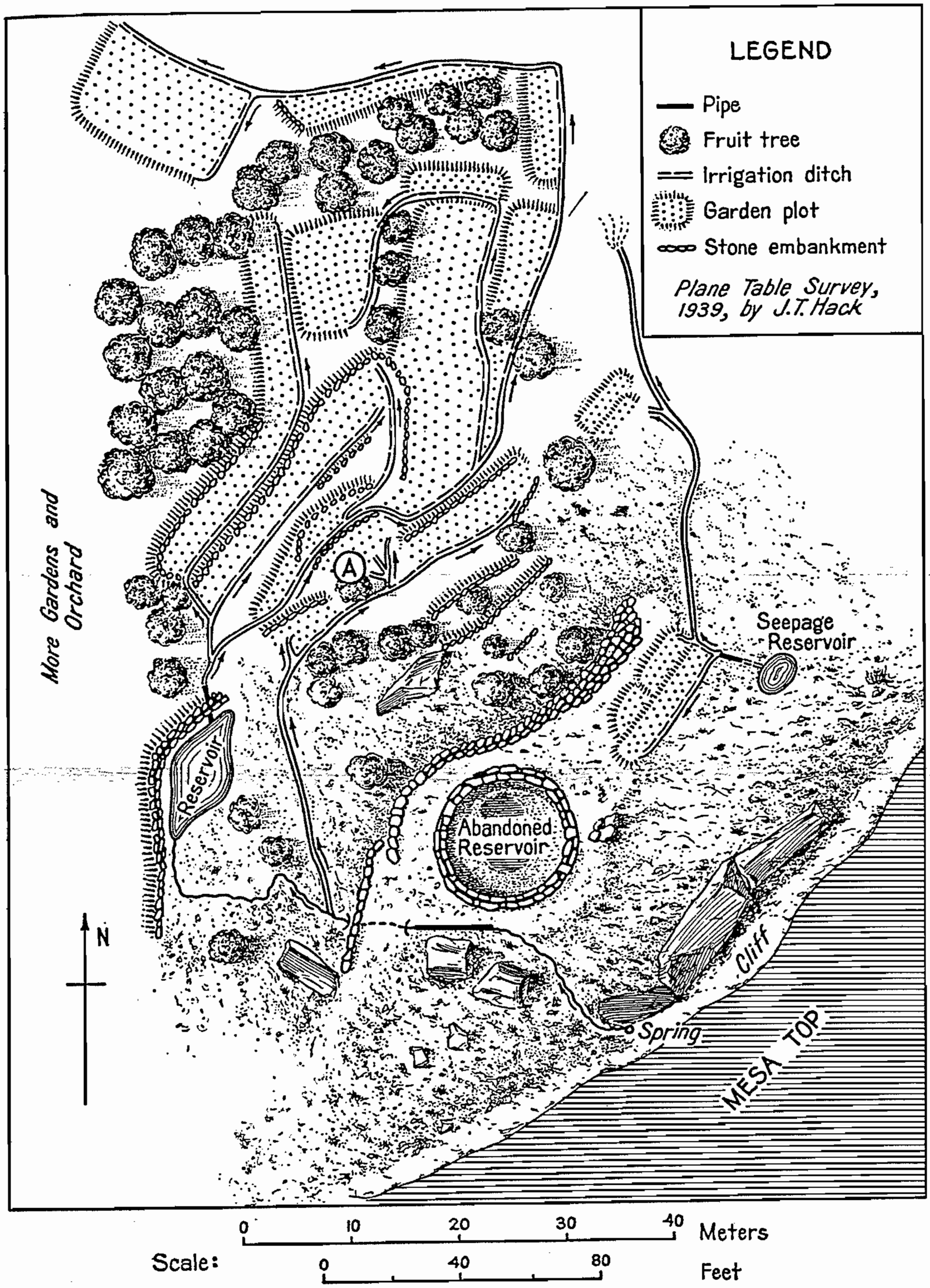

Fig. 20. Sketch map of a portion of the irrigated gardens in Tallahogan Canyon, north of the ruin of Awatovi, showing the method of watering.

is a permanent stream having an average discharge of about 10 second feet. The water is run into long supply ditches along the base of the canyon wall, and from there it is fed to field laterals at regular intervals and spread over the fields, which are planted on a low, but wide alluvial terrace on the canyon floor. Corn is the principal crop. For a more complete description see Gregory's study of this area.[22]

In the Hopi country itself, there is no large supply of permanent water and what little there is is derived from springs. The largest spring used for irrigation is the Wepo Spring on First Mesa (fig. 8) which has a flow of over 30 gallons a minute. Other large Springs are Tallahogan (5–10 gallons a minute), Canelva, and Hotevilla Spring. These are all mesa springs high on the mesa side. The water is conserved in a small reservoir, and from there fed when needed to the fields below by means of small ditches. All together there are only eleven acres of land thus irrigated. Nevertheless the irrigated land is of importance to the Hopi. The great labor expended in watering by this means justifies the planting of only the most desirable delicacies. The most abundant plants are squash, corn, turnips, carrots, cabbage, onions, chile, peaches, apricots, and apples. In addition many rarer plants are grown mixed with the others, such as tobacco and cotton for ceremonial purposes, and plants used for vegetable dyes.

Only clayey alluvial soils are suitable for garden areas. Sand is too porous and does not permit the water to run down the surface of the ground from the spring to the field. Thus nearly all the irrigated gardens are on steep slopes high on the mesa sides, in areas more or less free of sand.

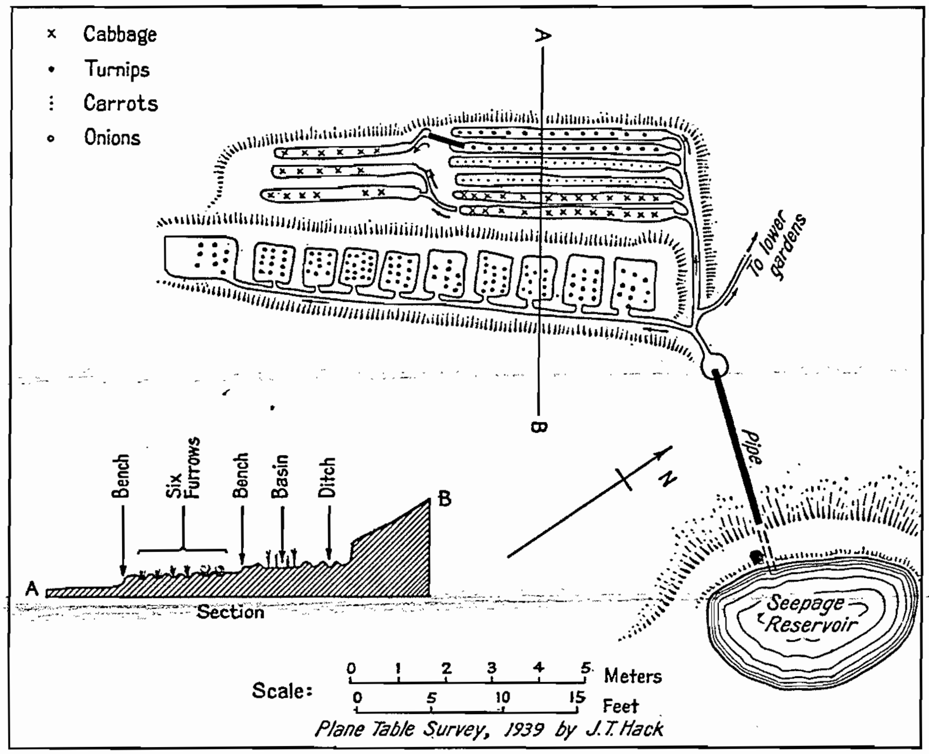

FIG. 21. Map and cross section of a single garden plot in the Tallahogan gardens. Each living plant is shown.

The Tallahogan Gardens as an Example of the Method of Watering

The gardens at Tallahogan Canyon close to Awatovi, are quite similar to the other gardens and serve as a typical example. They occupy a small area, but probably have over 25 owners, and contain numerous garden plots. On the south side of Tallahogan Canyon rather large springs break out in several places near the top of the

[22] Gregory, 1915b.

valley wall. Though dune sand covers much of this wall there are areas of colluvial soil watered by springs on which crops are planted. A portion of such an area is shown in fig. 20 (see also pls. VId and VII). The spring breaks out at the base of a sandstone cliff, about 25 feet high. The water runs down a steep slope in a little brooklet, surrounded by a thick growth of fragrant mint, to a small pool where it is caught and diverted to a pipe, which serves as a water fountain for the inhabitants of the houses nearby. In recent years a large stone reservoir was built just below the spring but it did not hold water and had to be abandoned. It still collects a little water, however, which seeps into the ground and waters the peach trees below by underground seepage. The main flow of water runs from the pipe into a tunnel in a stone terrace, and down to a cruder but more effective earth and stone reservoir. From there the distribution of the water through the gardens begins. A pipe taps the reservoir and can be stopped up when irrigation is not going on. The other end of the pipe feeds a small supply ditch about 6 inches wide and 4 inches deep which runs down to the various fields. Diversion to the proper place is carried out by damming the ditches and openings, not to be used, with stones and mud. The water is carefully guided by each owner, by means of these little artificial runnels and tiny earthen dams, to each plant around which one can see patches of wet ground after irrigation (pl. VIIIa). Apples, peaches and apricots are planted between the irrigated garden plots, and on the steep hillside below the reservoirs. They are watered by the moisture which seeps into the ground from the channels, basins, and furrows of the gardens, for no drainage is provided. The water must escape through the porous soil.

The method of watering each garden plot is shown more clearly in fig. 21, which is a map of the garden plot to the northeast of the abandoned reservoir. This plot is fed by its own reservoir. There is no flowing spring here, but the reservoir is dug just below the level of seeps on the mesa wall and is kept full of water by underground seepage. As in the main reservoir a pipe leads to a supply ditch. Two kinds of irrigation are illustrated. The upper level of the garden represents the basin system, in which water is diverted to square, shallow basins individually. The onions planted here are allowed to soak in the water until it seeps into the ground. When not being flooded the entrance to each basin is closed by a dam of stones and mud. The lower garden or terrace represents a similar system in which the crops are planted in the bottoms of large furrows rather than basins.

Onions, cabbage, turnips, carrots, and chile are usually planted in regular basins and furrows as in fig. 21. Corn and squash frequently is watered in areas between, by individual runnels as at A, fig. 20. Tobacco and probably other rare plants are grown by scattering seeds, and watered by the excess water that escapes from basins and furrows.

Terraces

As shown in fig. 20 the Tallahogan gardens contain many artificial terraces, or trincheras, which unlike the trincheras of flood-water fields are placed on the hillsides. The purpose of the terraces is obviously to provide roomy flat areas on the steep hillsides on which the crops can be planted in basins and furrows and fed with water from supply ditches. On steep hillsides the terraces are built of sandstone blocks. Such terraces average about 3 feet in height but may be as high as 10 feet. Lower down on flatter areas, earthen terraces are sufficient.

Such stone work is used throughout the Hopi country wherever this type of agriculture is practiced. At Hotevilla many closely huddled and picturesque stone terraces cling to the precipitous mesa wall directly beneath the village. They support lush-looking gardens, and make this place a favorite one for tourist visits.

The Question of Spanish Origin

One of the most important questions in regard to this system of farming is whether or not it is of pre-Spanish origin. No stone work has been seen by the writer anywhere in the Jeddito Valley region (inhabited by the Hopi before Spanish time) which could be identified as the remains of such gardens. On the other hand it is possible but rather improbable that large enough springs have occurred only where they are now. Cruder types of irrigation without the use of stone embankments may have been practiced, which would leave no trace of their existence. There are now only eleven acres of these gardens in the Hopi country which furnish only delicacies and rare plants, many of which were unknown to the Hopi before the coming of the Spaniards. The native plants here cultivated and not now grown in other types of fields, such as cotton and tobacco, probably could have been grown in flood-water fields.

CONCLUSION

Certain types of farming are used for special crops. Thus laborious terracing of gullies on mesa sides is undertaken probably to protect early corn from frost. Irrigation from springs is a more reliable way of farming and does not depend on the vicissitudes of the weather. It is laborious, however, and can be undertaken only in small areas, and is therefore reserved for specialized crops, such as carrots, onions, etc.

But by far the most important type of farming in the Hopi country is flood-water farming. Of this type, farming in akchin fields is the most common. Because the Oraibi, Dinnebito, Wepo, and Polacca Washes have become deeply entrenched since 1900, their floodwaters nowhere in the Hopi country can spread over the land surface. Before 1900, therefore, the area available for flood-water farming was much greater than it is today. Farming on main water courses may at that time have been more common than farming on the akchins of small arroyos. The effect of arroyo cutting has been to lower the acreage of agricultural land, and also to shift the position of farms from main arroyos to akchins of small arroyos. If the present cycle of erosion continues for a long enough time, trenching of arroyos and destruction of akchins may cause one watershed after another to be lost as a source of water supply for farming. At present the only watersheds of importance which are trenched, with the exception of the Keams Canyon Wash, are those of the main Tusayan Washes.

Another type of farming which is of great importance is sand dune agriculture, a form of "dry" farming which is not affected by the conditions of deposition and erosion in the valleys. In times of erosion, when flood-water farming is not possible in as many places as in more favorable times, sand dune agriculture may be relied upon as a surer means of obtaining crops. Thus at Hotevilla sand dune agriculture is now actually more important than flood-water farming. The abundant dune sand of the Hopi country is thus as important in watering crops as it is in providing springs. In addition to this contribution to the welfare of the inhabitants, the abundant wind blown sand makes the alluvium and the alluvial soil more sandy than in other parts of the Navaho country. This makes for better drainage, and prevents arroyo cutting from being as damaging as it is where there are fewer dunes.