A STUDY OF THE COSTS AND EFFECTS OF IRRIGATION IN THE PLANNING AND IMPLEMENTATION OF THE LAJAS VALLEY AGRICULTURAL DEVELOPMENT PROGRAMME

Project A-024-PR

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ABSTRACT

The present study was carried out in the course of the fiscal year 1969-1970 in the southwest area of Puerto Rico, better known as the Lajas Valley.

The irrigation project established in the area is the result of the combined efforts of various agencies, both State and Federal. Among the agencies which collaborated in the development of this project and which are still continuing to offer their services in the area, are the following: The Puerto Rico Department of Agriculture, The Agricultural Experiment Station of the University of Puerto Rico, The Federal Soil Conservation Service, The State Planning Board, The Puerto Rico Water Resources Authority and the Agricultural Extension Service of the University of Puerto Rico.

The first deliveries of water were made in August, 1955, and by the economic year 1969-1970 142 farmers had been admitted to the system. In this same year there were 256 properties under irrigation, totalling 19,242.0 acres.

The primary object of the present study was to investigate and analyze certain factors which, it was presumed, were affecting the cost of irrigation in the agricultural development of the farms. A further aim was to prove that the high cost of irrigation was determining the agricultural pattern and limiting the diversification of crops in the Lajas Valley.

The factors analyzed, as responsible for the high cost of irrigation were the following:

(1) the water available for irrigation;

(2) the topography of the farms;

(3) the types of soil;

(4) the methods of irrigation employed;

(5) the administrative aspects of the system;

(6) the structural amenities of the farms;

(7) the maintenance of irrigation and drainage structures;

(8) the size of the agricultural unit;

(9) the deployment of the land and

(10) the handling of water on the farms.

Other problems studied were: the low consumption of water; the various items which enter into the cost of irrigation; the low production per acre of sugar cane; the social and economic factors inherent to the farmer and farming; an evaluation of the services offered by some agencies; agricultural diversification and the opinions of the experts on this matter and an evaluation of the agricultural development of the area in general.

Thirty percent (30%) of the farms under irrigation (256 in all) were included in the study. These farms were classified according to their topography and the method of irrigation used. There are 51 level farms irrigated by gravity, while 59 of the farms are irrigated by pumping and 147 use combined methods of irrigation. From these, 77 farms were selected for the research to be undertaken. The study set out to prove the hypothesis that the high cost of irrigation has a negative effect on production and the diversification of crops, and that as a result changes are necessary in the agricultural programme for the Lajas Valley. It was proved that the cost of irrigation is a significant factor in production. Irrigation is costly, in particular the labour which it involves. The farmers frequently require considerable sums of money to meet the irrigational needs of their farms. In relation to this, this study encountered another factor affecting the consumption of irrigation water and, as a result,

the operational costs of irrigation. This is the inadequate financing which exists for agricultural operations in the area. The lack of economic resources seems to be the reason why many farmers find themselves obliged to use water from other sources, such as the drainage canals, gulches and streams present in the area.

The author, in agreement with the qualified authorities who have studied the agricultural situation in the Lajas Valley, is of the opinion that the area should not be dedicated to a single crop, as it is at present to sugar cane. Nevertheless, the study proved that agricultural diversification has to contend with a number of adverse factors. According to the data obtained, however, diversified agricultural development could be viable and may be achieved, even with high irrigation costs, if the following factors are controlled: the problem of marketing; inadequate financing; the limited amount of irrigation at certain periods of the year and, above all, if there is a change in public policy towards the solution of these problems in the Valley.

The study shows that among the factors investigated, the following are those which exercise the most significant influence on the cost of irrigation operations:

(1) the topography of the farms;

(2) the administrative aspects of the system;

(3) the methods of irrigation used and

(4) the size of the agricultural unit.

Another factor encountered during field research which is also responsible for the high cost of irrigation in the system is the lack of amenities for storing water. Those in charge of opening and closing the sluices cannot be on all the farms that ask for water at the same time. This means that some outlets are opened earlier and some later. The same is true when they are closed. The loss of time resulting from this

system causes unnecessary expenses in labour, thus increasing the cost of irrigational operations. This occurs most frequently on small farms, which in the majority of cases lack storage pools. These amenities facilitate the distribution of water to the property and at the same time limit the loss of water through a greater control of irrigation.

As is mentioned above, this study analyzes the different items of expense that enter into agricultural land under irrigation. In the analysis the costs of irrigation are specifically detailed according to the method of irrigation employed. This study also presents an analysis of outlay and income in the production of sugar cane, and compares the outlay and income of the farms which made use of irrigation during 1969-1970 with those that did not.

Apart from the other agronomic practices which are responsible for the development of the cane sown, the data obtained in this study show that the low yield per acre stems from the fact that the farmer does not use the quantity of water demanded by the physiological needs of the plant during its period of growth.

This work is divided into six chapters, in which the author attempts an exhaustive analysis of the data obtained from the research carried out during this study.

ACKNOWLEDGEMENT

The author is indebted to a variety of sources too numerous for individual mention, but appropriate recognition has been made in the footnotes.

Specific mention should be made of the graduate student in Public Administration, Mr. Carlos J. Perez, for his valuable contribution in the collection, assembly and analysis of the data.

I am under great obligation to Prof. Ernesto F. Colón, former Director of the Water Resources Research Institute, whose administrative support made this study possible.

All erros of commission or omission are, of course, the author's sole responsibility.

I- INTRODUCTION

The Lajas Valley is situated in the extreme Southwest of Puerto Rico. It comprises an area of 102,609 acres, or approximately 160 square miles.[1]

The Valley extends from the Bay of Boquerón in the West of the Island to the Bay of Guanica in the South. In the North it is bordered by a range of low hills which separate it from the Guanajibo River. In the South it is bounded by a strip of coastal land which stretches from Guanica to the extreme Western point of the Island.

The elevation of the terrain in the Lajas Valley varies between sea level in the Southeastern section and heights up to 900 feet in the North.

The mean rainfall is about 34 inches per year, varying between 30 inches along the Southeastern coast and 42 inches on the extreme Northern edge of the Valley[2] (See map No. 1). This amount of rainfall appears relatively high compared to other arid land under irrigation, especially in the Western States of the United States. However, factors such as constant wind, high evaporation, low humidity and high temperatures, account for the semi-arid character of the area.

Another factor of the first importance is the distribution of rainfall throughout year. The rainy season covers a short period lasting from August to November, with the highest rainfall occurring in September and October, as is shown in Table 1.* With the exception of the month of May when rainfall is plentiful, during the other

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1. Oliver R. Carter, Soil Survey of the Lajas Valley Area, Puerto Rico, United States Department of Agriculture Soil Conservation Service, Río Piedras, Puerto Rico, April 1965, p. 1.

2. Miguel A. Quiñones y Asociados, Salinity and Drainage Problems of the Lajas Valley, Puerto Rico, Water Resources Authority, San Juan, Puerto Rico, May 1964, p. 7.

* Infra, p. 3

months of the year rainfall is slight and almost ineffective.

The lack of rainfall and the unequal distribution of the same, make irrigation of the Lajas Valley necessary for the efficient development of agricultural operations.

Historical Account of the Irrigation District

Interest in establishing an irrigation system in the Lajas Valley dates from the beginning of the century. In 1908, a group of land owners organized a cooperative to investigate the possibility of providing irrigation for one part of the Valley by diverting the waters of the Guanajibo River. The project required the construction of a tunnel one mile in length, of a main canal 24 miles long and of a system of lateral canals for the distribution of water. The system was to provide irrigation for 5,000 acres of land at a cost which would have exceeded $3,500.000, which cost made the fulfillment of the project impossible.

In 1916, the Department of the Interior, now Public Works, by authorization of Law No. 72, passed 13 April, 1916, carried out preliminary investigations for an irrigation project utilizing the Guanajibo River and the headwaters of the Rivers Guaba, Lajas and Petrera, tributaries of the Añasco River.[3] Later, further studies were made (in 1917 and 1934), but none showed that such development was economically viable and nothing concrete was done.

For the Government, the Lajas Valley continued to be a suitable area for the expansion of agricultural land in Puerto Rico. In 1943, with the aim of developing

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3. Informe sobre los Estudios e Investigaciones en Relación al Proyecto del Valle de Lajas, Aspectos Técnicos y Económicos, The Puerto Rico Water Resources Authority, San Juan, Puerto Rico, 1959, p. 3.

Mean Rainfall in the Lajas Valley
During the years 1947-1964

(*) Table No. 1

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1947	0.13	1.06	0.03	1.08	3.17	0.86	0.42	2.92	4.83	3.42	3.70	0.51	22.13
1948	1.37	1.47	0.18	1.41	1.88	1.41	3.22	4.05	9.91	6.63	3.20	0.95	35.68
1949	0.88	0.04	1.80	0.89	1.33	4.80	5.76	3.80	11.98	4.25	1.38	2.57	39.48
1950	0.40	3.35	0.85	2.50	1.88	1.57	1.03	3.66	3.22	3.89	6.47	7.68	36.50
1951	0.00	0.25	0.63	0.76	5.50	1.76	3.69	4.58	3.87	5.38	1.80	1.44	29.66
1952	0.67	0.54	0.58	1.73	1.97	1.06	2.79	3.18	11.82	5.39	3.23	0.16	33.12
1953	0.75	0.32	0.58	1.90	1.68	1.95	2.94	6.30	4.16	6.75	3.64	1.82	32.79
1954	0.64	3.27	0.83	3.86	1.53	2.53	0.69	2.67	12.31	7.68	3.22	0.55	39.78
1955	0.08	0.28	0.82	1.75	2.19	4.40	2.70	2.93	4.99	4.63	4.98	1.07	30.82
1956	1.39	0.84	1.11	1.99	4.62	6.76	4.50	3.40	3.69	8.40	5.89	0.98	43.57
1957	0.91	0.81	0.37	2.62	1.39	1.25	0.77	4.45	6.66	5.05	2.23	1.54	38.05
1958	0.64	0.11	0.09	5.75	3.73	3.65	5.15	6.76	4.64	2.85	2.28	0.85	36.50
1959	2.30	0.45	0.89	4.70	2.36	0.19	3.15	4.60	3.56	1.04	3.46	2.36	29.06
1960	2.76	2.86	2.22	4.65	3.19	3.75	1.96	5.68	8.66	3.58	3.52	7.06	49.89
1961	3.24	0.54	1.94	3.30	1.20	1.41	3.33	5.69	3.65	6.10	4.18	1.41	35.99
1962	1.05	0.66	0.54	3.79	3.71	1.94	1.14	5.11	2.42	4.69	1.23	0.79	27.07
1963	2.04	2.14	0.83	3.43	5.85	1.23	2.06	10.72	7.50	4.24	2.57	0.48	43.07
1964	0.44	0.79	0.17	1.36	-	-	-	-	-	-	-	-	-
Mean Rainfall	1.09	1.10	0.80	2.64	2.78	2.38	2.66	4.74	6.34	4.94	3.35	1.90	34.89

NOTES: Records obtained from the Office of the Lajas Valley Irrigation District.

1. Rainfall records for 1947 to 1958 were obtained from 11 station situated throughout the Valley.

2. Rainfall records for 1959-1964 were obtained from 31 stations situated throughout the Valley.

this region, the "Committee for the Study of the Southwest of Puerto Rico" was organized, composed of officials from various government agencies. This committee was formed to coordinate government action and to determine the most effective means of developing the area. To this end, various studies were made in 1943 and 1945 under the aegis of the above mentioned committee.

At the same time, the Puerto Rico Water Resources Authority carried out studies and preliminary research based on the utilization of the headwaters of the Yahuecas, Guayo and Prieto Rivers on the northern slopes of the "Cordillera Central" and of the Yauco and Lares Rivers on the southern slopes. From these studies emerged the "Southwest Puerto Rico Project", a project conceived as one of multiple intent with the following objectives:

1. To achieve intensive agricultural production through the use of irrigation over 26,000 acres of land in the Lajas Valley.
2. To generate 100 million kilowatt hours[4] of energy in an average year.
3. To provide protection for the adjacent land against the flooding of the Loao and Yauco Rivers by the construction of dams.
4. To provide 6.5 million gallons of water for domestic consumption in the southwest area of Puerto Rico, an objective which was proposed later.[5]

In 1948, the Puerto Rico Water Resources Authority presented its final report on the project and in that same year began construction of the same.

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4. A kilowatt hour is a unit of work or energy equal to that produced by 100 watts in one hour.

5. Carl A. Bock, Informe sobre el Proyecto del Suroeste de Puerto Rico, Puerto Rico Water Resources Authority, March 1948.

For construction and financing purposes the project was divided into two phases. The first phase consisted of the carrying out of engineering work for the collection of water and the production of electricity. This work was finished in the course of 1956 and included the Guayo, Yahuecas, Prieto and Toro dams on the northern slopes of the "Cordillera Central", the Luchetti dam on the Yauco River on the northern slopes and 13 miles of tunnel interconnecting these. The hydro-electric plant consists of generating stations No. 1 and No. 2 in Yauco with a combined capacity of 35,000 kilowatts.

The State government contributed $10,923,000 and the Puerto Rico Water Resources Authority $14,564,000 to this first stage of the project.[6]

The second phase of the "Southwest Project" was composed of the Irrigation and Drainage System of the Lajas Valley. The principle constructions during this phase were the following:

1. The arresting and damming of the Loco River in which water already used for generating electricity is regulated for irrigation purposes.
2. A main irrigation canal, 23 miles long, together with 43 miles of secondary and lateral canals. These canals have a total of 300 sluices to regulate the delivery of water to the various farms.
3. Some 64 miles of overflow canals which provide drainage for the farms, collect excess rain and irrigation water and carry it out to the sea by way of the Bays Guanica and Boqueron.

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6. Harold Toro Luchetti, "Breve Reseña sobre los Sistemas de Riego Publico en Puerto Rico," Revista de Agricultura, July - December 1963.

The total cost of works for the irrigation and drainage system had reached $9,960,000 by June 30th 1963. This sum included the cost of establishing and organizing the Irrigation District of the Lajas Valley.[7]

The Administrative Functioning of the Irrigation System

The Puerto Rico Water Resources Authority has in its charge, by legal mandate, the administration and operation of public irrigation systems in Puerto Rico. These projects are divided by district as follows:

1. The South Coast Irrigation District
2. The Isabela Irrigation District
3. The Lajas Valley Irrigation District

In order to administer and operate the Lajas Valley irrigation system, the Puerto Rico Water Resources Authority has established the Yauco District Office. The basic responsibilities of this office are to store, convey, deliver, measure and invoice the deliveries of water to the farms on the basis of the acres authorized to receive irrigation.

In the higher parts of the farms, the water is generally delivered by gravity. Delivery is made by means of intakes through a spillway or module type "Cipalleti". This module has a known base and a scale divided into ten equal parts which shows the depth in hundredths. The flow of water passing through the spillway or module is measured in cubic feet per second. By means of a table the readings taken are converted into acre-feet,[8] after the length of time that water was being delivered has been verified.

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7. Ibid, p. 72

8. An acre-foot is the quantity of water required to cover an area of on acre (43,560 square ft.) to a depth of 12 inches. It is equal to 325,850 gal. (U. S.)

In those situations where the water cannot be distributed by gravity, owing to the steep nature of the farms, the Puerto Rico Water Resources Authority installs a metre to measure the water distributed from the irrigation canal. The farmer installs a pump to convey the water to his farm. Water conveyed by pumping carries a 50% discount to offset the additional expenses which this operation entails.

Article II of the Lajas Valley Public Irrigation Law establishes that the apportionment of water per acre of land included in the Permanent Irrigation District, will be determined by the Secretary of Agriculture in accordance with the information given and the recommendations made by the University of Puerto Rico's Agricultural Experiment Station. The amount of water thus apportioned shall not be more than four (4) acre-feet of water per acre per year.[9]

Taking into consideration the drainage problems existing in the Lajas Valley, the Department of Agriculture has determined that the apportionment of water shall be three (3) acre-feet per year. An additional acre-foot of water is provided without cost to those farms which exhaust their monthly allowance. This amount of water (3 acre-feet) is uniformly distributed throughout the twelve months of the year and each acre of land may recieve 0.25 acre-feet of water per month. The additional acre-foot of water is also uniformly distributed throughout the year.

Any farmer who has consumed 0.25 acre-feet of water per acre in the course of one month will receive free of charge an additional 0.08 acre-feet of water for

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9. Procedural Norms No. 3 approved by the Department of Agriculture, the Agricultural Experiment Station and the Puerto Rico Water Resources Authority for the setting up of the Lajas Valley Permanent Irrigation District.

each acre. In total a farmer, if he uses the maximum allowance, can receive 4.0 acre-feet of water per acre per year, of which 1.0 acre-foot is free of charge.

Organization for Agricultural Development

The planning of the agricultural and economic phases is as vital to a project as the planning of the necessary construction work.

At the outset there was a lack of a central organism to coordinate the efforts of all the State and Federal agencies involved in the Lajas Valley Irrigation Project. These agencies had to contend with the various problems that arose as irrigation water was being placed at the disposal of the farmers.

To correct this situation and plan the agricultural development of the Valley, it was necessary to adopt certain measures to channel all action into a common effort. The functions and responsibilities of the various agencies were first classified. Secondly, the Department of Agriculture set up the Lajas Valley Development Bureau. This bureau was established in 1956 by agreement of the Government Committee appointed by the Governor of Puerto Rico to direct public policy in the Lajas Valley. This committee, under the chairmanship of the Secretary of State, was composed of the directors of those agencies which, together with the Department of Agriculture, took responsibility for the development of the Lajas Valley, viz: the Director of the Agricultural Experiment Station, the Director of the Agricultural Extension Service, the Executive Director of the Puerto Rico Water Resources Authority, the Executive Director of the Land Authority and the Director of the Federal Soil Conservation Service. Also included were the President of the Government Party and the President of the Planning Board.[10]

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10. Antonio González Chapel, Planificación e Implementación de un Programa de Desarrollo Agrícola en el Valle de Lajas, Agricultural Experiment Station, University of Puerto Rico, Bulletin No. 192, April 1965, p. 28

From 1956 to 1958, the Lajas Valley Development Bureau was assigned the task of directing and coordinating in their advisory work the activities of all the agencies participating in the project. In 1958 this Bureau proposed the setting up of an Action Programme for the agricultural development of the area, which proposal was accepted by the Government Committee. This measure made it possible to achieve a real integration of government resources in the carrying out of the project. As the implementation of the programme, in which the levels of direction and responsibility to be assumed by each agency were laid down, continued, the Development Bureau ceased to be a coordinating agency and gradually assumed the direction of the programme for the development of the area.

The resulting division of work, for the utilization of agency resources, is as follows: group education and the implementation of the programme of work for each farm is carried out by agents of the Agricultural Extension Service. At present these agents do their work in areas assigned by the Mayaguez Regional Office of Services of the Department of Agriculture. In the year 1969-70, there were five agents from the Agricultural Extension Service. The general norms for carrying out drainage, the construction of irrigation pools and the plans for land levelling for irrigation and drainage purposes were entrusted to the Soil Conservation Service. The establishing of priorities for the construction of irrigation and drainage canals and other norms for the operation of the Irrigation System was taken over by common agreement by the Development Bureau and the Puerto Rico Water Resources Authority.

The technical researching of irrigation and drainage problems and the agricultural aspects of the project were in the charge of the Agricultural Experiment Station. The Lajas Experiment Sub-station dedicated the major part of its activities to these

tasks, and specialized technical personnel were placed in charge of them. Besides studying the soil problems of the Valley, the Experiment Station brought in as consultants from the United States several of the most outstanding scientists in these fields.

To facilitate the work of the Development Bureau a Technical Committe was set up composed of representatives of the various agencies collaborating in the realization of the project. This Committee had the functions of advising the Director and of taking part with him in decisions on technical matters and in the studies being effected as part of the Agricultural Programme for the Valley.

The participation of the farmers in the planning of the agricultural development of the area is represented by a consulting or Farmer's Advisory Committee appointed by the Director of the Development Bureau.

Agricultural Planning for the Lajas Valley

From its inception the Lajas Valley Irrigation Project presented varied and complicated problems, as much for maximum agricultural exploitation as for the conservation of the productivity of the land.

The problems of salinity, drainage, artesian pressures, and high phreatic levels were the object of study by the Agricultural Experiment Station of the University of Puerto Rico and by outside experts. On the basis of the results and observations of these studies, an Action Programme was adopted which included the following steps for the solution of the above mentioned problems:

1. The exclusion of salinated areas from the project.
2. The elimination of surface water by the construction of a main drainage canal, the canalization of gulches, the construction of interfarm canals

and the construction of interceptory canals and canals for the surface drainage of the farms.

3. The elimination of water from the subsoil by the connection of areas with artesian pressures, the establishment of drainage systems on the properties under cultivation and the use of underground pipes.

4. The control of the use of irrigation water through the design of the irrigation systems, the waterproofing of the irrigation pools and the establishing of water quotas and of regulations for the irrigation pools.

These measures have been put into practice to a lesser or greater degree, and the results up to now have been satisfactory.

In the formulation of the agricultural development plan for the Valley, the opinions of various scientists and technical experts were taken into consideration. For example, Koening[11] indicated that the necessity of educating the farmers in the value of irrigation and in the methods to be employed was not limited to any specific area. He further indicates that the majority of Puerto Ricans think of irrigation in terms of applying it to sugar cane alone, where as there are possibilities of developing other crops profitably and successfully under irrigation.

He suggests, in the case of the Lajas Valley, the possibility of establishing a commercial vegetable industry similar to that which exists in Southwest Florida.

The diversification of produce, according to Koening, could include some grains like high-production hybrid corn and sorghum for the feeding of animals on a commercial scale on the Island.

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11. Nathan Koening, A Comprehensive Agricultural Program for Puerto Rico, United States Department of Agriculture, (U. S. Government Printing Office, Washington, D. C. : 1953), pp. 142-144.

Mierhofer [12] recognizes the pressing need for diversification of crops. He indicates that the introduction of other obviously more lucrative produce is essential for the successful reclamation of the greater part of the land. In view of the fact that Puerto Rico imports a large part of the meat which it consumes, as well as milk, dairy produce, rice, potatoes and other fresh produce, he suggests that the production of sugar cane be restricted or even prohibited in this government financed project.

The long-term development projections made by the Lajas Valley Development Bureau according to González Chapel [13] are as follows:

The area included in the Development plan is 29,195.5 acres. Of this total 20,200 acres will eventually receive the benefits of irrigation. A total of 8,996 acres were not included in the irrigation system for various reasons. At present, 19,790.3 acres receiving irrigation, which shows that the goal is very near being reached.

The projected agricultural use of the area includes the establishing of 15,000 acres of cane under irrigation and 1,300 acres of cane without irrigation, 2,200 acres of vegetable produce and crops of diverse types, 3,500 acres of grass and pastureland under irrigation and 4,696 acres of unirrigated grass and pastureland. Also included were about 2,500 acres without any possible agricultural use, being land unfit for cultivation and in some cases being occupied by plant for the project.

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12. Charles R. Mierhofer, Report on a Reconnaissance Inspection and Some Considerations of Irrigation and Drainage on the Lajas Valley Development in Puerto Rico, Special Report, Water Resources Authority, San Juan, Puerto Rico, October 1965, p. 6.

13. Antonio González Chapel, Planificación e Implementación de un Programa de Desarrollo Agrícola en el Valle de Lajas, Agricultural Experiment Station, University of Puerto Rico, Bulletin 192, April 1965.

Based on the projections described above, the potential growth of the Valley's agricultural production was estimated at $11,250,000 for the fiscal year 1965-66. After 1958-59, these objectives were reevaluated every year until 1962-63. In this year a 15% increase in general terms over production in 1961-62 was projected. The following table shows the progress obtained in the production objectives of the Lajas Valley Development Programme during the years between 1955-56 and 1961-62.[14] It shows also all the objectives laid out in the plan for 1965-66. The constant increase in production observed between years 1955-56 and 1961-62 is the direct result of the use of irrigation.

The value of agricultural production in 1964 is estimated at $8,000,000.[15] After 1964 there are no reliable statistics available on land and cattle production in the Lajas Valley.

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14. Infra, p. 16

15. Commonwealth of Puerto Rico Department of Agriculture, Proposición del Programa para el Desarrollo Agrícola de la Region de Mayaguez, October 1964.

Production Objectives

nme. Lajas, Puerto Rico - 1962 [16]

	Projections		Projections
1961-62	1962-63		1965-66
$4,721,338	$5,251,338		$ 6,000,000
1,224,011	1,349,011		1,750,000
334,977	384,977		500,000
209,361	329,361		500,000
135,976	195,976		1,000,000
119,229	174,229		500,000
63,391	123,391		1,000,000
$6,808,283	$7,808,283		$ 11,250,000

Valley was taken. The figures that appear for the years 1962-63
Since 1966 the established projections have not been revised.

erspectives and Objectives for the Fiscal Year 1962-63.

OBJECTIVES OF REGIONAL PLANNING FOR THE LAJAS VALLEY

The regional structure for the provision of agricultural services was established by executive order in 1962. The Island was divided by the Department of Agriculture into five (5) regions in order to channel the efforts of all the government agencies which provide services to the Puerto Rican farmer. The basic objective is to achieve the maximum possible development of our agricultural potential, including a substantial improvement and acceleration in the efficiency of land and cattle production.

One of the five regional offices set up was the Mayaguez Regional Office of Agricultural Services. This office has the task of speeding up the agricultural development of the western region of the Island, including the municipalities between Isabela and Guánica. With this new organization, the Lajas Valley Development Bureau and the Isabela Irrigation District Development Bureau became attached to the Regional Office.

To carry out the above mentioned task, the Mayaguez region laid down a series of measures based on a long-term action programme. In the section, "The Land", the Agricultural Development Programme for the region considers the following long-term objectives for the Lajas Valley.

1- Better use of irrigation over 15,000 acres of sugar cane. (The amount of Water consumed in 1964 was approximately 1.6 acre-feet, which indicates that about a half of the total monthly ration was being used).

2- Extension of irrigation to 2,621 additional acres. (By 1965-66, 18,704 acres out of a total of 20,502 had been authorized for irrigation).

Among the short-term objectives were the following:

1- To increase the consumption of water to 2 acre-feet per acre. The water potentially available for use is 3 acre-feet per acre per year.

2- To carry out an economic study of the farmer's ability to pay.

3- To analyse the use of the farms by carrying out a special farm by farm educational campaign.

4- The improvement of irrigation facilities on the farms.

5- The extension of irrigation to 1,799 acres in addition to those already under irrigation.

In general terms the principal objective of the Lajas Valley project, in its economic phase, has been the high level increase of agricultural production. This represents an increase in total income for the economy of the island. The conservation of the fertility of the soil through the proper use of irrigation is another of the ends pursued.

These objectives are also contained in the plans formulated by the government agencies mentioned and described above.

II- THE IMPORTANCE OF THE STUDY AND A REVIEW OF EXISTING LITERATURE

Objectives of the Study

The intended goal of the introduction of irrigation on farms where the land is arid is to increase production and thereby better the standard of living of the farmer. Zimmerman has shown that the introduction of irrigation considerably increases the operational costs of the farms as larger amounts of fertilizer and the application of measures for the better control of pests and diseases are required.

In addition irrigation represents an additional cost to the farming industry, so that the use of irrigation, no matter how efficient, does not in itself increase income sufficiently to cover all the operational costs.[1]

The agricultural development taking place in the Lajas Valley necessarily entails high production costs. The use of irrigation and the costs involved play a significant role in this type of agriculture. During the time that the district has been functioning, since the first deliveries of water were made in 1955, the farmers of the area have been making use of irrigation without having precise data on the cost of this in the operation of their farms.

The knowledge of what irrigation costs represent in agriculture development would help to stimulate the farmer to control those factors which affect the efficient use of irrigation. There is no doubt that correct and efficient management of this resource will increase profit margins.

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1. Joseph D. Zimmerman, Irrigation, (New York: John Willey and Sons, Inc. 1966), P. 18.

The principal objective, among others, of the research carried out is to present an analysis of irrigation costs and their constituents under the conditions in which the farms are operating at present.

The Lajas Valley is physically and topographically varied. It includes topographically flat terrain, where gravitational irrigation is made easy, and undulating or sloping terrain where irrigation has of necessity to be effected through the use of pumps. These factors determine the system of irrigation used, and, as a result, the costs of this operation are variable. This study attempts to describe the factors which affect these costs as well as their importance in the planning and implementation of the agricultural development of the area.

This study also attempts to present relevant data and information which may be used for the planning of government measures to stimulate the consumption of irrigation water, the which would result in an increase of agricultural production. At present, in spite of the efforts of the technical experts, the consumption of water continues to be low. On June 30th 1968 this consumption was 1.46 acre-feet per acre overall, excepting that of the Land Authority.[2]

Another objective pursued in this study is the provision of information relative to the management of the irrigation district in relation to the services offered to the farmer.

It was also the purpose of this study to obtain reliable data on the operators and the farms under irrigation which might be used both by the government agencies

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2. Information provided by the Lajas Valley Development Bureau, Puerto Rico Department of Agriculture.

and technical experts concerned in the development of the project and by the land-holders in the Valley. This information may help the farmers in improving their efficiency in the use of irrigation and, therefore, achieve greater success in the development of their farms.

For its part the Government could use the information provided in the study in taking the pertinent steps to encourage the farmers of the valley toward a highly diversified and profitable agriculture.

The study also has as a final objective, the presentation of a comparative analysis of the results obtained in this project, based on the goals originally laid down for the agricultural development of the area, in the light of the economic importance of irrigation.

Previous Studies and Related Literature

The technical problems presented by the project during its development were related to specific areas. Among these were the problems of drainage, the salinity of the land, economic problems, the planning and use of the land, the organization and coordination of the various government agencies involved in the implementing of the project and specific problems on individual farms. These projects have been studied by Puerto Rican experts and outside consultants.[3]

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3. In order to study the soil problems of the Lajas Valley, the Agricultural Experiment Station brought in the following consultants from the United States:
   1) Dr. Orson W. Israelson, Head of the Irrigation and Drainage Department of the College of Agriculture, University of Utah.
   2) Mr. Robert Gardner, Research Professor of the State University of Colorado.

For example, Bonnet and Tirado Sulsona of the Agricultural Experiment Station of the University of Puerto Rico carried out an initial study on the soils of the Lajas Valley. In this study they pointed out that the maximum growth of crops, given the conditiens in the Valley, depends on the supply of good quality water and an efficient system of irrigation. On the latter point they show that Puerto Rican farmers follow an irrigation system that is routine and largely inefficient. It is impossible to calculate in monetary terms the amount of water lost on land under irrigation through inefficiency. The study presents a table of the distribution of non-saline soils suitable for irrigation, of saline soils reclaimable through irrigation and of saline soils which require special treatment with sulphur and gypsum to be productive.

The study embraces a total of 39, 136 acres of land in the Lajas Valley. Based on physical characteristics and other considerations, the soils were divided into five categories as shown by Table No. 3.

To study other aspects of the drainage problem, including the design and construction of plant, operational aspects and the channeling of the resources of other agencies, the Puerto Rico Water Resources Authority brought in the following consultants:

Mr. J.R. Lakish, Consultant Engineer, farmer by Head of the Drainage Division of the "U. S. Bureau of Reclamation".

Mr. C.R. Mierhofer Head of the Drainage Division of the "U. S. Bureau of Reclamation".

Mr. Goodrich W. Lineweaver, Technical Advisor on irrigation and drainage problems to the Federal Senate Committee of the Interior and Island Affairs.

Mr. D.S. Mitchell, Jr., Head of the Lands and Waters Section of the Irrigation Division of the "U. S. Bureau of Reclamation".

Mr. W.I. Palmer, Assistant Head of the Irrigation Division of the "U. S. Bureau of Reclamation".

The Department of Agriculture, for its part, brought in Mr. Wiebe H. Van Der Molen, Engineer in the Dutch Firm of NEDECO - ARONT MIJ Ltd., specialist in irrigation and drainage works.

Distribution of the Soils of the Lajas Valley According to Physical Characteristics and other Considerations after Bonnet and Tirado Sulsona.[4]

Table No. 3

Group of Soils	Area in Acres	Percentage of Total
Soils appropiate for irrigation	25,248	64.5
Saline Soils reclaimable by Water	5,453	14.0
Saline Soils reclaimable by Sulphur and Gypsum	5,028	12.9
Shallow Soils where rock is found at a depth of 2 feet or less.	2,944	7.5
Soils where the phreatic level varies between depths of 1 to 4 feet	417	1.1
Totals	39,090	100%

4. J. A. Bonnet and P. Tirado Sulsona, Soils Studies in Lajas Valley, University of Puerto Rico, Agricultural Experiment Station, Bulletin No. 86, August 1950.

Bonnet and Eduardo J. Brenes, made earlier a more detailed study of the same problem and the data was published in 1958 in a study entitled, Detailed Salinity Survey of Lajas Valley, University of Puerto Rico, Agricultural Experiment Station, Bulletin No. 141, July 1958.

Mitchell studied the soils in the Lajas Valley and established a series of specifications for the classifying of these according to their economic viability for irrigation. In this work the specifications used by the U. S. Bureau of Reclamation served as guidelines. Mitchell divided the soils into 5 classes according to their suitability for irrigation and their productive capacity. These classes are described as follows:

Class 1 - The soils included in class 1 are highly suitable for cultivation under irrigation and are capable of sustaining produce with a relatively high yield. They are free of salt accumulations, and the topographical and climatic conditions allow of their being used for a great variety of crops.

Class 2 - These soils are moderately suitable for cultivation under irrigation. They are lower in productive capacity than those in Class 1 and are suitable for a smaller number of crops. These soils are more costly to develop under irrigation. They are moderately saline soils and require some drainage of the subsoil.

Class 3 - The soils in this class are suitable for development by irrigation, but they are limited by severe deficiencies in the characteristics of the soil, topography and internal drainage. With appropriate management these soils could yield satisfactory profits.

Class 4 - Under the existing conditions, these soils are considered uncultivable. Nevertheless, they have a potential value which warrents separate classification. These soils through special practices and treatments could be dedicated to Agriculture under irrigation. Besides having

inadequate drainage they contain a high concentration of salts and excessive alkalinity.

Class 5 - Into this class fall all those soils which do not fulfill the minimum requisites of the other classes. These soils are not recommended for development by irrigation.[5]

The intensive cultivation of the land under irrigation increased to such a point that it was later necessary to make a much more detailed survey of the soils in the Lajas Valley. The Soil Conservation Service of the Federal Department of Agriculture made itself responsible for carrying out this task and presented a report on work done in 1965.[6] In this study the Soil Conservation Service divides the soils of the Lajas Valley on a general map into five associations according to the series encountered.[7] The study describes in detail the physical characteristics of the various series included in each group. In addition the soils of the Lajas Valley are divided into classes according to their adaptability to different crops.

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5. Donald S. Mitchell, Jr., Report on Land Classification of Lajas Valley Irrigation Project, Special Report, Water Resources Authority, San Juan, Puerto Rico, November 1957.

6. Oliver R. Carter, Soil Survey of the Lajas Valley Area, Puerto Rico, United States Department of Agriculture Soil Conservation Service,; Rfo Piedras, Puerto Rico, April 1965.

7. Soil is defined as that fine textured natural material which is found on the Earth's surface. It is composed of disintegrated rock minerals and organic material. A soil series is a group of soils with almost the same profile. By profile is understood the sequence of natural strata or horizontals of a soil. These extend from the surface down to the material which has not been affected by plant roots or climatic factors. The horizontals are classified by the letters A, B and C depending on the mineral and organic composition of the same.

Israelson, in his study of the drainage and reclamation of land in the Lajas Valley, found that upward hydraulic pressures exist in some low areas of the Valley. These pressures are known as artesian pressures. This presents the problem that in these areas the subterranean water has the tendency to rise to the surface instead of descending to the lower strata of the subsoil. The condition described makes the internal drainage of the Valley soils difficult as it operates in a direction contrary to the force of gravity which carries the irrigation water not used by the plants to the natural drains. Dr. Israelson recommended the boring of deep wells as a means of avoiding the movement of this water towards the surface. He also pointed out that the farmers alone could not resolve the drainage problems of the Valley. The government would have to attack some aspects of these problems on an overall basis.[8]

Professor Gardner, of the University of Colorado, studied the same problems as Israelson and came to the conclusion that the land in the Lajas Valley, according to the norms prevalent in the west of the United States, would be considered sub-standard for an irrigation project in view of its drainage and salinity characteristics. He says, however, that, because of the need for agricultural land in Puerto Rico and other favourable factors existing in the Valley, a profitable agriculture under irrigation could be established, even if the pressures of artesian waters cannot be overcome. He adds that agriculture under irrigation can be successfully developed if careful attention is given to the control of the water.[9]

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8. Orson W. Israelson, Drainage and Reclamation Problems in Lajas Valley Puerto Rico, Special Report, Agricultural Experiment Station, Río Piedras, Puerto Rico.

9. Robert Gardner, Report on Soil and Water Control Problems of the Lajas Valley Development Project, Special Report, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, August 1954.

Lakish showed that, in other parts of the world, irrigation projects had been successfully developed in areas with artesian pressures without adverse effects on the development of the projects. In addition he points out that, until water is applied to the land and the behavior of this under irrigation is observed, it is impossible to determine exactly the drainage problems that might arise. The plans and measures to be considered in relation to these problems have to be made later. He suggested also the possibility of including relatively good land at a higher level than the irrigation canal to be served by pumping. [10]

Mierhofer in his report makes the following recommendations and observations on the project:

1- He recommends that, if legislation cannot reduce the size of landholdings, some incentive should be given so that the large farms are divided into smaller units. He foresees that an excessive amount of land in the possession of a single owner could reduce the project's possibilities of success.

2- He points out that, as opposed to the majority of areas under irrigation in the world, in Puerto Rico crops can be established throughout the year.

He also recognizes the pressing need for the diversification of crops and the avoidance of the sole cultivation of sugar cane in the Lajas Valley.

3- The farmers should use irrigation on the basis of rotative deliveries of water over 24 hour periods. This procedure should be followed from the outset so that the farmers do not become accustomed to any other method. This will save

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10- J. R. Lakish Report on Drainage of the Lajas Valley Southwestern Puerto Rico Project, Water Resources Authority, San Juan, Puerto Rico, September 1954.

water, thus reducing operational costs and contributing to the success of the project.

4- The deliveries of water should be limited to a small quantity above that required by evaporation and transpiration, this quantity to be determined by the Agricultural Experiment Station.

5- The organization of the activities of the various government agencies should be revised in order to define their responsibilities and coordinate government efforts in the implementation of the project.

6- As for drainage problems in the Valley, Mierhofer shows that all irrigation projects require surface and subsoil drainage facilities besides those for the supply and distribution of water. He points out, also, that drainage is a process of continual maintenance as essential to productivity as irrigation water itself.[11]

Van Der Molen, a Dutch Soil Scientist, invited by the Puerto Rican Department of Agriculture to study drainage and salinity, showed in his study that, apart from some small saline areas, the low land in the Valley is free of soluble salts and alkalinity in the first two feet of soil. So long as this condition remains unaltered, a normal crop growth can be obtained without recourse to the application of gypsum and sulphur. He further points out that, if irrigation is not combined with adequate drainage, the salts may spread through the soil causing major salinity problems. Consequently, he

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11. Charles R. Mierhofer Report on Reconnaissance Inspection and Some Consideration of Irrigation and Drainage of the Lajas Valley Development in Puerto Rico, Special Report, Water Resources Authority, San Juan, Puerto Rico, 1956.

recommends that each lowland farm be provided with a pre-designed drainage and irrigation system, before irrigation of the land begins. He says also that in Holland it is considered economically viable to invest in land reclamation approximately ten times the increase in agricultural production resulting from such reclamation. The Dutch Government contributes 70% of the cost of the improvement of the land, and the balance is paid by the land owners over a period of 30 years.[12]

Lineweaver, in his study, makes a series of recommendations on the economic and agricultural phases of the project. He suggests that test farms be established in the Valley to provide the farmers with practical information on irrigation methods and to demonstrate the various types of crop that can be cultivated on a commercial scale.

He points out, besides, that a maximum tenency of 160 acres has been established as a basis for irrigation projects in the United States. The object is to distribute the benefits of irrigation amongst the greatest possible number of families. The situation in the Lajas Valley is different. Lineweaver, like Mierhofer recognizes the problem of landholding. A relatively small number of farmers in the Valley own farms covering large areas. He suggests, therefore, that the government take those measures which it deems necessary to reduce the size of the farms to the maximum area that shall be established.[13]

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12. Wieve H. Van der Molen, Report on Salinity, Irrigation and Drainage Conditions in the Lajas Valley Development Project, Puerto Rico, Special Report, Puerto Rico Department of Agriculture, San Juan, Puerto Rico, January 1957.

13. Goodrich W. Lineweaver, Observations and Recommendations on Lajas Valley Irrigation Project, Water Resources Authority, San Juan, Puerto Rico, December 1956.

W. I. Palmer advised the Water Resources Authority of Puerto Rico on administrative aspects and the organization of the activities of the different agencies included in the project on the required legislation and on other considerations of economic importance. In his report he emphasizes, among other things, the necessity of making an analysis of the economic capacity of the farmers to pay the costs of irrigation and the maintenance of irrigation plant plus the amortization of capital. He also lays stress on the necessity of making an economic study to serve as a basis for measuring the effect on the local and state economy, and finally the necessity of classifying the responsibilities of the agencies in charge of the different phases of the project. He points also to the exploration of the possibility of establishing variable irrigation rates which could be reduced for certain crops. He says also that the possibility of seeking aid from the State Government for new crops should be explored, and that a system of quotas and subsidies be set up to stimulate diversified agriculture. [14]

In 1965, Mr. Antonio González Chapel published a study on the planning and implementation of an Agricultural Development Programme of the Lajas Valley. [15] The study is primarily an historical account of the implementation of the irrigation project, of the way in which the various technical problems that arose were faced, and of the different aspects considered in the Agricultural Development Programme established. The study details the long-range development projections that were made and the establishing of annual objectives. It is important to note that, even though the

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14. William I., Preliminary Report on the Organization and Operation of the Lajas Valley Irrigation Project, Water Resources Authority, San Juan, Puerto Rico, January 1957.

15. Antonio González Chapel, Planificación e Implementación de un Programa de Desarrollo Agrícola en el Valle de Lajas, Agricultural Experiment Station, University of Puerto Rico, Bulletin 192, April 1965.

programme considered, among its objectives, the establishing of a variety of crops, the long-range projections of agricultural potential were based on the improvement of expansion of industries already established.

The study did not take into consideration statistics on irrigation costs nor on other agricultural production costs. Therefore, the effects that these costs might have on the fulfillment of the goals laid down was not taken into account.

The studies made by the Water Resources Authority, with the object of planning the Southwest Project, were carried out between 1928 and 1946. Based on the information obtained in these studies, the average annual yield of water from the rivers that serve the project was set at 130,000 acre-feet and the minimum annual yield at 81,000 acre-feet. After the plant was constructed it was found that the water flowing to the dams was much less. Between 1955 and 1962 data was collected on the waters which flow into the River Loca dam and on the variations in the Guayo and Luchetti dams. These statistics were much more reliable and it was calculated that the average inflow of water (escorrentía) during these years was 64,000 acre-feet. Using this new data, Miguel A. Quiñones and Associates, carried out a study in 1963 for the Water Resources Authority of Puerto Rico.[16] This study concluded that the amount of irrigation of water that could be delivered annually did not depend upon whether the assigned allowance was 3 or 4 acre-feet of water per year; rather it depended on the recorded inflows (escorrentías) from the rivers serving the project, of their distribution throughout the year and of the regulation attained by damming. Based on the inflows* recorded

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16. Miguel A. Quiñones y Asociados, Estudio Sobre el Agua Disponible para Riego en el Distrito de Regadío del Valle de Lajas, San Juan, Puerto Rico, January 1963.

* Inflow- Water which flows from the collection area to the rivers and gulches which feed the dams.

during the seven years between 1955 from the rivers serving the project, the following was decided: the average annual delivery of water for irrigation that could be made for 20,000 acres, if a ration of 3 acre-feet per acre per year were established, would be about 63,000 acre-feet. If a ration of 4 acre-feet were established, the required amount of water would be around 66,000 acre-feet. The available water, therefore, is not enough to cover the latter. The establishing of a ration of 4 acre-feet per acre per year would not significantly increase the annual consignment of water, on the other hand there would be a continual debt to the farmer because of the resulting deficits.

The study made by Miguel A. Quiñones and Associates, based on the statistics for those years, finally decided that the system was capable of confidently serving 3 acre-feet of water per acre per year to an area of 20,000 acres, which would be the area ultimately authorized for irrigation.

The Agricultural Experiment Station conducted a field experiment on green fodder common in Puerto Rico to measure the effect of different irrigation and nitrogen levels on the production of dry materials. The grasses included were Guinea Grass, Para Grass and a mixture of these and tropical Kudzú.[17] This study showed that the efficient use of irrigation on these three varieties significantly increased production. Dr. Vázquez points out in this study that Puerto Rico cannot count on research on or experience of irrigation

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17. Roberto Vázquez, "Effects of Irrigation and Nitrogen Levels on the Yields of Guinea Grass and Guinea Grass-Kudzú and Para Grass Kudzú Mixture in the Lajas Valley", The Journal of Agriculture of the University of Puerto Rico, Vol. XLIX, No. 4, October 1955.

and that the farmers lack readily available information on the problems that have to be faced in trying to employ irrigation effectively. Similar experiments have been carried out on White Sorghum[18] and Corn.[19]

At present a long-term experiment is being conducted on sugar cane under varying levels of irrigation in different valley soils. Dr. Roberto Vázquez, in a preliminary analysis, has found production volumes varying between 50 and 65 tons of sugar per acre.

The primary object of these studies was to determine the intervals at which the crops submitted to this kind of experimentation would require irrigation water. These studies were of an agronomical character, and their results are of great importance to the efficient use of irrigation water. Nevertheless, in the above mentioned studies, irrigation costs are not taken into consideration. The present study has as its aim the investigation of this area which, up to now, has not been covered by other researchers in the Valley. George E. Pringle and Jaime Zapata published a study of agricultural methods used in sugar cane production in Puerto Rico.[20] A total of 192 farms were studied with the object of determining the effect of different agronomical methods on sugar production. Irrigation was one of the methods studied, though not the only one. The study concluded

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18. R. Vázquez, R. Eshenwald, M. J. Martínez Luciano, "Response of Native White Sorghum to Irrigation Under Different Nitrogen Fertility Levels and Seeding Rates in Lajas Valley", The Journal of Agriculture of the University of Puerto Rico, Vol. L, No. 2, April 1966.

19. Roberto Vázquez, "Effects of Irrigation Nitrogen Levels and Plant Population on Corn Yields in Lajas Valley, Puerto Rico", The Journal of Agriculture of the University of Puerto Rico, Vol. XLIV, No. 3, July 1960.

20. George E. Pringle, Jaime Zapata, Practices Used on Puerto Rico Farms With High Production of Sugar, Agricultural Experiment Station, University of Puerto Rico, Bulletin 212, February 1969.

that sugar cane requires approximately 6 inches of water per month during its period of growth. These results agree with those of A. C. Barnes, who shows that, in the absence of irrigation, sugar cane requires 80 to 90 inches of rain over its growth period of 14 months if a good yield is to be obtained.

Pringle and Zapata's study also shows that, although not all sugar cane farms were irrigated, 56.2% of the farms which produced 4.01 tons or more of sugar per acre had access to irrigation. This is shown in table No. 4.*

Distribution of the Farms by Use of Irrigation and Sugar Production per Acre, 192 Farms, Puerto Rico, 1962.

Table No. 4.

	Tons of Sugar per Acre					
Irrigation	3.0 or less		3.01 to 4.0		4.01 or more	
	No. of Farms	Percentage	No. of Farms	Percentage	No. of Farms	Percentage
Used Irrigation	5	13.9	16	21.1	45	56.2
Did not Use Irrigation	31	86.1	60	78.9	35	43.8
Totals	36	100%	76	100%	80	100%

* Infra, p. 38

A. C. Barnes has shown that the rainfall most suitable to meet the exact requirements of the profitable production of sugar cane depends upon its distribution over the growth period. He shows also that the productivity of the land dedicated to sugar cane can be greatly increased by supplementing rainfall with irrigation. Sugar cane can be produced in abundance in those areas where rainfall is deficient or badly distributed so long as other climatic factors favour the development of the plant by irrigation.[21] Such is the situation prevailing in the Lajas Valley.

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21. A. C. Barnes, The Sugar Cane, (New York: Interscience Publishers Inc., 1964), PP. 136-138.

III- RESEARCH PROCEDURES

The Field

To obtain the primary information required in this study, the field was taken as being composed of all the farms with irrigable land in the Lajas Valley Irrigation District.

Two hundred fifty-six (256) farms with irrigable land were authorized to receive the services of the system in the fiscal year 1969-70. The farm belonging to the Agricultural Experiment Station of the University of Puerto Rico, Mayaguez Campus, was excluded from this study.

The farms studied were owned by a group of 142 farmers who were also in themselves part of the study.

For the purposes of the study the 256 farms were divided into three groups according to topographical characteristics. The following table shows the method of classification and the number of farms included in each group.

Table No. 5 - Classification of the Farms of the Lajas Valley on the Basis of Topography, Lajas, Puerto Rico, 1969-70.

Group	Number of Farms	Percentage of Total
1. Flat Farms	51	20
2. Undulating Farms	146	57
3. Steep Farms	59	23
Totals	256	100

Selection of the Sample:

The study carried out was based on a random sample comprised of 30% of the unit. Seventy-seven (77) farms out of a total of 256 made up the sample. The sample includes 16 farms from group 1, 44 farms from group 2 and 17 farms from group 3.[1]

Research Techniques:

The basic field statistics (primary data) and other information required by the study were obtained by means of a poll. A questionnaire was employed for the compilation of the data. The questions necessary and relevant to the objectives of the study were included in this questionnaire.

Consultations on the nature of the problems to be studied were held with experts from the Agricultural Experiment Station, the Department of Agriculture, the Water Resources Authority of Puerto Rico, the Federal Soil Conservation Service and the Agricultural Extension Service. The suggestions received were incorporated in the questionnaire, including that of having a separate leaf to facilitate the tabulation of data in the Computer Center of the University of Puerto Rico, Mayaguez Campus.

The author personally interviewed each of the farmers whose farms was included in the study. In this interview the farmer was asked specific questions about irrigation operations on his farm and especially about those factors involved in irrigation costs. Subjective questions were also asked about various aspects of the irrigation system which

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1. On flat farms, Group No. 1, irrigation water is supplied to the land by open furrow through the use of irrigation by gravity. On undulating farms, Group No. 2, irrigation is applied by contour furrows and, depending on the inclination of the land, is effected by pumping or by gravity. On steeper farms, Group No. 3, the water is pumped to the highest point of the property to be later distributed by gravity in the open furrow.

might affect the development of his farming.

During the study, consultations and personal interviews were also held with the various agricultural agencies working in the Valley. The object of these was to obtain opinions about the factors which affect irrigation costs and the diversification of agriculture in the area.

The secondary data used in this study was provided by government agencies and private institutions. The following government agencies collaborated in the study: The Water Resources Authority of Puerto Rico, the Puerto Rico Department of Agriculture, the College of Agriculture and Mechanic Arts at Mayaguez*, the Agricultural Extension Service of the University of Puerto Rico and the Federal Agricultural Stabilization and Conservation Service. The private firms which gave the project valuable information were the Guánica, Igualdad and Eureka refinaries.

A large part of the information obtained during research, especially the statistics related to the determinants of irrigation costs, was processed by the Mayaguez Campus of the University of Puerto Rico. The computations made of the information submitted facilitated the analysis and interpretation of these statistics, here given in the form of tables and graphs following the order of the objectives laid down.

In order to provide significant data, which might be used as the basis of agricultural planning in the area, this study also provides analytic information on the operators, farms and the farming industry in general.

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* Now officially the University of Puerto Rico, Recinto Universitario de Mayaguez.

IV- ANALYSIS AND PRESENTATION OF RESULTS

A. General Description of the Farmer

From several points of view, the statistics obtained show that the farmers of the Lajas Valley, selected for this analysis, are not a homogeneous group. Various groups are found among them. The tables below show this on the basis of the social and economic factors studied.

1. The Age of the Farmers

Table No. 6 is related to the age of the farmers who operate the 77 farms included in the study.[1] It is significant to note that the age of these varies between 30 and 77, the average age being 54.04 years. The largest group of farmer (63% of the total) is made up of men over 50. This percentage is divided as follows: 30% are 60 or more years old, and 33% are between 50 and 59 years old. On the other hand, the group of relatively young farmers constitutes only 16% of the total and includes those of less than 30 and less than 39 years of age. The remaining 21% is composed of middle-aged farmers with the exception of 4% who are more than 70 years old.

The results obtained on the age of the farmers are very similar to those encountered in other studies.[2]

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1. Infra, P. 45

2. Jorge López Zapata, Algunos Factores que Influyen en el Nivel Tecnológico de los Agricultores del Valle de Lajas, Thesis presented as a partial requirement for the Master's Degree in Agricultural Sciences, Recinto Universitario de Mayaguez, July 1967.

   Commonwealth of Puerto Rico Department of Agriculture, Mayaguez Region, Proposición del Programa para el Desarrollo Agrícola de la Región de Mayaguez, October 5, 1964, pp. 46-47.

The farmer is an essential element who, together with the land potential and efficient planning, plays an extremely important part in the success of any agricultural plan. Furthermore, the age factor can negatively affect the farmer's response to technical advice and the adoption of the more advanced methods so essential to modern agriculture. Van De Ban in Holland, while studying the reluctance of the farmers to adopt new methods, observed that the younger farmers were the most progressive.[3] Other researchers like Blackstone, Dimit and Baum have found a greater acceptance of new agricultural methods among younger than among older farmers.[4]

For these reasons, it is cause for concern to know that a large sector of the agriculture in the Lajas Valley is in the hands of people of relatively advanced age. This situation could constitute a serious obstacle to the implementation of the Agricultural Development Programme for this area.

Table No. 6 Distribution of the Farmers According to their Age, 51 farmers in the Lajas Valley, Puerto Rico, 1969-70.

Age of Group	Number of Farmers	Percentage of Total
Less than 30 years	1	2
30 - 39	7	14
40 - 49	11	21
50 - 59	17	33
60 - 69	13	26
70 6r more	2	4
Totals	51	100

3. A. W. Van De Ban, "Some Characteristics of Progressive Farmers in the Netherlands", Rural Sociology, Vol. XXII, No. 3, September 1957, pp. 205-212.

4. John Blackmore, R. M. Dimit and E. L. Baum, Test Demonstration Farms and the Spread of Improved Farm Practices in South Virginia, Report No. p. 55, Tennessee Valley Authority, Knoxville, 1955.

2. Educational Preparation of the Farmers

The management of a farm within the framework of a highly commercialized agriculture requires that the farmer be capable of learning new techniques and assimilating new knowledge. The researchers, Van De Ban in Holland[5] and Eugene A. Wilkening in North Carolina, U. S. A.[6], have found a significant relationship between the age of the farmers and their acceptance of new agricultural practices.

In manufacturing operations, different people perform the specialized tasks of accounting, buying, sales, management etc., while the farmer, in the administration of his business, has to carry out these functions himself. For this reason his educational preparation is an extremely important factor in the training of the farmer as an administrator.

Table No. 7 shows the distribution of the farmers included in the study according to their educational preparation. It is satisfactory to observe that 67% have an educational preparation of between 9 and 16 years.

Table No. 7 - Distribution of the Farmers According to their Educational Preparation, 51 Farmers in the Lajas Valley, Lajas, Puerto Rico, 1969-70.

Academic Preparation	Number of Farmers	Percentage
0 - 3 years	4	8
4 - 8 years	13	25
9 - 12 years	12	24
13 - 16 years	20	39
16 years or more	2	4
Totals	51	100

5. Ibid, pp. 205-212

6. Eugene A. Wilkening, Acceptance of Improved Farm Practices in Three Coastal Plains Counties, Technical Bulletin No. 98, North Carolina Agricultural Experiment Station, Raliegh 1952, P. 50.

We also find two farmers with 16 or more years of education, which is something significant among the farmers who operate farms in the Lajas Valley. Twenty-five percent (25%) have between four (4) and eight (8) years of education and eight percent (8%) have three (3) or less years of education. The average educational preparation is 11.1 years.

The results of this study show that the educational preparation of the farmers is relatively higher than that found by other researchers in similar studies made in Puerto Rico.[7]

3. The Types of Farm Tenancy

It is important to make clear that a large number of farms in the Lajas Valley are not being operated by their owners. Some are so operated, the greater part are rented and a limited number are operated by administrators. This situation is clearly demonstrated by Table No. 8 which gives the distribution of farmers according to their type of tenancy of the land under study in the Lajas Valley.

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7. This factor has been analyzed in the following works of research in Puerto Rico:

A. Department of Agriculture of the Commonwealth of Puerto Rico, Mayaguez Region, Proposición del Programa para el Desarrollo Agrícola de la Región de Mayaguez, October 5, 1964, pp. 46-47.

B. Oliver Padilla, Otis, The Role of Value and Channel Orientation in the Diffusion and Adoption of News Ideas and Practices. A Puerto Rican Dairy Farmers Study, 1963, Ph.D. Thesis (Unpublished), Michigan State University.

C. Jenaro Collazo Collazo and Reinaldo Calero, Los Recursos Humanos en la Industria del Café en Puerto Rico, July 1963, Bulletin 166, Agricultural Experiment Station, p. 11.

Distribution of the Farmers According to Type of Tenancy of their Farms, 51 Farmers of the Lajas Valley, Lajas, Puerto Rico.

Table No. 8

Type of Tenancy	Number of Farmers	Percentage
Owned	15	29
Rented	31	61
Administrated	5	10
In Usufruct	0	0
Totals	51	100

The resulting statistics show that 29% of the farmers interviewed were owners of their farms. Sixty-one percent (61%) operated rented farms, and the remaining 10% were administrators.

Some researchers, Wilkening for example, have shown in their studies that farmers who own the land they work have greater control over decisions connected with their business and, as a result, adopt a greater number of modern land and cattle production methods.[8] On this rests the importance of the various types of landholding for the agricultural planning of the Lajas Valley.

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8. Wilkening, op.cit., p. 52.

B. Agricultural Pattern of the Lajas Valley

1. The Size of the Farms:

The 77 farms included in this study covered a total area of 12, 195.24 acres. (Table No. 9). The average area per farm was 158.39 acres.

Farms of 50 acres or less make up the largest percentage, 35%, of the farms included in this study. Sixteen percent (16%) of the farms are of between 50.1 and 100 acres, 13% of between 100.1 and 150 acres, and 24% of between 150.1 and 350 acres. Twelve percent (12%) of the total are of more than 350 acres.

Table No. 9 — Distribution of the Farms Studied by the Size of the Operation, 77 farms in the Lajas Valley, Lajas, Puerto Rico, 1969-70

*Distribution by Area (Acres)	Number of Farms	Percentage of Total
50 acres or less	27	35
50.1 to 100.0	12	16
100.1 to 150.0	10	13
150.1 to 200.0	6	8
200.1 to 250.0	6	8
250.1 to 300.0	5	6
300.1 to 350.0	2	2
350.1 or more	9	12
Totals	77	100

* For the purposes of this study the farms were classified on the basis of area as follows: small farms those of 100 acres or less, medium farms those of between 100.01 acres and 250 acres, large farms those of more than 250 acres.

2. Present Employment of the Land:

Sixty-four percent (64%) of the total area of the farms is under cultivation, which indicates considerable variation. Thirty-six percent (36%) of the total area is dedicated to other uses. This percent is distributed among land occupied by pastures, woodland, brush, buildings and roads. Table No. 10 shows the distribution of the farms studied according to size and employment of the land.[9] As can be seen, the greatest area under cultivation is found on farms of 500.1 acres or more, followed by those farms of between 250.1 and 300 acres. The least area under cultivation is found on those farms of between 450.1 and 500 acres. It is significant to observe that in order of importance the area under cultivation is followed by natural and improved pastures. The proportion of the area of natural pasture and that of improved pasture is approximately 2 to 1. The area given over to natural pastures is 2,083.98 acres and that given to improved pastures is 1,146.43 acres. Although this shows that the area of improved pastures is much less it is relevant to note that among cutting grass and improved pastures the area reaches 1,278.61 acres which shows that the farmers who are also concerned in cattle-raising are extremely interested in bettering the parts of their farms dedicated to green fodder.

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9. Infra, p. 51

and, by Size of Farms
lley, Puerto Rico, 1969-70

Natural Pastures (Acres)	Woodland (Acres)	Thickets and Mountains (Acres)	Buildings and Roads (Acres)	Total Area (Acres)
47.52	--	21.85	28.17	719.84
112.81	--	--	23.46	998.82
142.67	--	23.16	39.70	1,311.37
122.69	--	36.91	34.50	1,001.46
273.87	--	14.56	186.38	1,307.91
115.11	--	--	113.61	1,366.84
12.63	38.85	--	5.83	663.73
--	--	--	--	--
227.65	--	77.70	33.99	814.79
171.42	--	--	--	485.08
857.61	--	272.91	47.80	3,525.40
083.98	38.85	452.09	513.44	12,195.24

3. Sugar Cane:

Sugar cane occupies 18,000 acres of land in the Lajas Valley. This represents 93.6% of the total irrigable area of some 19,241 acres.

The rest of the land under cultivation represents 6.4% of the irrigable land and is mainly dedicated to improved pastures. Six thousand two hundred and forty-six point forty-two (6,246.42) acres of the 77 farms studied were dedicated to the cultivation of sugar cane of which 5,652.00 acres were harvested. The rest were sown with slow-growing cane which was not harvested that year.[10] Of the cane harvested, 1,305.00 acres were cultivated without irrigation during 1969-70.

It is significant to note that the average production per acre of the farms irrigated was 27 tons. This yield is much lower than that obtained in the South Coast Irrigation District, where the average tonnage per acre of the farms is around 40 tons. Further, the cane yield of the farms in the Lajas Valley is much lower than that obtained by the Land Authority. The yield per acre of the Land Authority Fraternity Farm, situated in the Lajas Valley, and thus operating under similar soil conditions, is 42 tons per acre.[11] This shows that there is a series of factors affecting the development of the crop in the area, among the most significant of which is the low consumption of water.

On the South Coast, as on the Land Authority Farm in the Lajas Valley, over 3.0 acre-feet of water per acre per year are used. Table No. 11 shows the relation-

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10. Slow-growing cane - cane sown in the Autumn and harvested after 18 or 20 months.

11. Information provided by the Land Authority of Puerto Rico.

ship between the number of acres cultivating sugar cane under irrigation and the production obtained.[12] In addition the production on those farms using irrigation is compared to the production on those farms not using irrigation.

It seems almost unnecessary to point out that the average tonnage of acres cultivated under irrigation was 27 tons per acre, while on the farms not using irrigation the average was 22.8 tons per acre.

4. The Cattle Industry:

In the Lajas Valley the raising of cattle is next in importance to the cultivation of sugar cane. Of the 77 farms studied, 20 possessed herds of cattle. Five (5) farms were dedicated exclusively to the raising of dairy cattle, while the other 15 produced beef cattle. In some cases animals were raised for both purposes.

The annual production of milk from the dairies on the farms under study was 1,293,925 litres. This production represents for the farmers a gross annual income of $242,319.87 (See Table No. 12).

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12. Infra, p. 54

Distribution of Cane Farms Under Irrigation Farms Not Using Irrigation
in Relation to Production, 77 Farms in the Lajas Valley,
Lajas, Puerto Rico, 1969-70.

Table No. 11

Distribution of the Farms by Area	Crops Under Irrigation			Crops Which did not Use Irrigation		
	Area Harvested	Production in Tons	Average Production in Tons per Acre	Area Harvested	Production in Tons	Tons per Acre
0.0 - 50 Acres	591.64	15,340.00	29.0	196.00	4,169.00	21.0
50.1 - 100 "	635.72	16,619.00	26.0	182.70	3,600.00	20.0
100.1 - 100 "	825.93	20,161.00	24.0	125.00	2,179.00	17.0
150.1 - 200 "	525.56	14,190.00	27.0	230.90	5,162.00	22.0
200.1 - 250 "	752.46	22,328.00	30.0	401.00	10,368.00	26.0
250.1 - 300 "	217.35	5,932.00	27.0	169.40	4,300.00	25.0
300.1 or more	868.34	23,420.00	27.0	-	-	-
Totals	4,347.00	118,000.00	*27.14	1,305.00	29,778.00	*22.81

*Averages

Distribution of Cattle as Related to Production, 20 Farms in the Lajas Valley, Puerto Rico, 1969-70*

Table No. 12

Type of Cattle	Number of Farms	Percentage of Total	Number of Animals	Percentage of Total	Annual Production	Gross Income
Dairy Cattle	5	25	861	59	1,293.925 (litre)	$242,319.87
Beef Cattle	15	75	596	41	3,820 (arrobas*)	$ 68,760.00
Totals	20	100	1,457	100		$311,079.87

The sales of beef cattle represent a value of $68,760 for the cattle farmer. Thus the raising of dairy cattle is considerably the greater of the two, making up 59% of the herds.

Table No. 13 shows the distribution of farms according to size and the existing number of cattle. It can be observed that farms of 100 acres or less do not produce dairy cattle but that these are produced on the larger farms.

Distribution of the Farms by Area and in Relation to the Number of Animals, 20 farms in the Lajas Valley, Puerto Rico, 1969-70

Table No. 13

Distribution of the Farms (Acres)	No. of Farms	Percentage of Total	No. of Animals (Dairy)	Percentage of Total	No. of Animals (Beef)	Percentage of Total	Total No. of Cattle
0.0 to 100	6	30	-	-	181	32	181
100.1 to 200	6	30	356	41	128	23	484
200.1 to 300	1	5	-	-	40	7	40
300.1 or more	7	35	505	59	217	38	722
Totals	20	100	861	100	566	100	1,427

* 20 farms of the 77 studied raise cattle.

* Spanish weight of twenty-five (25) pounds.

5. Areas Dedicated to Pasture Land:

The acres devoted to the cultivation of pasture land, whether under irrigation or not, were directly related to the size of the farms (Table No. 14) . The area of pasture land per group of farms increased according to the size of the farms.

Forty-two (42) farms of the 77 included in the sample, possessed land devoted to forrage grass. The area of pasture land irrigated in the farms under study was 289 acres out of a total of 3, 545.5 acres, or about eight (8) percent.

Table No. 14 - Distribution of Pasture Area Under Irrigation and Without Irrigation by Size of Farms, 42 Farms in the Lajas Valley, Puerto Rico, 1969-70.

Table No. 14

Group of Farms by Size of Operation	No. of Farms	Percentage of Total	Acres Under Irrigation	Percentage of Total	Acres Without Irrigation	Percentage of Total	Total Pasture Area
0.0 - 50.0	6	14.0	9.0	3.0	21.0	0.6	30.0
50.1 - 100.0	6	14.0	25.0	9.0	103.0	3.2	127.5
100.1 - 150.0	7	17.0	70.0	24.0	294.0	9.0	364.5
150.1 - 200.0	4	9.5	--	--	175.0	5.4	175.5
200.1 - 250.0	3	7.0	--	--	176.0	5.4	176.0
250.1 - 300.0	4	9.5	--	--	409.0	12.6	409.0
300.1 or more	12	29.0	185.0	64.0	2,078.0	63.8	2,263.0
Totals	42	100.0	289.0	100.0	3,257.0	100.0	3,545.5

In the Lajas Valley, irrigation water is used mostly for the cultivation of sugar cane and pastureland. Nevertheless, if the area of pastureland under irrigation is compared with that of sugar cane under irrigation, it is noticeable that the extent of irrigated pasture is very limited. Sugar cane is the most irrigated crop in the area.

6. The Farmers and Agricultural Diversification:

One of the basic objectives pursued in the establishing of an irrigation system is a number of varied crops. From the outset the development of a highly diversified agriculture was planned for the Lajas Valley. In practice the success or failure of a farm is often attributable to its level of diversification. Agricultural diversification is commonly defined as the number of concerns to which a farm or agricultural area is devoted. This definition of the term is not exact. G. W. Forster in his book Farm Organization and Management gives a better definition of this concept.[13] Dr. Forster suggests that not only the number of crops should enter into agricultural diversification but that the income from each of these should also be considered. To measure the level of diversification of a farm or agricultural area he introduces the diversification index.[14] Table No. 15 demonstrate this mathematical excercise performed on the basis of the incomes of the farms under study.[15]

As is shown in the above table the diversification index of the farms studied is very close to the unit. This shows that agricultural diversification in the Lajas Valley is very limited.

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13. G. W. Forster, Farm Organization and Management, Revised Edition, New York: Prentice-Hall, Inc. 1946.

14. The diversification index is obtained by squaring the fraction of the incomes from each concern represented in the total income of the farm and by dividing the unit (one) by the sum of all the squares of these fractions of income arising from each concern. If there is a total lack of diversification the result is the unit. Therefore, diversification can be measured by the amount by which the diversification index exceeds the unit.

15. Infra, p. 59

Calculation of Diversification Index in 77 Farms in the Lajas Valley, Lajas, Puerto Rico, 1969-70.

Table No. 15

Concern	Income	Fraction of Total Income	Square of Fraction of Total Income
Sugar Cane	$1,722,442.29	.847	.7174
Dairy Cattle	242,319.87	.119	.0142
Beef Cattle	68,760.00	.338	.1142
Totals	$2,033,522.66		.8458

$$\frac{1}{.8458} = 1.1823$$

Agricultural development in the Valley is largely directed towards one crop, sugar cane. This crop occupies 93.6% of the irrigable area, some 18,000 acres of cane being cultivated in the area.

At the beginning of this study, the hypothesis was put forward that the high cost of irrigation was a factor having a negative effect on agricultural production and diversification in the area. As a direct result of this factor it was necessary to make changes and adjustments in the planning of the land and cattle development of the area.

During field research based strictly on the opinions of the farmers, it was found that there are other factors responsible for the limited diversification practiced in this project. Table No. 16 shows the distribution of the farmers in percent related to the factors which in their opinion limit such diversification. [16]

It is interesting to note that, according to the farmers, the high cost of water is not such a significant factor in the little or restricted agricultural diversification in this irrigation project. Only 12% considered it a limiting factor. Thirty-seven percent (37%) of the farmers interviewed were of the opinion that the factor that most limits land and cattle diversification in the area is marketing. This opinion is highly logical and reasonable as there is an assured market only for the sugar and milk produced. The decision to cultivate any other product would involve marketing risks. The limited quantity of water follows the marketing factor in importance, and is the major factor in the opinion of 20% of the farmers. However, this is owing mainly to the fact that on most occasions the farmers order water simultaneously in times of drought. When these dry periods occur,

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16. Infra p. 61

Distribution of the Farmers in Percent in Relation to their Opinions of the Factors Responsible for the Little or no Agricultural Diversification in the Lajas Valley, 51 Farmers in the Lajas Valley, Puerto Rico, 1969-70.

Table No. 16

Factors	Number of Farmers	Percentage of Total
1. High Cost of Irrigation Water	6	12
2. Limited quantity of Irrigation Water	10	20
3. Lack of Technical Orientation	5	10
4. Marketing Problems	19	37
5. Inadequate Financing	7	13
6. Others Factors	4	8
Totals	51	100

and they are frequent in the Lajas Valley, the consumption of water increases, reducing the content of the dams. As a result the farmer's water ration is reduced. Thirteen percent of the farmers agree that inadequate financing is the main factor limiting agricultural diversification in the area.

Ten percent (10%) of the farmers state that lack of technical orientation is the leading factor and four percent (4%) believe that the lack of diversification is caused by other factors.

7. The Technical Experts and Agricultural Diversification:

With the object of obtaining more balanced data and opinions on the questions raised in the study, it was necessary to include some of the agricultural experts operating in the Lajas Valley.

In order to measure the opinions of the experts on the factors limiting agricultural diversification in the Valley, a scale was prepared divided in percent from 0 to 100. This is further divided into intervals of 5 units. Table No. 17 shows the results obtained on the opinions given by 20 of the experts who in one way or another are working on the agricultural development of the Valley.[17]

Concerning the high cost of water in relation to the other factors, six (6) experts out of a total of 20, thought that this factor affected agricultural diversification by 5%. Three (3) experts, or 15% of the total, thought that diversification was affected by 10%. According to three (3) other experts, this factor is affecting diversification by 20, 25 and 30% respectively. One expert thought that this factor affected the diversification of the farms by 40% and another by 15%. It is significant to note that the majority of experts attribute to this factor a limited value in comparison to the other factors.

On the limited quantity of water the opinion of the majority of the experts are divided. Twenty-five percent (25%) believe that this factor affects diversification by 5%, and another 25% of the experts believe that this factor is responsible for limited diversification by 30%. The opinions of the remaining experts are divided between the values of 10, 25 and 35% respectively.

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17. Infra, p.63

Operating in the Lajas Valley to Each of the
on Practical in this Project, Lajas, Puerto Rico

Percentage of Total	Factor No.4	No. of Experts Informing	Percentage of Total	Factor No. 5	No. of Experts Informing	Percentage of Total
0	-	0	0	-	0	0
50	-	0	0	+	1	5
25	-	0	0	+	3	15
10	-	0	0	+	3	15
5	+	6	30	+	8	40
10	+	1	5	+	3	15
0	-	0	0	+	2	10
0	+	3	15	-	0	0
0	-	0	0	-	0	0
0	+	1	5	-	0	0
0	+	6	30	-	0	0
0	-	0	0	-	0	0
0	-	0	0	-	0	0
0	+	1	5	-	0	0
0	+	2	10	-	0	0
0	-	0	0	-	0	0
0	-	0	0	-	0	0
0	-	0	0	-	0	0
0	-	0	0	-	0	0
0	-	0	0	-	0	0
100	-	20	100	-	20	100

3- Lack of Technical Orientation
4- Marketing Problems
5- Inadequate Financing

Even so it can be argued that for many of the experts this is an important factor in the agricultural diversification of the valley.

As for the lack of technical orientation, 50% of the experts assign it a value on the scale of only 5%. Twenty-five percent (25%) of the experts give it a value of 10% in comparison with the other factors.

According to these values, it can be concluded that this is the factor that least limits agricultural diversification in the area. According to the statistics presented in Table No. 17, the experts believe that the factor most affecting the agricultural diversification of the Valley, is the problem of marketing. The opinion of the experts on this is in agreement with that of the majority of farmers. Thirty percent (30 %) of the experts assign to this factor a responsibility of 50% on the scale of values. Another 30% give it a value of 25%, and 10% of the experts believe that this factor affects diversification, in comparison to the other factors, by 70%.

As for inadequate financing, 40% of the experts assigned it a value of 20% on the scale. From this it can be deduced that it is a factor to be taken into consideration in the agricultural diversification of the area. The opinions of the other experts are mainly distributed among the assignation of valuēs of 10, 15, 30 and 35% respectively.

To summarize, for the agricultural experts the factors most relevant to agricultural diversification in order of importance are: the problems of marketing, the limited quantity of water and inadequate financing. The high cost of water and the lack of technical orientation are far less relevant to the problem of diversification.

8. Opinions of the Farmers on Various Aspects of the System:

A- General Opinions:

The investigation carried out included a series of subjective questions whose purpose was to find out the opinion of the farmer in the Valley on some factors and circumstances which might throw light on the problem under study. Among general opinions of the study the following were encountered:

1- Ninety-four percent (94%) of the farmers were of the opinion that the Lajas Valley Irrigation Project had been a success. The remaining six percent (6%) were of the opinion that it had been a failure.

2- A hundred percent (100%) of the farmers stated that the Lajas Valley Drainage and Irrigation System had greatly benefited their farms, although they were not explicit about the amount of benefit obtained.

3- As for the series offered by the Water Resources Authority of Puerto Rico, 34% of the farmers found them excellent. Thirty-seven percent (37%) found them good, 20% found them satisfactory and 9% deficient.

As shown by Table No. 18, the farmer's opinion of the services offered by the Department of Agriculture in the Lajas Valley is much the same.[18] Thirty-seven percent (37%) find these services excellent, 23% find them satisfactory and only 3% find them deficient. In general the services offered by the agencies in the Valley are satisfactory.

4- As to the agrarian policy followed by the Government in the Lajas Valley Irrigation District, 71% of the farmers consider it correct. Twenty-nine percent (29%) differ, stating that it has not been that effective.

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18. Infra, p. 67

Quality of the Service Offered by the Water Resources Authority and the Department of Agriculture of Puerto Rico, According to the Farmers, Lajas Valley, Puerto Rico, 1969-70

Table No. 18

Agency	Quality of the Services									
	Excellent		Good		Averages		Deficient			
	No. of Farmers Giving their Opinion	Percentage	No. of Farmers Giving their Opinion	Percentage	No. of Farmers Giving their Opinion	Percentage	No. of Farmers Giving their Opinion	Percentage		
Water Resources Authority of Puerto Rico	17	34	19	37	10	30	5	9		
Department of Agriculture of Puerto Rico	19	37	19	37	12	23	1	3		

5. With the object of obtaining from the farmers some value judgments on the agricultural development of the area, the author presented the following propositions to the farmers for their opinions: Agriculture in the Lajas Valley is highly developed and poorly developed. The results obtained are presented in Table No. 19. It is noticeable that only six percent (6%) of the farmers consider the agriculture in the Valley to be highly developed. Eighty percent (80%) stated that the agriculture shows light development, and 14% are of the opinion that the agricultural development of the area is very poor.

Distribution of the Farmers According to their Opinions of the Agricultural Development of the Lajas Valley Irrigation District, Puerto Rico, 1969-70.

Table No. 19

Term Evaluated	No. of Farmers Giving their Opinion	Percentage of Total
Highly Developed Agriculture	3	6
Lightly Developed Agriculture	41	80
Poorly Developed Agriculture	7	14
Totals	51	100

C. Factors Affecting Irrigation Costs

With the purpose of studying the problem presented by irrigation costs in the Lajas Valley Project, the author identified ten factors which, in his opinion, affect these costs. These factors are enumerated as follows:

1. The water available for irrigation
2. The topography of the farms
3. The soils
4. The irrigation methods used
5. The administrative aspects of the system
6. The structures on the farms
7. The handling of water on the farms
8. The maintenance of irrigation and drainage structures
9. The size of the agricultural unit
10. The employment of the land

Twenty agricultural experts who work and collaborate in the agricultural development of the Lajas Valley were interviewed for the purposes of this phase of the study. To evaluate their opinions of the factors which it is presumed are affecting irrigation costs and which are enumerated above, a scale of values was prepared which lays these out in percent from 0 to 100. That is to say that the total value assigned to all the factors adds up to 100%. Each expert, individually, according to his own criteria and experience, assigned a value to each factor depending on how it affects the cost of irrigation as compared to the other factors.

1. The Water Available for Irrigation

The Lajas Valley Irrigation system is capable of serving 3.0 acre-feet of water per acre of irrigable land to the farms of the project. In addition each farmer has the right to receive, free of charge, 1 acre-foot of water once his monthly ration has been exhausted. Nevertheless it was found that the average consumption of the farms studied was 1.1 acre-feet per acre per year. This shows that the farmers are not using the maximum quantity of water that they have a right to, and that the great majority do not take advantage of the free water offered once their ration is exhausted. Because of this the price of water is higher for these farmers than for those who take advantage of the subsidy resulting from the use of free water.

On the other hand, many of the farms lack pools to store water. This situation limits them to using water only during the day and leads to an inefficient deployment of labour and a low water consumption.

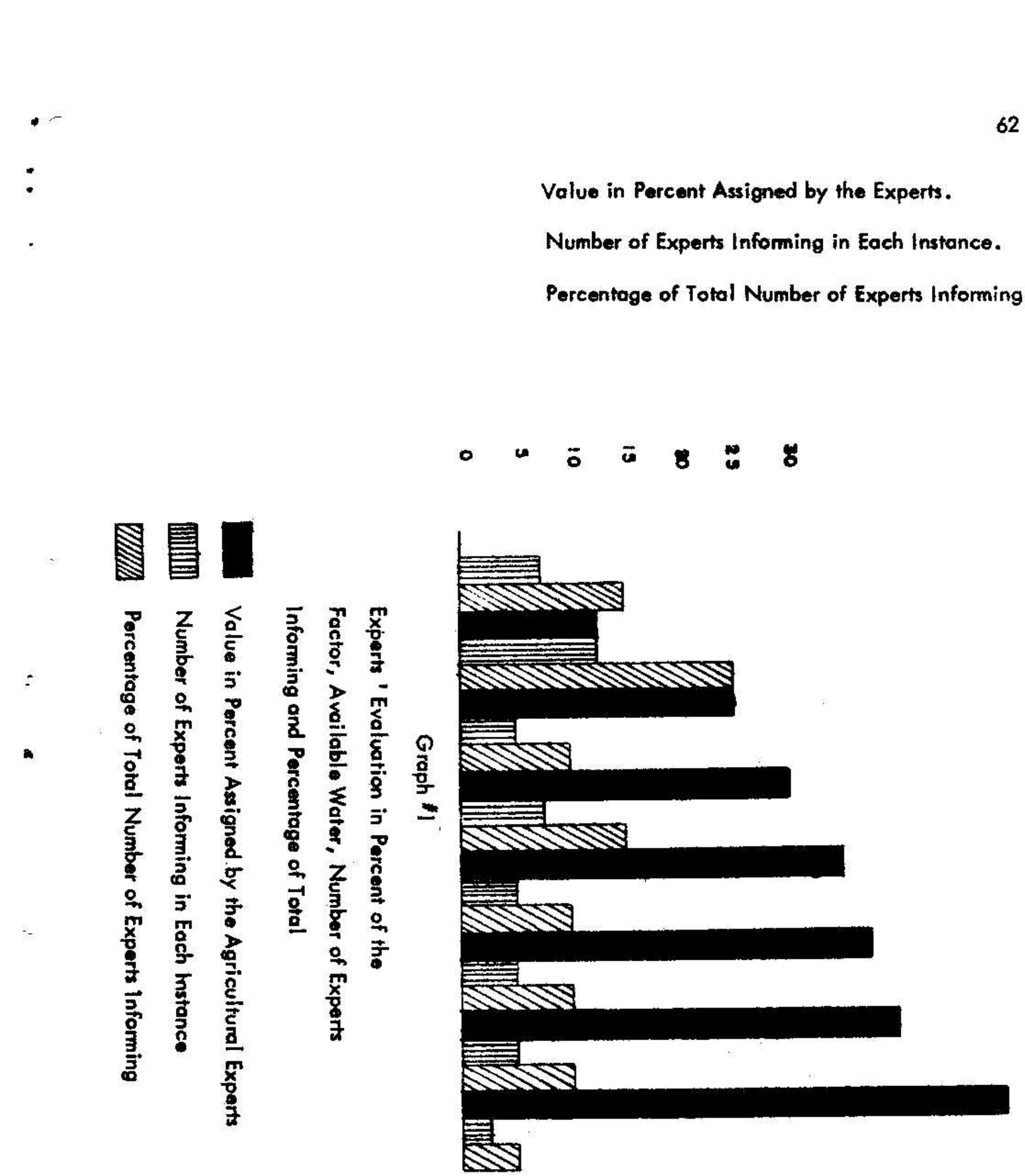
This study has shown that the amount of water available is not a significant factor in the cost of irrigation. According to the data collected during research and presented above, the low consumption of water is a much more significant factor in the cost of irrigation than the amount of water available. This latter factor, as the opinions of the experts show, is of little importance in irrigation costs. In graph No. 1 [19] it can be seen that 5 experts out of a total of 20, or 25%, state that the water available for irrigation affects irrigation costs by 5% . Three (3) experts stated that the factor exercised an influence on irrigation costs equivalent to 12%. Values of 10, 14 and 16% were given by two experts in each case. One expert was of the opinion that this factor affected the cost of irrigation by 20%. Three (3) experts expressed the opinion that the water available was a factor that did not affect irrigation costs at all.

[19. Infra, p. 71]

Value in Percent Assigned by the Experts.

Number of Experts Informing in Each Instance.

Percentage of Total Number of Experts Informing.



Graph #1

Experts ' Evaluation in Percent of the Factor, Available Water, Number of Experts Informing and Percentage of Total

Value in Percent Assigned by the Agricultural Experts

Number of Experts Informing in Each Instance

Percentage of Total Number of Experts Informing

2. The Topography of the Farms

The steeper properties in the Lajas Valley are generally irrigated by pumping. The water is pumped to the highest part of the farms and then distributed by gravity through lateral canals and open furrows. The soil topography plays an important part in the use of irrigation on these farms.

The water applied in the irrigation of a soil requires a continuous gradient and uniform surface configuration. This condition exercises a profound influence on the efficient use of irrigation water. In those soils where the topography is not uniform or which lack adequate levelling, the lower areas are irrigated to excess while the higher areas receive little or no water. As a result there are losses in harvest and a wastage of water, thus increasing the operational costs of irrigation in the majotity of cases.

Graph No. 2 presents the evaluation of the topographical factor made by the technical experts. * As can be seen, eight of the experts felt that this factor affected irrigation costs by 20%, while a second group of five (5) experts were of the opinion that this factor affected irrigation costs by 5%. Values of 7.10 and 15% were given by two experts in each case. It should be pointed out that 40% of the experts give a significant value to this factor in its effect upon irrigation costs.

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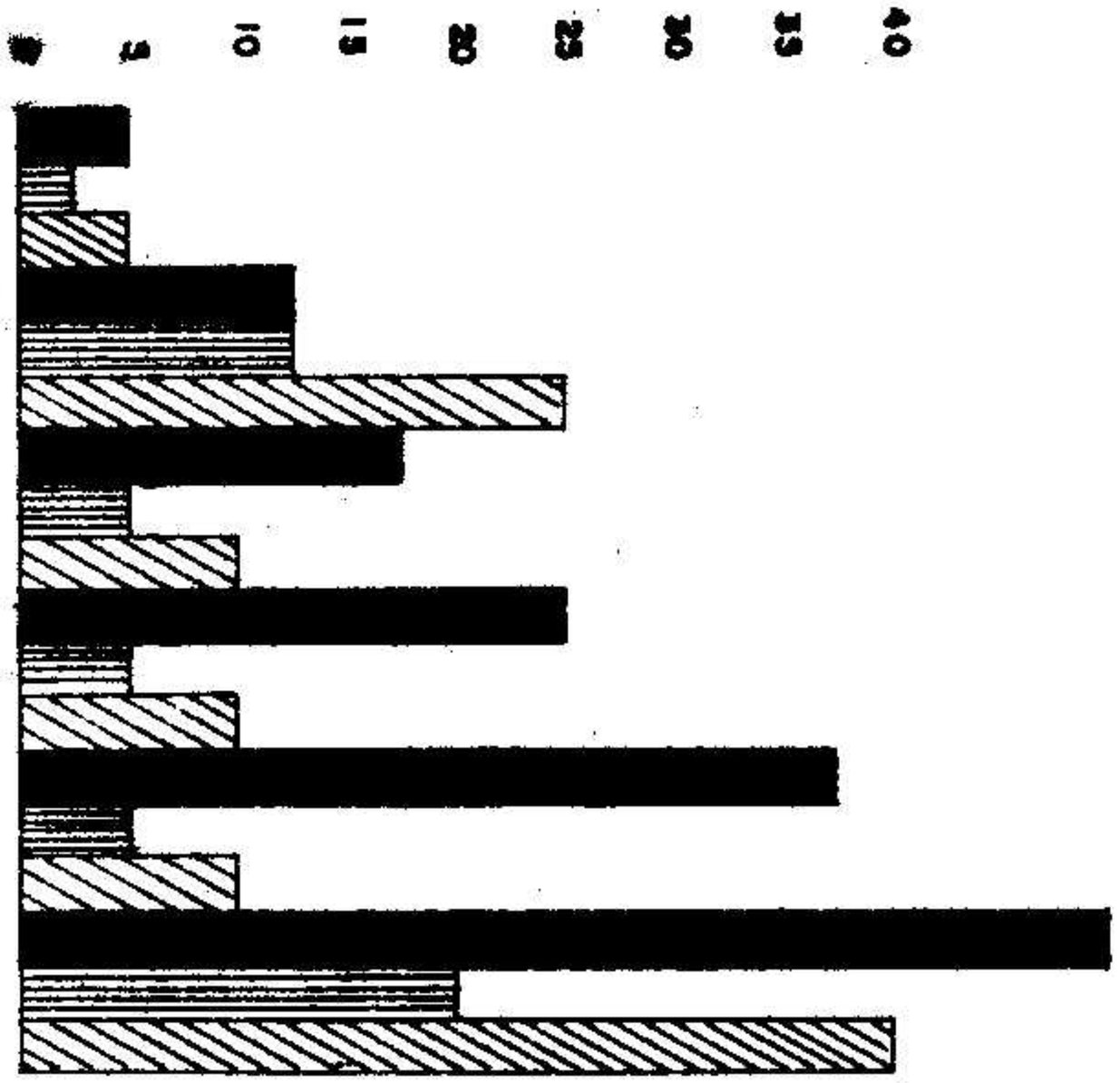
* Infra, p. 73

Value in Percent Assigned by the Experts

Number of Experts Informing in Each Instance

Percentage of Total Number of Experts Informing



Graph #2

Experts Evaluation in Percent of the Factor, Topography, Number of Experts Informing and Percentage of Total.

Value in Percent Assigned by the Experts

Number of Experts Informing in Each Instance

Percentage of Total Number of Experts Informing.

3. The Soils of the Lajas Valley

The Federal Soil Conservation Service made the most recent classification known of the soils of the Lajas Valley.[20] Based on this classification a general map of the soils was prepared in which these were divided into five associations. In general each association contains major and minor soils in a typical though not always uniform pattern.

The soils making up any association can differ in some of their properties, for example: inclination, depth and drainage, so that the map does not show the class of soil in a given place, but the soil pattern. In each of the patterns there are generally several different classes of soil. Each association is designated by the largest soil series that it contains, although soils of other series may also be present. These associations are described as follows:

(a) Fraternidad - Aguirre - Cartagena

This Association takes in a long broad area extending across almost the whole of the Northern part of the Lajas Valley. It includes slightly sloping alluvion plains, except in the lower parts of the Valley where the terrain is almost flat. Approximately 75% of the area covered by this Association is under irrigation and is dedicated to the cultivation of sugar cane. Almost all of this Association is highly productive and does not present serious irrigation problems.

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20. Oliver R. Carter, Soil Survey of the Lajas Valley Area, Puerto Rico, United States Department of Agriculture Soil Conservation Service, Rio Piedras, Puerto Rico, April 1965, pp. 5-9.

(b) Fe - Guánica - Aguirre

This group of soils is found in the East-central area of the Lajas Valley. This is an almost flat plain which includes the old Guánica lagoon, the area known as the "Anegado" and the wet and marshy areas adjacent. A large proportion of these soils are saline, sodic, and poorly drained. Twenty five percent (25%) of this Association is under irrigation for sugar cane, the remaining land being mainly dedicated to pasture for dairy cattle.

(c) Américas - Guayabo - Sosa

This Soil Association is found in two small areas of slightly undulating plain in the extreme west of the Lajas Valley. The majority of the soils are acid and of a totally sandy profile. In most of this Association the yield in crops and pastures is low. This land does not lend itself to cultivation on a commercial scale.

In general the soils of this Association are not under irrigation.

(d) Guánica - Aguilita - Amelia

This Association is found in the area known as the "Sierra Bermeja" and the "Peñones de Melones" and also at the foot of the hills close to the base of these mountains. Soils of this Association are also found in the alluvial cones formed by sedimentary material washed down from the mountains. This Association is found in one of the dryest regions of the Island and is not irrigated at all.

(e) Descalabrado - Jácana - San Germán

This Association of Soils is found in the mountainous ring which forms the Northern part of the project. It surrounds the River Yauco Valley in the East and extends along the Southern part of the area. There are steeply sloping soils at the foot of the mountains with narrow valleys and alluvial cones of medium breadth. A small area of the soils, especially in the valleys and cones already mentioned, is under irrigation for sugar cane. Approximately 10% of the area is covered by unirrigated crops, and about 50% of the Association is dedicated to pastures. The remaining area is composed of weeds and cactus.

The farms studied are grouped by soil associations according to their positions on the general map. Table No. 20 gives the distribution of the farms, the number of these per association and the area they cover. [21] As can easily be seen, the majority of these farms are included in the Association Fraternidad-Aguirre-Cartagena and Descalabrado-Jácana-San Germán. A smaller percentage is found in the Association Fé-Guánica-Aguirre. Farms from Associations "c" and "d" are not included in this study, as these areas are almost entirely unirrigated and in some cases present difficult physical and chemical problems for agriculture under irrigation.

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21. Infra, p. 77

Table No. 20 — Distribution of the Farms Studied by Soil Associations, 77 Farms in the Lajas Valley, Puerto Rico, 1969-70.

* Distribution of Soils	No. of Farms	Percentage of Total	Area of Farms (Acres)	Percentage of Total
1- Fraternidad - Aguirre-Cartagena	53	68.8	8,775.42	71.96
2- Fe-Guánica-Aguirre	3	4.0	707.64	5.80
3- Americus-Guayabo-Sosa	-	-	-	-
4- Guayama-Aguilita-Amelia	-	-	-	-
5- Descalabrado-Jácana-San Germán	21	27.2	2,712.18	22.24
Totals	77	100.0	12,195.24	100.0

* Classification made by the Federal Soil Conservation Service.

It was found in this study that the soil factor [22] does not have a significant influence on irrigations costs in relation to the other factor analyzed. Graph No. 3 shows the values given to this factor by the agricultural experts. [23] As can be seen the greatest percentage of the experts (30% of the total) are of the opinion that the effect on irrigation costs of the soil factor is five percent (5%). Twenty percent (20%) were of the opinion that the soils of the Lajas Valley do not have any influence on irrigation costs. Five of the experts interviewed thought that the factor under consideration affected costs by 10%. Another group of three (3) experts thought that the soil factor affected costs by 15%, while a value of 20% was given by 10% of the experts.

4. The Irrigation Methods Used

Of the methods used in the Lajas Valley Project, the most common is irrigation by open furrows (Furrow Irrigation). Water is applied to the furrows and is moved by gravity. In irrigation by pumping, which is also common in this area, the contour irrigation system by means of open furrows (Contour-Furrow Irrigation) is used. The system of irrigation from the air (Sprinkler Irrigation) is little used on the crops in the Project. It is used on a small scale to irrigate pastures, although there is some land under sugar cane irrigated by this system.

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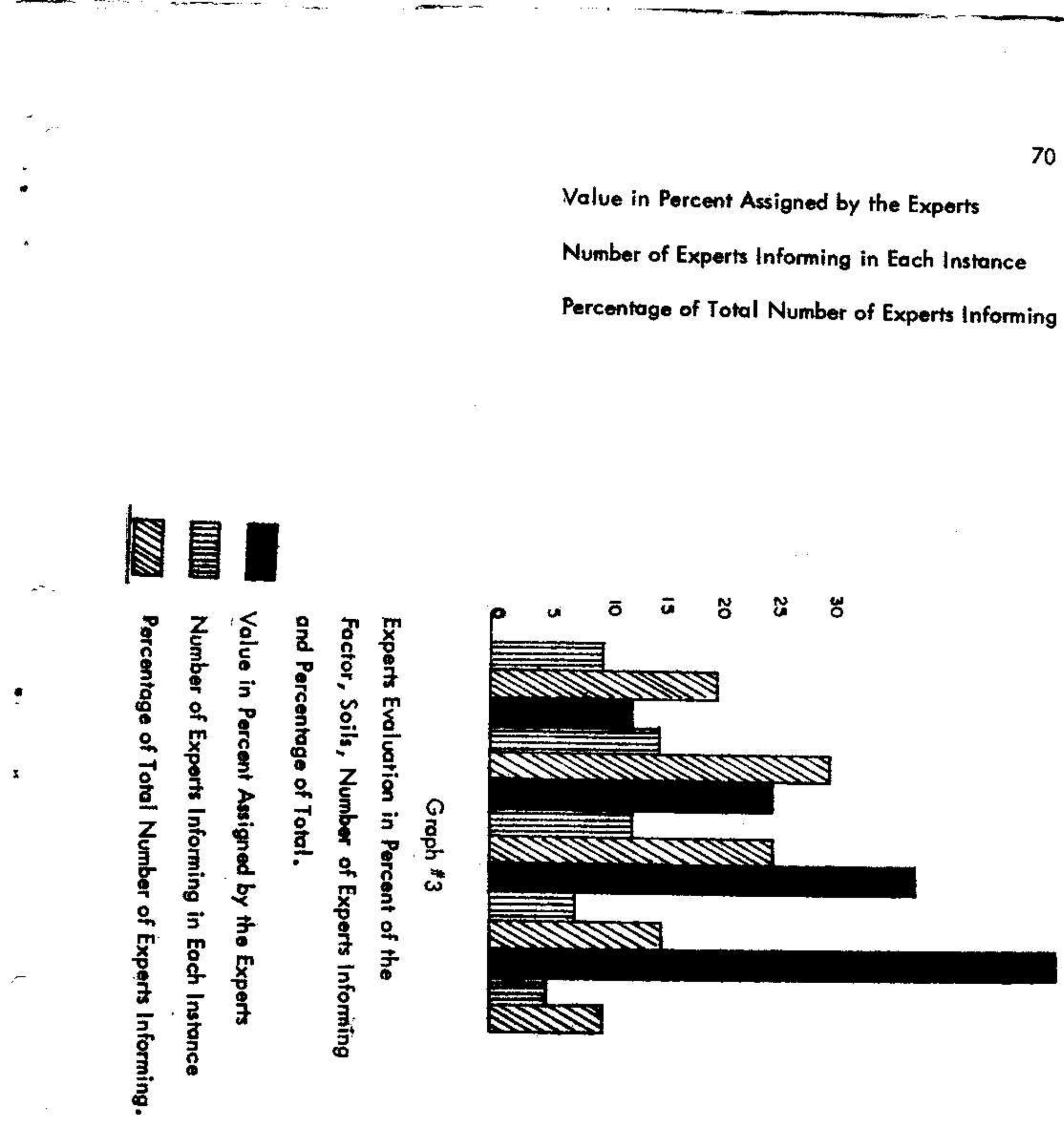
23. The types of soil existing in the Lajas Valley are referred to here.
24. Infra, p. 79.



Graph #3

Experts Evaluation in Percent of the Factor, Soils, Number of Experts Informing and Percentage of Total.

Graph No. 4 shows the evaluation made by the experts interviewed of the factor, the methods of irrigation used. [24] According to the data given it can be seen that the greatest percentage of experts (40% of the total) attributed a value of 15% to the affect of this factor on irrigation costs. Twenty five per cent (25%) were of the opinion that this factor exercises an influence of 10%. Three (3) experts gave it a value of five percent (5%). Values of 12 and 13% were given by two (2) experts in each instance. It can be concluded that, in the opinion of the majority of the experts, this factor has a slight relation to irrigation costs as compared to the other factors.

5- Administrative Aspects of the Systems

The Puerto Rico Water Resources Authority is in charge of the Lajas Valley Irrigation System. [25] This agency has set up a timetable for water deliveries in agreement with the petitions made by its Worker's Union. It was found in the present study that this schedule does not answer the needs of the farmers. This situation is affecting the cost and the maximum exploitation of irrigation water. The majority of experts interviewed shared this opinion.

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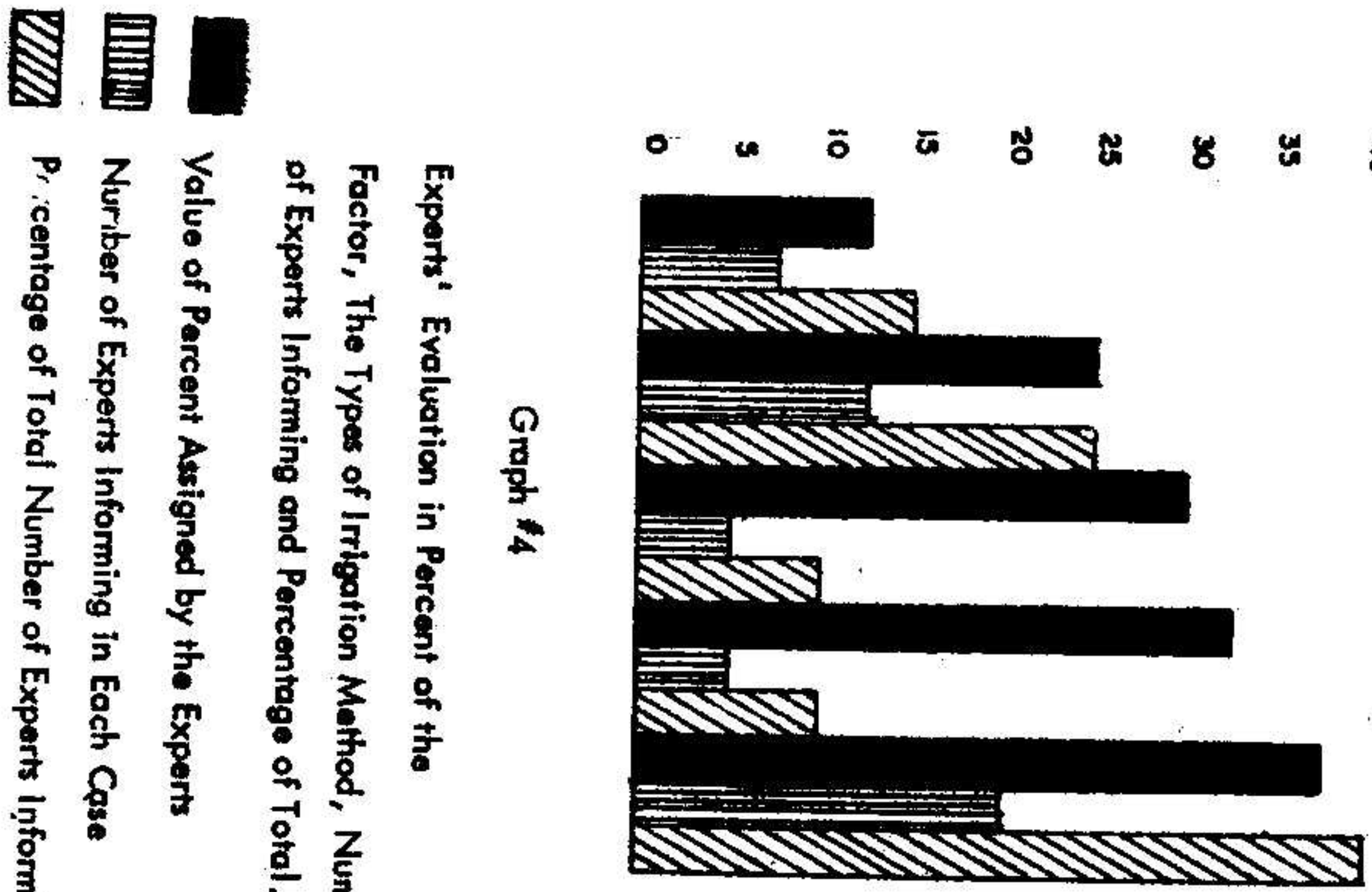
24. Infra, p. 81
25. Supra, p. 7



Graph #4

Experts' Evaluation in Percent of the Factor, The Types of Irrigation Method, Number of Experts Informing and Percentage of Total.

Value of Percent Assigned by the Experts

Number of Experts Informing in Each Case

Percentage of Total Number of Experts Informing.

In graph No. 5 it can be seen that the largest group of experts, 6 from a total of 20, or 30%, stated that the administrative aspects of the system was a factor which affected irrigation costs by 17 %. * Another group of 5 experts, or 25 % of the total were of the opinion that this factor affected irrigation costs by 20%. Ten percent (10%) of the experts assigned it a value of 25%. A smaller group of experts (two in each instance), felt that the factor in question affected the operational costs of irrigation by five (5) and nine percent (9%) respectively.

It should be pointed out that the majority of the values given by the experts fluctuate between 17 and 25%, which makes this a factor of extreme importance in the cost of irrigation.

6. The Structures on the Farms

This factor refers to the system of structures on the farms for the handling of water, such as irrigation and drainage canals, etc. As is mentioned above furrow irrigation is the method most commonly used to irrigate the crops in the project. On many farms, particularly where the terrain is undulating , the furrows do not have the necessary inclination. This causes an improper control of irrigation water with subsequent losses of water and of soil by erosion. In other instances the land is not correctly levelled which makes it impossible for the furrows to discharge excess water throughout their whole length. In other instances the land contains hollows which prevent the water circulating freely and cause deposits which result in some areas remaining without irrigation, thus occasioning losses in water and crops. Many of the canals which supply water to the land require frequent repairs and lining to avoid filtration of water. In other cases the canals within the farm,

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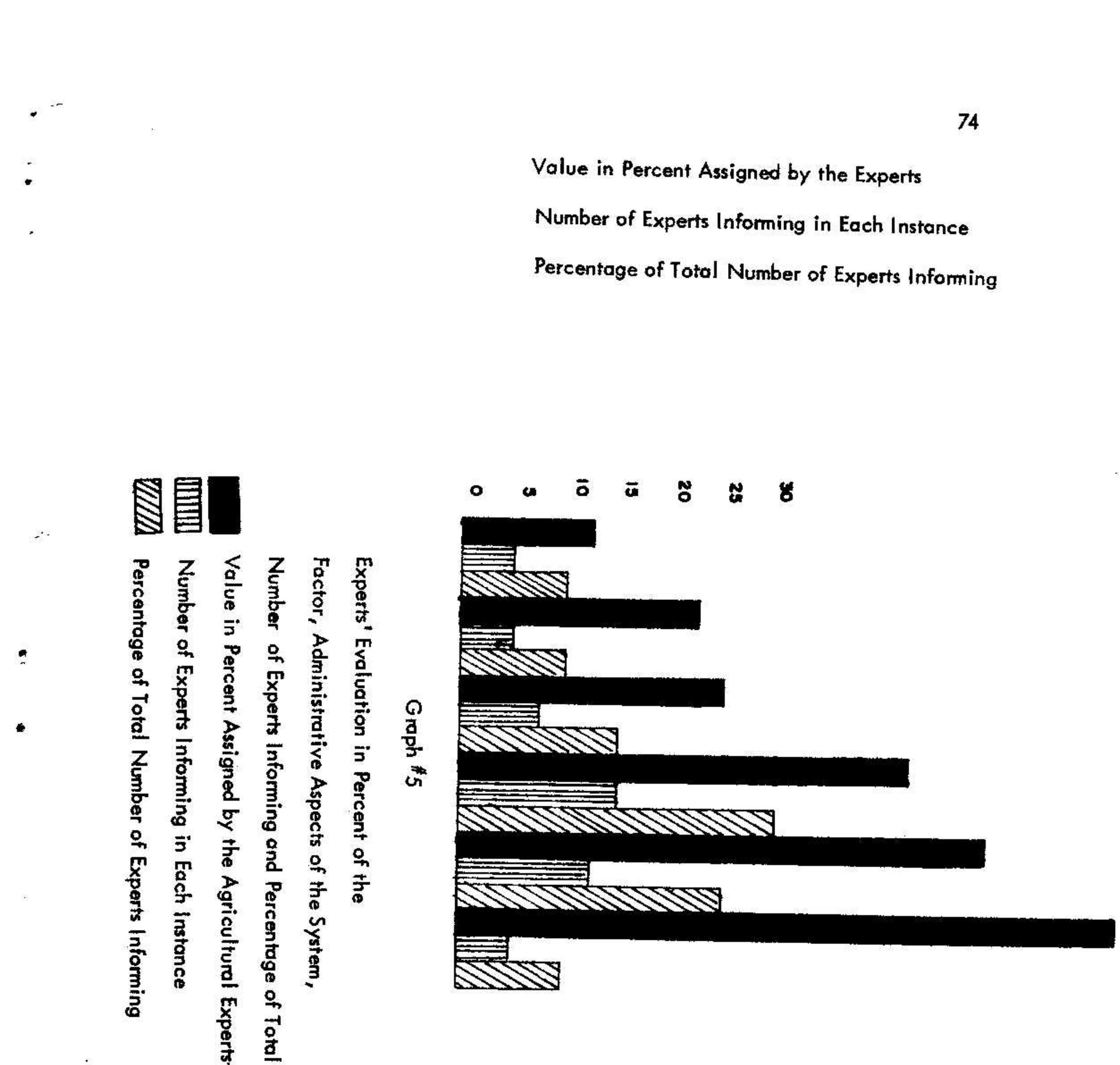
* Infra, p. 83.

Value in Percent Assigned by the Experts

Number of Experts Informing in Each Instance

Percentage of Total Number of Experts Informing



Graph #5

Experts' Evaluation in Percent of the

Factor, Administrative Aspects of the System,

Number of Experts Informing and Percentage of To

Value in Percent Assigned by the Agricultural Exp

Number of Experts Informing in Each Instance

Percentage of Total Number of Experts Informing

the responsibility for which is the farmers', are not built to the required dimensions, and water overflow is frequent. The difficulties cited above bear a close relation to the management and correct construction of farm structures for the effective distribution of irrigation water.

Graph No. 6. shows the experts' evaluation of the factor, farm structures.[26] From the data given in the graph, it can be seen that a large number of the experts, eight of them, are of the opinion that this factor affects irrigation costs by 11%. Two experts (2) thought that costs were affected by 13%, one gave a value of 10%, four a value of five percent (5%), and a group of five (5) experts a value of twelve percent, (12%). It is significant to point out that a large number of the experts attribute a relative importance to this factor in its affect upon irrigation costs as compared to the other factors.

7. The Handling of Water on the Farms

The improper use of irrigation water causes damage to the soil through erosion, accumulation of salts in the lower areas, an ever present situation in this project, and creates serious drainage problems. If the excess water circulates around the area of the plant roots it washes away the nutrients disposable for their development. The waste of water arising from bad management increases the costs of crop production and impairs the soil by causing erosion.

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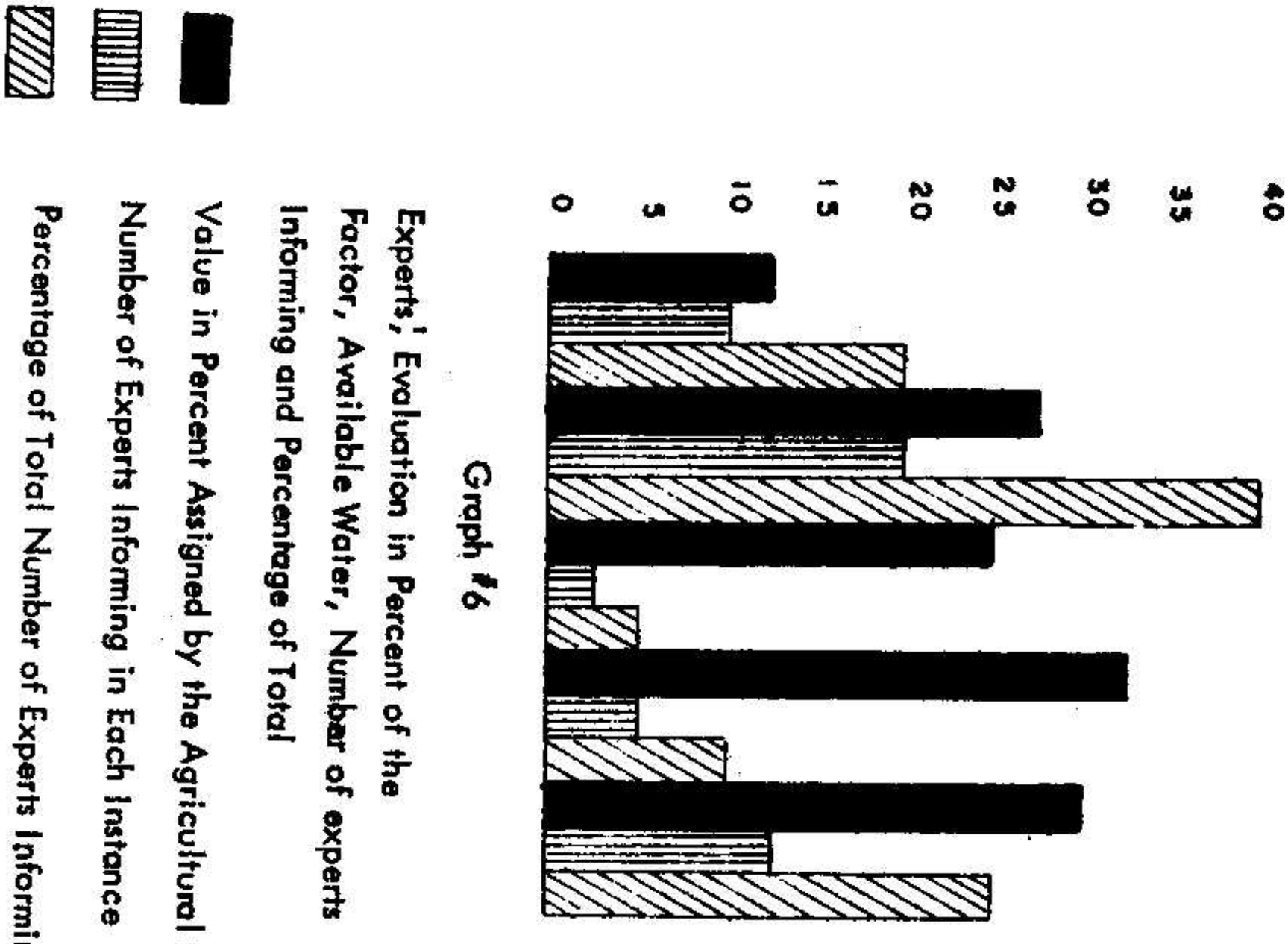
26. Infra, p. 84.

Value in Percent Assigned by the Experts

Number of Experts Informing in Each Instance

Percentage of Total Number of Experts Informing



Graph #6

Experts' Evaluation in Percent of the Factor, Available Water, Number of experts Informing and Percentage of Total

Value in Percent Assigned by the Agricultural Experts

Number of Experts Informing in Each Instance

Percentage of Total Number of Experts Informing

Graph No. 7 gives the experts' evaluation of the factor, handling of water on the farms.[27] This graph shows, among other things, that the largest percentage of experts were in agreement that this factor affects irrigation costs by five percent (5%). Two (2) experts were of the opinion that the factor under discussion was responsible for 20% of irrigation costs, five (5) experts believed that this factor affected costs by 15%. A further two (2) experts atributed to it a value of two percent (2%). It should be pointed out that this factor, even though a large number of experts gave it a value of only five percent, (5%), is one that must be considered among those affecting irrigation costs.

8. The Maintenance of Irrigation and Drainage Structures

In general, there is a great loss of water in the agriculture under irrigation in Puerto Rico. There are various reasons for this: one is the Puerto Rican farmer's lack of knowledge of the specific water requirements of the different crops. Another and very important reason, is the lack of adequate maintenance of the irrigation and drainage canals. The loss of water owing to filtration in the farm canals is enormous. The failure to clean the irrigation and drainage canals pertaining to the system as well as those on the farms plays an important part in the efficient use of irrigation water.

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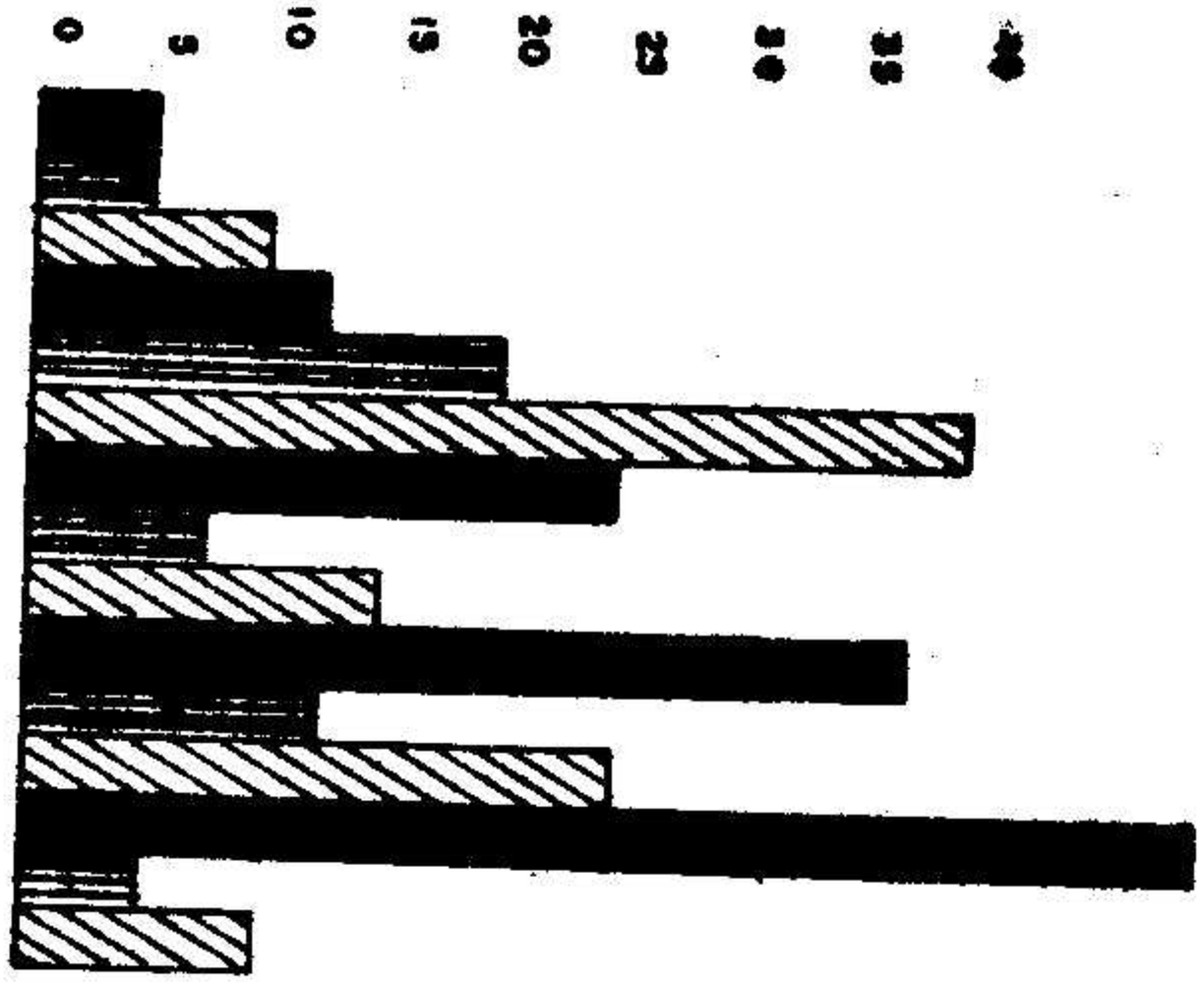
27. Infra, p. 87.

Value in Percent Assigned by the Experts.

Number of Experts Informing in Each Instance.

Percentage of Total Number of Experts Informing.



Graph # 7

Experts' Evaluation in Percent of the Factor, Handling of Water on the Farm, Number of Experts Informing and Percentage of Total

Value in Percent Assigned by the Agricultural Expe

Number of Experts Informing in Each Instance

Percentage of Total Number of Experts Informing

Graph No. 8 shows an evaluation of the experts' opinions of the factor, maintenance of irrigation and drainage structures.[28] According to 35% of the experts, the irrigation and drainage structures in the Lajas Valley affect irrigation costs by 10%. Twenty percent (20%) of the experts were of the opinion that this factor affected irrigation costs by four percent (4%). Fifteen percent (15%) of the experts gave this factor a value of three percent (3%). Values of nine (9), 14 and 15% were given by two experts in each case. Although the largest percentage of experts gave the factor in question a value of only 10%, it is important to point out that the maintenance of irrigation and drainage structures is a factor of relative importance in irrigation costs.

9. The Size of the Agricultural Unit

The size of the farm will depend on the type of concern to which the farmer is dedicated. For example aviculture requires less acreage than cattle-farming. Furthermore, whatever the type of land and cattle concern, the administrator must determine the precise extension of the agricultural unit in order to defray operational and family expenses.

Land and cattle statistics have shown, in the majority of cases, that large agricultural units achieve a greater net income over a given period than the smaller units. This is due to a more advantageous use of machinery, labour, capital and other items. On this point it is necessary to call attention to the fact that the large agricultural units are not always profitable. In some cases, faults in the administration and organization of the farm reduce benefits considerably. On the other hand, there are small well organized and directed units which provide greater profits.

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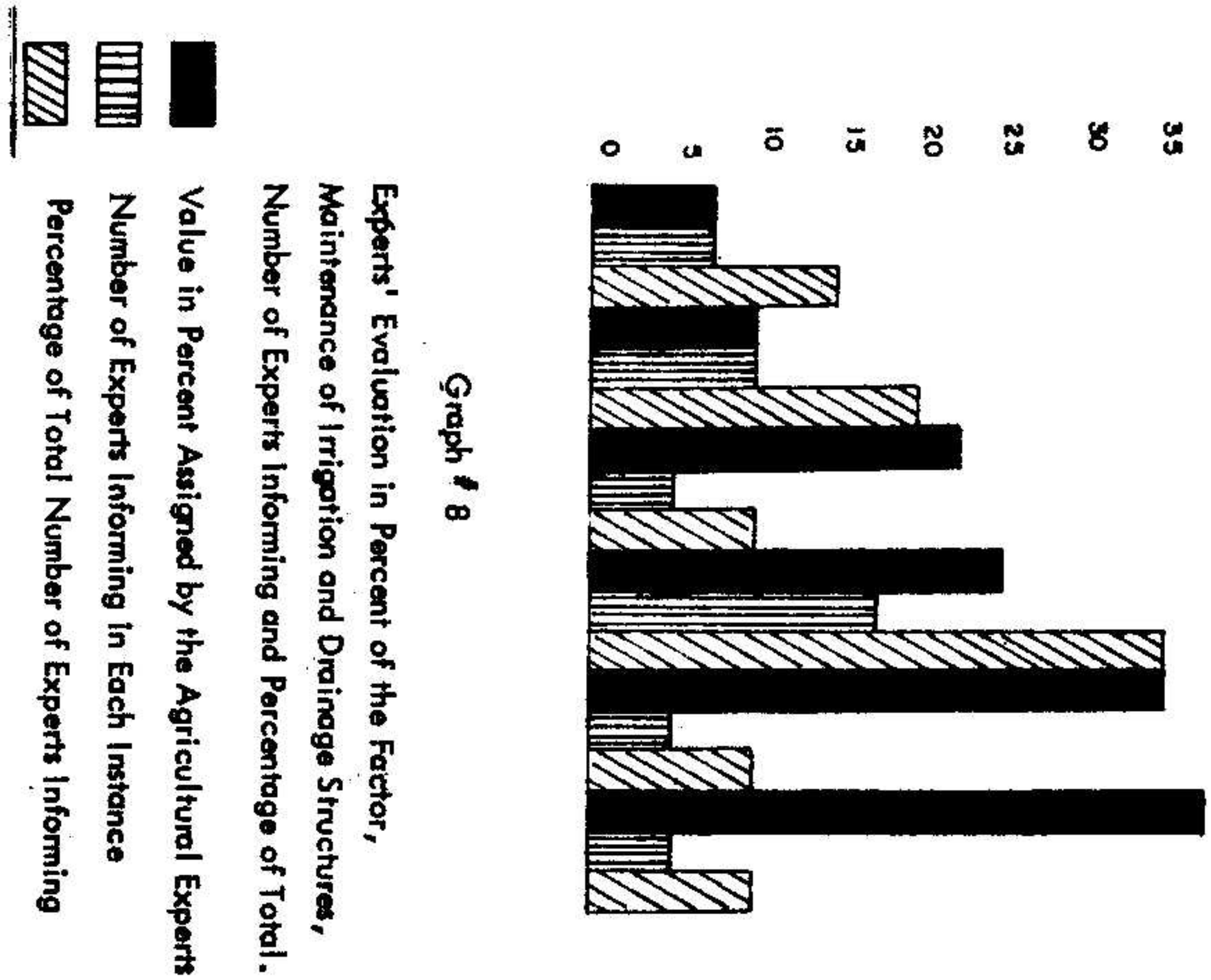
28. Infra, p. 89.



Graph # 8

Experts' Evaluation in Percent of the Factor,
Maintenance of Irrigation and Drainage Structures,
Number of Experts Informing and Percentage of Total.

Value in Percent Assigned by the Agricultural Experts

Number of Experts Informing in Each Instance

Percentage of Total Number of Experts Informing

The Lajas Valley is a special case. Generally the land and cattle industries established in the area, for instance cattle farming and the cultivation of sugar cane, require agricultural units of considerable size. However, in the Lajas Valley there are a small number of large farms and a greater number of small and medium units. Fifty one percent (51%) of the farms included in the study could be described as small units. The medium-sized units make up 35% and the large units 20% of the total.[29] It should be pointed out that, according to the statistics given in this study, irrigation costs vary with the size of the farms.[30]

Graph #9 gives the experts' evaluation of the factor, the size of the farm, as related to its effect on irrigation costs.[31] The greatest number of experts, nine (9) in all, considered that this factor affected irrigation costs by 13%. A group of four (4) experts gave the factor a value of 10%. Two experts gave it a value of eight percent (8%) and three (3) were of the opinion that the size of the agricultural unit affected irrigation costs by five percent (5%). As can be seen in the graph, 45% of the experts assigned this factor considerable value in relation to the other factors, which indicates that this is a factor of great importance in irrigation costs.

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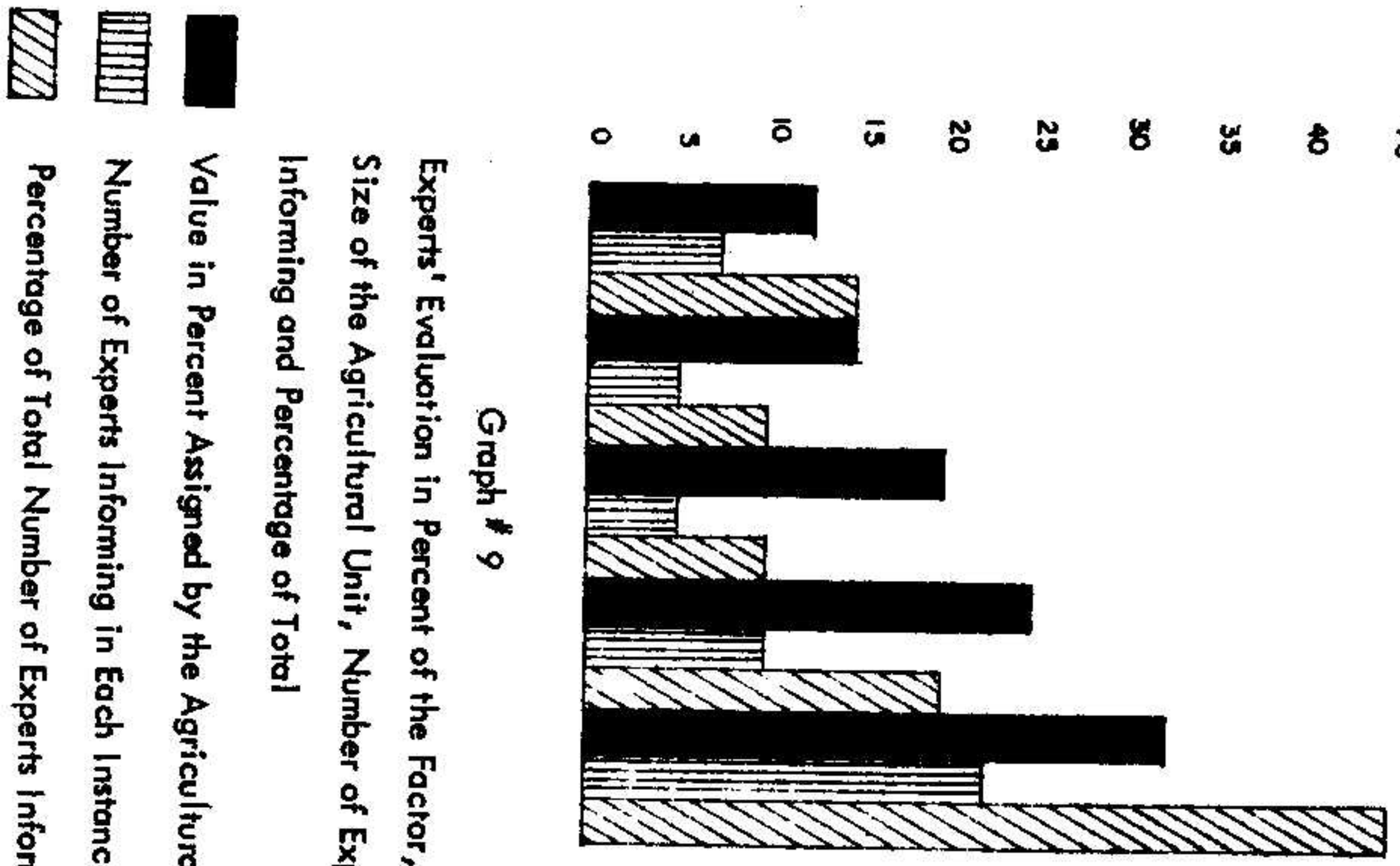
29. Supra, p. 49.
30. Infra, pp. 97-99
31. Infra, p. 91



Graph # 9

Experts' Evaluation in Percent of the Factor,
Size of the Agricultural Unit, Number of Experts
Informing and Percentage of Total

Value in Percent Assigned by the Agricultural Expe

Number of Experts Informing in Each Instance

Percentage of Total Number of Experts Informing

10. The Deployment of Farm Lands

This factor has to do with the use of the land making up the agricultural unit; that is the land and cattle industry to which the unit is dedicated. The land under irrigation in the Lajas Valley is, in the main, dedicated to the cultivation of sugar cane.

In graph No. 10 [32] it can be seen that the largest percentage of experts, nine (9) out of a total of 20, were of the opinion that the deployment of farm land affects irrigation costs by three percent (3%). A group of three (3) experts thought that the factor mentioned affected irrigation costs by eight percent (8%). A further group of three (3) experts gave it a value of six percent (6%), and another group of three (3) a value of six percent (6%). Yet another group of three (3) experts was of the opinion that this factor affected costs by 10%, and a limited number of experts, two (2) in this instance, gave it a value of two percent (2%). According to the majority of experts, the deployment of farm lands does not at present constitute an important factor in irrigation costs. This is owing in great part to the fact that in the Lajas Valley Project there is little diversification of crops, and therefore, the cost of irrigating various crops cannot be compared.

Table No. 21 presents the factors studied in order of importance, according to the analysis made of the opinions of the experts. [33]

D. Analysis of Irrigation Costs

The cost of water, labour and other costs, such as fuel and the maintenance of pumps, are variable items of cost which enter into the use of irrigation in the Lajas Valley.

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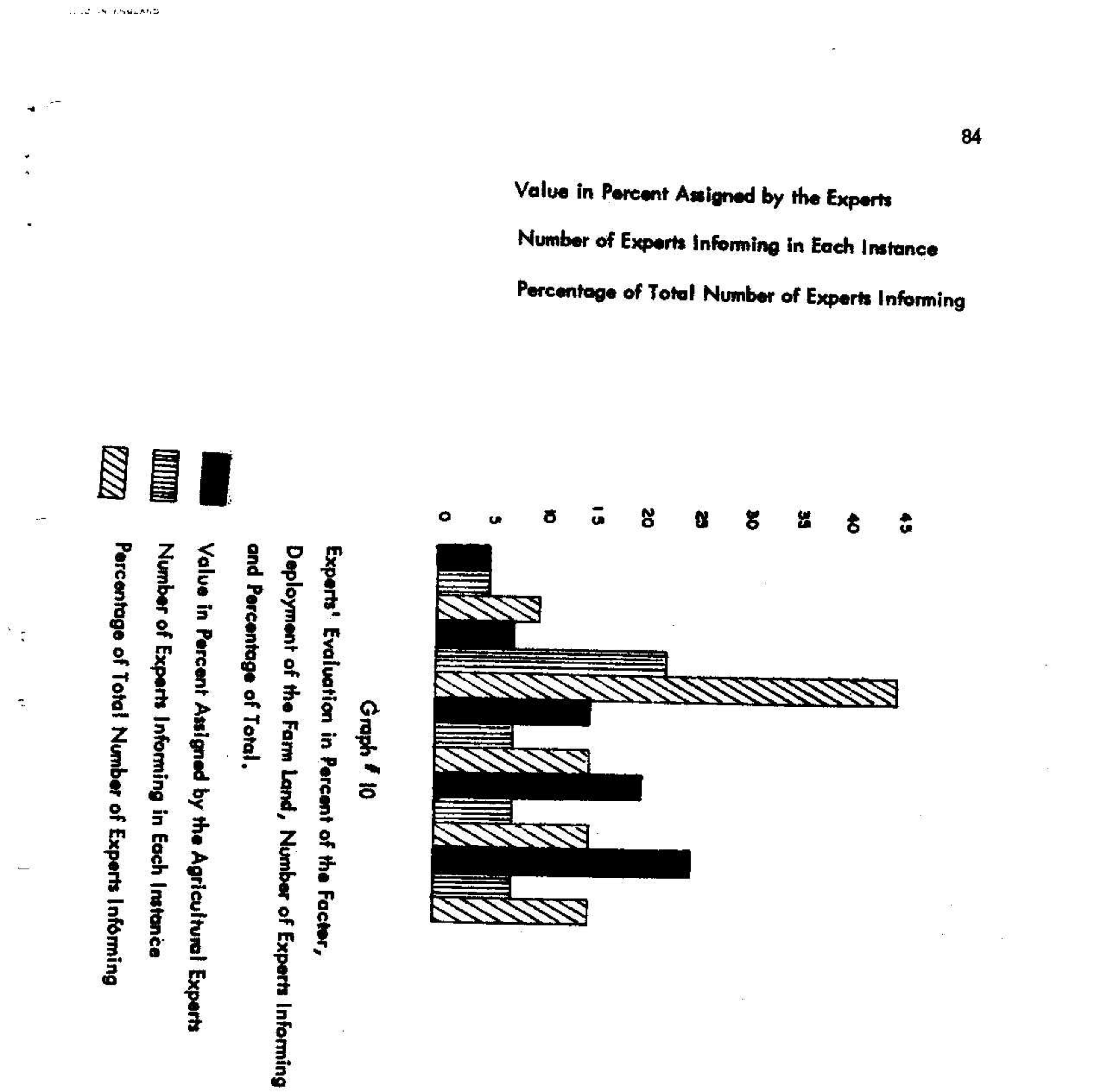
32. Infra, p. 93.
33. Infra, p. 94.



Graph # 10

Experts' Evaluation in Percent of the Factor, Deployment of the Farm Land, Number of Experts Informing and Percentage of Total.

Value in Percent Assigned by the Agricultural Experts

Number of Experts Informing in Each Instance

Percentage of Total Number of Experts Informing

Factors Affecting Irrigation Costs in Order of the Values Assigned in Percent by the Agricultural Experts in the Lajas Valley, 1969-70

Table No. 21

Factors	Highest Value in Percent Given by the Greatest Number of Experts	Number of Experts Informing	Percentage of Total
1. Topograhy	20	8	40
2. Administrative Aspects of the System	17	6	30
3. Irrigation Methods	15	8	40
4. Size of the Agricultural Unit	13	9	45
5. Farm Structures	11	8	40
6. Maintenance of Canals and Other Irrigation Structures	10	7	35
7. Soils	5	6	30
8. Handling of Water	5	8	40
9. Water Available	5	5	25
10. Deployment of Farm Land	3	9	45
Totals	104	74	370

In order to clarify these items of cost, the farms were classified according to their topography which determines the method of irrigation used on them.[34]

Water costs were obtained from the delivery records of the Yauco District Office of the Puerto Rico Water Resources Authority. The cost of labour was calculated on the basis of the number of men and days employed to apply the water bought, (this information was provided by the farmer). The cost of fuel and the maintenance of pumps and other equipment was obtained from the records of the farmers included in the study. The daily wage of the irrigators in the year in which the study was carried out was $7.20.

1. Irrigation by Gravity

The study revealed that the small farms, with the exception of those of between 50 and 100 acres, consume much less water per acre than the larger farms. The statistics given in Table No. 22 reveal that those farms of 250 acres and above, consume more than an acre-foot of water per acre per year, and that the cost, although it seems to be higher, is in proportion lower per unit than on the small farms.[35]

The majority of farms irrigating by gravity have an area of 100 acres or less. Thirty percent (30%) cover an area of 50 acres or less and 23.3% vary between 50 and 100 acres. The study showed that irrigation costs tend to be less per unit of water consumed although they seem to become greater as the consumption of water increases. The water consumed varied from .31 acre-feet on the farms of 50 acres or less to 1.96 acre-feet on the farms of 250 to 300 acres. The cost of applying .31 acre-feet of water per acre was $5.82, and that of applying 1.96 acre-feet per acre was $23.28. If the increase in cost were directly proportional to the increased quantity of water used, the application

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34. Supra, p. 39.
35. Infra, p. 96.

'ze of the Farms Irrigating by Gravity and the Cost of Irrigation,
Lajas Valley, Lajas, Puerto Rico-1969-70

Acres	Annual Consumption Average No. of Acrefeet per acre	Cost of Water Per Acre per Year	Cost of Labour Per Acre per Year	Total Cost per Acre per Year	Average Cost of Irrigation per Farm per Year
	.31	$1.86	$ 3.96	$ 5.82	$ 128.04
	'5	6.90	9.58	16.48	945.95
		4.08	5.33	9.41	614.47
		4.74	3.24	7.98	514.71
		5.40	7.20	12.60	1827.00
		11.76	11.52	23.28	1226.86
		9.24	8.35	17.59	2022.85

of 1.96 acre-feet of water per acre would cost approximately $36.80. It is therefore, significant to note that the greater the amount of water used the less per unit the cost of irrigation. The same situation occurs with the use of labour, but not with the cost of water which has a fixed price.

2. Irrigation by Pumping

Twelve (12) farms using this system were studied. The average water consumption of this group of farms during the economic year 1969-70 was .64 acre-feet per acre per year. This consumption can be considered very low. Of the group the larger farms consumed the greatest quantity of water, especially those of between 250 and 300 acres. As occurs with the farms irrigating by gravity, the small farms in this group are those which consume the least quantity of water.

Based on the statistics given in Table No. 23, it is possible to make observations similar to those made on irrigation by gravity. [36] With the use of a greater quantity of water, the cost, although it seems to be greater, is in fact less per unit. For example, if the farms irrigated 1.23 acre-feet of water per acre and if the costs increased directly with the increased amount of water used, the cost per acre would exceed $20. The same situation would occur with the farms that used 1.11 and 1.06 acre-feet of water respectively.

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36. Infra, p. 98.

the Size of the Farms Irrigating by Pumping and the
ms in the Lajos Valley, Lajas, Puerto Rico, 1969-70

sumption of Acre	Cost of Water Per Acre Per Year	Cost of Labour Per Acre Per Year	Other Costs Per Acre Per Year	Total Cost Per Acre Per Year	Average Cost of Irrigation per Farm per Year
	$ .63	$ 1.87	$ 2.57	$ 5.07	$ 67.94
	.84	2.12	2.40	5.36	348.40
	.36	1.08	.48	1.92	172.42
	1.41	3.49	3.18	8.08	791.84
	3.33	8.43	5.17	13.60	1455.20
	3.69	8.00	6.78	18.47	4096.65
	3.18	6.80	5.72	15.70	2700.40

In the investigation carried out it was found that the costs of irrigation by pumping vary according to size of the farms and the amount of water consumed. The study showed that in the pumping system the cost of labour tended to increase proportionally following a definite pattern. As opposed to irrigation by gravity the cost of labour does not tend to decrease per unit of water used; on the contrary it increases. As is explained above, the pumping system involves additional cost for the fuel which the pumps use and for the maintenance of the pumps and other equipment. These costs tend to increase as the consumption of water increases.

It is important to point out that the total cost of irrigation per acre per year appears to be less by the pumping than by the gravity system. Although in pumping the operational costs are greater, the cost per acre per year is reduced because of the price of the water. While the price of water for the gravity method is $6.00 per acre-foot, the price for the pumping system is half of this, $3.00.

It should be pointed out that water consumption by this method on the Valley farms during the year in which the study was carried out was far below the level required by the crops.

3. Combined Irrigation by Gravity and Pumping

Those farms in the Lajas Valley which have an undulating topography, in general are irrigated by the combined method of gravity and pumping. The study showed that the farms in this group use greater quantities of water, especially those farms of 250 acres or more.[37] The farms consuming the greatest quantity of water were those of 300 acres or more. These farms used 2.15 acre-feet of water per acre per year. The small farms were those that consumed the least water. The study showed also that irrigation costs were

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37. See Table No. 24, Infra, p. 101.

greater per unit of water consumed on the small farms than on the larger farms.

In the use of combined irrigation, the cost of labour on those farms of 150 acres or less tends to be higher in proportion than on the larger farms. For example, the cost of labour on the farms that use 2.15 acre-feet of water is $9.94. If this cost were proportional to the amount of water used, .43 acre-feet in the case of the smaller farms, it would be a little less than $2.00, while in fact the cost of labour on this latter type of farm was $6.62.

The cost of fuel and maintenance per unit of water consumed is considerably reduced in combined irrigation. The total cost per year varies greatly with the amount of water consumed and the labour involved. As can be seen Table 24, in order to irrigate .43 acre-feet of water per acre per year, the farmer incurs an expense of $8.94, while the irrigation of 2.5 acre-feet per acre per year costs $19.77. Although the use of greater quantities of water appears to be much more expensive, the actual cost of the application of the water per unit tends to be much lower. If costs varied proportionally the farms consuming .43 acre-feet of water per acre per year would spend about $4.00 per acre per year on irrigation, while in practice this cost reaches approximately $9.00. On the farms that use 2.15 acre-feet the cost is $19.77, but the quantity of water used is 5 times that used on the small farms.

e Size of the Farms Irrigating by the Combined Method
t the Cost of Irrigation, 29 Farms in the Lajas Valley,
Puerto Rico, 1969-70

nsumption of re	Cost of Water Per Acre Per Year	Cost of Labour Per Acre Per Year	Other Costs Per Acre Per Year	Total Cost Per Acre Per Year	Average Cost of Irrigation Per Farm Per Year
	$ 1.94	$ 6.62	$ .38	$ 8.94	$ 160.92
	2.16	3.38	.12	5.66	244.80
	4.37	6.26	.10	10.73	622.34
	4.55	4.39	.10	9.04	592.12
	6.75	7.49	.40	14.64	614.88
	7.02	7.70	.12	14.84	1,282.92
	9.68	9.94	.15	19.77	1,818.84

The cost of the water is arrived at by taking an average of the cost by pumping and that by gravity. This average cost is $4.50 per acre-foot of water. The price of the water is fixed and the cost naturally varies with the amount of water consumed. In relative terms, in some groups of farms, the cost of irrigation by the combined method tends to be less than with the other methods. For example, on farms of 200 to 250 acres, those irrigating by gravity consumed .90 acre-feet of water per acre per year. The total cost per acre was $12.60, while on those farms who used approximately the same amount of water by combined irrigation, as did those farms of 100 to 150 acres, the cost was $10.73.*

The same comparison can be made with farms irrigating by gravity and consuming approximately 2.0 acre-feet of water. The total cost of irrigation on these farms was $23.28; while by the combined method approximately the same amount cost the farmer $19.77. Furthermore, in irrigation by gravity thereare not the items of extra cost, although the price of the water is greater. In irrigation by pumping much the same situation is found: the costs tend to be relatively higher than in combined irrigation despite the lower cost of water. In combined irrigation, as with the other methods, the consumption of water on the small farms tends to be lower than on the large farms. Further, the cost per unit of water applied on these small farms is higher. Naturally the small farms suffer greater limitations in the consumption of water than the large farms; first, because of the administrative aspects of the system, and secondly, because the small farms do not possess artificial pools for the storage of water. In general the larger farms possess these structures as they have greater economic resources and sufficient space to construct them.

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* See Tables 22 and 24, Supra, pp. 96 and 101

Farms that do not have storage pools can receive water only during the day. Those that have pools can receive water at night. The fact that a farm has structures for storing water gives it a considerable advantage over those that do not. These farms can begin irrigation early in the morning without having to wait until the officials of the system open the outlets. On the small farms which generally do not have pools, the irrigators have to wait until the outlets are opened in order to begin irrigation and have to stop early in the afternoon as soon as the Puerto Rico Water Resources Authority official closes the outlets. As a result, on the small farms maximum advantage is not taken of labour in the irrigation process. The irrigators on these farms receive a full days wages, but do not work a full day.

It is impossible for the officials who open and close the outlets to be on all the farms at the same time. Because of this some farmers receive the service first and others later. The same occurs in the afternoon when the outlets are closed.

In summary it can be said that, based on this experience, a further factor affecting the efficient use of irrigation and, as a result, the cost, is the lack of structures for storing water on many of the farms. The farms which have these structures, usually the larger farms, irrigate more efficiently and consequently reduce their operational costs.

4. The Relationship Between Costs and Consumption

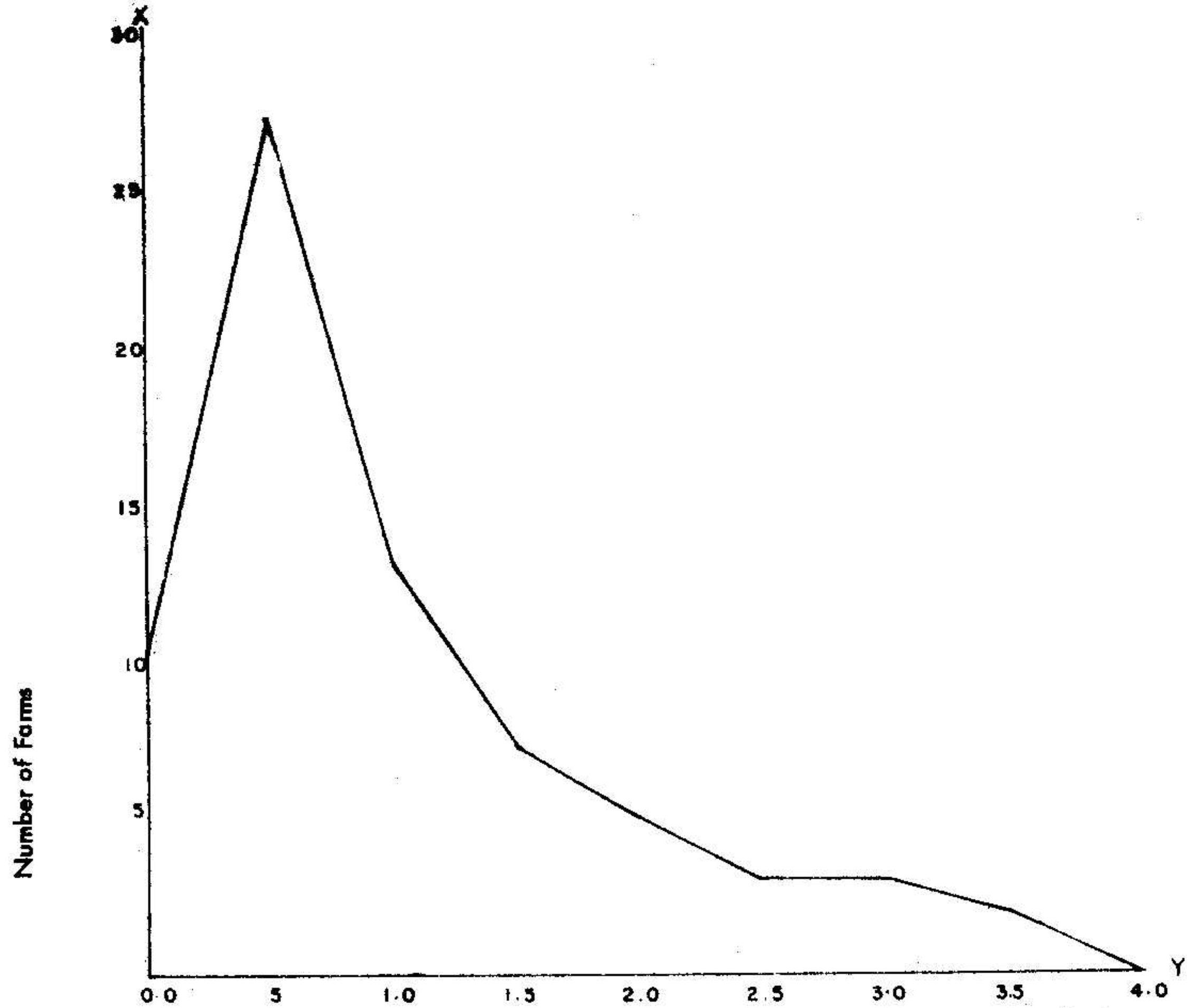
The consumption of irrigation water in the Lajas Valley Project for the economic year 1969-70 was low. Graph No. 11 shows the relationship between the amounts of water consumed and the number of farms.[38] It can be observed that the majority of farms under study consumed .5 acre-feet of water or less during the year.

The cost may possibly be the factor most responsible for the low consumption of water in this project. Irrigation plays a costly part in the agronomic management of the farms. The farmer has to have ready money to meet the costs of irrigation. This is owing to the fact that labour has to be paid weekly and the bills for water on a monthly basis.

38. Infra, p. 105.

Graph #11

Relationship Between the Number of Farms and the Annual Consumption of Water in Acre-feet per Acre per Year, 77 Farms in the Lajas Valley, Puerto Rico, 1969-70



According to the results of the study, the low consumption of water is owing to factors such as the following: the high cost of labour in the application of irrigation water; the farmers' lack of economic resources and the lack of adequate structures for the storage of water. As a result of this low consumption, the majority of farmers do not use their full allowance of water and, as a result, do not take advantage of the additional free water to which they have a right, which, in the long term, would reduce costs.

As was mentioned above, the cost of irrigation in the Lajas Valley varies according to the size of the farms and the amount of water consumed. Fifty six point seven percent (56.7%) of the farms irrigated by gravity consumed 1.0 acre-feet of water or less. The total cost of irrigation was $4.68 per acre per year. [39] Thirty-three point three percent (33.3%) of the farms used between 1.0 and 2.0 acre-feet of water and the cost was $15.52 per acre per year. The consumption of 10% of the farms varied between 2.0 and 4.0 acre-feet of water. The cost per acre per year in this group of farms varied between $14.00 and $15.00.

As has been indicated above, the larger farms among the group irrigating by gravity consume more water than the smaller farms. On the properties irrigated exclusively by pumping, 42% used 1.0 acre-feet of water per acre per year or less. It should be pointed out that on these farms a greater amount of labour was used than in the other groups irrigating by pumping. Thirty-three percent (33%) of the farms consumed between 1.01 and 2.0 acre-feet of water. Only two farms consumed between 2.01 and 3.0 acre-feet per acre during the year, and one consumed more than 3.0 acre-feet. [40]

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39. See Table No. 25, Infra, p. 107.
40. See Table No. 26, Infra, p. 109.

'arious Items of Cost Which Enter into the Application
he Distribution of Annual Consumption in Acre-feet
'ajas Valley, Lajas, Puerto Rico, 1969-70

Men Days	Cost of Labour	Cost of Water	Total Cost	Cost Per Acre Per Year
3	$ 6,213.60	$ 67.50	$ 6,281.10	$ 4.68
3	5,853.60	89.82	5,493.43	15.52
3	309.60	12.24	321.84	14.00
3	792.00	35.88	827.88	15.35

The consumption of water was slightly higher on the farms using combined irrigation. Twenty percent of the farms consumed between 2.01 and 3.0 acre-feet of water per acre during the year. Nevertheless, the same phenomenon occurs in the groups irrigating by gravity and pumping; a higher percentage of farms consume limited quantities of water, generally less than 1.0 acre-feet per year. In the main this group is made up of small farms which, in this case, account for 48% of the total number of farms. Twenty-four percent (24%) of the farms using the combined method of irrigation consumed between 1.0 and 2.0 acre-feet of water during the year, and a further eight percent (8%) consumed between 3.01 and 4.0 acre-feet per acre.[41]

It is significant to note that of the items of cost that enter into the irrigation expenses of all the groups, that of labour is the highest. In the interviews held with the farmers included in this study, questions were put on several of the items of cost which enter into the agriculture under irrigation being carried out in the Lajas Valley Project. The object was to get their opinions on the items of cost mentioned. The analysis of these opinions is presented in Table 28.[42]

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41. See Table No. 27, Infra, p. 110.
42. Infra, p. 111.

s Items of Cost Which Enter into the Application
tribution of Annual Consumption in Acre-feet
Valley, Lajas, Puerto Rico, 1969-70

Cost of Labour	Cost of Water	Other Costs	Total Cost	Cost per Acre per Year
$2,815.20	$362.20	634.60	$3,811.80	$6.18
1,512.00	1,659.60	836.00	4,007.60	9.11
1,713.60	1,350.00	280.44	3,344.04	14.67
2,066.40	775.32	125.00	2,842.97	25.84

'ween the Items of Cost Which Enter Into the Use of the
'1 Method of Irrigation and the Distribution of Annual
'e-feet per Acre, 25 Farms in the Lajas Valley
Puerto Rico, 1969-70

	Cost of Labour	Cost of Water	Other Costs	Total Cost	Cost per Acre per Year
	168.00	$ 742.50	$ 1,300.00	$ 3,410.50	$ 8.28
	89.60	1645.38	529.07	5,364.05	19.36
	13.60	4612.50	406.00	10,332.10	25.20
	48.80	710.43	35.00	1,494.23	32.48

Distribution of the Farmers in Relation to their Opinions on Which of the Items of Cost Given Has the Greatest Influence on Irrigation Costs, 51 Farmers, Lajas Valley, Lajas, Puerto Rico, 1969-70

Table No. 28

Items of Cost	Number of Farmers	Percentage of Total
1. Cost of Irrigation Water	15	30
2. Labour	21	40
3. Preparation of Land	7	14
4. Cost of Equipment	4	8
5. Operation and Maintenance of Equipment	4	8
Totals	51	100

It can be seen in this table that 40% of the farmers interviewed agreed that labour is the most costly factors in irrigation activities in the area. Thirty percent (30%) of the farmers were of the opinion that the cost of irrigation water was more imporrant than the other factors in the total costs of irrigation. Fourteen percent (14%) of the farmers gave greatest importance to the preparation of the land as a determining factor in irrigation costs. Eight percent (8%) of the farmers considered the cost of equipment and eight percent (8%) considered the cost of maintenance to be the items of greatest importance.

5, Comparative Consumption Among the Users of the System

There are various users of the waters of the Lajas Valley Irrigation Project. Among them are the following: private farmers with earlier concessions from the Spanish Crown to use the waters of the Yauco River, the Lajas Aqueduct, the Puerto Rico Land Authority, the Laguna Cartagena, and the private farmers of the Lajas Valley. Table No. 29 shows the way in which the water from the dams on the project is distributed. [43] The Land Authority and the private farmers are in general those who use the water for agricultural purposes. The farmers who hold concessions dating from the Spanish Rule use a total of 6,000 acre-feet of water a year. The amount of water consumed per acre is unknown. However, the amounts of water consumed by the Land Authority and the private farms of the Lajas Valley can be compared. Graph No. 12 presents a comparison of the consumption of water among these two groups of farms. [44]

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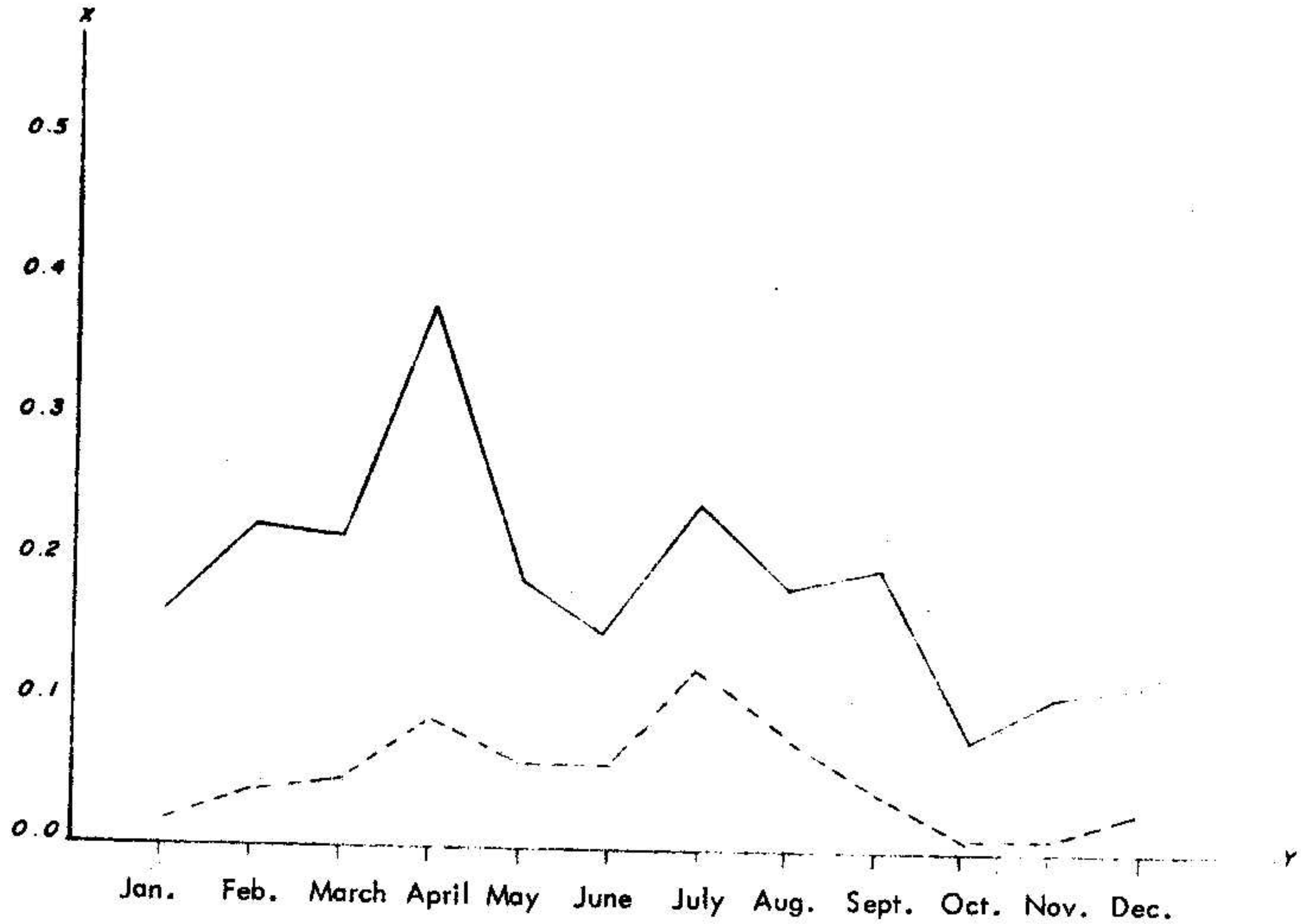
43. Infra, p. 113.
44. Infra, p. 114.

Distribution of the Water from the Dams of the Lajas Valley Irrigation Project by Consumers, Water Lost and Other Considerations Southwest Project Water Resources Authority District Office, Yauco, Puerto Rico, 1969-70

Table No. 29

Consumers of Water	Amount Calculated in Acre-feet	Percentage of Total
Concessions to Farmers by the Spanish Crown	6,000	7.3
Lajas Town Aqueduct	1,100	1.3
Laguna Cartagena	1,071	1.3
Operational Losses through Filtration in the Canals and Sluices	5,600	6.8
Overflow of the Loco River (to produce electricity)	3,000	3.7
Other Operational Losses	729	.9
Used for Irrigation by Lajas Valley Farmers and the Land Authority	64,500	78.7
Totals	82,000	100.00



Graph # 12: Comparative Consumption per Month of the Land Authority and the Private Farmers of the Lajas Valley During the Fiscal Year 1969-70.

Legend

_____ L. A. Land Authority

--------- P. F. Private Farmers.

As can be seen in this graph, the Land Authority consumes greater quantities of water than the private farmers in Valley. It is possible that this is one of the reasons why the tonnage of cane per acre produced by the Authority is greater than that produced by private farmers.

It is interesting to note that the months of highest consumption are April and July. After this latter month consumption is reduced in both cases. This is because the rainy season begins at this time in the Southwest of the Island, and the farmers order the suspension of deliveries of water.

The low consumption of water in the Lajas Valley has been noted almost from the time that the first deliveries of water began. Graph No. 13 shows the water consumption of the private farmers in the Lajas Valley and of the Land Authority in the last ten years.[45]

As can easily be seen, the irrigation pattern is almost the same for every year. The Authority consumed greater quantities of water than the private farmers. The obvious deduction is that this is the result of the Government body having greater economical resources than the farmers in the area.

E. Irrigation and the Sugar Cane

It is evident that irrigation is a practice of vital importance in the production of sugar cane in the Lajas Valley. Earlier investigations have shown that there is a series of agronomic practices related to high production of this crop.[46] Among these practices are the frequent renovation of seed, the control of weeds, frequent irrigation and especially the use of high nitrogen applications. However, in areas like the Lajas Valley, where

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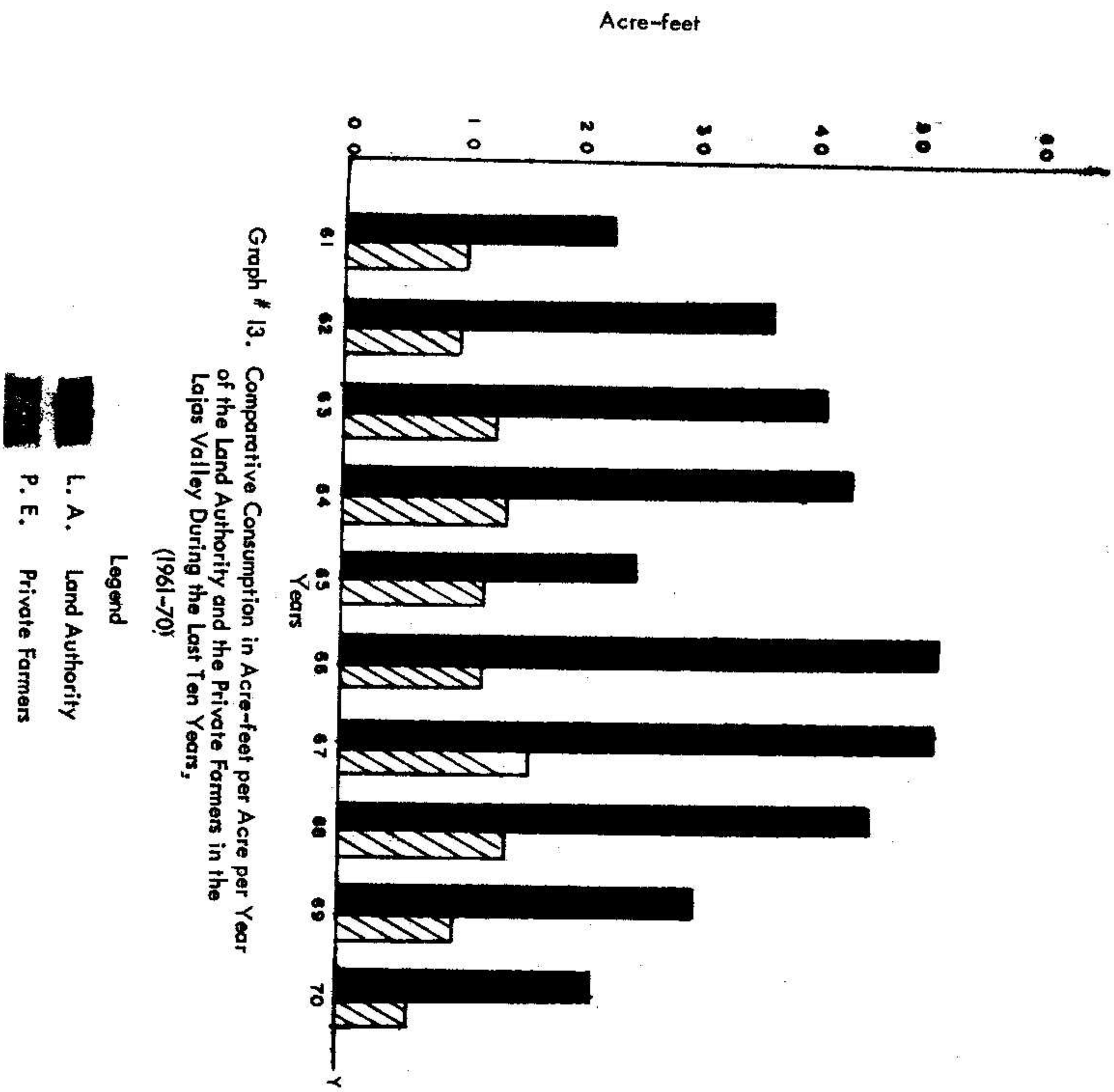
45. Infra, p. 116.
46. Supra, p. 37.



Graph # 13. Comparative Consumption in Acre-feet per Acre per Year of the Land Authority and the Private Farmers in the Lajas Valley During the Last Ten Years, (1961-70).

Legend

L. A. Land Authority

P. E. Private Farmers

rainfall is scarce and poorly distributed throughout the year, irrigation is a determining factor in sugar cane production.

According to the statistics given in this study, the farmers who did not make use of irrigation produced an average of 4.32 tons of cane less per acre than the farmers who did use irrigation on their farms. If the recommended quantities of water had been used the difference would possibly have been greater. In the light of the statistics presented in Table No. 30, it is significant to point out that the farmers who irrigated their farms received on average $55.25 more per acre than those who did not irrigate at all.[47] In addition, the statistics in this table show that the income per acre from all items is higher on farms using irrigation which makes the total income per acre also much higher. It should be pointed out that the income received by the farmer in this type of industry depends principally on the volume of the harvest. The lands under irrigation in this area are provenly more productive and obviously their incomes are higher.

The disproportionate difference observed in the incomes drawn from the incentives provided by the island government, stems from the fact that those farms using irrigation also made new sowings of cane. The farmers owning these farms received the incentives corresponding to this practice. The farmers on the farms studied who did not irrigate did not renew their plants during 1969-1970.

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47. Infra, p. 118.

Gross Income per Acre and per Ton from the Production of Sugar Cane Under Irrigation and Without Irrigation in the Lajas Valley, 77 Farms, Lajas, Puerto Rico, 1969-70

Table No. 30

Source of Income	Unirrigated Cane: Total Income per Item	Unirrigated Cane: Income per Acre	Unirrigated Cane: Income per Ton	Cane Under Irrigation: Income per Item	Cane Under Irrigation: Income per Acre	Cane Under Irrigation: Income per Ton
1. Sale of Sugar	$ 224,877.29	$172.32	$ 7.55	$890,550.33	$ 204.86	$ 7.55
2. Honeys	14,889.00	11.40	.50	58,937.54	13.56	.50
3. Island Government Incentives	21,463.38	16.44	.50	111,581.04	25.66	.95
4. Federal Compensation	38,169.53	29.24	1.28	149,207.21	34.32	1.26
5. Charters	32,457.94	24.87	1.09	124,596.99	28.66	1.06
6. Other Sources	10,315.48	7.98	.35	45,397.09	10.44	.38
Totals	$342,172.62	$262.25	$ 11.49	$1,380,270.20	$ 317.50	$11.70

The total costs of production per acre cultivated were less on the farms not irrigating than on those using irrigation.[48] It must be pointed out that the same is not true of the total costs per ton. These costs were much lower on farms under irrigation in all items, as can be seen in Table No. 31. It should be mentioned that these farms, because they are more productive, produce a greater volume of cane per acre and as a result the costs are lessened per unit produced.

The net profits per acre and per ton were greater on those farms which used irrigation. As can be seen in Table No. 32, the farmers who did not use irrigation on their farms failed to receive an additional net profit of $39.91 per acre under cultivation.[49] The difference in net profit per ton of cane produced on both types of farms was on average $1.18. Naturally, this shows that the additional cost of using irrigation water is recompensed by greater profits.

Graph No. 14, shows the relationship between the quantity of water consumed and the net income obtained.[50] For the purposes of analysis, the farms studied were classified into four groups according to the quantity of water consumed. It should be pointed out that the group of farms with the greatest net income was that whose farms used 2.25 to 3.0 acre-feet of water per acre per year. This group had a net income per ton of $3.21. The lowest net income is found in the group of farms which used no water at all. These farms produced a net income of $1.83 per ton, which can be considered very low in comparison to the other farms in the valley. In addition one can note the difference between the group of farms not using irrigation and that using from .1 to .75 acre-feet of water per year. The difference in the net profit per ton obtained by these two groups is $0.98. This proves once more the positive way in which sugar cane in this area responds

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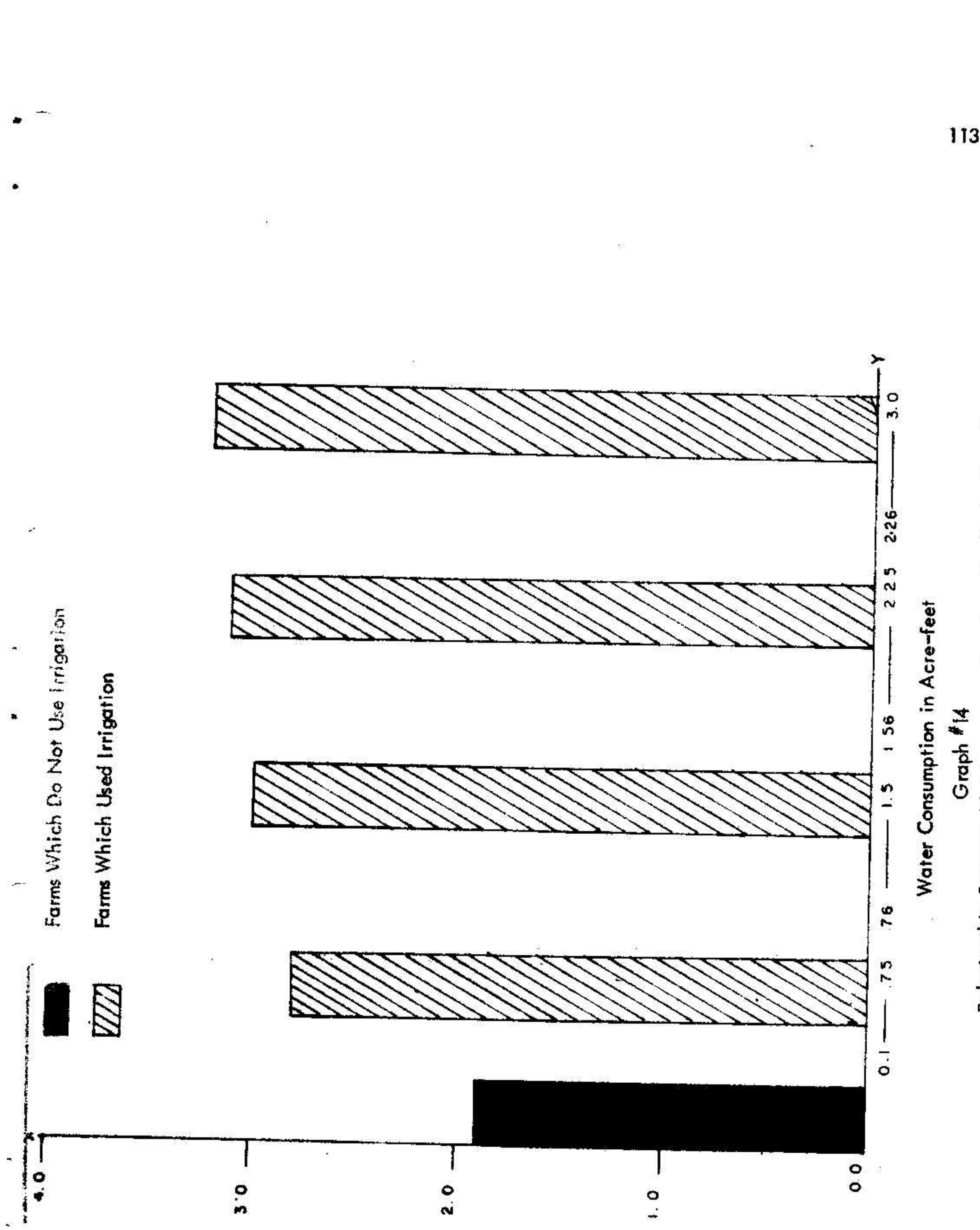
48. See Table No. 31, Infra, p. 120.
49. Infra, p. 121.
50. Infra, p. 122.

er Acre and per Ton of the Production of Sugar Cane
ion and Without Irrigation in the Lajas Valley,
Lajas, Puerto Rico, 1969-70

	Cane Under Irrigation		
Cost per Ton	Total Cost per Item	Cost per Acre	Cost per Ton
$ 2.93	$ 247,638.00	$ 56.97	$ 2.10
-	67,136.96	15.44	.57
3.28	357,722.11	82.29	3.03
1.43	148,623.80	34.19	1.26
.91	106,291.64	24.45	.90
1.09	97,579.22	22.45	.83
$ 9.64	$1,024,991.73	$ 235.79	$ 8.69

...e and Outlay in the Production of Sugar Cane Under Irrigation
...tion, 77 Farms, Lajas Valley, Lajas, Puerto Rico, 1969-70

	Total Costs	Net Income	Net Income per Acre	Net Income per Ton
	...4,991.73	$ 355,278.44	$ 81.72	$ 3.01
	509.10	54,563.52	41.81	1.83
	500.83	$ 409,841.96	$ 72.51	$ 2.77



Relationship Between Net Income per Ton from the Production of Sugar Cane and the Consumption of Irrigation Water, 77 Farms in the Lajas Valley, Lajas, Puerto Rico, 1969-70

Graph #14

to the use of irrigation. With the use of more than .75 acre-feet per acre per year the net profits continue increasing, but on a lower scale.

To summarize, the costs, incomes and net profits were higher on those farms which made use of irrigation than on those which used no irrigation at all. It has been proved, therefore, that the production of sugar cane in the Lajas Valley depends on the quantities of water used.

V- SUMMARY AND CONCLUSIONS

In view of the objectives originally laid down, the present study has been fruitful. This chapter presents a series of conclusions drawn from the analysis of the data obtained on the following subjects.

1. Socio-economic factors related to agricultural planning in the Lajas Valley.
2. The problems of cattle-raising.
3. Factors which affect the diversification of agriculture.
4. Evaluation by the farmers of the land and cattle development of the area of the Lajas Valley under irrigation.
5. Evaluation by the farmers of the services offered by the Department of Agriculture and the Puerto Rico Water Resources Authority.
6. Evaluation by the farmers of the public policy governing the Irrigation Project in the area.
7. Evaluation of the factors affecting irrigation costs.
8. Evaluation of the items of irrigation costs by the farmers.
9. The costs of irrigation according to the method used.
   A. The cost of irrigation by gravity.
   B. The cost of irrigation by pumping.
   C. The cost of irrigation by combined method of irrigation and pumping.
10. The causes of the low consumption of irrigation water by the private farmers in the Lajas Valley.
11. Comparison of the outlay and income in the cultivation of sugar cane and the apparent benefits of irrigation.

A. Specific Conclusions

1. The socio-economic factors related to the agricultural planning of in the Lajas Valley.

The Age of the Farmers

The majority of farmers who operate farms in the Lajas Valley are over 50 years old. According to the statistics included in this study, this group constitutes 63% of the total. The average age of these farmers is 54.

Education

The farmers of the Lajas Valley, compared with other farmers on the Island, have a high level of education. The average educational level of the farmers in the area is 11.1 years. Sixty-four percent (64%) of the farming population studied had between nine (9) and sixteen (16) years of education. This is a fact of great significance for the adoption of new methods in the agricultural field, for the taking of decisions and for the general administration of the land and cattle industry.

Tenancy of the Farms

The farms of the Lajas Valley are not all operated by their owners. The farmers operating rented farms made up 61% of the population studied. Only 29% of the farmers run their own farms.

It may be concluded that one of the reasons for the failure to adopt more advanced methods, as much in the field of modern irrigation as in that agricultural cultivation, seems to be the fact that a great majority of the farmers in the Lajas Valley do not own the farms they operate.

The Size of the Farming Unit and the Employment of the Land

Of the farms studied, 64% were farms of 150 acres or less whcih can be considered small farms. As to water consumption and irrigation operations, the small farms are those which consume the least water and which have the highest operational costs.

Economically the most important crop in the Valley is sugar cane. This occupie 96.6% of the present irrigable area. This is followed in importance by pasture area for livestock. Improved and natural pastures take up approximately 28% of this area. Vegetables and fruits are cultivated to a lesser degree, only 2% of the total area being dedicated to these.

2. The Problem of Cattle-raising.

Irrigation is necessary in the Lajas Valley to sustain and increase land and cattle production. Cattle raising in this area is an industry whose profit and loss depenc upon the amount of rainfall and its distribution throughout the year. This stems from the fact that the majority of areas given over to pastureland do not make use of irrigation.

When periods of extreme drought occur, the production of both milk and beef falls to levels far below the costs of production. Farmers possessing herds of beef cattle are forced to sell at very low prices, and on many occasions to dispose of the herds altogether. Farmers dedicated to milk production find themselves involved in heavy investments in concentrated foods in order to maintain their stock. On several occasions the Government has had to intervene and establish emergency programmes to relieve the situation.

It is obvious that to avoid this problem it is necessary to convert a sufficient and

practicable area of pastureland now unirrigated into pastureland under irrigation. This problem should be studied in greater depth, especially in respect to the raising of dairy cattle.

3. Factors which Affect Agricultural Diversification

The level of agricultural diversification in the Lajas Valley is very low. It can be said that the agricultural development of the area has not achieved the diversification of crops and of land and cattle enterprises originally planned at the beginning of the project. The predominant crop is sugar cane, which takes up over 90% of the land under irrigation in the area.

According to the farmers and the technical experts, the factor most responsible for the reduced diversification in the Lajas Valley is the problem of marketing. For some farmers, the second most important factor is the limited quantity of irrigation water. This seems paradoxical, as apparently the water in the dams is sufficient to allow each farmer at least 3 acre-feet of water per acre per year.

There are various reasons why the farmers consider the limited quantity of water to be an important factor in agricultural diversification. In the first place, the amount of water available for irrigation in the Lajas Valley depends on the rain which falls on the collection areas of the project. The months of highest rainfall in the collection area which supplies the dams are September, October and November. In years of extreme drought the dams are not filled to capacity and little water is stored. The Puerto Rico Water Resources Authority therefore finds it necessary to ration the supply of water. In the second place the water collected from the "inflows"[1] is stored in the lakes, but

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1. For a definition of this term see Chapter II, Supra, p. 34

the deliveries are controlled during the summer so that there will be sufficient water during the dry season from December to April. In the third place, the dams in the summer do not contain much stored water as generally most of this has been used in the spring sowing. Further, in these months greater quantities of water are consumed, as the cane sown is in its development stage.

Another very significant factor in agricultural diversification is inadequate financing. Irrigation is a costly practice and demands that the farmer always have economic resources available for this activity. In spite of the fact that there are many agencies which give credit to the farmer, these are very demanding in their procedures and the loans take a long time coming through.

According to the observations made during this study, the farmer himself is one of the important factors responsible for low diversification. Although this factor was not strictly included in the research, it has been found that the farm operator per se limits both agricultural diversification and the productivity of his lands.

For example, the soils of the Lajas Valley area have a productive capacity for varied crops. Nevertheless, the investments which the farmers have made and continue making in machinery and equipment, albeit for less productive crops, impede diversified agricultural development in the area.

4. Evaluation by the Farmers of Land and Cattle Development in the Area Under Irrigation in the Lajas Valley.

For the majority of landholders in the area, agriculture in the Lajas Valley shows only slight improvement. Eighty percent (80%) of those included in the study shared this opinion. Only 6% considered agriculture in the Valley to be highly developed. On the other hand, 14% were of the opinion that agricultural development had been slow and costly.

5. Evaluation of the Services Offered by the Department of Agriculture and the Puerto Rico Water Resources Authority.

According to the majority of farmers the services offered by the Department of Agriculture in the area are excellent. In addition, the farmers find the services offered by the Puerto Rico Water Resources Authority to be satisfactory.

6. Evaluation by the Farmers of the Public Policy Ruling the Irrigation Project in the Area.

For the majority of farmers the irrigation project in the Lajas Valley has been a success. For many of the landholders in the area, the irrigation and drainage system established has been of great benefit to their farms.

According to the data obtained during the study, the public policy followed in the Lajas Valley project can be considered effective.

7. Evaluation of the Factors Affecting Irrigation Costs.

According to the statistics given in this study, of the ten (10) factors presumed to affect irrigation costs, five (5) are of significant importance. According to the experts these factors are, in order of importance:

(1) topography,

(2) the administrative aspects of the system,

(3) the method of irrigation used,

(4) the size of the agricultural unit and

(5) the farm structures.

The study shows that the influence of the other factors on irrigation costs is less, and in some cases, insignificant.

Of the above mentioned factors, topography is the most important in relation to

irrigation costs. It is obvious that on the steeper farms where irrigation has of necessity to be effected by pumping this process is much more costly, even though the cost of water is less.

The size of the farms is another very significant factor in irrigation costs in the Lajas Valley. According to the statistics presented in this study, the highest irrigation costs are borne by the smallest farms. The larger farms, apparently because they have larger economic resources and structures for storing water, tend to be more efficient in their use of irrigation.

8. Evaluation by the Farmers of the Items of Irrigation and Operational Costs.

Among the items effecting the costs of agriculture by irrigation in the Lajas Valley area, labour is the most significant. The great majority of farmers share this opinion. Besides, this study has proved that among the total costs of irrigation operations the cost of labour is the highest. For many farmers, the second most important item of expense is water. This, however, is the result of low consumption. An acre-foot of water carries a fixed price of $6.00 if supplied by gravity and of $3.00 if the farmer has to use pumps. The price per acre-foot could be lower if the farmer would use all the water to which he is entitled each month. In this way he could take advantage of the additional water which the system provides for those farmers who exhaust their monthly ration and which is given free of charge. This would reduce the cost of water consumed.

The preparation of land to be irrigated for sowing is also a very significant item of cost in the agriculture of the area. This preparation includes, among other things, the levelling of the land, the construction of drains, and, in the case of undulating farms, the provision of contour furrows. The other items of cost, although they are

of relative importance in the total cost of irrigation operations, are not so heavy for the farmers in the Valley.

9. The Cost of Irrigation According to the Method Used.

A. The Cost of Irrigation by Gravity.

Of the total number of farms irrigating by gravity the majority are small farms of 100 acres or less. With this system of irrigation, these small farms consume much less water than the larger farms. Despite the lower consumption of water, the cost of irrigation is much greater per unit of water consumed than on the large or larger farms. Based on the statistics presented in this study it can be concluded that the cost of irrigation, although it appears to increase as the amount of water increases, in fact tends to decrease in proportion to the units of water consumed.

The cost of labour tends to decrease with increased water consumption, although the cost of the water itself does not follow this pattern as it carries a fixed price. In the gravity method of irrigation the application of an acre-foot of water per acre costs about $14.00. The application of an additional acre-foot costs $9.70 or $23.70 for two acre-feet of water. This shows that the greater the quantity of water consumed, the lower the cost per unit.

B. The Cost of Irrigation by Pumping.

As in the case of irrigation by gravity the small farms are those which consume the least water. As the size of the farm increases so the quantity of water consumed increases also. The consumption of water by the pumping method is far less than by the other methods operating in the Lajas Valley. In 1969-70 consumption was much lower than that required by the crops.

As opposed to irrigation by gravity, the cost of labour tends to increase per unit

of water consumed. In pump irrigation the cost of the application of one (1) acre-foot of water per acre per year is around $12.25, lower than that of the application of the same amount of water by gravity. This is explained by the fact that irrigation water for application by pumping costs less.

C. The Cost of Irrigation by the Combined Method of Gravity and Pumping.

The undulating farms are those which are irrigated by the combined method of gravity and pumping. These farms tend to use slightly larger quantities of water than those which are irrigated by other methods.

The small farms follow the same irrigation pattern as those irrigated by other methods. These smaller farms are those which consume the least water. In addition, the cost of irrigation on the small farms which use this method is much higher than on the larger farms.

The cost of irrigation per acre per year on undulating farms varies according to the consumption of water and the labour used. For example, the application of one (1) acre-foot of water per acre per year by the combined method, costs $9.00, but the application of more than 1.5 acre-feet per acre per year tends to double the cost. The application of two (2) acre-feet of water per acre per year is about $18.00. This is contrary to the other methods.

The low consumption of water and the high cost of irrigation shown in the small farms irrigating by the three methods is the result of a lack of structures for storing water. In general the larger farms have artificial pools and tend to be more efficient in their use of irrigation.

10. Causes of the low Consumption of Water by Private Farmers in the Lajas Valley.

It has been recognized that the productivity of land dedicated to sugar cane can be greatly increased by supplementing rainfall with irrigation. The cultivation of sugar cane with growth periods of 12 to 14 months requires from 110 to 120 inches of water, which is equivalent to an average of 9.6 acre-feet. For growth periods of 10 to 12 months, 90 to 110 inches of rain are required or approximately 8.3 acre-feet.[2] If we discount the average rainfall in the area of 34 inches per year, or approximately 2.4 acre-feet of water per year, then the supplementary amount of water required in each case would be 6.8 and 5.5 acre-feet of water respectively.[3] In the light of these facts we find that the farmers of the Lajas Valley area are not using the amount of water needed by their plants. The following are among the possible causes of the low consumption of irrigation water.

a) The economic situation of the farmers. Irrigation operations required considerable sums of money at frequent intervals, while the income of the farmers is annual, after each harvest.

b) Irrigation operations are costly, especially the labour involved.

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2. A. C. Barnes, The Sugar Cane, (New York: Interscience Publishers Inc., 1964).

3. The equivalencies are calculated on the basis of the conversion tables supplied by the Puerto Rico Water Resources Authority. One point zero (1.0) inches of rain equals 27,167 gallons per acre and one (1) acre-foot of water equals 325,850 gallons.

c) A large number of the farmers do not have structures for the storage of irrigation water, especially the owners of small farms. These farmers are at the mercy of the employees of the Puerto Rico Water Resources Authority who open and close the sluices according to their hours of work which are not always convenient to the landholder.

d) The way in which the water is supplied. Those farmers who receive water by pumping use less water.

e) There is a considerable group of farmers who use other sources of water. These farmers make use of water from gulches and streams and many of them use water from the project's drainage system.

f) The limitation of the system itself.

It is worth noting that, even if the farmers were economically able to apply the supplementary water required for the optimum growth of their cane plants, they could not do so. This stems from the limitations of the system and the established norms. The system can supply up to 4.0 acre-feet of water per acre per year, although on occasions, when the dams are filled to capacity, additional amounts could be supplied. The norms laid down make this impossible.[4]

11. Comparison of Outlay and Income in the Production of Sugar Cane and the Profits Obtained through Use of Irrigation.

The use of irrigation has a marked influence on the production of sugar cane and on the income of the farmer in the Lajas Valley. The effectiveness of irrigation in the area is proved by the fact that the farms irrigated achieve a higher level of production than those that do not use irrigation.

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4. Supra, p. 8.

Even in 1969-70 when the consumption of water was very low, the statistics presented in this study show how economical is the use of water on sugar cane farms. This is also proved by the fact that the farmers using irrigation had an average profit of $55.25 more per acre harvested than those who did not use irrigation[5].

Rainfall in the Lajas Valley is not sufficient to cover the basic needs of the crops. Therefore, to achieve the optimum development of the plant and to obtain greater production it is essential to supply the required water by irrigation.

To achieve reasonable profits in the production of sugar cane in the area, high volume production is required. This is proved in the study by the fact that those farmers who irrigated obtained greater crop volume and that the total cost per ton was much lower. As a result, the net profit of the farmer increased. The farms irrigated received $39.91 net additional income per acre harvested more than those not irrigated [6]. Besides the increased income received by the farmer, other benefits of irrigation are the increase in salary and other benefits received by the employees.

B. General Conclusions

Alternatives for the Project in the Employment of Land.

In the economic year 1969-70, the agricultural sector of Puerto Rico achieved a gross income of $270.5 million[7]. It is important to point out that, besides this income,

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5. Supra, p. 117

6. Supra, p. 118

7. Governor's Office, Puerto Rico Planning Board, Four Year Economic Programme, San Juan, Puerto Rico, January 1971, p. 25.

the agricultural sector is a considerable source of employment, of raw material for industry and of nutritious produce for the country.

Nevertheless, despite better prices, secure markets for many products and the substantial incentives offered by the Government, the reduction of harvests continues at an increased rate. One of the items whose falling production has been marked in the last few years is sugar cane. In the sugar-making seasons before 1960 the production of sugar surpassed one million tons on many occasions. Production had fallen to 460,000 tons for the sugar-making season of 1969-70 and it continues to fall.

With respect to the Lajas Valley, sugar cane should continue to be produced, not only because of what has been said above but also for the following reasons: in the first place, sugar cane still produces a considerable income and can rely upon an assured market; secondly, the production of cane in the area helps the operations of the Guanica Central, as the majority of farmers crush their cane in this mill. Thirdly, the heavy investments made by the Government and private farmers make it necessary that the area continue in production; and for the moment, sugar cane offers good prospects for the area. This is so because the farms in the Valley are highly mechanizable. Nevertheless, if the present crisis in the industry lasts and the costs of production continue to rise while the sugar yield per ton continues to decline, then considerable changes will have to be made in the agricultural planning for the Lajas Valley with respect to the lands that are being used for sugar cane.

The prices of agricultural produce are sensitive to supply and demand. Therefore, the production of other crops, which cannot rely on a large and assured market and on more or less stable prices, would bring with it uncertainty and changes of attitude in the farmer towards farming. As regards this situation, it should be pointed

out that the outlook is changing. At present the demand for items of nutritive produce such as vegetables and legumes is increasing in Puerto Rico.

In 1969-70 these items brought to the economy of the Country $14 million. This represented 15% of the total gross agricultural income for this year [8]. It is important to point out that the Government is extremely interested in increasing production of these items. To this end a plan has been drawn up to stimulate the increased production and marketing of nutritious produce

This production will be organized according to the necessities of internal consumption and the possibilities for export. The basic unit of production in this plan is known as a growth pole, which is the concentration of technical and economic efforts in collaboration with a group of farmers in an area for the production of certain agricultural produce.

The programme for the Development of Nutritious Produce has the following objectives:

1. To increase the production of nutritious produce to supply internal demand and for the export of this produce where it is possible to compete with advantage.
2. To change the agricultural pattern from a subsistence agriculture to production on a commercial scale.

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8. Department of Agriculture, Plan para Estudiar el Desarrollo de la Producción y Mercadeo de Frutos Alimenticios, San Juan, Puerto Rico, August 1971.

3. To achieve the highest level of agricultural production in the least possible time.

4. To achieve a rational commercialization of these products, both fresh and manufactured, protecting the consumer and at the same time the farmer.

5. To increase the income of the farmer.

6. To achieve the best use of the agricultural land in the Country.

7. To increase the production of native produce in Puerto Rico.

The Lajas Valley offers a series of advantages for the localization of a growth pole. Some of the advantages that can be mentioned are the following:

1. It possesses an irrigation system by which production is possible throughtout the year.

2. The soils are fertile and respond to irrigation.

3. The greater part of the land is flat and mechanization is feasible.

4. The Mayaguez and Ponce markets are accessible outlets for the produce.

5. There are trained technical personnel and an Experiment Station in the area. These could be of great help in solving such problems of technical importance that may arise.

6. A large number of farmers have shown their interest in devoting themselves to other concerns besides sugar cane and cattle raising.

Aspects of Soil and Water Conservation

Agricultural planning carried out in areas like the Lajas Valley with a view towards the increased productivity of the land and the stimulation of land and cattle development in the region necessitates the delineation of an action programme for the conservation of soil and water.

According to many authorities the loss of irrigation water in the fields occurs in the following ways:

1. By evaporation when the water is carried in open canals. This is common in the Lajas Valley project.
2. Through the "inflow" on the surface of the fields.
3. Through filtration owing to the porousness of the soil.
4. Through plant transpiration.
5. Through evaporation on the surface of the soil.

Another cause of the loss of irrigation water is the excessive length of the furrows and canals on the farms. The greater the length, the more filtration and percolation occurs in the soil. For the water to reach the lower end of the furrows when irrigation is carried out by this method, great quantities are applied at the beginning of these. To avoid this loss of water the furrows should be made of convenient length. In addition there should be control of the water from the time it enters the farm canals until the excess is carried away by the drainage canals.

Soil erosion is a great danger in irrigation areas, as much in dry as in wet regions. Besides the damage occasioned by irrigation, uncontrolled water causes serious problems of drainage and salt accumulation in the low-lying land. This is a latent danger in the Lajas Valley.

The Drainage Problem

Drainage is a fundamental necessity in any irrigation project. Whenever irrigation water is applied to an area the resulting excess must be removed by natural or artificial means. In this respect the Lajas Valley is no exception; on the contrary the area suffers severe drainage problems which increase the possibility of salt accumulations in the soil.

In this area there is a lack of natural drainage both on the surface and in the soil. For this reason, in order to protect the land, it is necessary to maintain the established drainage system in operation.

In accord with the observations made, it is worthwhile pointing out that the maintenance of the drainage canals both by the farmers and, in the case of the main drainage canal, by the Government is not as complete as it should be.

In addition it is vital that the farmers in the area carry out to the full the required soil and water conservation practices. Technical recommendations on this matter are apparently not being adequately followed. This situation should arouse the interest of the technical personnel concerned so that practical solutions to the problem may be found.

VI- RECOMMENDATIONS

1. The Agricultural development of the future will depend on young farmers who are enterprising and innovative and who use the new technology in the most effective possible way. For this reason it is recommended that, through the combined action of the Mayaguez Regional Agricultural Bureau and the Lajas Valley Development Bureau, a plan be set up to direct the training of young men in the techniques of modern agriculture: Those who show high potentital and great interest in land and cattle production should be found the means of becoming bona fide farmers in the Lajas Valley. The farms should be acquired through government aid or by means of acredited agencies. These individuals would gradually replace the present farmers, the majority of whom are over 50 years old.

2. Studies carried out in the United States and Holland have shown that those farmers who operate self-owned farms have a greater tendency to accept and adopt new

agricultural techniques than those who do not own their land[9]. In the Lajas Valley, as this study shows, a relatively high number of farms are not operated by their owners but are either rented or worked by administrators. It is recommended that the Lajas Valley Development plan include measures to encourage the buying of rented or administrated farms by those with the potential to become competent farmers and who are receptive to the changes in modern technology.

3. The use of irrigation water alone does not insure the appropriate development of farms. A revision of the objectives to be pursued is required as well as much more dynamic programming to achieve the efficiency and high production necessary to provide the farmers with a reasonable profit, so that he in his turn can pay more and better salaries.

The Agricultural Development Programme for the Lajas Valley should be revised on the basis of the following criteria:

In the first place, the statistics and results of the present study should be considered as a framework of reference and, secondly, the changes should be made in the light of the present agricultural incentive programme offered by the Department of Agriculture.

4. The new programme set up should take into consideration the production of other crops such as green vegetables and legumes. In this way the farmer could take advantage of the aid offered by the Government in its plan to stimulate the development and marketing of nutritious produce.

5. The present study has shown that one of the principal limitations confronting the farmer in taking advantage of irrigation is inadequate financing. Irrigation is costly, and therefore it is recommended that, through the Agricultural Credit Corporation, an agency attached to the Department of Agriculture, a system of loans with yearly payments be es-

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9. Supra, pp. 44, 45

tablished for the financing of irrigation operations. The farmer would be able to pay this loan at the end of each harvest. Such financing should stimulate the consumption of irrigation water in the Valley.

6. A large number of farmers within the project are not using the irrigation water from the system. These persons have equipment or other means for utilizing the water from the drainage canal. It is a matter of urgency to draw the attention of the proper authorities to this in order that they may adequately control the problem. The use of drainage water is highly detrimental to the Valley soils owing to the quantity of salts it contains.

7. One of the causes of the high irrigation costs discovered during the study is the lack of uniformity in the schedule of water deliveries. It is recommended that the pertinent authorities look for means to better the water distribution service. A schedule of deliveries should be arranged which answers the needs of the farmer, so that the water can be applied with the greatest efficiency and at the least cost.

8. The study shows that another of the factors responsible for the high cost of irrigation, particularly on the smaller farms, is the lack of structures for storing water. It is recommended that the construction of artificial pools be encouraged in the Lajas Valley. Although government aid already exists for the building of these structures, a large number of farms do not have this facility. These pools not only allow the farmer to lower the operational costs of irrigation but give him flexibility in controlling irrigation on his farm.

9. So that the farmer in the Lajas Valley is up to date on new technology, he should be kept informed of the results which the Agricultural Experiment Station is obtaining in its researches in the field of irrigation. This is of vital importance, especially

to the cultivation of sugar cane, the predominant crop in the area. During the last few years in the United States, notably at Fort Collins, Colorado, they have been testing a fully automated irrigation system with a series of sluices that open and close automatically. These sluices are adjustable in such a way as to permit the controlled outlet of water. In Hawaii, automatic and semi-automatic systems of opening and closing sluices are also being tested, in order to reduce to a minimum the part played by the irrigator. It is recommended that these advanced techniques be introduced into Puerto Rico by the pertinent authorities and be the object of analysis and evaluation by the Experiment Station. These new techniques in irrigation by canals and furrows, the methods common in the Lajas Valley, could be of great benefit to the farmers by reducing the operational costs of irrigation.

11. The consumption of irrigation water is much lower than the physiological needs of the crops. To stimulate the consumption of irrigation water a study should be carried out to determine the possibility of reducing the price of water. It should be feasible to price the water delivered by pumping at $2.00 per acre-foot and that delivered by gravity at $4.00 per acre-foot. The possibility of giving a third acre-foot free of charge should also be studied as very few farms make use of the fourth acre-foot of water.

12. Frequent short courses should be set up for the farmers in the Valley offering the following material:

a) Characteristics, properties and limitations of the soils in the area.

b) Means and recommended practices for the conservation of soil and irrigation water.

c) Water requirements of various crops.

d) The planning of water distribution on the farm, so that there is sufficient water for all cultivable land.

e) Means of adjusting irrigation methods to the crops and to the supply of water available.

f) Factors affecting irrigation costs.

13. The Government of Puerto Rico plans to establish an international airport in the Lajas Valley. This would mean the dedication of an enormous area to commercial and urban development with the consequent loss of agricultural land.

Considering the investments made in the irrigation project, as much by the Government as by private businesses, and considering also what this area means to the agricultural development of the Country, it would be worthwhile analysing in greater detail this proposed airport. The permanent dedication of this area to agriculture should be planned as well as the continued operation of the project as heretofore.

14. One of the faults of the irrigation system is the loss of water that occurs for various reasons. For example, if only three (3) or four (4) farmers ask for irrigation water the main canal always has to be filled and the excess water is lost in the sea.

In order to correct this situation, the construction of a regulator lake in the Valley is recommended in order to recover the excess water from the main canal which is at present lost.

15. The farmers in the Valley flood or over-water the land when irrigating. In general irrigation takes place once a month with amounts of water which in many cases exceed the absorption capacity of the soil. This undesirable practice should be corrected to avoid both the waste of water and the adverse affects on soil conservation. The setting

up of an irrigation plan is recommended in which water supplies are regulated by means of a permanent rota. In this way the monthly ration could be distributed in two or three applications according to the amount of water required by the crops.

By programming the deliveries of water, if possible by groups of farms, the distribution of irrigation would be improved, thus making more efficient use of the operators who open and close the sluices or outlets. As a result the operational costs of irrigation should be considerably reduced.

BIBLIOGRAPHY

1. Barnes, A.C., The Sugar Cane, Interscience Publishers Inc., New York: 1964.

2. Blackmore, John, Dimit R.M. and Baum, E.L., Test Demonstrations Farms and the Spread of Improved Farm Practices in South Virginia, Tennessee Valley Authority, Knoxville: 1955.

3. Bock, Carl A., Informe Sobre el Proyecto Suroeste de Puerto Rico, the Puerto Rico Water Resources Authority, San Juan, Puerto Rico, March 1948.

4. Bonnet, J.A. and Tirado Sulsona, P., Soil Studies in Lajas Valley, Agricultural Experiment Station, University of Puerto Rico, Bulletin No. 86, August 1950.

5. Bonnet, J.A. and Brenes, E.J., Detailed Salinity Survey of Lajas Valley, Agricultural Experiment Station, University of Puerto Rico, Bulletin No. 141, July 1958.

6. Carter, Oliver R., Soil Survey of the Lajas Valley Area, Puerto Rico, United States Department of Agriculture, Soil Conservation Service, Río Piedras, Puerto Rico, April 1965.

7. Collazo Collazo, Jenaro and Calero, Reinaldo, Los Recursos Humanos en la Industrial del Café en Puerto Rico, Agricultural Experiment Station, University of Puerto Rico, Bulletin No. 166, July 1963.

8. Department of Agriculture of the Commonwealth of Puerto Rico, Mayaguez Region, Proposición del Programa para el Desarrollo Agrícola de la Región de Mayaguez, October 1964.

9. Forster, G.W., Farm Organization and Management, Revised Edition, New York: Prentice-Hall, Inc., 1946.

10. Gardner, Robert, Report on Soil and Water Control Problems of the Lajas Valley Development Project, Special Report, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, August 1954.

11. González Chapel, Antonio, Planificación e Implementación de un Programa de Desarrollo Agrícola en el Valle de Lajas, Agricultural Experiment Station, University of Puerto Rico, Bulletin No. 192, April 1965.

12. Lakish, J.R., Report on Drainage of the Lajas Valley Southwestern Puerto Rico Project, Water Resources Authority, San Juan, Puerto Rico, September 1954.

13. Informe Sobre los Estudios e Investigaciones en Relación al Proyecto del Valle de Lajas, Aspectos Técnicos y Económicos, the Puerto Rico Water Resources Authority, San Juan, Puerto Rico, 1959.

14. Israelsen, Orson W., Drainage and Reclamation Problems in Lajas Valley, Puerto Rico, Special Report, Agricultural Exoeriment Station, University of Puerto Rico, July 1954.

15. Koening, Nathan A., A Comprehensive Agricultural Program for Puerto Rico, United States Department of Agriculture, U.S. Government Printing Office, Washington, D.C., December 1956.

16. Lineweaver, Goodrich W., Observations and Recommendations on Lajas Valley Irrigation Project, Special Report, Water Resources Authority, San Juan, Puerto Rico, December 1956.

17. López Zapata, Jorge, Algunos Factores Que Influyen en el Nivel Tecnológico de los Agricultores del Valle de Lajas, Thesis presented as part of the requirement for the Degree of Master in Agricultural Sciences, University of Puerto Rico, Mayaguez Campus, July 1967.

18. Toro Luchetti, Harold, "Breve Reseña Sobre los Sistemas de Riego Público en Puerto Rico", Revista de Agricultura, July - December 1963.

19. Mierhofer, Charles R., Report on a Reconnaissance Inspection and Some Considerations of Irrigation and Drainage of the Lajas Valley Development in Puerto Rico, Special Report, Water Resources Authority; San Juan, Puerto Rico, October 1956.

20. Mitchell Jr., Donald S., Report on Land Classification of Lajas Valley Irrigation Project, Special Report, Water Resources Authority, San Juan, Puerto Rico, November 1957.

21. Oliver Padilla, Otis, The Role of Value and Channel Orientation in the Diffusion and Adoption of New Ideas and Practices. A Puerto Rican Dairy Farmers Study, 1963, Ph.D. Thesis (unpublished), Michigan State University.

22. Palmer, William I., Preliminary Report on the Organization and Operation of the Lajas Valley Irrigation Project, Water Resources Authority San Juan, Puerto Rico, January 1957.

23. Pringle, George E. and Zapata, Jaime, Practices Used on Puerto Rico Farms With High Production of Sugar, Agricultural Experiment Station, University of Puerto Rico, Bulletin No. 212, February 1969.

24. Quiñones, Miguel A. and Associates, Salinity and Drainage Problems of the Lajas Valley, Water Resources Authority, San Juan, Puerto Rico, May 1964.

25. Quiñones, Miguel A. and Associates, Estudio Sobre el Agua Disponible para Riego en el Distrito de Regadio del Valle de Lajas, the Puerto Rico Water Resources Authority, San Juan, Puerto Rico, January 1963.

26. van der Molen, Wieve H., Report on Salinity, Irrigation and Drainage, Conditions in the Lajas Valley Development Project, Puerto Rico, Special Report, Puerto Rico Department of Agriculture, San Juan, January 1957.

27. van de Van, A.W., Some Characteristics of Progressive Farmers in the Netherlands, Rural Sociology, Vol. XXII, No. 3, September 1957.

28. Vázquez, Roberto, "Effects of Irrigation and Nitrogen Levels on the Yields of Guinea Grass and Guinea Grass-Kudzú and Para Grass Kudzú Mixture in Lajas Valley", The Journal of Agriculture of the University of Puerto Rico, Vol. XLIX, No. 4, October 1965.

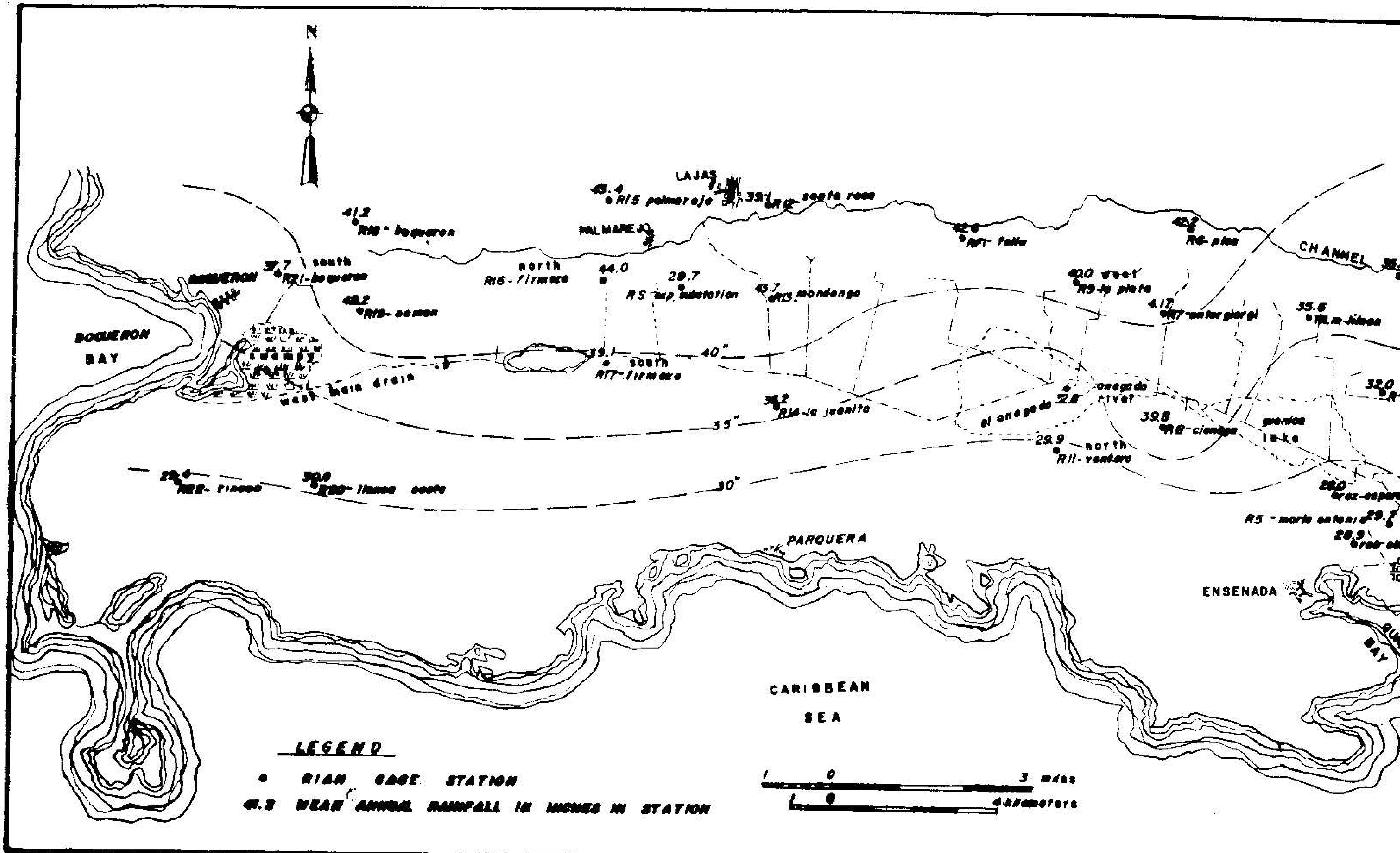
29. Vázquez, Roberto, Eschenwald Hess, A., Martínez Luciano, M.J., "Response of Native White Sorghum to Irrigation Under Different Nitrogen Fertility Levels and Seeding Rates in Lajas Valley", The Journal of Agriculture of the University of Puerto Rico, Vol. L, No. 2 April 1966.

30. Vázquez, Roberto, "Effects of Irrigation, Nitrogen Levels and Plant Population on Corn Yields in Lajas Valley", The Journal of Agriculture of the University of Puerto Rico, Vol. XLIV, No. 3. July, 1960.

31. Pringle, George E., Zapata, Jaime, Practices Used on Puerto Rico Farms With High Production of Sugar, Agricultural Experiment Station, University of Puerto Rico, Bulletin No. 212, February 1969.

32. Wilkening, Eugene A., Acceptance of Improved Farm Practices in Three Coartal Plain Countries, North Carolina Agricultural Extension Service, Technical Bulletin No. 98, Raleigh, 1952.

33. Zimmeman, Joseph D., Irrigation, New York: Jon Willey & Sons, Inc., 1966.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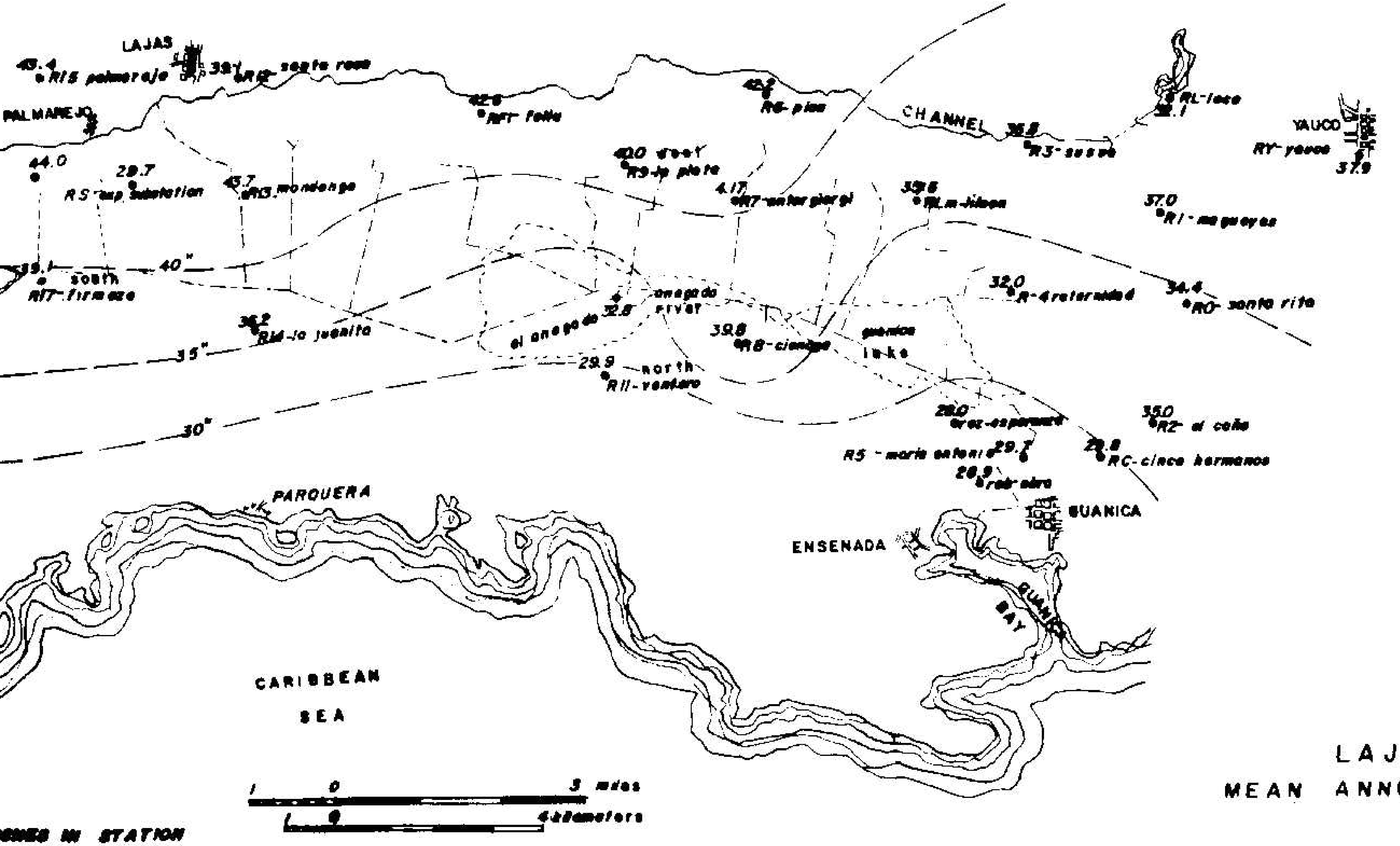
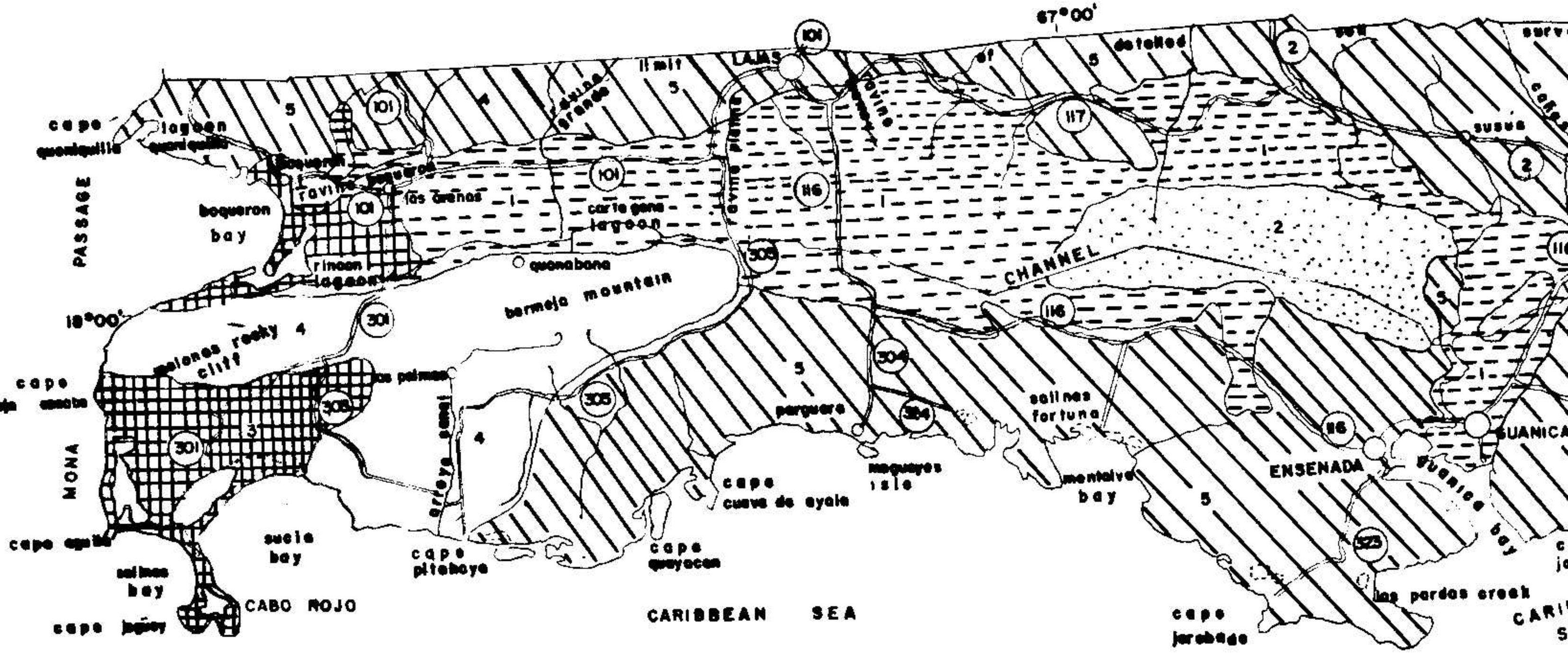


LAJAS VALLEY

MEAN ANNUAL RAINFALL

GENERAL SOIL MAP

LAJAS VALLEY AREA, PUERTO RICO



SOIL ASSOCIATIONS

scale 1:126,72

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fraternidad-aguirre-cartagena association: moderately well drained to poorly drained, nearly level to sloping calcareous alluvial soils.

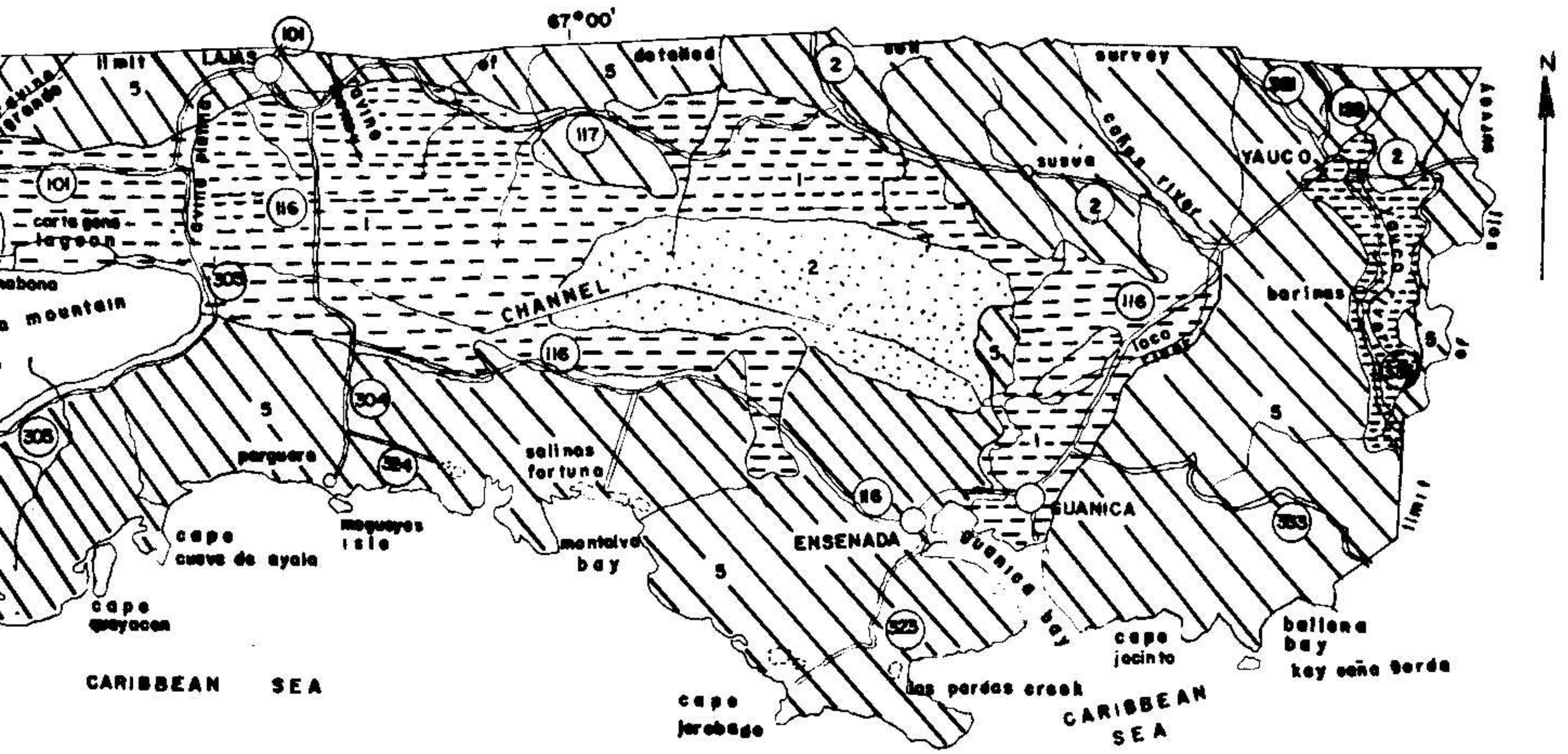
fa' guanica-aguirre association: moderately well drained to poorly drained, nearly level, saline-alkali and nonsaline alluvial soils.

emerenus-queyabo-sosa association: well-drained to excessively drained, level to sloping, sandy soils.

queyame-aguilita-amelia association: steep soils on mountainsides, strongly sloping soils on foothills, and soils in narrow to fairly wide valleys.

descalabrado-jacana-san germán association: steep soils on mountainsides, strongly sloping soils on foot slopes, and soils in narrow valley and on fairly wide alluvial fans.

GENERAL SOIL MAP
LAJAS VALLEY AREA, PUERTO RICO



SOIL ASSOCIATIONS

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queyame-aguilita-amelia association: steep soils on mountainsides, strongly sloping soils on foothills, and soils in narrow to fairly wide valleys.

descalabrado-jacana-san germon association: steep soils on mountainsides, strongly sloping soils on foot slopes, and soils in narrow valley and on fairly wide alluvial fans.

scale 1:126,720

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LAJAS

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CARTAGENA LAGOON

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LEGEND

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ADITIONAL AREA TO IRRIGATE ——— 952 ACRES

TOTAL PROYECT AREA ——— 20,200 ACRES

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——— 20,200 ACRES

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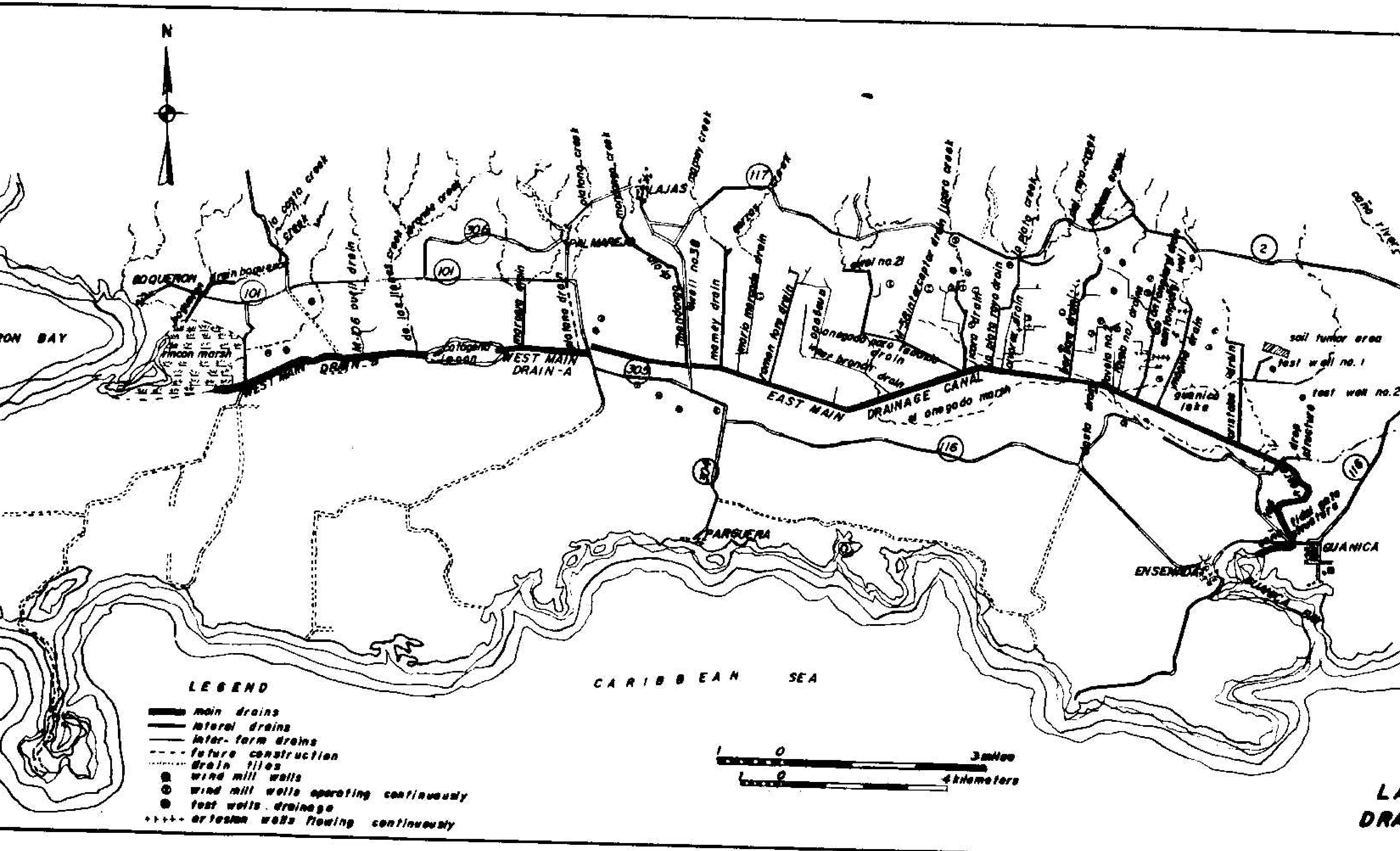
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LAJAS
PARGUERA
GUANICA
ENSEMADA
CARIBBEAN SEA
guanica lake
soil tumor area
test well no. 1
test well no. 2
drop structure
el anegado marsh
la costa creek
mamey drain
well no.38
well no.21
palmarejo creek
lajas creek
mamey creek
lo plata creek
LEGEND
main drains
lateral drains
inter-farm drains
future construction
drain tiles
wind mill wells
wind mill wells operating continuously
test wells. drainage
artesian wells flowing continuously
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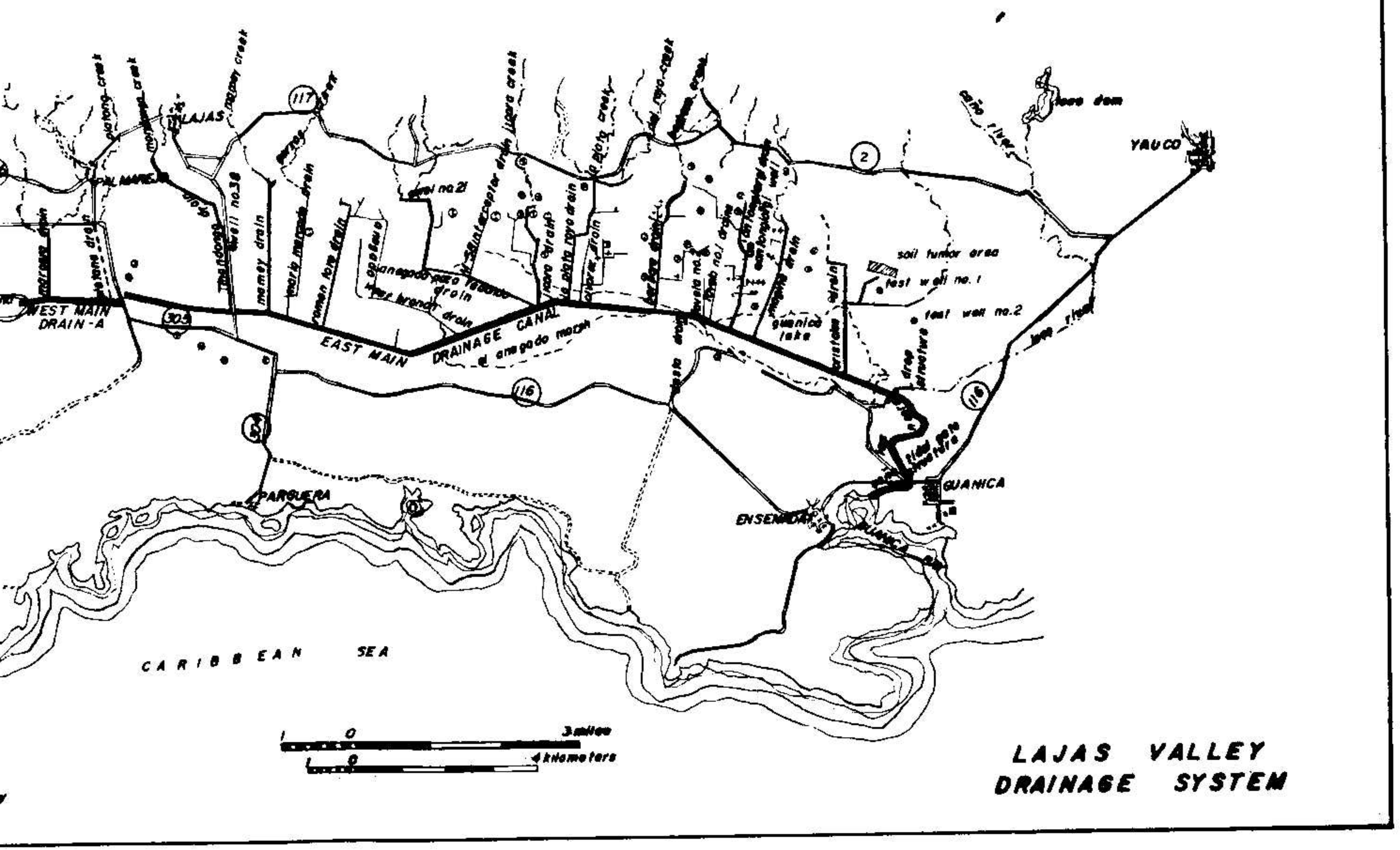
WEST MAIN DRAIN-A
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LAJAS VALLEY
DRAINAGE SYSTEM