AN ABSTRACT OF THE THESIS OF

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Title The Periyar-Vaigai Project (India) - A Geographical Appraisal of a Water Resource Development

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The Periyar-Vaigai project is one of the important water resource developments in South India, designed and constructed in part during the last decade of the nineteenth century, to accelerate the growth of the economy of Madras state. A noteworthy feature of this project is that the waters of the westward flowing Periyar river has been diverted to flow eastward for use on the east sloping plains of Madurai. The Periyar dam project which actually diverts the water was completed in 1896. The Vaigai regulating dam and reservoir were additions, finished in 1959, to provide better control and thus more efficient utilization of the water.

The thesis study begins with a descriptive statement of the macro-physical environmental complex - the terrain, hydrography, and climate - in which the project developed. It is followed by an appraisal of the pre-Periyar resource utilization, covering the

people of the area, pattern of settlement, and cropping and irrigation systems carried out on a precarious land. An analysis of daily rainfall data for a 30-year series, 1931-1960, is made to indicate the need for the project being considered and accomplished. The entire project is then described as a single unit, including a brief historical account of its inception, the inter-state agreement; and finally the physical project that consists of the Periyar dam that impounds the Periyar waters in the Periyar lake, the tunnel through which the water is led to Suruliyar, and the dam and reservoir on Vaigai. The details pertaining to the two main canals of the system, Periyar Main Canal and Tirumangalam Canal, as well as the land irrigated by them are given.

The impact of the project is considered in terms of utilization of water, changes in land use, and increased production, limiting the appraisal to the five taluks in Madurai district. A case study of Jothimanickkam village and Farmer John Veeramani Thevar from this village is further used to illustrate the impact of the project.

As a result of the project, the average area cultivated has increased by 22 percent; but, even more important, the water has given essential cropping stability to approximately a third of the cropland of the locale. Prior to the project, when the cultivation depended on the rainfall of the locale, the net produce per acre

ranged from 8 to 12 bags of paddy. After the completion of the project, the yield increased to 22 bags per acre, due to the assured supply of water.

Thus, as a result of the Periyar-Vaigai development, the average farmer is now able to produce more than his family needs; and the tenant farmer, after paying the landlord's share, is able to feed his family and even make a small profit on his surplus produce.

THE PERIYAR-VAIGAI PROJECT (INDIA) - A GEOGRAPHICAL APPRAISAL OF A WATER RESOURCE DEVELOPMENT

by

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CHAPTER I

INTRODUCTION

The Periyar-Vaigai Project is one of the important water resource developments in South India, designed and constructed in part during the last decade of the nineteenth century, to accelerate the growth of the economy of Madras state. A noteworthy feature of this project is that the waters of the westward flowing Periyar river have been diverted to flow eastward for use on the east-sloping plains of Madurai. The Periyar dam project which actually diverts the water, was completed in 1896. The Vaigai regulating dam and reservoir were additions, finished in 1959, to provide better control and thus more efficient utilization of the water. The major portion of the water diverted and regulated is utilized for irrigating 300,000 acres of land in the Madurai district, to benefit an agrarian population of approximately two million persons.

The Periyar project is a major engineering feat of the last century in water diversion because of the tremendous difficulties which were surmounted, especially the problems of remoteness, the intense rainfall, lack of hydrographic data, prevalence of

malaria of a virulent type, and the rugged terrain. In addition, it is a significant example of interstate agreement, since the waters are diverted from Kerala state for use in and for the benefit of Madras state. The Periyar-Vaigai project is, thus, a notable example of man's increasing capability for developing resource potentials.

Reason for Selecting Topic

The writer of this thesis has had a special interest in the Periyar-Vaigai project for several years. From childhood days, she has spent many summer vacations in one town or another in the area, tramping over the country-side and observing the "miracle" that the rushing waters in the irrigation canals has brought to the land and to the lives of hundreds of farmers. The fact that her ancestral village and the family holdings are in the Periyar-Vaigai area has contributed to the increase in the number of visits from year to year. Thus, a primary reason for the selection of the Periyar-Vaigai project as a thesis study, is the personal acquaintance and knowledge of the area spanning many years. This experience has provided a measure of background and insight into the problems and accomplishments of the people, especially the farmers, and sharpened the writer's value judgment.

Statement of Objectives and Outline of the Thesis

The purpose of this thesis is to describe the Periyar-Vaigai water development project and to appraise in a small part the impact of the project on agricultural land use, especially in the upper and middle basins of the Vaigai river, in Madras state, South India. The study area is confined to the Madurai district. (See Figure 1)

Plan and Procedure

The proposal to appraise such a large water resource development as the topic for a master's thesis raised many problems. Of particular concern were the questions related to limiting the scope of the study and securing adequate data in census and other reports. The decisions, made by the writer and the major professor, leading to the selection of objectives and organization of the thesis are briefly outlined in the following section.

It was agreed that the physical geography of the locale should be overviewed only as a descriptive statement of the macro-physical environment in which the project developed. The precipitation regime of the area, however, was considered to require additional analysis as an indication of the need for the project and therefore, the reason for the project being considered and accomplished. It was realized early in the study that the rainfall analysis could be

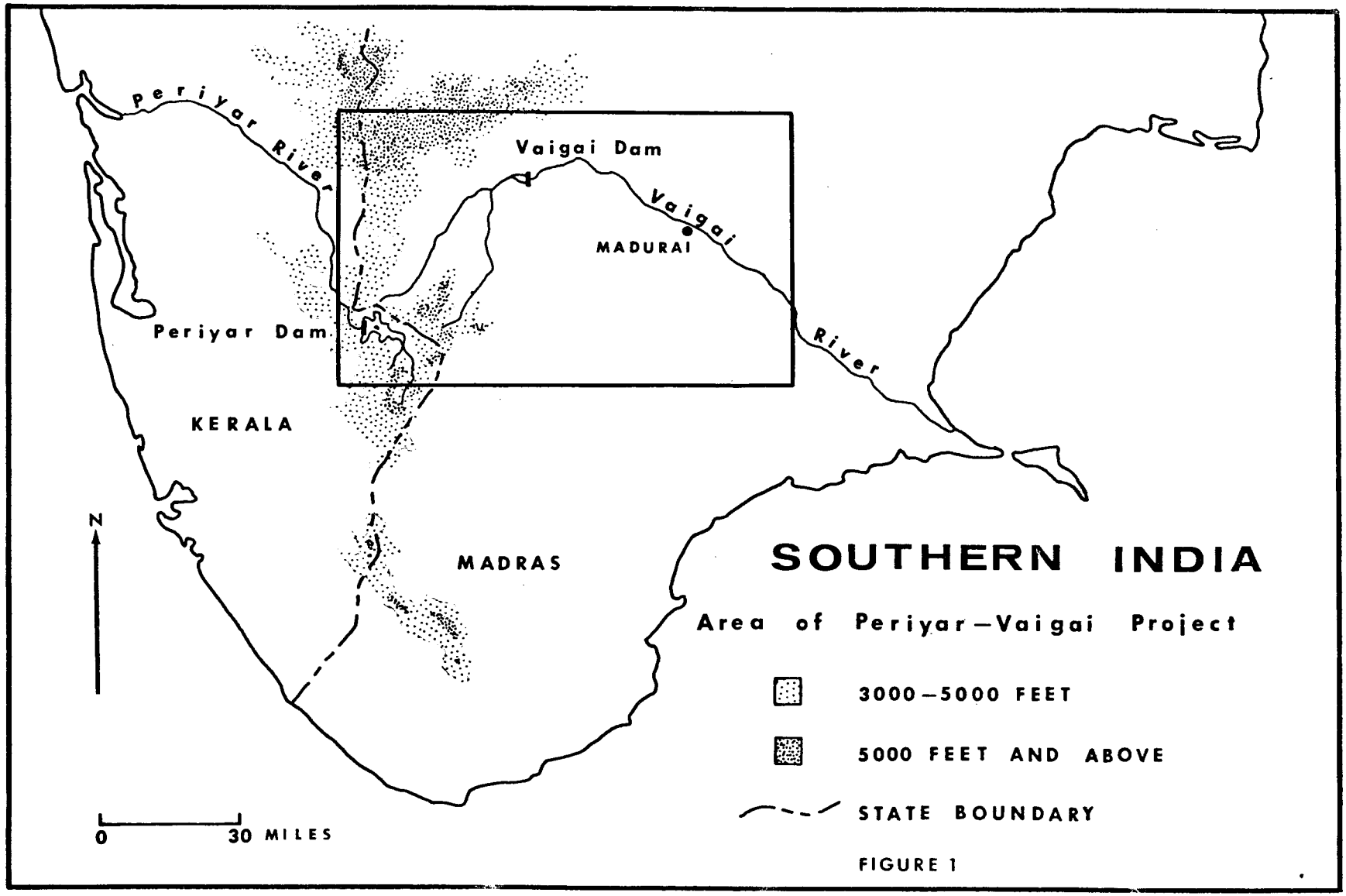

Periyar River
Vaigai Dam
Vaigai River
MADURAI
Periyar Dam
KERALA
MADRAS
N
0
30 MILES
SOUTHERN INDIA
Area of Periyar–Vaigai Project
3000–5000 FEET
5000 FEET AND ABOVE
STATE BOUNDARY

FIGURE 1

an entire thesis; thus the problem was to limit this analysis, yet to present enough information to show the need and in turn the magnitude of the accomplishment by the water development project. Daily rainfall data for a 30-year series, 1931-1960, were secured from the Meteorological department, Government of India, for analysis. A selection of significant data was made and these are included in the thesis.

It was decided that the entire project should be described as a single unit, including a brief historical account of its inception, the interstate agreement, and finally the physical project. The Public Works Department of Madras state generously co-operated in making available large-scale maps and data covering the entire project. From these source materials, the significant elements were extracted and are here presented. In addition, many documents and maps were consulted in the Oregon State University library, especially in connection with the physical environment of South India.

Limiting the scope of the project, in terms of utilization of the water, modification of land use, and benefits, was a major problem. It obviously was not practical or reasonable for a master's thesis to encompass the entire continuum of resultants of the project or even to study all of it in detail. It was, hence, decided to focus consideration upon:

(1) the appraisal of five taluks (administrative subdivision of a district) of Madurai district, which receive 90 percent of the benefit of the scheme. The five taluks are Periyakulam, Tirumangalam, Nilakottai, Madurai and Melur, and

(2) a case study of one village and one farmer of the village.

The village chosen is called Jothimanickkam. The entire agricultural land belonging to the village was examined in detail, in regard to ownership, fragmentation of plots, patterns of land use, crop system, and change resulting from the irrigation of land. Large scale unpublished maps showing, such as, field divisions, land use, and other relevant information were obtained from the Public Works Department and taluk headquarters for analyses and as bases for thesis maps. Field observations were made in this village during December, 1964.

The farmer, John Veeramani Thevar, from Jothimanickkam was selected to represent the farmers of the study area. Information was collected from him on his crops, land use system, routine of farm work, and changes resulting from the Periyar-Vaigai project.

The thesis study is reported in sequence. It begins with an appraisal of the physical character of the area and progresses through an analysis of the pre-project resource use, the project development, and the impact of the development. It is closed

with a brief summation of findings.

CHAPTER II

OVERVIEW OF THE PHYSICAL ENVIRONMENT: UPPER BASINS OF PERIYAR AND VAIGAI RIVERS

The Periyar-Vaigai project is situated in an environmental complex which includes the Cardamom Hills and outlier ranges, the high Cumbum Valley encircled by them, and the Madurai plains of the east-sloping plateau of South India. The hills form a rugged mountain complex, whose slopes support dense forests, evergreen broad leafed on higher elevations merging into deciduous forest associations at lower elevations. The plains have been altered by man through agriculture, with the result that only scattered vegetation remains, most of it xerophytes, except along stream and canal courses. The following is a brief overview of the macro-environment, especially the terrain, hydrography, and climate.

The Cardamom Hills

The Cardamom Hills, which constitute the western zone of the study area, are the southward continuation of the Western Ghats. It is generally considered that the Western Ghats swing in an easterly-northeasterly direction to meet the Eastern Ghats, thus forming the Nilgiri Hills. The Nilgiri Hills are separated from the Cardamoms to the south by the distinct Palghat Gap. The

Cardamom Hills, in reality, consist of three main groups: The Annamalai Hills facing the Nilgiri Hills across the Palghat Gap; the Palani Hills extending northeastward; and the Cardamom Hills proper which form the main north-south range. (See Figure 2)

The Cardamom Hills form the hydrographic divide between the Malabar coast of Kerala state and the eastern plains. They are of ancient crystaline rocks, chiefly gneiss and schists of the Archaean system that have been subject to complicated faulting (31, p. 50-56). The parallelism of the hills - Palanis, High Wavy and Varashanad and Andipattis - are attributed to faulting in the southwest-northeast direction. To the northwest, the Cardamoms and Annamalais fray out into long southeast and northwest ridges which suggest faulting in that direction as well. In this complex, reticulate faulting is reflected by the trellis pattern formed by the streams of the area (See the hydrographic map) (27, p. 643).

The Cardamom Hills are highest in the south, rising to peaks of 6000 feet elevation, although the single highest peak of the peninsula is in the Annamalai Hills section. In the thesis area, the Cardamom Hills scarp rises approximately 3500 feet from the plains and extends for 70 miles in a southwest-northeast direction. In many places the scarp stands out in precipitous cliffs, forming scenery of the boldest forms.

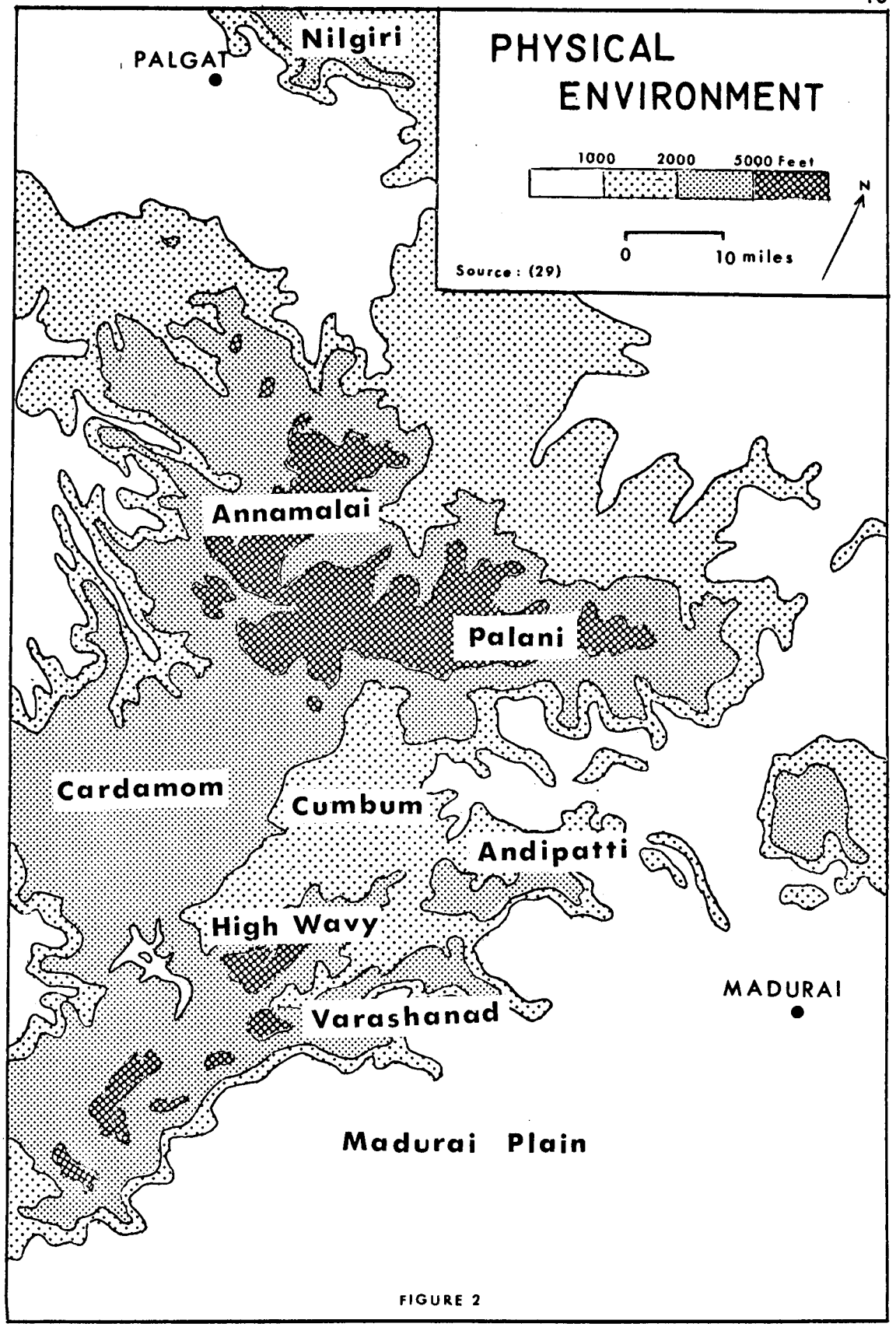

PHYSICAL
ENVIRONMENT
1000
2000
5000 Feet
N
0
10 miles
Source : (29)
PALGAT
Nilgiri
Annamalai
Palani
Cardamom
Cumbum
Andipatti
High Wavy
Varashanad
MADURAI
Madurai Plain

FIGURE 2

The Palani Hills

The Palani Hills, projecting northeast across the Madurai district for some 50 miles, are the northeast continuation of the Cardamom Hills. Their highest peaks are more than 8000 feet, with an average height of 7000 feet. They are divided into higher and lower Palanis. The former, lying to the west, have an abundant supply of water throughout the year. The latter are much lower, sloping gradually towards the Madurai plains, and supplying mainly seasonal runoff.

The Varashanad and Andipatti Hills

The Varashanad and Andipatti Hills are spurs of the Cardamom Hills and extend northeast almost parallel to the Palanis but on the east side of the Cumbum Valley. A higher spur on the western side, called the High Wavy mountains, has an average height of 5000 feet. The eastern portion of the Varashanad and Andipatti Hills is comparatively lower and has gentler slope. It is a discontinuous range, however, and in many parts of it are scattered blocks of granite.

The Cumbum Valley

The Cumbum valley floor is the broad flood plain of the

Suruliyar and its tributaries. The valley with an average surface elevation of 1500 feet is enclosed on three sides by the ranges. To the west of the valley is the Cardamom scarp, and to the east lies the Varashanad and Andipatti Hills. The valley has a general southwest-northeast trend, opening northeast into the Madurai plains. The slope is gentle, dropping from 2000 to 1000 feet in 40 miles; its width varies from five to thirty miles.

Madurai Plains

The core of this thesis study area is the Madurai Plains, which lie to the east of the western mountains. These plains are the surface of the igneous block of South India which has been tilted to slope eastward from the mountains to the Bay of Bengal. In the study area, the elevation of the plains ranges downward from 1000 to 300 feet. The soils of the plains have evolved generally to red ferruginous types with some areas of black earth. Nearly all the plains environment has been modified by man's occupance and is or has been cropped. Natural vegetation is scattered, much of it xerophytes. Deciduous trees,that have been planted for shade, are found along the lines of highways and coconut groves,on the banks of rivers.

Climate

The climates of the Periyar-Vaigai project area are greatly influenced by the Cardamom Hills, which form not only the hydrographic divide between the watersheds of Periyar and Vaigai but also constitute a marked climate and vegetation divide. The west facing slopes of the hills and the narrow coastal plain receive abundant rainfall, associated with the southwest monsoon; but the area east of the Cardamom scarp is a distinct "dry shadow".

Cochin, a west coast city, almost on the same latitude as Madurai, has a mean annual rainfall of 115", 75" of which are received during the four monsoon months, June through September. (See Table 1 and Figure 3) The rainfall increases up the western slopes of the hills. There are no recording stations in this vicinity, however, this area is presumed to have an annual rainfall ranging from 150" to 250". Thekkady, approximately 40 miles from the west coast, at an elevation of 3000 feet in the Cardamom range, receives 73" of rainfall per year. The lesser precipitation is probably due to its location in lee of the high peaks. At Uthamapalayam, only 15 miles from Thekkady and situated in the Cumbum valley, 1000 feet above sea level, the annual mean is only 27" and this exemplifies the "dry shadow" region, east of the hills.

TABLE 1 - Monthly and Annual Averages of Rainfall and of Rainy Days

Station	No. of Years Rec.	J	F	M	A	M	J	J	A	S	O	N	D	Total
Cochin	20	0.8	0.8	1.7	3.7	11.4	27.8	25.3	12.5	9.2	12.9	6.7	1.9	114.7
Thekkady	30	0.2	0.8	1.9	5.2	5.3	15.5	15.1	8.6	5.0	9.9	4.5	1.3	73.3
		1	1	4	13	6	20	22	21	11	15	7	3	124
Uthamapalayam	50	0.4	0.7	0.7	2.3	2.5	4.1	1.5	1.2	1.4	7.0	5.3	2.1	29.2
		1	1	1	4	4	5	5	4	3	11	8	3	50
Madurai	60	1.10	0.69	0.82	3.14	2.45	1.20	2.01	4.78	7.76	7.75	6.10	1.65	39.45
		1	1	1	3	5	2	3	6	8	11	8	3	52

Averages of rainfall and rainy days are presented one below the other.

A rainy day is one on which 0.1" or more of rain was recorded.

Source: 13 and 30.

ANNUAL PRECIPITATION
KERALA COAST TO MADURAI PLAINS

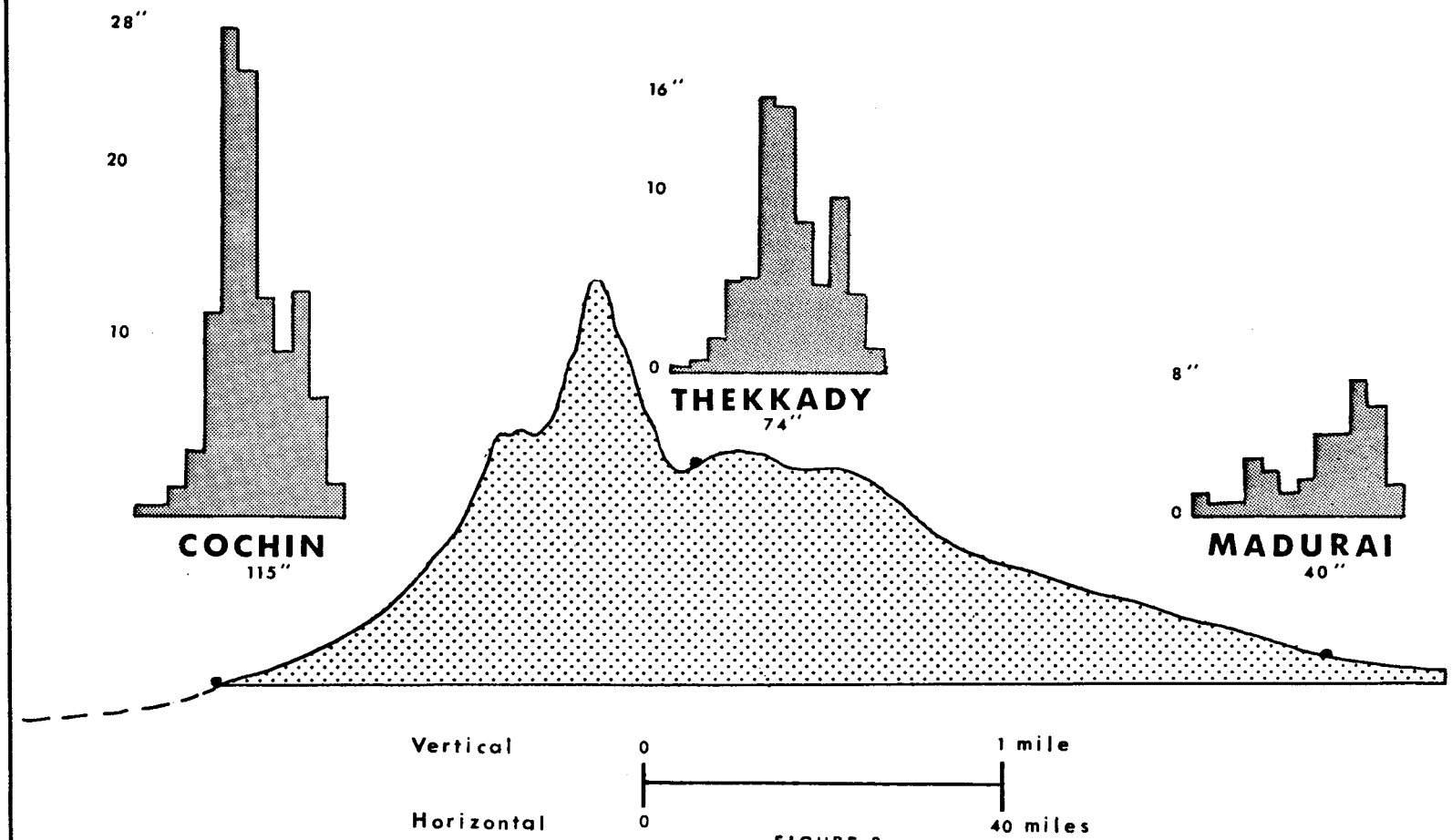


FIGURE 3

The Madurai plain as a whole has a mean annual rainfall of 34". (Table II gives data for stations in the Madurai district for a 35-year period) Slightly more than a quarter of the rainfall is recorded during the southwest monsoon and about half during the northeast monsoon. Excluding the hill station, Kodaikanal , the highest amounts are received in Melur and Madurai taluks and the lowest in Dindigul, Periyakulam, and Palani. The last three taluks receive lesser amounts because of their position close to the highest protions of the range of mountains, while Madurai and Melur stand farther away from the "shelter" of these hills and opposite a lower portion of them. Hence, they receive a somewhat larger supply from the southwest monsoon.

The monsoon regime leads to the division of the year in Madurai district into the period of the southwest monsoon (early June to the close of September) and the period of northeast monsoon (October to December). January to March is the cool, dry season and April and May comprise the hot season. During the cool, dry season, the rainfall is less than an inch and the temperature averages 78°-80°. The hot season is marked by the rise in temperature to day time highs of 95°-100°.

For a 70-year period in the Madurai district, the maximum rainfall in any one year was 50.76" and the minimum was 18.48". The mean for the period was 37". It is evident that the precipitation

TABLE II - The Division of the Year According to Precipitation by W. Francis

Station	Elevation in feet	Jan. to March	April & May	June to Sept.	Oct. to Dec.	Total
Dindigul	1000	1.55	5.00	9.57	14.18	30.30
Kodaikanal	6900	6.43	11.43	21.00	26.50	65.37
Madurai	440	1.70	5.11	12.34	15.85	35.00
Melur	400	1.44	4.80	15.33	16.31	37.88
Nilakottai	750	1.45	5.49	8.24	14.86	30.04
Palani	1100	1.30	4.69	4.94	15.13	26.06
Periyakulam	970	3.58	5.38	6.19	14.13	29.28
Tirumangalam	450	1.41	5.58	9.93	14.89	31.81
Average		2.17	5.80	9.72	16.19	33.88

(Source 9, p. 160)

in Madurai district is unreliable in character and the total amount fluctuates greatly from year to year. Moreover, the variations in the beginning of the monsoon rains or their end, or their concentration may be even more serious than the total. The effect of the unreliable rainfall on land use is further analysed in the next chapter.

Drainage Pattern

The Cardamom Hills are the chief watershed area of both Periyar and Vaigai. These two rivers have their source very close to each other but follow entirely different courses, almost in opposite directions. The Periyar river flows westward through Kerala state and empties into the Arabian Sea. The Vaigai runs east and joins Bay of Bengal at Palk strait.

The Periyar River

The Periyar river, the biggest of the Kerala rivers, has its source in the west-facing slopes of the Cardamom Hills at an altitude of approximately 4500 feet. With its several tributaries, the Periyar first flows north and northwest, probably following structural faults. It then turns westward, flowing through a fault basin at elevation 2860 feet. This basin is now utilized for storing the headwaters of the river for the Periyar project (20). The river then enters a deep canyon and flows northwestward for 34 miles,

almost parallel to the trend of the Cardamom Hills. Turning sharply westward, it breaks out on the western coastal plain, which it crosses, flowing northward for 55 miles before reaching the sea, near Cochin. The catchment area of the headwaters of the river which flows into Periyar lake is 240 square miles. The average annual discharge, estimated at the Periyar dam site, over a period of 22 years, is 8,932 million cubic feet, the maximum in any one year being 37, 231 million cubic feet. During five non-consecutive years of the 22, there was no surplus runoff (18, p. 7).

The Vaigai River

The Vaigai river is formed by the merging of several forest streams, the chief among them being Vairavanyar, Suruliyar, Teniyar, and Vaigai. Vairavanyar, one of the tributaries of Suruliyar, has its source in the Cardamom Hills, east of the Cardamom scarp, very close to Thekkady and almost in the Periyar drainage. Across the Cumbum valley, from the lower spurs of High Wavy mountains, flows the Suruliyar; and the two drain the Cumbum valley. After flowing through the valley for some 40 miles, the Suruliyar is joined by Teniyar, an almost perennial stream that rises in the northern end of the Cardamom scarp. Another two miles farther, the combined waters of Suruliyar and Teniyar join the Vaigai. (See Figure 4)

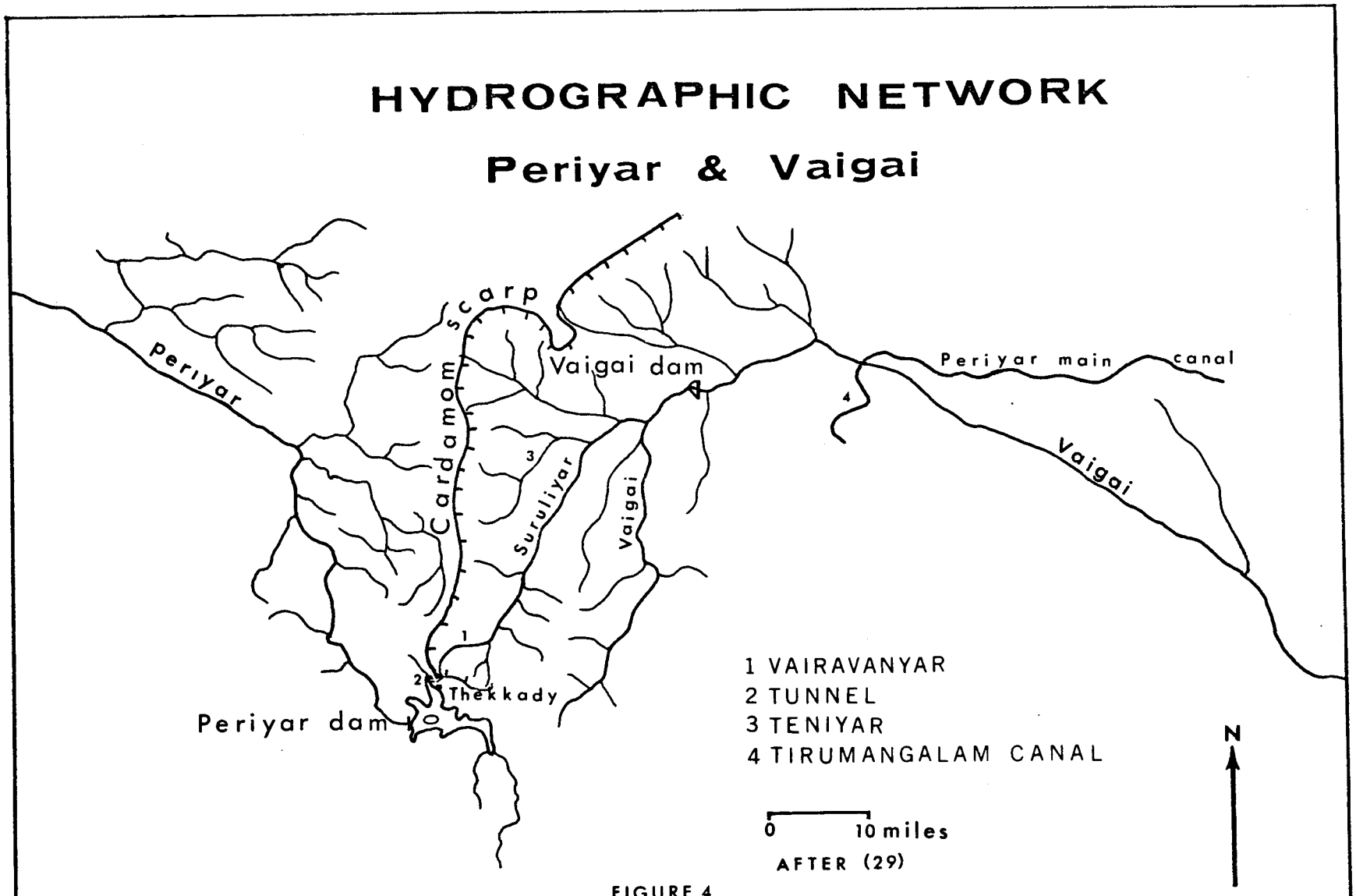

HYDROGRAPHIC NETWORK
Periyar & Vaigai
Periyar
Cardamom scarp
Vaigai dam
Periyar main canal
Vaigai
Suruliyar
Vaigai
Thekkady
Periyar dam
1 VAIRAVANYAR
2 TUNNEL
3 TENIYAR
4 TIRUMANGALAM CANAL
0 10 miles
AFTER (29)
N

FIGURE 4

The river Vaigai rises in the rugged Varashanad range at approximately 5000 feet. At first, Vaigai flows parallel to Suruliyar, following the narrow gorge between the High Wavy and Varashanad and then turns due north through the gap between the High Wavy and Andipatti Hills. After continuing north for about 12 miles, its confluence with the combined waters of Suruliyar and Teniyar takes place. The combined headwaters flow northeast and are joined by the Varahanadi and the Manjalar, both of which have their source in the Palani Hills. The Vaigai, now a deep and rapid river, turns round the Andipatti Hills, making a sharp bend in keeping with the Nagamalai trend and begins its south-easterly course, which it continues until it reaches the sea.

The Vaigai has a catchment area of 520 square miles of hills and 870 square miles of plains. Before the diversion of Periyar water into the Vaigai system, the river carried from (May to September) 10 to 150 cubic feet a second. The average annual inflow, measured at the Peranai regulator, is 22,591 million cubic feet (15, p. 131 and 18, p. 10).

CHAPTER III

PRE-PERIYAR RESOURCE UTILIZATION

The district of Madurai, during the last decade of the nineteenth century, was far from being prosperous. Subsistence agriculture was the main activity for the majority of the population, industries having not been developed to any great extent. The farmers followed the traditional methods of cultivating their fragmented plots with rudimentary impliments. The uncertainty of the rainfall and the lack of perennial rivers in the district further handicapped their efforts, and agricultural operations were seldom rewarded by a good crop.

In the following paragraphs,an overview of the pre-Periyar occupancy pattern, including agricultural practices, is presented along with an analysis of the rainfall data as background for the need and the achievements of the water control project.

People of the Area and Pattern of Settlement

The population of the Madurai district, according to the 1891 census, was 1,699,477, approximately one half of what it is today. In 1891, the average density of the population was about 380 people per square mile. Excluding Madurai, the headquarters of the district, the density was highest in Palani taluk, and Dindigul was

next. The population density was lowest in Periyakulam due to the existence of a large area of uninhabitable hills and forests. Where the land was cultivable, however, the density must have been well up to the average. (See Table III)

The majority of the cultivators were Hindus. The Hindus formed 94 percent of the population and Christians four percent. The Muslims who comprised the rest of the population very seldom took to cultivation. The mother tongue of four fifths of the people was Tamil, one of the Dravidian languages, because Madurai district formed the heart of the Tamilnad (the land of the Tamil speaking people). The people who immigrated from the north and west spoke Telugu, Canarese, and Patnuli.

Brief accounts of some of the prominent Hindu castes of the district, who were the chief agriculturists, are given with a view to illustrate the pattern of man's occupancy before Periyar days.

Kallar

The Kallar were the most prominent caste of the district, especially in the Melur and Tirumangalam taluks and the Teni, sub-taluk of Periyakulam. They have always borne a reputation for anti-social activities. They were noted for their dacoity of travelers at night, calculated cattle lifting, blackmailing, and theft. (Kallan means "thief" in Tamil.) They were never ashamed of

TABLE III - Population of the Madurai District Prior to the Bifurcation of Madras Presidency

Population							Agriculturalists		Non Agri-culturalists
Year	Males	Females	Total	Hindus	Muslim	Christian	Cultivator	Laborer	
1891	1,251,568	1,356,836	2,608,404						
1901	1,357,056	1,474,224	2,831,280	2,550,783	168,618	111,837	985,529	285,593	1,560,158
1911	946,306	986,526	1,932,832	1,795,753	76,558	60,510	833,357	242,169	857,306
1921	987,468	1,019,614	2,007,082	1,862,857	78,922	65,301	749,286	183,912	929,659
1931	1,081,437	1,114,310	2,195,747	2,021,336	90,587	83,769	499,484	155,603	1,540,660
1941	1,211,923	1,234,678	2,446,601	2,243,398	106,788	96,331	-	-	-
1951	1,439,258	1,452,559	2,891,817	2,670,241	119,543	101,885	1,307,593	517,110	1,067,114
Population in the Madurai District Adjusted to the Present Jurisdiction									
1901	830,729	868,748	1,699,477						
1911	938,739	978,413	1,917,152						
1921	982,391	1,014,346	1,996,737						
1931	1,076,123	1,108,809	2,184,932						
1941	1,225,370	1,248,498	2,473,866						
1951	1,439,258	1,452,559	2,891,817						

Note: The bifurcation of Madras presidency took place in 1956.

Source: Census report. 1951

their theiving, but considered it their righful bread-winning vocation. They seldom farmed in earnest, even though some of them were tenant farmers and they were among the first to feel the pinch of a bad season. Then they would thieve with more than usual energy or emigrate light heartedly with their few belongings to Rangoon or Ceylon (9, p. 88-95).

Idaiyans and Valayans

After the Kallar, the Idaiyans and Valayans were the next most numerous castes in the district. Idaiyans were the shepherds and cowherds of the community. The name 'Valaiyan' is derived from 'Valai', meaning a net, because they formerly lived chiefly by snaring birds and small animals. By the end of the 19th century, many of them had become cultivators.

Kunnuvans and Pulaiyans

The Kunnuvans were the principal cultivating caste and Pulaiyans formed the chief laboring caste of the Palani Hills. They were not the hill-men in the strict sense of the word, since all of them had come in some distant past from the plains. The Pulaiyans, however, were apparently the earliest inhabitants of the Palani Hills and had things their own way until the arrival of the Kunnuvans, who later became their masters.

Land Use

In Madurai district approximately 87 percent of the population depended on agricultural pursuits for their existence. They were subsistence farmers whose farm holdings were small, seldom over three or four acres. Moreover, these holdings were commonly sub-divided into several plots, generally scattered within the owner's village boundaries.

Cropping System

During the pre-Periyar days, the most common wet crop was paddy (rice), the area of sugarcane and betel-vine being very small. Of the dry crops, cholam was the most popular, followed by groundnut, varagu, cumbu, ragi, samai, and horsegram. Cotton and tobacco were industrial cash crops raised on a small scale.

The paddy crop was cultivated from October to January or February, depending on the type of paddy raised. After the harvest of paddy, the farmers grew a dry crop on the same fields. In areas where water was not available for a wet crop, only one dry crop was raised per year, normally from September to January.

Rise of Irrigation System

The productivity of the fragmented plots mainly depended on

the amount and regularity of the monsoon rains, which were noted for their vagaries and uncertainty. Thus, the need for water storage and regulation was recognized in early times. The farmers of the district, from time immemorial, had used ingenuity in developing various devices for water diversion and distribution to increase the cropping possibilities. These devices for supplementing water were specially used for raising a wet crop like paddy. The three common irrigation sources used at that time, for paddy cultivation were wells, tanks, and spring channels.

Wells: One well, normally irrigated one to three acres of land, the water being baled out by bullocks. Wherever well irrigation was possible, the farmers grew two crops per year, one irrigated by the wells and the other dry. However, wells offered an assured supply of water for only a small area.

Tanks: The tanks, which are in reality small reservoirs, date back to ancient times in Madurai and adjacent districts. Some of them are ponds dug to catch the rain water and others were made by constructing anicuts (weirs or small dams) across the streams. The tanks vary in size, covering from less than an acre to many square miles. Often a whole stream has been reduced to a string of tanks, the lower ones tapping the surplus water from those above.

Under the tank system, generally, only one crop was possible

since the tank normally held only half the supply required for a crop and two fillings were needed to assure a crop. If the rainfall did not vary greatly, there was enough water for two fillings and a good harvest was assured.

Spring channels: Spring channels were excavated in the bed of the river, when it was dry and carried downstream, often for several miles, at a flatter gradient than that of the river. At the head of the channel and for a varying distance below this, the channel was below the level of saturation in the sand of the river and the water flowed into and along it. Towards its lower end, the bed of the channel became high enough to be taken through the bank of the river and continued above the ground level. In this way water under flow was secured for direct irrigation purposes or as additional supply to the tank, apart from its own catchment area. Spring channels irrigated 100-200 acres by direct irrigation and provided sufficient water for one wet crop.

In the taluks of Madurai, Melur, and Teni, tank irrigation was widespread. Ancient anicuts were used in the Cumbum valley. In Dindigul and Palani, tanks were few but well irrigation was common. Two of the ancient canals of the pre-Periyar period, the Vadakarai and Thenkarai channels were built by the Pandia kings in the twelfth and thirteenth centuries. Vadakarai channel, a branch from Peranai anicut, was 38 miles long and six feet deep and

irrigated land in Nilakottai taluk.

Thus during the pre-Periyar days, with the help of indigenous devices developed for tapping and collecting water, the farmers commonly cultivated one wet crop per year. But the successful harvest of this one wet crop, depended to a large extent on the monsoon rains since only half the water needs could be assured by tanks and wells. Therefore, due to vagaries of the monsoon, crop failures were common.

Analysis of Rainfall Data

An analysis of the daily rainfall data for a 30 year series, 1931-1960, for Madurai was carried out to indicate the marked variations in the precipitation regime. (See appendix for data) The variations peculiar to the monsoon rainfall are fourfold. Delay in the commencement, prolonged break during the season, premature cessation, and concentration in one part of the region are the main characteristics of the vagaries of monsoon rains. All these variations are present in the pattern of the rainfall of Madurai district. However, the analysis is limited to the following two aspects.

(1) Consideration of monthly rainfall to show the macro-seasonal variation.

(2) Examination of daily rainfall for two months to indicate the extent and severity of the dry season.

Monthly Rainfall

The average annual precipitation for the 1931-1960 series is 39.45". Nearly 90 percent of the total is received from April to November. The dry months are February and March and receive only 3.7 percent of the annual total. The annual variation is 30.72", the wettest year, 1944, being 49.20", and the driest, 18.48". Only nine years received rainfall above the average and eight years received less than 30". During the driest year 1952, every month, except February, had rainfall lower than the average and the deficiency was more pronounced during the notheast monsoon period than during the southwest. (See Table 4)

The monthly variation and 74 percent concentration interval are graphically shown in Figure 5. Considering the dry season, January has the greatest variation, the range being 11.85" for an average of 1.1" and June has the least variation, with a range of 3.98" for almost the same average as January. The greater annual variability is not limited to the lower amount of rainfall received. During the southwest monsoon months, August to November, the monthly rainfall variation ranges between 12" and 15".

The 74 percent concentration interval also follows approximately the same pattern as that of the monthly variation except for the two months, January and May. In January and May, two out of

TABLE IV - Summary of Madurai Rainfall Data - (1931-1960)

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Maximum	11.85	4.02	5.22	10.30	10.80	3.98	7.31	12.43	14.24	16.40	14.00	8.72	49.20
Minimum	0	0	0	0.39	0.14	0	0	0.66	0.23	1.32	0	0	18.48
Median	0.48	0.08	0.2	2.42	2.37	1.00	1.30	4.0	3.5	7.1	5.75	1.0	37.46
Mean	1.10	0.69	0.82	3.14	2.45	1.20	2.01	4.78	7.76	7.75	6.10	1.65	39.45

Values are in inches.

Source: appendix

TABLE V - Thornthwaite's Climatic Water Balance, Madurai, India

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Potential Evaporation	117	128	163	174	185	177	177	173	161	152	122	116	1845
Precipitation	15	10	18	53	71	41	48	109	122	203	127	51	868
Soil Moisture	33	22	14	9	6	4	3	2	2	53	58	46	
Actual Evaporation	28	21	26	58	74	43	49	110	122	152	122	53	868
Water deficiency	89	107	137	116	111	134	128	63	39	0	0	53	977
Water surplus	0	0	0	0	0	0	0	0	0	0	0	0	0

Values are in millimeter (Source: 1, p. 122)

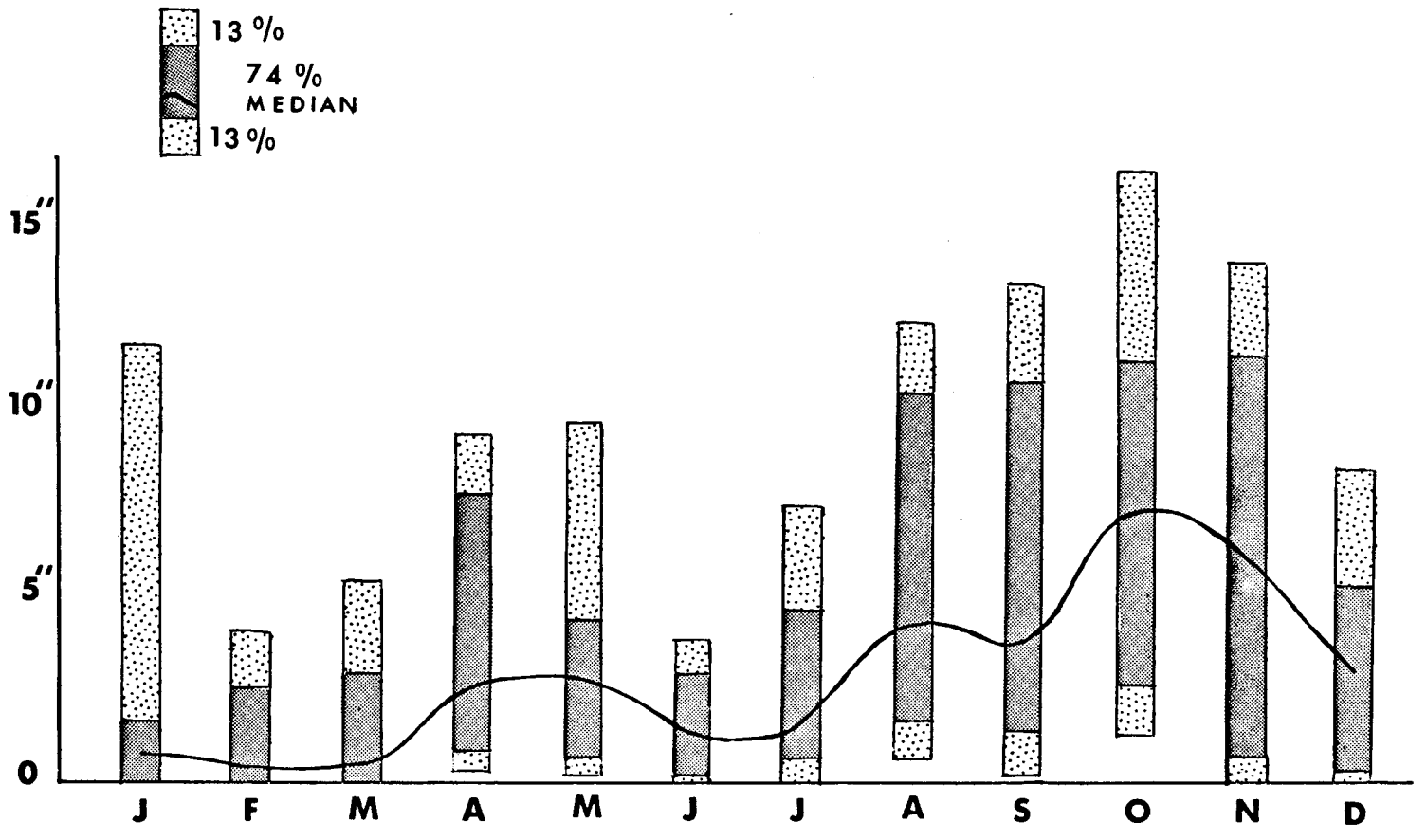

VARIATION IN MONTHLY RAINFALL 1931–60
13 %
74 %
MEDIAN
13 %
15"
10"
5"
0
J
F
M
A
M
J
J
A
S
O
N
D

FIGURE 5

the 30 years receive a rainfall of more than 10", and decrease the 74 percent concentration interval for these two months. Thus, the analysis shows that there is a macro-seasonal variation that seldom follows a regular pattern.

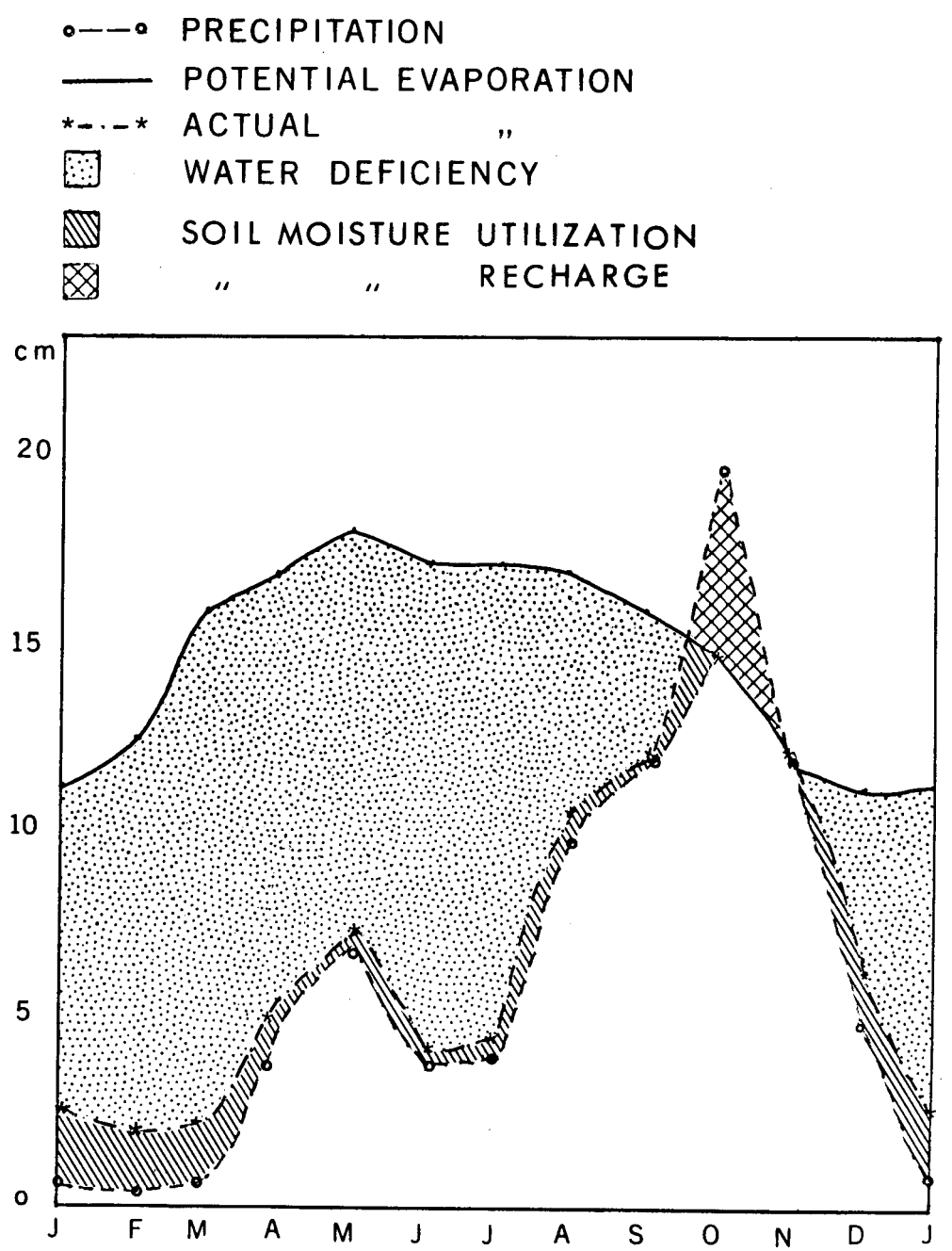
According to Dr. C. W. Thornthwaite's water balance table for Madurai, worked out for a 60 year period (1881-1940), the imbalance between water supply and water need is marked. (See Table 5 and Figure 6) His table shows that during 10 months out of the 12, there is water deficiency. The precipitation excess during September, October and November is presumed to recharge the soil moisture and thus there is no water surplus. Thornthwaite's evaluation clearly shows the necessity for irrigation if crop agriculture is to be assured.

Daily Rainfall

For the purposes of the daily rainfall analysis, the dry season is considered to be June and July, the total amount of rainfall received during these two months being 3.21".

It is assumed that the best period for transplanting paddy seedlings is from June 15 to July 15, if the southwest monsoon rainfall is to be made use of, for the growth of paddy after transplantation. Conversely this is the period most critical for water need. Hence, the period of study coincides with the transplainting

WATER BALANCE—MADURAI



Source:(1)

FIGURE 6

time and is further extended to a month to show that the marked drought period is followed by the monsoon rains.

Each rainy day, from June 14 to August 15, for the 30 year series, is plotted on the graph in Figure 7, considering a rainy day as having a precipitation of 0.1" or more. Between June 14 and July 15, for the 30 years, there were only 69 rainy days, averaging 2.3 days per year. Only one year had as many as seven rainy days and four years had none. For the period July 15 to August 15, the total amount doubled, and rainy days numbered 146, 4.9 being the average per year. Correspondingly, the total amount of rainfall increased to 3.38". The data clearly shows that irrigation is essential between June 15 to July 15, for the transplanting of paddy seedlings.

Thus, the physical environment of the locale is that of a "dry shadow" region with notably erratic rainfall. Through centuries the people who have occupied the plains area have been victims of the vagaries of the monsoon rains and have lived precarious agrarian lives.

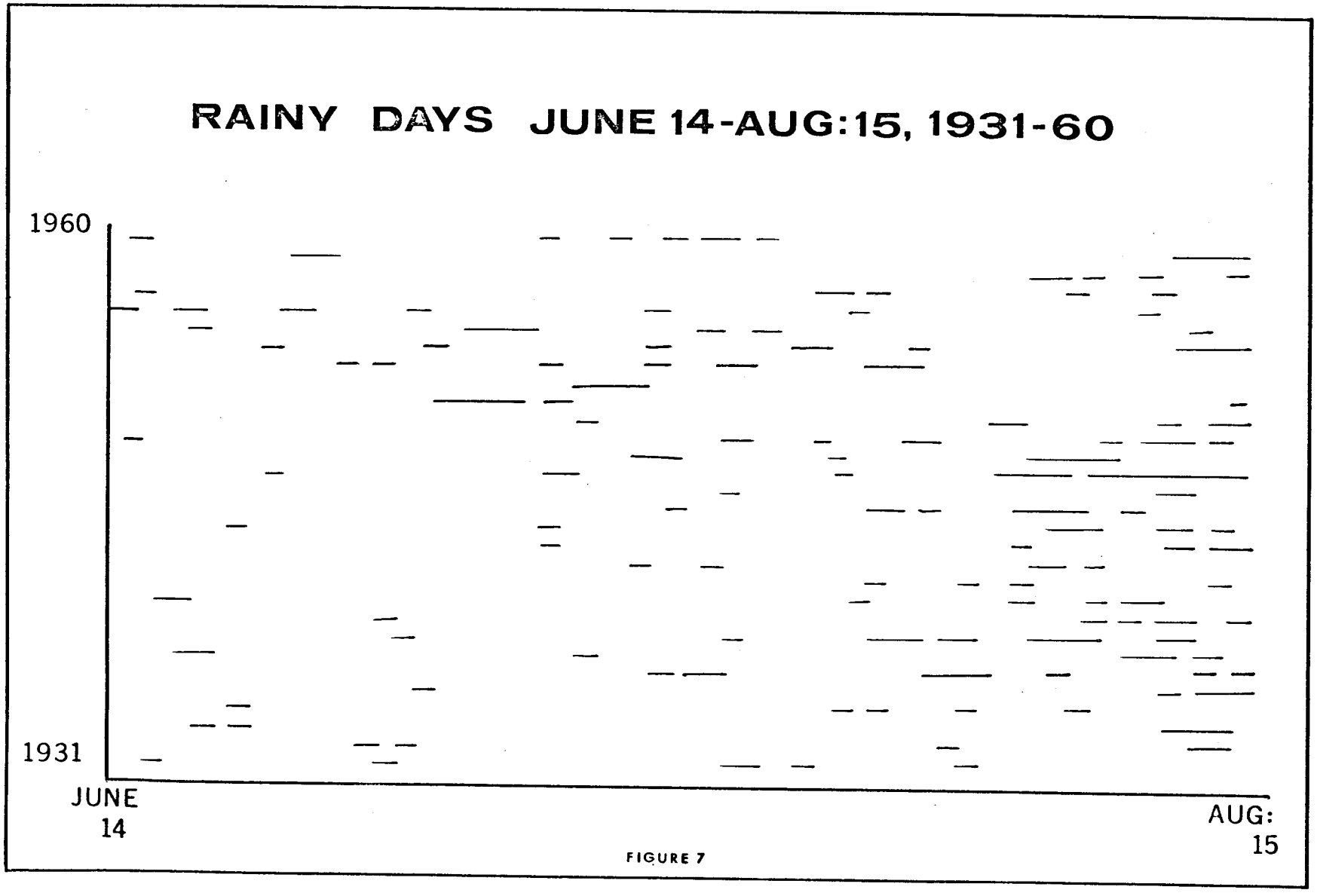


FIGURE 7

CHAPTER IV

THE PERIYAR-VAIGAI PROJECT

The two rivers, the Periyar and Vaigai, originally presented a marked contrast in utilization and in the way they affected the land and life of man on the two sides of the Cardamom Hills. The perennial Periyar river flowed uselessly through the forested and well-watered Kerala state to the Arabian Sea, with little use even in the agricultural plains. On the east side of the range the Vaigai was at best a meager stream, poorly fed by the monsoon rains and in the dry season often dwindled to a trickle, wandering ineffectively through the arid district of Madurai. Nevertheless, Vaigai waters were cherished and intensively used - it has been written that "not a drop" was unused. It is thus easy to understand that peoples of the Madurai plains early came to look with desire on the unused water of the west slope.

Conception of the Periyar Project

The idea of diverting the water of the Periyar and utilizing it for irrigating the arid tracts of Madurai district is more than 150 years old. According to Captain Ward's Survey Account, the first person to suggest the scheme to the then Rajah of Ramnad was Muthu Arula Pillai, Rajah's Prime Minister, and that was in 1798

(9, p. 126). The lack of funds to undertake such a vast scheme prevented any action.

The idea was brought up, however, from time to time, by one District Engineer or another. In 1867, Major Ryves, one of the royal engineers of the Madras presidency, put it forward in a practical form which included the main ideas of the plan eventually approved. His idea was merely to divert the water and not to store it. His proposal, nevertheless, was not immediately approved by the British Government in India, as it was considered that sufficient information was lacking.

For another 15 years, investigations were carried out and modifications to Major Ryves' scheme were suggested by engineers. Finally, in 1882, Col. Pennycuick, chief engineer, was relieved of his regular duties and was directed by the Government to undertake the revision of plans and estimates for the whole project. His plan included a main masonry dam across the Periyar to form a large reservoir, a surplus escape and a mile long tunnel through the watershed. His scheme was approved by the Government in 1884.

Interstate Agreement

The work on the project did not start for another three years, because there was a disagreement between the independent

Travancore state (now Kerala) and the British Government of Madras presidency, over the terms on which the use of water and compensation for the land submerged by the reservoir. The site of the dam and the lake being in its territory, the Travancore state contended that, even though the water was not required for its people and the land was uninhabited, the value of both land and water should be appraised in terms of its utility to the British Government.

After prolonged negotiations which lasted well over two years, an agreement was finally reached by which the British Government would pay annually a sum of Rs. 40,000 ($8,430) for certain specified areas and certain defined rights. Term of agreement was 999 years with the option for renewal. Sovereign rights over the site of the dam were reserved by the Travancore state (15, p. 25-26).

The Project

The construction commenced in September, 1887. The immense difficulties which arose and were overcome during the actual construction of the great project are detailed in the "History of the Periyar Project" by A. T. MacKenzie, one of the engineers who helped to carry it through.

The chief engineering problem concerned the river itself. In order to appreciate the problem, one has to realize that the

discharge of the Periyar is equal to half the average flow of the Niagara and that sudden and heavy floods are common. The worst flood occurred during October, 1891, washing away 7,000 cubic feet of rubble and 20,000 cubic feet of concrete. Though the damage to the main dam was not great, many coffer-dam piers were washed away. The force of the current was such that boulders weighing 3/4 ton were carried down the river during floods (18, p. 4).

Besides the great difficulties caused by sudden floods, unhealthfulness of the locality was the greatest impediment to the progress of work. A virulent type of malaria inflicted heavy casualties among the laborers, specially at the earlier stages of the construction. Malaria besides enfeebling the constitution of the laborers, made them offer little resistance to rheumatism, dysentery and pulmonary complaints. From 1887 to 1891, the hospital was not organized properly, and this contributed to the untold sufferings among the laborers. It was only at the later stages that malaria was brought under control. The cholera epidemics were also frequent, in spite of best precautions.

The statistics for the worst month, June, 1895, show that the hospital attendance rose to the extraordinary figure of 1,465 man-days per month per thousand laborers employed. For that year the average number of laborers was 2,449 and the average monthly hospital attendance was 1,081 (12, p. 66-67). During the

construction period, the total number of deaths from sickness and other causes reached an alarmingly high figure and one is reminded of the attitude that "no big enterprise of the kind can be carried through without a long death-roll that must be balanced against the number of other lives that are likely to be saved or benefited by the finished work" (8, p. 181).

After eight years of work, in October, 1895, the Periyar dam was completed. It had taken nearly half a century to materialize the scheme and divert the Periyar waters to irrigate the parched-up Madurai plains.

The Periyar Dam

The masonry dam is constructed of random rubble masonry for the interior and faced with chisel or hammer dressed stone. The Periyar dam, 1,241 feet long and 158 feet high, in a "V" shaped gorge, at an elevation of 3,000 feet, stands today as a monument to the engineering skill and enterprise of that period.

The Periyar Lake

The Periyar lake, which has been artificially created by the damming of the Periyar river, has a water surface of 10.21 square miles, and a useful storage capacity of 15,662 million cubic feet. The area around the lake has been converted into a wildlife

sanctuary and is one of the finest national parks in the whole of India. Here is a unique opportunity of watching various species of wild animals in their own habitat, not from watch towers as in other sanctuaries but from boats which ply the waters of the Periyar lake.

Tunnel

From the north arm of the lake, the stored water is led by an open cut and a tunnel to the Vaigai watershed. The passage to the latter watershed consists of an open cut 500 feet long. The tunnel is 12 feet wide by 7-1/2 feet high and is 5704 feet long. It has a gradient of 1 in 75. A sluice gate at the head of it controls the outflow. From the lower end, the water rushes down the face of the hill into the stream Vairavanyar, whence it flows into the Suruliyar, and thence into the Vaigai. The quantity of water drawn annually has varied from 20,000 to 25,000 million cubic feet up to 1957 and after that increased by 4,000 million cubic feet (18, p. 10).

Periyar Main Canal

There are several ancient anicuts on the Suruliyar and Vaigai rivers and supply to these has been increased since the Periyar water was passed into these rivers. A great volume of water, however, is not utilized until it reaches the Peranai anicut, where

the Vaigai changes its course to the southeast. Peranai anicut is 86 miles from the mouth of the tunnel.

The Peranai is an ancient anicut which fed a channel on the north bank of the river called Vadakarai channel. Silt accumulation had choked the river bed above the anicut so that a modern regulator had to be constructed above the old anicut. The Periyar Main Canal leads off from below this regulator. It is a contour canal, 36 miles long and runs nearly due east. It has 12 branch channels and 64 distributaries. The map shows the branch and the distributaries as well as the tanks, which serve as temporary reservoirs. (See Figure 8)

Improvements of the Periyar Project

After half a century of operation it was realized that the avaiable resources had not been fully utilized.

(1) The entire runoff from the Periyar catchment area was not tapped for utilization by the Periyar dam. The 22 year record indicates that there was surplus water on an average of 8,932 million cubic feet overflowing the Periyar dam, going waste into the Arabian Sea (18, p. 7).

(2) A large portion of the water that the dam impounded was not available for irrigation purposes, mainly because it was required to raise the level at which it can be delivered by way of the

PERIYAR MAIN & BRANCH CHANNELS

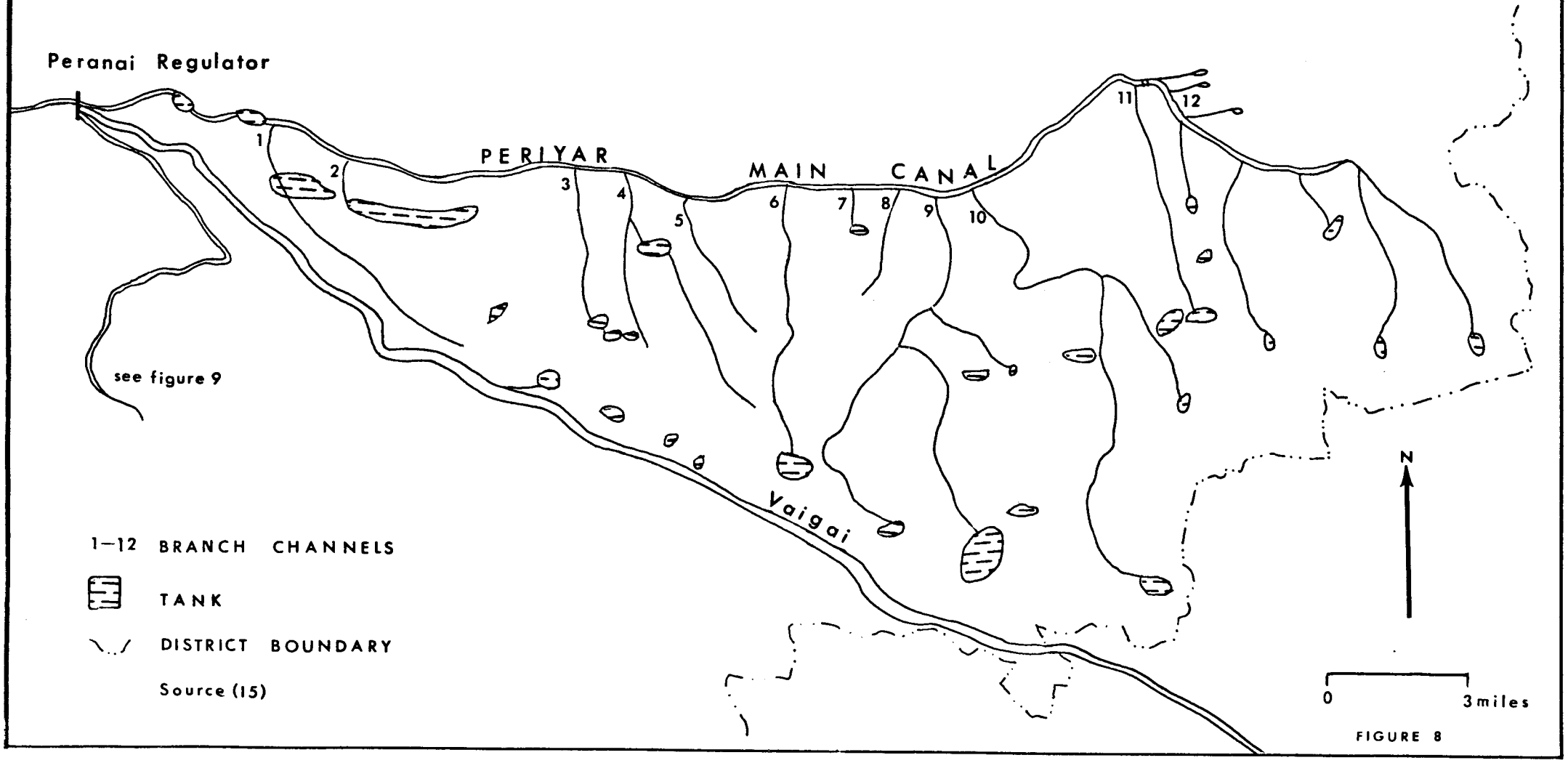


FIGURE 8

tunnel to the further side of the watershed. This tunnel was only 50 feet below the crest of the dam.

(3) The fall of 1,200 feet below the exit of the mile long tunnel extended a good opportunity for the generation of hydroelectricity which was unused.

Periyar Hydroelectric Project

After prolonged negotiations with the erstwhile Travancore state, the Periyar hydroelectric scheme was the first improvement to be taken up and it was completed in 1954. Under this scheme, the existing irrigation tunnel was widened from 92 square feet to 152 square feet of cross sectional area; a fore-bay dam was constructed at the exit of the tunnel; and a power tunnel, 4,188 feet long, with a cross section of 150 square feet was added. Thus, it was possible to draw water from the Periyar river throughout the year for power purposes, instead of during only nine months for irrigation purposes as was done hitherto.

The Periyar hydroelectric plant generates annually 18,000 kilowatts. At the rate of Rs 10.00 ($2.00) per kilowatt hour, between Rs 150,000 ($31,580.00) and Rs 200,000 ($42,110.00) per year is paid to the Kerala state for the power developed.

Vaigai Reservoir Project

In order to impound and store the tail race waters from the hydro-plant during the non-irrigation season, a subsidiary reservoir was necessary. Such a reservoir was completed in 1959 on the Vaigai, 20 miles above the Peranai regulator and nine miles below the confluence of the Suruliyar and the Vaigai. This reservoir also stores some of the surplus that occurs at the Periyar lake during the monsoon season. In addition, it is designed to store to the extent possible, the surpluses of the Vaigai that would otherwise go to waste in the sea. At the same time, there was built a new canal 17-1/2 miles long, called Tirumangalam canal and some extensions to the Periyar project. (See Figure 9)

The length of the Vaigai dam is 11,675 feet, its maximum height 111 feet and gross capacity 6,818 M c. feet. (See Table 6)

During the construction of the Vaigai reservoir and dam, work was carried out at Thekkady to lower the existing outlet cut by another five feet, so as to utilize some of the dead storage of the Periyar lake so that the power developed might be extended throughout the year.

Recreational Use

One of the notable features of the Vaigai project is that the

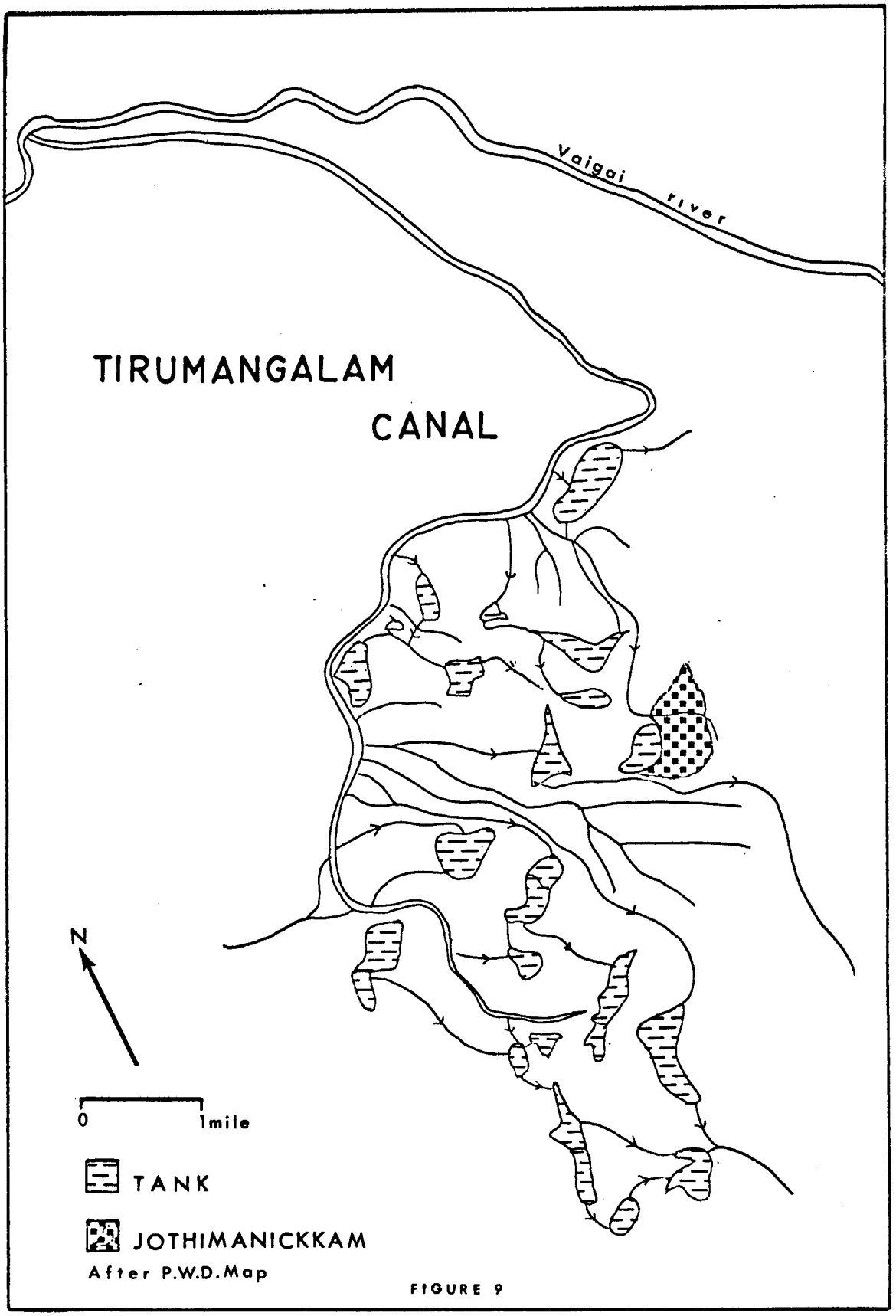

Vaigai river
TIRUMANGALAM
CANAL
N
0
1mile
TANK
JOTHIMANICKKAM
After P.W.D.Map

FIGURE 9

TABLE VI - Basic information of Periyar-Vaigai Project

	Periyar Project	Vaigai Project
Year completed	1896	1959
Catchment area of the lake / reservoir	240 sq. miles	870 sq. miles
Area of water spread of the lake / reservoir	11 sq. miles	8 sq. miles
Cross capacity of the lake / reservoir	15,622 Mcft	6878 Mcft
Length of the dam	1241 ft	11675 ft
Maximum height of the dam	158 ft	111 ft
Full reservoir level	+2861 MSL	+916 MSL
Length of the tunnel	5704 ft	-
Length of the main canal	36 miles	17-1/2 miles
Total length of branch channels	116 miles	5 miles
Total length of distributaries	118 miles	7 miles
Total ayacut irrigated in the locale	144,000 acres	16,400 acres
Stabilizing the existing ayacut	-	132,070 acres
Power generated	105,000KW	-
Total expense	Rs. 10.8 million	Rs. 20.8 million
(Source: P.W.D. data)	$2.3 million	$4.4 million

dam is on the route to the Periyar lake at a convenient distance from many towns for picnickers. It has been a major attraction on this score and its parks, cascades, fountains, toy train,and other amusement facilities are eagerly sought.

Structural Improvements of Periyar Dam

Precautionery measures are being taken to insure the safety of the 70 year old Periyar Dam. As the dam has no pressure relief arrangements, such as drainage galleries that are built into modern dams and as no curtain grouting had been done to the bedrock at the time of the construction of the dam, a considerable amount of leakage in the rear of the dam had developed. To stop this leakage, engineers decided to drill at specific intervals, by rotary drills, and to pump grout to fill the crevices. This procedure has practically stopped the leakage but has raised the problem of uplift pressure. To counteract this, remedial measures are being considered. An inspection of the dam by the concerned engineers of the two states has resulted in the opinion that the dam would be able to serve its purpose for many more years, provided action is taken to counteract the uplift created by the drilling and grouting.

CHAPTER V

IMPACT OF THE PROJECT ON AGRICULTURAL LAND USE

The completion of the Periyar-Vaigai water resource project resulted in significant changes within the project area, namely in the taluks of Melur, Madurai, Nilakottai, and Periyakulam. The Suruliyar and Vaigai rivers, formerly reaching flood stage for a week or two and then nearly dry for almost the rest of the year, have now a nearly constant flow of water most of the year. Consequently, their waters are able to feed the ancient channels and the new ones, that branch off from them. As a result, irrigation has been extended to larger acreage and there is assured supply of water for greatly expanded wet crop land use.

Land Benefited by Irrigation

In pre-Periyar years the agricultural land use mainly consisted of dry crop cultivation, the wet crops being limited to only small areas having access to water from wells, tanks, and spring channels. It has been estimated that approximately 33 percent of the land in the study area was cultivated during that period. The locale has an area of 3400 square miles. However, the nineteenth century cropping was notably hazardous and seldom produced

adequate crops because of the unreliable rainfall. As a result of the Periyar-Vaigai project, the average area cultivated has increased by 22 percent but,even more important,the water has given essential cropping stability to about a third of the district cropland.

Periyar Main Canal

The land irrigated under Periyar Main Canal comprises 45,000 acres of double crop and 85,000 acres of single crop in the taluks of Nilakottai, Madurai, and Melur. (See Table 7) There is direct as well as indirect irrigation in Periyar system. The term "direct irrigation", as used in Madras state, implies that water is drawn directly from the flow of a river or a canal. For indirect irrigation, the water is drawn from a storage work, such as a tank, which is filled by the irrigation canals or rainfall or from its own catchment area. Most of the time, the supply is from a combination of these sources.

Vaigai

The following benefits were derived from the completion of the Vaigai reservoir:

(1) Stabilization of the existing irrigation under Periyar system.

(2) Extension of irrigation to 22,818 acres comprising (a) 1000 acres in the Cumbum Valley (b) 10,385 acres

under the new Tirumangalam Canal and (c) 11,433 acres under the Periyar Main Canal.

(3) Provision of additional water for 132,070 acres in Vaigai-fed channel area.

Tirumangalam Canal

Through the Tirumangalam Canal, the extent of ayacut (assigned irregable area under an irrigation source) in direct irrigation is 3700 acres and 6685 acres by the tanks. Subsequent masonry lining of the canal has reduced seepage and thus allowed the irrigation of an additional 1000 acres. (See Figure 10 and Table 7)

The extension of irrigation to 11,433 acres under the Periyar Main Canal includes 3000 acres of "hard cases". The "hard cases" refer to plots of land, that lie between the lands irrigated by the Periyar-Vaigai system which formerly did not receive irrigation water due to their position and distance from the distributaries. They are not confined to one block or to a single village but are in scattered patches within and on the outskirts of the existing irrigated area in Nilakottai and Melur taluks.

The large number of tanks found in the ayacut of Periyar Main Canal and Tirumangalam Canal have served as additional storage and helped reduce the draw-off in the main canals during the irrigation season. Moreover, because of these tanks, it has

TABLE VII - Periyar-Vaigai System - Land Brought Under Irrigation in the Locale

	Acres
Periyar System	
Land irrigated by Periyar Main Canal	130,000
Land irrigated in Cumbum Valley	14,000
Extension under Vaigai	
Land irrigated by Tirumangalam Canal	11,385
Land irrigated in Melur taluk	2,015
Hard cases in Periyar system	3,000
	160,400
Areas by Taluks	
Periyakulum	14,000
Tirumangalam	11,385
Nilakottai	34,905
Madurai	54,010
Melur	43,100
Hard cases distributed in five taluks	3,000
	160,400

Source: P.W.D. data

TABLE VIII - Number and Capacity of Tanks

Taluk	Number	Capacity in million cubic feet
Madurai	171	300.05
Melur	166	1105.48
Nilakottai	24	540.70
Periyakulam	19	174.08
Tirumangalam	32	340.92

Source: P.W.D. data

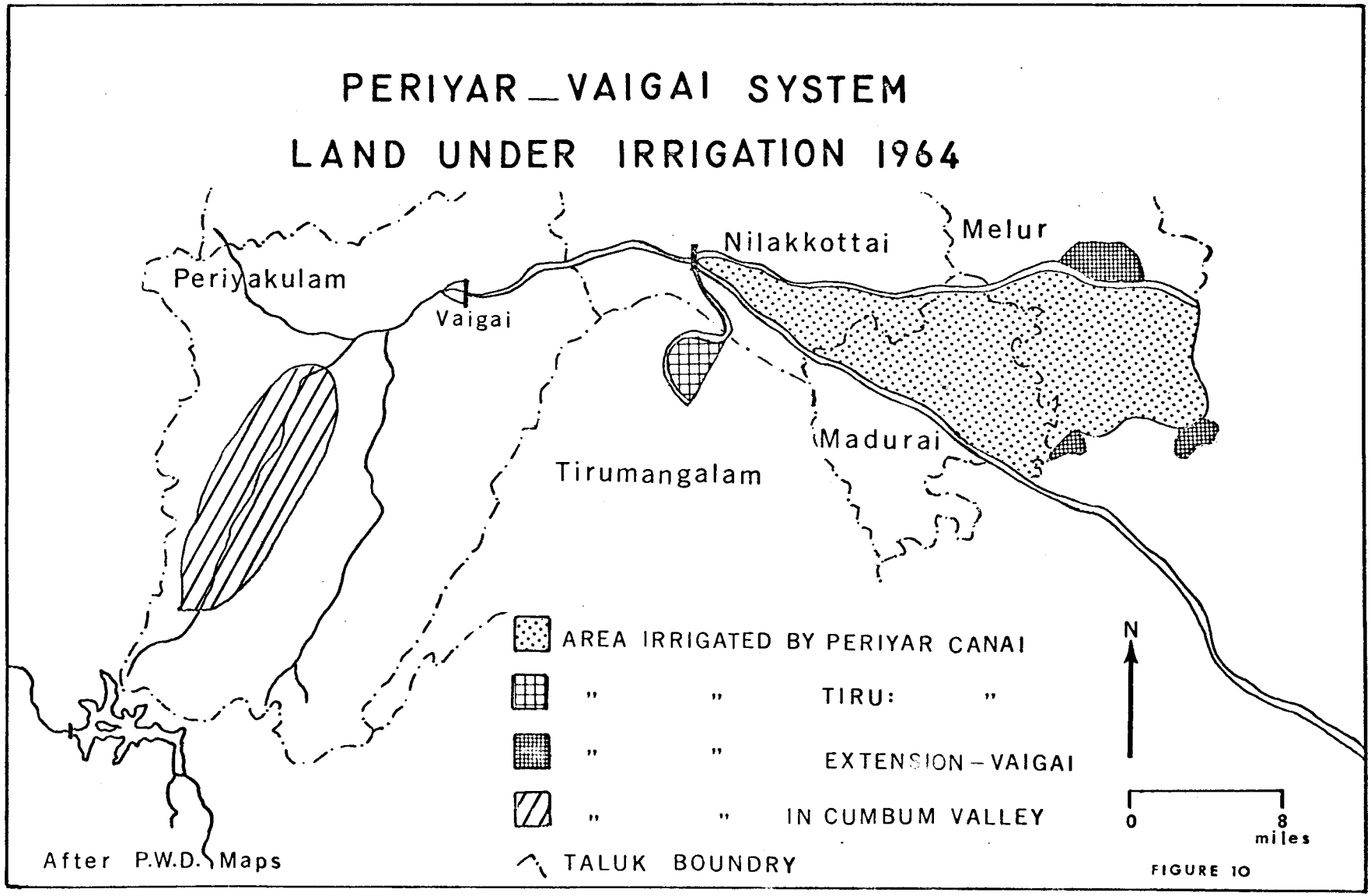

PERIYAR_VAIGAI SYSTEM
LAND UNDER IRRIGATION 1964
Periyakulam
Vaigai
Nilakkottai
Melur
Madurai
Tirumangalam
AREA IRRIGATED BY PERIYAR CANAI
" " TIRU: "
" " EXTENSION – VAIGAI
" " IN CUMBUM VALLEY
TALUK BOUNDRY
N
0
8
miles
After P.W.D. Maps

FIGURE 10

been possible to work at a very high water duty in the area irrigated by the Periyar-Vaigai system. The number of tanks in the system, their capacity and the area of their beds are given in Table 8.

Water Requirement

The yield of rice is known to increase with the increase of water supplied. At the Paddy Breeding Station, Coimbatore, experimentation was carried out to determine the optimum quantity of water required for a medium duration variety (Vellaisambai CO3). This variety ripens within 160 days in both Coimbatore and Madurai districts. An average duty of 84.8 acre-inches of water was found to be the optimum for this crop, including both irrigation and rainfall.

The quantity of water required at different stages of growth is given below:

	Inches
From preparation of plots to transplanting	25.63
From transplanting to flowering	48.27
From flowering to last irrigation	10.89
	84.79

The Public Works Department, which is in charge of irrigation water, estimates and regulates the amount of irrigation water needed during each growing period, depending on the amount of

rainfall received each year, during each period. Actual diversion of the water is done by an employee of the Public Works Department, who operates the regulators according to pre-arranged schedule.

The levy of water used for irrigation of lands under the Periyar-Vaigai project is made according to the rules framed by the Government of Madras and published in the Fort St. George's Gazetteer. For a first wet crop the rate per acre is Rs 5.00. Normally the villagers make the payment for water used, after the harvest and sale of their crops.

Changes in the Cultivation System

As a result of providing assured water, the system of land utilization has greatly changed. The pattern of paddy cultivation adopted at present, is different from that of pre-Periyar days. Formerly paddy was cultivated from October to February, making use of the notheast monsoon rains for the growth. Now the paddy cultivation takes place between May and December in the irrigated areas of Madurai district. Usually the six month variety of paddy is grown. Seeds are sown in nursery beds at the beginning of May and the seedlings are transplanted between June 15 and July 15, before the beginning of monsoon rains. Because of the availability of the irrigation water, transplanting is possible even during the dry season. The monsoon rains are utilized for the growth of

the crop; however, when the rains fail, irrigation water is rushed to the fields and crops are saved.

Net Increase

Prior to Periyar-Vaigai project, the net produce per acre ranged from 8-12 bags of paddy. After the completion of the project the yield averages approximately 22 bags, resulting in a hundred percent increase. (one bag is equal to 2.74 bushels)

The total acreage of the land in the Madurai district benefited by the Periyar-Vaigai project consists of 160,400 acres of dry land converted to wet and an additional 132,070 acres which receive an assured supply of water for at least one crop. It is therefore, proper to indicate 292,470 acres as the total benefit in acres. On this basis this project directly resulted in an increase of nearly five million bags of paddy.

Population Change

The population of the district has almost doubled since the completion of the Periyar-Vaigai project. One of the chief factors that contributed to the increase in population is the influx of agricultural workers from the drought affected areas of the neighboring districts to the Periyar irrigated area.

The Periyar-Vaigai scheme is generally credited with

"making honest men" of the notorious Kallar, where the army, police, and magistracy had failed. During the first half of the 1930's, the Government of Madras state, then Madras presidency, made a determined effort to divert their attention from theivery and other criminal habits to farming by implementing a special project called "the Kallar reclamation scheme". The assured water supply for the cultivation of wet crops has been the main incentive for the Kallar to take up to agricultural activities. The Tirumangalam and Melur taluks, being the kallar area, have benefited to a large extent by the irrigation facilities offered by the Tirumangalam Canal and Periyar Main Canal.

CHAPTER VI

JOTHIMANICKKAM VILLAGE

This case study of a representative village is presented in-order to show in a quantitative measure the patterns of changes and benefits of the Periyar-Vaigai scheme. Jothimanickkam is a sample village, chosen by the writer, the selection being based upon her knowledge of the study area. The entire agricultural land belonging to the village was examined in detail: ownership, fragmentation of plots, land tenure, patterns of land use, crop system, and changes resulting from the irrigation of land.

The Village Site and Situation

Located on the Madurai plains, the village is nearly 20 miles east of the Andipatti Hills in Tirumangalam taluk. Being equi-distant from Madurai and Tirumangalam towns, the village receives an annual rainfall between 30" and 35". The Vaigai river flows some ten miles north of the village. The chief source of water supply for the agricultural land adjacent to the village is the Jothimanickkam tank which is southwest of the village. The area of the tank bed is 185 acres. The soils of the village agricultural lands typically are red ferruginous in character. The natural vegetation has been altered considerably by man; in fact there is little,

if any, primeval vegetation, the land having been subject to intensive cultivation for a long period.

The Village

The village occupies 3.25 acres of land. The houses are arranged along two main streets, foot paths connecting the sub-lanes in the rest of the village. Out of the 58 houses in the village, one is a terraced house, 16 have tiled roofs, and 41 are thatched houses. The number of occupants varies from 14 inhabitants in one house to one or two in several houses. The village has two temples but there is no church or mosque.

The village is three and a half miles from the Madurai to Teni Highway and is connected to it by an unpaved road, the only cart route for the transportation of produce.

The village has no hospital and is in need of a Primary Health Center dispensary. There is no electricity yet (1964) but the villagers are looking forward to having electricity in the near future. Water for domestic use is secured from two wells in the village from which women carry water to their houses in brass or earthern jugs. Sewage facilities are lacking.

The Land

The total land area associated with the village is 632.92

acres, which includes area occupied by the village site, roads, ponds, and other uncultivable land, totalling to 225.32 acres. (See Table 9) Out of the 407.60 acres of agricultural land, at present only 87.05 acres are used for dry crops such as groundnut, cholam, ragi, and other millets. The remaining acres are "wet lands", using supplementary irrigation waters mainly for paddy cultivation. (See Figure 11)

The People of the Village

The population of the village in December 1964, was 285, (males - 163, females - 122) and consisted of 59 families. Hindus formed the majority, the Christians were only 20 in number. Within a period of 15 years, the population has decreased from 500 to 250. The chief loss has been due to the migration of the people to towns or other villages in search of employment. There are only four skilled non-agricultural workers; a blacksmith, a carpenter, a teacher, and a Brahmin priest.

Education is provided for the village children in a recently opened school, that has five grades and is run by the Panchayat Board (Village governing board). There are two teachers in the school, one is a local man and the other comes from a nearby village. The total strength of the school is 57, 50 boys and 7 girls, varying in age from 5 to 12. The strength of the school is

TABLE IX- Jothimanickkam Village Lands

Non-Agriculture Land in Acres		
Village site		3.25
Channel poromboke		5.13
Tank poromboke		186.00
Ponds		1.28
Foot paths and roads		3.51
Thrashing floors		0.38
Temples		0.36
Burial grounds		2.00
Well, waste land, other poromboke, land for public purposes, etc.		23.41
	Total	225.32
Agricultural Lands		
Dry		87.05
Wet		320.55
	Total	407.60
	Grand Total	632.92

Poromboke = government land

Source: P. W. D. Section office

THE VILLAGE LAND

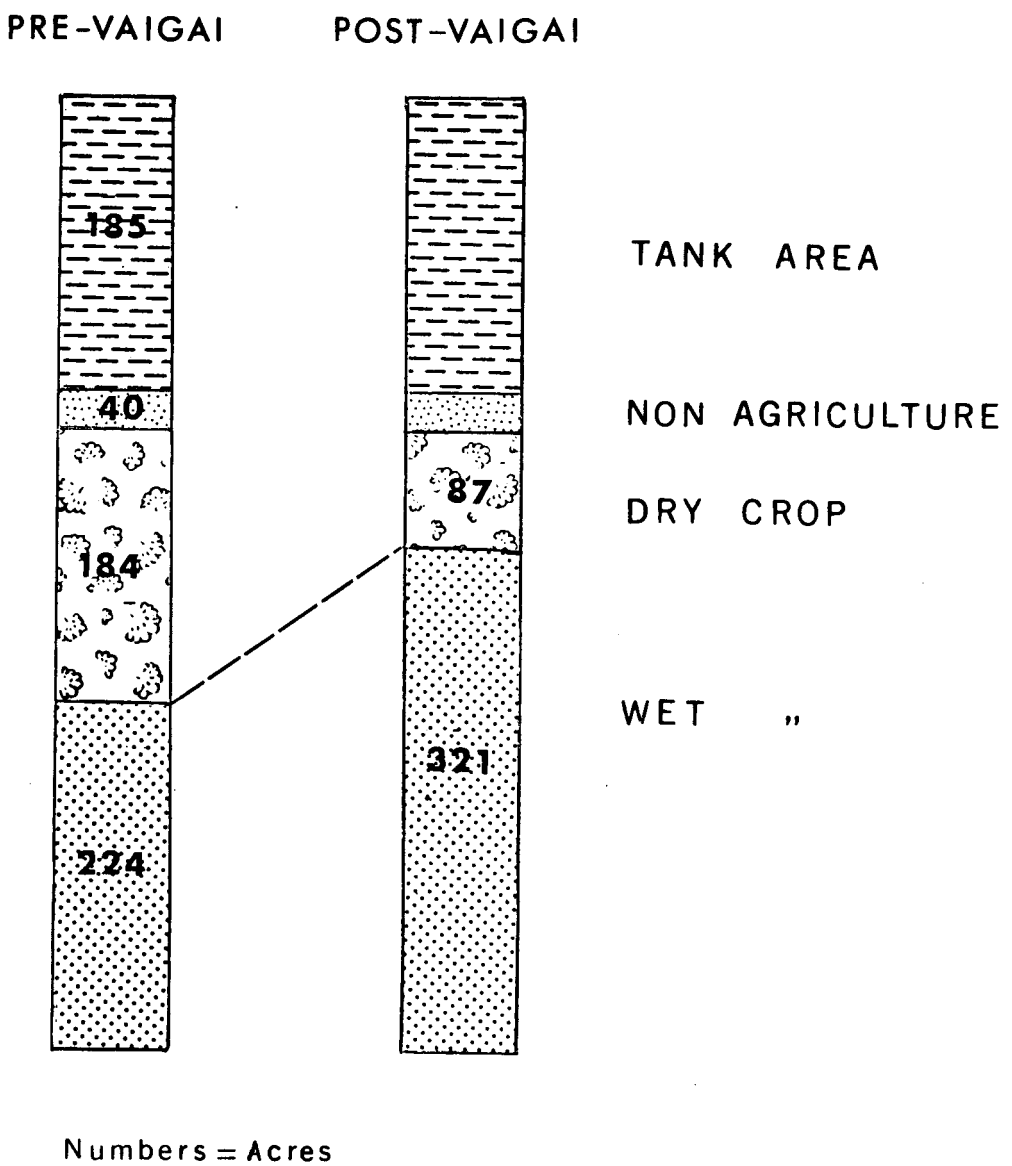


FIGURE 11

high, specially for a village having a population less than 300. Perhaps, it is due to the free noon meal furnished by the government. There are, as yet, no cases of students going outside the village for higher education mainly because of their low economic and social status.

Land Tenure and Fragmentation

The agricultural land belonging to the village, 407.60 acres, is owned by 89 people. Each owner's land is subdivided into a number of plots which are not adjacent to each other. Within the village area of about one square mile, there are 548 fragmented plots belonging to the 89 owners. (See Figure 12) The largest single plot has an area of 10.30 acres and 21 owners have less than one acre of land. The chief land owner of the village has 65 plots scattered within the village boundary, the total extent of which is 53.59 acres. Ten owners hold half the agricultural land of the village and 79 exist on the produce of the other half. (See Tables 10 and 11, and appendix)

This fragmentation of village lands has resulted from the practice of dividing the land among the heirs - children and dependents - who vary in number from 1 to 14. Under the inheritance system each plot is subjected to sub-division so that no heir gets only "good" or "bad" land. The villagers are aware of the

FRAGMENTATION OF LAND
JOTHIMANICKKAM
VILLAGE

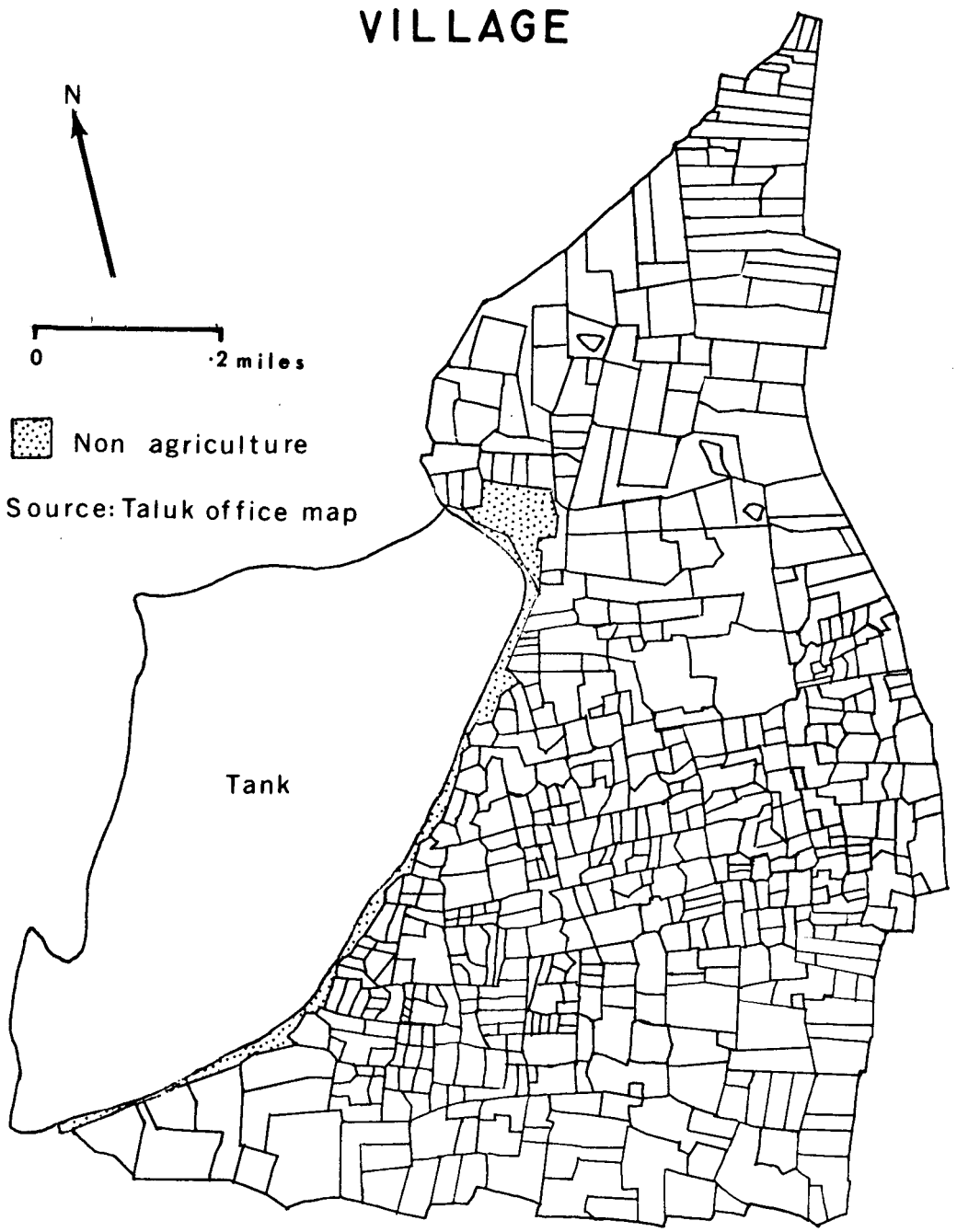


FIGURE 12

TABLE X - Jothimanickkam Village - Size and Ownership of Land

Interval in Acres	Total Acres	No. of Plots	Owners			Bullocks Owned
			Total	Owners in the Village	Absentee Landlord	
0-0.99	9.38	26	21	6	15	10
1-2.99	62.93	109	32	22	10	38
3-4.99	61.58	92	15	10	5	20
5-6.99	47.54	49	8	5	3	4
7-9.99	26.75	34	3	2	1	2
10-19.99	74.31	78	6	2	4	10
20-29.99	71.52	95	3	1	2	48
30-60	53.59	65	1	1	-	10
				49	40	
Total	407.60	548	89			142

Based on ownership register

TABLE XI - Jothimanickkam Village - Farmers Cultivating Ten Acres and Over

Name	Acres	No. of Plots	Bullocks Owned	Type of Farmer
Periakaruppan	53.59	65	10	Owner
Periamaya Thevar	28.44	41	40	Tenant
Karuppayee	22.36	33	-	Tenant
Raman	20.72	21	8	Owner
P. P. Mayandee	18.50	15	-	Tenant
Temple Ownership	12.90	2	-	Tenant
K. Andi	11.21	11	4	Owner
R. Virumandee	10.80	16	2	Tenant
Veerannan	10.70	23	4	Owner
Angan	10.20	11	-	Tenant
	199.42	238	68	

Based on ownership register

uneconomical aspect of the resulting fragmented land units but are reluctant to introduce any other method of sub-division, for fear of receiving less productive land.

A statistical analysis was conducted to examine the relationship among the total acres of land owned by each person, number of plots in each owner's land and the cumulative distance of each owner's plots from the village. The results show that there is a significant relationship between any two variables. The simple correlation coefficient being highest for acres and cumulative distances (r_{xz}=0.932, see appendix). The partial correlation coefficient, however, points that there is very little relationship between distance and plots, when acreage is adjusted to a constant ($r_{zy.x}$=0.153). Thus, the analysis reveals that there is greater and more significant relationship between acres and distances and least between number of plots and distance. The important factor, in terms of problems causing additional work for the farmers and their animals is the size and the distance of the plots and surprisingly not the number of plots. The area analyzed, however, is less than a square mile and perhaps, further statistical analysis of the impact of fragmentation on the economy of land use is needed.

Absentee Ownership

Out of the 89 "owners", 40 are absentee landlords. In

Jothimanickkam Village, according to the share tenancy system, the tenant gets 1/3 of the yield and the landlord the rest, which works out to be 14 to 15 bags of paddy per acre for the absentee landlord. The average yield per acre in Jothimanickkam Village is 22 bags of paddy.

Land Values

Most of the villagers are not in sufficient economic position to own land, land values are normally above their means. Land values vary depending on the type of land and specially after the construction of Tirumangalam Canal, the prices of wet land has increased in this area. An acre of "wet land" ranges from Rs. 3000 to Rs. 4000. The value per acre for "dry land" is Rs. 400 to Rs. 600. The annual income per capita is Rs. 327 or less than one rupee a day. Thus, the reason for a little over two fifths of the agricultural land, 168.22 acres, farmed by tenants in Jothimanickkam Village is apparent.

Water Supply and Irrigation

Two wells that are located in the village site provide water for domestic purposes. There are 30 wells within the agricultural land of the village and normally well water is used for raising seedlings in the nursery beds, especially for the first rice crop.

The irrigation canal, a branch of Tirumangalam Canal, flows northeast and east of the village. It feeds the Jothimanickkam tank and also directly irrigates the land on either side of the canal. The irrigation season is from June to September and the irrigation water is used for raising the first crop of rice. The canal water stored in the tank, as well as the well water, is utilized for raising the second crop.

Prior to the project, irrigation was carried on by the use of well and tank water. The supply of water, however, was seldom sufficient since the tank storage depended on the amount of rainfall received.

Before the project, the land used for wet crops was 184 acres and for dry crop was 223.6 acres. But after the Vaigai project, the acreage was increased in the wet land. At present, the acreage under wet crop cultivation is 320.55 acres and dry crop 87.05. Thus a little over 60 percent of the dry land has been converted into wet land. (See Figure 13) In addition, the wet land received a regular supply of water for raising successfully one rice crop per year where in pre-project days even the wet crop was precarious. The water stored in the tank also helps in the cultivation of the second crop.

The farmers long have used green manure and farm yard manure. After the availability of Vaigai waters, the use of

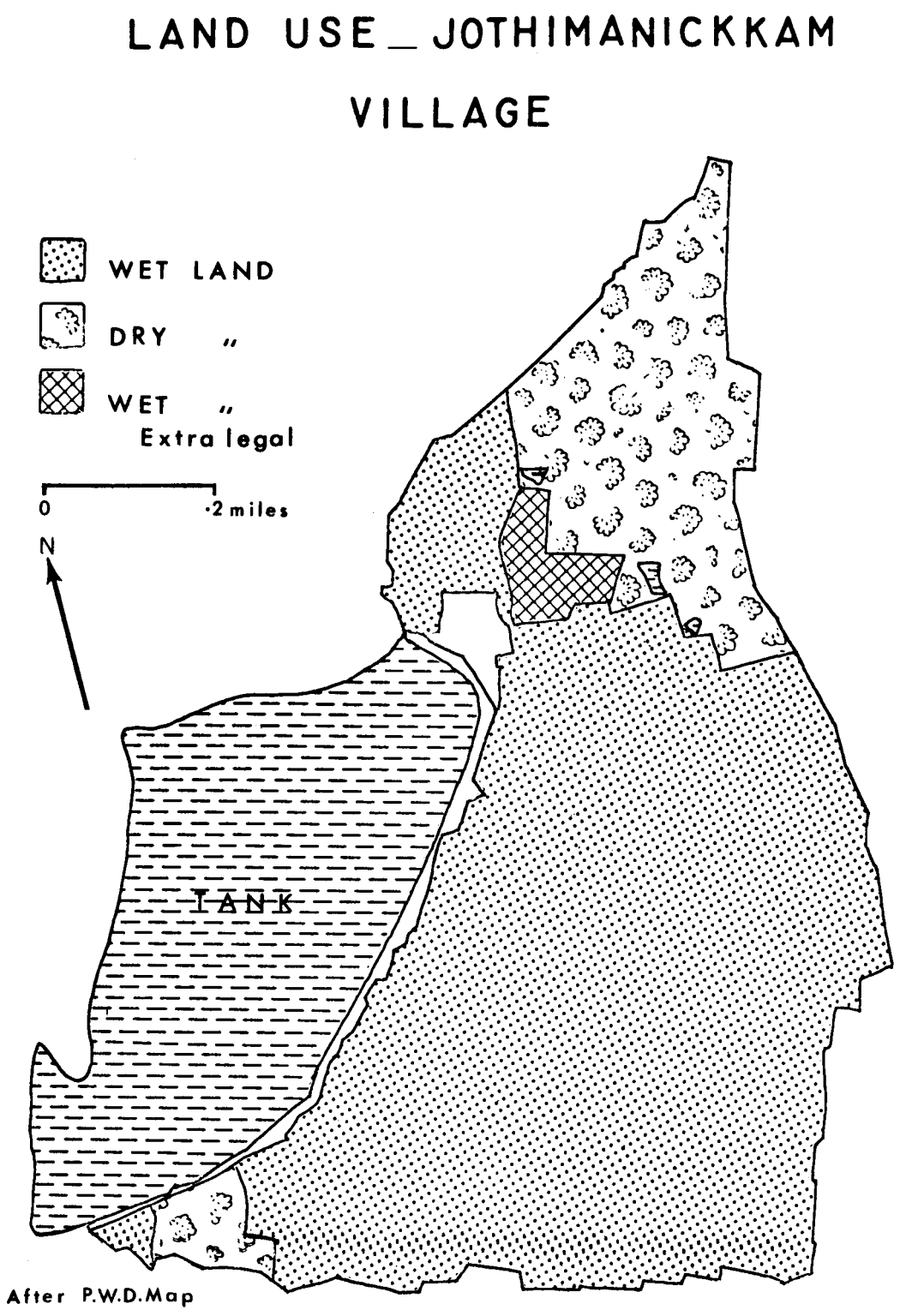

LAND USE _ JOTHIMANICKKAM
VILLAGE
WET LAND
DRY "
WET "
Extra legal
0
·2 miles
N
TANK
After P.W.D.Map

FIGURE 13

chemical fertilizers became economical and today they are being resorted to extensively by the "big" landlords. In other areas, they are limited by the means of the farmer.

Crop Enterprises

In Jothimanickkam Village, the land is subject to intensive cultivation and a system of multiple cropping is followed. In a year, normally two crops are raised on the same land, one "wet crop" from the middle of May to the middle of December and a "dry" crop from January to the end of April; rarely are the fields allowed to lie fallow. In areas where supplementary irrigation water is not available, a single dry crop, taking advantage of the monsoon rains, is raised in the period April to September or October. During years of adequate rainfall, which are rather uncommon, farmers of the village attempt a second dry crop in October, after the harvest of the first.

The wet crop cultivated in Jothimanickkam Village is a six-month variety of rice. It occupies an area of 320.55 acres, or three fourths of the agricultural land. Rice cultivation needs constant care and attention, especially during the first two or three months of its growth. The seeds are first soaked in a container made of tin sheets or brass for three days, and are then transferred to a basket for drying before sowing in the nursery beds.

The sowing takes place about the middle of May. After 30 to 40 days, the seedlings are hand-transplanted to the prepared fields, on which water stands 12" to 24", by the women folk of the village. The irrigation canals are opened by the Public Works Department at this time, since the water requirement for paddy is highest during the transplanting period and continues high during its grand period of growth. Weeding is completed by the end of August and the paddy is harvested in mid-December. On an average, an acre requires 32 measures of seed for each paddy crop and the yield is normally 21 to 23 bags or approximately 1056 measures, a return of 33 for 1.

Cholam and groundnut are the leading dry crops grown on 87.05 acres. Both require three months to mature and are commonly sown in January and harvested by the end of April or beginning of May.

Increased Production and Profits

Prior to the project when the cultivation depended on the rainfall of the locale, the net produce per acre ranged from 8 to 12 bags of paddy. After the completion of the project, the yield increased to approximately 22 bags per acre, due to assured water supply and to increased use of manure.

The average farmer in the village is now able to produce

than his family needs and the tenant farmer, after paying the landlord's share, is able to feed his family and even make a small profit on his surplus produce. Much of the surplus produce, however, is consumed in the village or sold in adjacent villages. In summary, the water control project has given the village farmers for the first time enough to eat and a small surplus.

Presented below is the cost of produce per acre of paddy, cholam, and groundnut as determined by field interviews in the village.

Cost of Produce Per Acre of Paddy

Ploughing for the first rice crop, 7 ploughs for 3 days at Rs. 2/ per day	Rs. 42.00
Bund (mud bank) formation	12.00
Cost of 32 measures of seeds	32.00
Manure	31.00
Removing seedlings	17.00
Transplanting seedlings	10.00
Weeding	6.00
Harvesting and thrashing	60.00
	210.00

An acre of paddy yields 22-1/2 bags of paddy, which brings a return of Rs. 620/ for the paddy (Rs. 27.50 per bag) and Rs. 75/ for the straw, the total being Rs. 695/. The net return from

an acre works out to Rs. 485/.

Cost of Produce Per Acre of Cholam

Ploughing, 3 ploughs for 5 times	Rs. 37.50
Cost of seeds, 6 measures	4.00
Manure	30.00
Weeding (twice)	9.00
Pest control (D. D. T.)	2.50
Harvesting	15.00
	98.00

A yield of 30 bags from an acre is valued Rs. 320 including the straw. In the case of cholam, on the same acre, a variety of bean called "mochai" is also raised, the entire expenditure being Rs. 5/, the cost of the seed. Mochai brings a return of Rs. 120/. Thus, the net return from an acre of cholam is Rs. 337/.

In the case of groundnut, the net return from an acre works out to be Rs. 278/. Thuvarai, a variety of pulse, is also grown along with groundnut.

The farmers are now able to grow one wet crop, without the fear of crop failure. Because of the assured water supply, the yield of the wet crop has been doubled. In addition, two crops, one wet and one dry, are now produced; one crop was not always possible before the advent of the project. Thus, Jothimanickkam Village exemplifies the villages in Madurai district that have been

benefited by the Periyar-Vaigai water resource development project.

The Case Study of a Village Farmer

This case study of an individual farmer is presented as a further quantification of the impact of the Periyar-Vaigai project in Madurai district. The farmer, John Veeramani Thevar, represents the farmers of the study area. Details of his family and possessions, crops, land use, routine of farm work, and changes resulting from the Periyar-Vaigai project are described.

Family

John Veeramani Thevar is 50 years old and has studied up to the fourth grade. His wife, Pechiammae, has no formal education. They have five children, three sons and two daughters, varying in age from 25 to 10. All of them had their education in the village school. The two sons have completed the fifth grade, one the fourth and the two daughters have studied only up to the second grade. The first two sons are married and the oldest, Pandiyan, has three children ages eight, seven and three. The second son, Ragali, has one girl and two boys, between the ages of five and one. All of John's grandchildren above four years attend the village school. His married sons live with him and share

the farm work.

Possessions

Farmer John's agricultural land consists of five fragmented plots totalling to 4.30 acres, jointly owned by him and his sons. The details of which are given below.

No.	Extent In Acres	Distance In Miles	Type of Land
1	1.12	0.14	Wet
2	0.55	0.44	Wet
3	0.71	0.44	Wet
4	0.61	0.30	Wet
5	1.31	0.80	Dry
	4.30	2.12	

The plots are scattered within the village boundary; one plot is north of the village and the rest are south and southeast. (See Figure 14) The cumulate distance between the plots and the village is 2.12 miles. He has one well in the plot north of the village, which he uses for the raising of paddy seedlings. His thatched house is valued Rs. 500/ and he has a pair of bullocks.

Crops

Two crops are harvested per year by Farmer John, one a

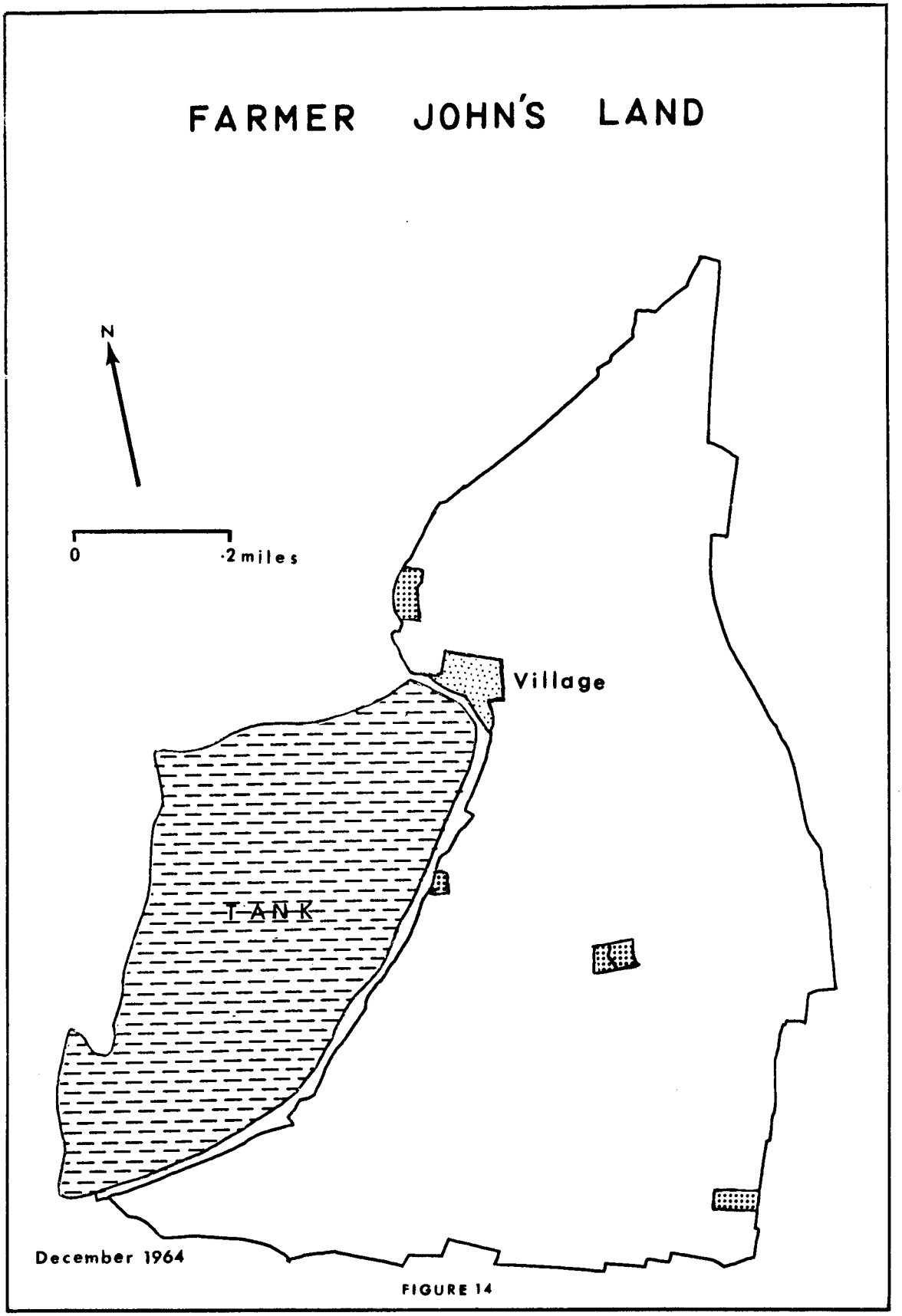


FIGURE 14

wet crop, rice, and another a dry crop, either cholam or groundnut. The wet crop is raised with canal water.

Irrigation Water and Duty Paid

Farmer John and other families in Jothimanickkam village pay duty on water at the rate of Rs. 5/ per acre, for the first wet crop.

The irrigation season normally begins about the middle of May. The date of opening the canal is published in the local district gazetteer and also given by tom-toms to the villages. The decision to open the canals is taken by the Government in consultation with the Irrigation Engineers and the District Collector, depending upon the available supply in the reservoirs and also the monsoon indication.

Routine of Farm Work - First Crop

Farmer John uses 0.24 acres adjacent to his well to supply seedlings for the entire joint enterprice of three acres of land. Before the seeds are sown in the seedbed, water with manure is stagnated in the paddy for at least ten days. At intervals of two days, the seed beds are ploughed three times. This operation requires approximately three hours. Farmer John requires two bags or 96 measures of seed and sows the seeds around the middle

of May. After the seeds have sprouted, John spends three hours daily for a month or so, in baling water onto the seed beds. The water is released from the seed beds by opening the bund.

As soon as water is received in the canal, paddy fields are prepared for transplanting the paddy seedlings. The fields are completely soaked and ploughing and mulching operations take place. Ploughing is done for four hours from 7:00 a.m. to 1:00 p.m. To plough three acres of his land, John uses seven ploughs drawn by seven pairs of bullocks. As he has only one plough and one pair of bullocks of his own, he hires the rest. If the bullocks are easily available for hiring, and additional labor is obtained readily, the entire work of ploughing can be done in two to three days. Since the village farmers, as well as John, require the use of their ploughs and bullocks at the same time, the ploughing period is extended over a week or more.

As soon as the ploughing is completed, about July 1, Farmer John transplants the seedlings. The task is done by ten women laborers and two men and requires two days but is commonly extended to a week due to the scarcity of laborers. For the next month or so only watering is done to the fields. It takes about seven to eight hours for an acre to fill up with water. John pays personal attention to the diverting of water, to assume his legitimate share.

A month after transplantation weeding is done. Farmer John engages women to weed his three acres and the time taken is four days. The women weed for only four hours a day and the task is spread over four days mostly because the land is fragmented and the plots are far apart.

During the second week in December, normally, the crop is ready for harvesting. Farmer John hires 30 to 40 men and women to harvest the three acres and stores the rice stalks in stacks. Here again if the laborers are readily available, John can harvest his fields in a day but normally it is spread over a week. These field laborers are commonly paid Rs. 0.50 a day.

Manure

Before ploughing, farm yard manure collected by Farmer John in his back yard, is first heaped on the fields and then spread on the land in a dry state. Though as much as 50 cart loads can be spread per acre, the normal practice of the farmers, including John, is to spread between 30 to 40 cart loads per acre. (A cart load is roughly 25 cubic feet in volume.) After transplantation, a commercial fertilizer is used at the rate of about three to four bags per acre. (A bag of fertilizer weighs 80 pounds.)

Produce

Farmer John obtains from his fields, 22-1/2 bags of paddy per acre. Two bags of paddy give one bag of rice. Excluding the expenses and the cost of water, John reports that he gains a net income of Rs. 490/ per acre, for the wet crop.

Second Crop

After the paddy is harvested, the land lies fallow for about a month and then dry ploughing is done for the dry crop. Farmer John starts the ploughing work about the middle of January and does it intermittently until the middle of February when either groundnut or cholam is transplanted. Normally, the cholam or the groundnut is sown broadcast but in Jothimanickkam Village, the method of transplanting the seedling is followed. John weeds his crop twice, hiring ten women of the village to do the work. The crop is harvested in the beginning of May and the field is fallow for about a month before ploughing is carried on for the cultivation of the wet crop.

Table of Work Periods for Farmer John

May 15th to June 15th	Preparing seed beds and raising paddy seedlings
June 15th to July 15th	Preparing land, ploughing, watering and transplanting
August 25th to 31st	Weeding

Sept., Oct. and Nov.	Watering of lands, in case of insufficient rain
December 10th to 15th	Harvesting
January 15th	Dry ploughing - raising of seed bed
February 15th	Transplanting (or sowing)
March 15th	Weeding
May 10th to 15th	Harvesting

Summary of Benefits

Before the completion of Tirumangalam Canal, all of Farmer John's land, except the half acre near the tank,was under dry cultivation. Due to the availability of canal water, 2.44 acres of his dry land has been converted into wet land. Moreover, now, he is able to get one successful crop of paddy from three fourths of his land and a dry crop on the whole land. Thus, his net income has been increased to three times that which he obtained during pre-Vaigai days. The income benefit from the project according to Farmer John is as follows:

Pre-Periyar days - net income

From wet land of 0.55 acres	Rs. 100.00
From dry land of 3.75 acres	1000.00
From second crop on wet land	150.00
	1150.00

After Project - net income

From wet land of 2.99 acres	1500.00
From dry land of 1.31 acres	500.00
From second crop on wet land	1000.00
	3000.00

CHAPTER VII

SUMMARY AND CONCLUSIONS

On the basis of evidence presented in this thesis, the Periyar-Vaigai project of Southern India stands as an outstanding example of interstate agreement in developing water resources, mainly for agricultural purposes. The project is notable in several ways. It was the first in India to divert surplus waters from the west coast to the east for irrigation. It was the first in the south to utilize a tunnel to cross the watershed. It is also noteworthy because the project was planned and constructed during the second half of the nineteenth century when difficulties encountered in the fields of construction, labor, and transport were surmounted by means of the limited technology and knowledge of that period.

The construction of the Periyar dam to impound the Periyar waters and the tunneling of the watershed to divert the stored waters to Vaigai river were only the first steps in this great project. Further developments have included constructing an additional reservoir on the Vaigai river to store the surplus waters, widening the tunnel, and utilizing the drop of the water from the tunnel for the generation of electricity. These have not only brought added advantage but have also stabilized the whole system.

Summary of Benefits

In this thesis the appraisals of benefits resulting from the Periyar-Vaigai project have been limited to those material benefits that are directly measurable, such as changes in land use, increased production, and increased net income of the farmer. No effort has been made to quantify the benefits related to social and other factors.

As seen by the writer, the material benefits of the Periyar-Vaigai project are summarized as:

(1) Increased wet land cropping by 22 percent

(2) Brought under wet crop cultivation 106,400 acres

(3) Provided assured supply of water to an additional 132,070 acres

(4) Resulted in increased production of paddy on the average of ten bags per acre

(5) Resulted in a total increase of 5,000,000 bags of paddy for the locale

(6) Made it possible for the farmers of the locale to produce enough for their families and a little surplus

(7) Increased the net profit from Rs. 145/ to Rs. 485/ per acre

(8) Increased the total net income from the locale by Rs. 87 million

(9) Raised the standard of living of the individual farmers. Farmer John reported an increase in net income of Rs. 1850/ annually.

(10) Developed a significant recreational facility at the Periyar Lake and at the Vaigai Dam.

Problems

From this limited study of Periyar-Vaigai Project a number of problems were identified which appear to the writer as to require further research and solutions. These suggested studies include:

(1) Fragmentation of agricultural lands.

Fragmentation of land has reached serious proportions, in terms of both the small size holdings and the fragmentation of individual ownerships. The long established inheritance practices and the strong attachment of villagers to the land are parts of the problem. One may assume that it is not a simple matter of removing people from the land and giving them jobs in factories and industries. At least three types of studies are suggested:

a. A study for the purpose of better determining what is the optimum size of land holding for the Indian villager.

b. A study to consider the feasibility and desirability of consolidating fragmented holdings into more economic units.

c. A study to investigate ways of modifying the ancient inheritance practices before further land fragmentation occurs.

(2) Wasteful water use

This thesis study made no effort to quantify water lost through inadequate use methods, but it was clear that much could be done to enhance water use. Several possibilities are

as follows:

a. Need for more careful control of water in the branch channels

b. Need for vigilant policing of extra legal supply of water

c. Study to determine techniques for the prevention of high evaporation rate of water in reservoirs and tanks

d. Restoration of the old anicuts by clearing silt accumulation

(3) Absentee Ownership

Absentee ownership and tenant farming may be a problem. There is a need for a study to determine whether or not absentee ownership results in poor land use or other undesirable qualities.

(4) Finance

There is an urgent need for providing capital to the farmers on a low interest rate. Starting of co-operative societies may be one of the solutions.

(5) Education of the farmer

There is a need for educating the farmer in modern agricultural practices which are within his reach, such as, use of hybrid seeds, commercial fertilizers and better ploughing, weeding, and harvesting methods. The department of Agricultural Extension Services needs to do more work in this area.

(6) Marketing

Need for better facilities for marketing the produce. Co-operative societies may be of help.

In conclusion, this thesis study reveals that the Periyar-Vaigai water development project is one of the notable examples of man's capacity to improve the physical habitat for his benefit toward a better way of life. Its contributions in direct material benefits are clear, but what additional indirect benefits may be achieved in years ahead will depend upon further sophistication of land use and the economy, rather than upon developments of new water resources. There is little prospect for extending the irrigable area but advances may yet be made through solutions to the problems noted.

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APPENDICES

Appendix I - Monthly Rainfall for Madurai. 1931-1960.

	J	F	M	A	M	J	J	A	S	O	N	D	Total
1931	0.54	0	0.63	2.20	1.41	0.27	1.93	0.66	2.34	8.91	10.79	6.02	35.70
32	0	0.84	0	1.79	3.65	1.65	0.51	4.47	0.23	10.03	9.12	0.85	37.73
33	0.02	0.02	0.02	3.28	5.21	0.07	2.32	10.53	1.33	7.03	7.50	0.43	38.76
34	4.12	0	0.14	0.87	2.18	1.36	1.23	0.69	1.20	9.81	2.90	0.07	24.47
35	0.73	0.04	0	2.41	0.14	2.44	0.70	6.20	2.77	5.84	3.81	1.20	26.28
36	0.10	2.56	2.62	2.43	0.62	0.79	3.81	0.76	4.66	2.51	0	1.53	22.39
37	0.05	0	0.53	1.64	1.80	0.43	0.65	5.35	6.28	3.50	8.08	0	28.31
38	0.02	0.34	4.17	1.95	1.99	0.30	5.52	2.50	2.49	1.90	4.49	2.64	28.31
39	0.93	0.38	1.25	7.12	2.51	2.62	0.04	3.22	6.12	6.57	5.42	0.06	36.24
1940	0	0	0.60	3.84	4.23	3.98	1.38	6.35	4.79	4.10	14.00	1.95	45.22
41	1.44	0	0	7.77	0.79	1.43	1.08	5.03	3.01	11.51	5.14	1.02	38.22
42	0	0	0.02	3.35	0.86	0.61	0.60	6.81	10.93	9.99	1.84	5.17	40.18
43	11.85	0.23	0.03	3.43	1.41	0.67	0.44	2.10	3.07	8.26	6.90	0.56	38.85
44	0.14	2.24	3.28	1.27	3.10	1.94	1.02	4.71	14.24	8.85	5.77	2.75	49.20
45	0.08	0.51	0.02	2.28	3.55	0	1.51	4.79	2.06	6.53	5.75	0.33	27.45
46	0.13	0	2.09	1.54	2.53	1.05	0.54	2.91	11.07	7.25	12.28	6.09	47.48
47	0.85	0.08	5.22	10.30	2.39	0.37	1.82	3.22	5.97	15.22	0.25	0.87	46.56
48	1.39	0.54	0	0.39	3.46	0.11	2.48	3.43	3.71	8.65	7.05	1.34	32.55
49	0.95	0	0	5.18	4.63	1.22	4.62	11.13	5.02	1.32	3.73	0	37.80
1950	0	3.90	0.75	0.56	2.36	0	1.54	10.90	0.93	11.05	0.31	0.41	32.21
51	0.48	0	0.36	5.93	0.67	0.02	5.95	5.53	8.74	5.24	4.27	0	37.19
52	0.90	4.02	0.06	0.09	1.06	1.43	0.76	2.48	2.92	3.03	0.85	0.98	18.48
53	0.13	0.69	0.06	9.09	0.81	3.77	2.84	2.67	7.05	11.98	5.66	0.45	44.20
54	3.43	0.07	1.26	2.01	3.05	0.44	1.23	12.43	3.02	7.16	2.11	0.81	37.02
55	0.20	0	0.70	4.26	3.01	0.53	3.97	2.14	5.01	10.17	6.33	8.72	45.04
56	1.34	0	0	1.04	0.34	3.52	0.55	6.25	4.96	16.40	11.57	1.18	47.15
57	0	0.11	0.08	0.51	2.64	0.11	3.70	3.05	7.78	8.64	5.45	2.17	34.24
58	0.48	1.30	0.52	2.51	10.80	1.34	0	4.81	1.73	4.44	8.40	0.56	36.12
59	1.20	2.30	0	1.22	2.90	2.89	0.38	1.74	3.12	3.92	10.0	0.11	28.73
1960	0	0	0.25	3.40	1.20	0.62	7.31	5.84	6.92	2.8	13.20	1.12	42.66
Mean	1.10	0.69	0.82	3.14	2.45	1.20	2.01	4.78	7.76	7.75	6.10	1.65	39.45

Source: Daily Weather Report, Indian Meterorological Department

Appendix II - Jothimanickkam Village Land

x = acres y = number of plots z = distance in miles

x	y	z	x	y	z
0.04	1	0.24	2.45	5	3.66
0.07	1	0.54	2.54	7	1.08
0.10	1	0.40	2.57	2	0.24
0.19	1	0.50	2.64	1	0.44
0.26	1	0.40	2.65	13	5.20
0.26	1	0.90	2.67	3	1.50
0.28	1	0.50	2.76	2	0.74
0.37	1	0.64	2.79	8	4.62
0.41	2	1.08	3.04	7	1.98
0.42	1	0.80	3.15	7	4.10
0.46	1	0.60	3.43	5	1.58
0.50	1	0.64	3.53	1	0.24
0.52	1	0.64	3.72	13	5.98
0.59	2	1.00	3.91	15	8.94
0.60	2	0.80	3.98	5	2.96
0.62	2	1.20	4.24	2	1.20
0.63	1	0.50	4.30	5	2.12
0.63	1	0.54	4.35	5	2.08
0.77	1	0.50	4.58	9	4.30
0.80	1	0.54	4.61	3	1.00
0.86	2	0.20	4.80	4	1.18
1.08	1	0.20	4.97	4	2.08
1.14	1	0.60	4.98	7	2.84
1.16	3	1.64	5.04	6	4.26
1.18	1	0.40	5.16	2	1.54
1.38	3	0.54	5.28	1	0.34
1.38	3	1.84	5.48	3	0.68
1.39	1	0.44	6.36	7	3.68
1.39	3	1.10	6.50	15	6.60
1.52	1	0.40	6.77	9	3.60
1.54	7	3.98	6.95	6	1.70
1.70	5	1.72	8.05	7	2.60
1.71	5	2.12	8.96	12	7.96
1.72	2	0.70	9.94	15	7.82
1.72	2	1.08	10.20	11	8.20
1.96	2	1.44	10.70	23	8.46
2.04	1	0.20	10.80	16	4.36
2.12	3	1.42	11.21	11	4.64
2.16	2	0.72	12.90	2	1.14
2.21	3	1.58	18.50	15	9.44
2.22	3	1.68	20.72	21	11.90
2.22	7	3.00	22.36	33	15.00
2.25	2	0.64	28.44	41	15.60
2.30	2	0.34	53.59	65	33.80
2.36	5	1.88	407.60	548	256.20

N = 89

Appendix III - Result of Statistical Analysis

Simple correlation coefficient

$$r_{xy} = 0.8825$$

$$r_{xz} = 0.9316$$

$$r_{yz} = 0.9054$$

Partial correlation coefficient

$$r_{xy.z} = 0.253$$

$$r_{xz.y} = 0.666$$

$$r_{zy.x} = 0.153$$