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Relationships between water, fertilizers and yield in certain crops of Bangalore district, Mysore state, India

S. B. Tambad

To the Graduate Council:

I am submitting herewith a thesis written by S. B. Tambad entitled "Relationships between water, fertilizers and yield in certain crops of Bangalore district, Mysore state, India." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Economics.

W. P. Ranney, Major Professor

We have read this thesis and recommend its acceptance:

W. E. Goble, B. D. Raskopf

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

July 27, 1962

To the Graduate Council:

I am submitting herewith a thesis written by S. B. Tambad entitled "Relationships Between Water, Fertilizer and Yield in Certain Crops of Bangalore District, Mysore State, India." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Economics.

W. P. Ranney
Major Professor

We have read this thesis
and recommend its acceptance:

William F. Goble

B. D. Raskopf

Accepted for the Council:

Hilton A. Smith
Dean of the Graduate School

RELATIONSHIPS BETWEEN WATER, FERTILIZERS AND YIELD IN CERTAIN CROPS OF BANGALORE DISTRICT, MYSORE STATE, INDIA

A Thesis

Presented to

The Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

S. B. Tambad

July 1962

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S. B. T.

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CHAPTER I

INTRODUCTION

Importance of the Study

In a predominantly agricultural economy like that of India, irrigation occupies a very important place in crop production. In the low rainfall areas it ensures protection against the poor distribution of rains and simultaneously promotes greater intensity of cropping. In the arid and semi-arid zones water is a limiting factor and its importance in crop production is difficult to overemphasize.

Irrigation has been practiced in India from times immemorial. Tanks, for impounding rain waters, were constructed by numerous rulers in the past. Wells have provided drinking and irrigation water since very ancient times.

The water resources of India are estimated to be 1356 million acre-feet, of which, only about 450 million acre-feet can be used for irrigation. About 88 million acre-feet constituting 19.5 per cent of the utilizable water had been made use of up to 1951.[1] It was estimated that by the end of the Second Five-Year Plan, 119 million acre-feet, i.e., about 26 per cent of the usable water, will be utilized. The Third Five-Year Plan is expected to increase the use of water by another 41 million acre-feet,

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[1] India, 1961. The Publications Division. Ministry of Information and Broadcasting, Government of India. p. 282.

bringing the total proportion to about 35 or 36 per cent. Besides, there are subterranean water resources which can be tapped by tube wells, percolation wells, etc. Area under irrigation is expected to be 90 million acres by the end of the Third Five-Year Plan, compared with 70 million acres by the end of the Second Five-Year Plan.[2] Irrigation is likely to increase still more in the following decades.

While the area under irrigation is on the increase, basic information needed for determination of economic levels of water application is still lacking. It is a matter of common knowledge in India, that either more or less quantity of water than needed for optimum net returns is applied to crops. In the canal irrigated areas of India water is extravagantly used for irrigation, since the payment for the use of water is on the number of acres irrigated, and not on the volume of water used. The assessment for the use of water is irrespective of the number of irrigations as well as the quantity of water used per irrigation. This results in a lack of incentive on the part of farmers to effect economy in the use of water. Hence, the knowledge of the optimum levels of water application is of paramount importance. This is necessary since water is a scarce factor and there is some cost involved in using it for irrigation. If the water is relatively free, one needs to know the level of water application where the maximum physical product occurs.

The Indian government contemplates through its Five-Year Plans an increase in production of fertilizers to a considerable extent. The

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[2] Third Five-Year Plan. A Draft Outline. Planning Commission. Government of India. June, 1960. p. 33.

production of nitrogenous fertilizers is proposed to be stepped up from 210,000 tons in terms of nitrogen at the end of the Second Five-Year Plan, to one million tons at the end of the Third Five-Year Plan. Production of phosphatic fertilizers is proposed to be increased substantially.[3] With the increase in the irrigation facilities, along with the increase in the production of fertilizers, the knowledge of the optimum levels of application of water and fertilizers to maximize the net returns to farmers becomes all the more imperative. This study was undertaken to determine the optimum levels of application of water and fertilizers so as to maximize net returns to farmers.

Objectives of the Study

The study was undertaken with two-fold objectives: (1) to determine the relationship between water and yield; and (2) to determine the maximum profit point for the use of irrigation water by different kinds of water lifts.

Sampling Procedure Used

The study was based on a selected sample of representative villages and typical farmers. The following criteria were used in selecting the sample villages:

(1) Villages located in red soil areas

(2) Villages having 15 per cent or more of total cropped area under irrigated crops, of which at least 15 per cent was in

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[3] *Ibid.*, p. 34.

crops other than sugarcane and paddy.

(3) Villages having above 30 and less than 90 households.

Five talukas (a local administrative unit) in Bangalore district, viz. Bangalore South, Bangalore North, Hoskote, Anekal, and Nelamangala were selected. Of the villages from these talukas which nearly fulfilled the above three conditions, ten villages which followed better irrigation practices were selected. Farmers in each of the selected villages were classified into five groups depending on the total area cultivated by them. From each group, two farmers were selected thus totaling ten for each village.

Collection of Data

In each of the selected villages an investigator was placed to collect the data from each group of farmers. The investigators were given training in the methods of collecting data before being sent to their respective villages. The schedules and questionnaires designed for the collection of data were explained to them in detail before they actually took up the work of collection of data. At the beginning of each month, the field investigators were called to Bangalore---the headquarters of the Farm Management Scheme, and the mistakes in the collection of data were corrected. This also gave the field investigators a unique opportunity to solve their problems. The work of the following month was also explained to them in detail. The work of the ten field investigators was supervised by two Agricultural Supervisors who toured the villages and guided them in the collection of the data. The work of compilation and computation was done by the Technical Assistants, Senior

Statistical Assistant, and the computors who were stationed at the headquarters. During the first one or two months of the working of the Farm Management Research Center at Bangalore, the Technical Assistants also toured the villages and furnished guidance to the Agricultural Supervisors and the field investigators in their work. In addition, the Research Officer who is in charge of the Farm Management Research Center also contacted and guided on the spot the Agricultural Supervisors and the field investigators. Thus, the work of collection of data was carried out under close supervision. The field investigator visited every farmer at least once a week and obtained from him the details of all the work done during the week.

Irrigation Research in India

Research on irrigation is done in India at the Agricultural Research Institute, the Agricultural Colleges, and the Agricultural Research Stations. Besides, the Indian Council on Agricultural Research has subsidized many schemes on irrigation farming and has also established many agronomic research stations in different parts of the country. These institutions study the problems relating to the water requirement of crops, time and interval of application of water, effect of irrigation on the physico-chemical properties of soils, interaction of manures with irrigation and other factors. Studies in regard to the economics of water use are very scare in India. Attention of research workers needs to be focused on important water use problems both from the individual farmer's point of view, as well as for the nation's economy and welfare. From the individual farmer's point of view, research can be directed toward maximizing returns to farmers, while from the national viewpoint, the goal may be increasing agricultural production.

CHAPTER II

IRRIGATION

Sources of Irrigation

India has a total cropped area of 359.2 million acres, of which nearly 16 per cent is under irrigation. The principle sources of irrigation are the canals, tanks and wells. The area irrigated and the percentages under different sources of irrigation are given in Table I.[1]

Canals are used to irrigate about 41 per cent; tanks 20 per cent; wells 29 per cent; and other sources about 10 per cent, respectively.

Canals

Canals form one of the chief means of irrigation in India. Two types are in vogue--the perennial canals and the inundation canals. In the case of perennial canals water is stored by constructing artificial dams across the rivers, and water is available throughout most of the year. In the inundation canals, water accumulates when the rivers overflow their banks. These canals, to some extent, help in controlling the floods of the rivers. The perennial canals are better as they serve during periods of drought when the inundation types become dry and unusable. Thus, in canal irrigation, the water supply may be seasonal or perennial. The water in the canals is made available to the fields

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[1] India, 1961. The Publications Division, Ministry of Information and Broadcasting. Government of India. pp. 243-244.

TABLE I

AREA UNDER IRRIGATION IN INDIA IN 1957-58
ACCORDING TO DIFFERENT SOURCES
OF IRRIGATION

Sources	Area irrigated in million acres	Per Cent of the total irrigated area
Canals	22.9	41.11
Tanks	11.1	19.93
Wells	16.2	29.08
Others	5.5	9.88
Total	55.7	100.00

through a system of subcanals and distributaries. In canal irrigation, water is usually conducted through gravity flow.

There are certain concomitant disadvantages of canal irrigation. It gives rise to the problem of waterlogging which has occurred in Punjab. It is estimated that only about 55 per cent of the water that enters the canal finally reaches the fields. The loss mainly can be attributed to absorption, percolation, seepage and evaporation. About 15 per cent of this loss occurs in the main canals, 10 per cent in distributaries, and 20 per cent in water courses.[2] These difficulties, however, can be overcome by lining the canals.

Tanks

Tank irrigation is common in the South of India, particularly in the Madras and Mysore States. The tanks vary in size from big lakes to the small village pools. The tanks are both natural and artificial. They are filled during the rainy season and supply water during the remainder of the year or until the supply is exhausted.

Tank water is fertile and is good for irrigation since it contains various minerals. The commonest problem regarding the tanks is that of silting which reduces their water holding capacity. The problem of silting can be overcome by deepening the tank from time to time. The water is taken from the tanks to the fields through canals or pipes. Flowing of water through canals is more wasteful than that through the

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[2] Handbook of Agriculture. Indian Council of Agricultural Research, New Delhi. June, 1961. Ch. XI, p. 545.

pipes. Hence, the water supply of tanks can be more economically used by constructing the pipe lines from the tanks to the fields.

Wells

Wells are the oldest but still an important source of irrigation in India. They are usually constructed in areas where the water level is not very deep. They are owned both by private individuals, singly or jointly, as well as by government.

Irrigation from wells is useful since it contains many minerals which enhance the fertility of land. Proper judgment must be exercised in using well water, as often, the water contains elements which are harmful to plant growth. The advantage of well over canal irrigation is that there is no danger of water logging with the former. It is also a dependable source of irrigation. Unlike canals, farmers do not have to wait for their turns to secure water from wells. The efficiency of water use is very high in the case of wells, compared with canals, since there is very little loss of water in transportation from the wells to the area of irrigation.

In the selected villages of Bangalore district, irrigation is through wells and tanks. Of the total area under irrigation, about 63 per cent is irrigated by tanks and 37 per cent from wells.

Methods of Irrigation

The methods of irrigation can be grouped broadly into: (1) surface irrigation, (2) subsurface irrigation, and (3) over-head irrigation. The various methods of surface irrigation are: (1) flooding, (2) bed or border method, (3) basin method, and (4) furrow method.

Flooding

This method is often used in the early stages of new irrigation projects because the lands are not properly levelled and an adequate number of water courses are not provided. Flooding consists of opening a water channel through a plot of land, and directing water through it so that it flows freely in all directions and spreads in a thin layer on the land. This method is most inefficient as only about 20 per cent of the water reaches the plants and the rest is lost as run off, seepage, and evaporation.[3] Water will accumulate in the land depressions and will not reach the points on higher levels. The free flowing of water on the land, not only results in its wastage, but also causes soil erosion. This method is suitable where the land is uneven, the cost of levelling land is prohibitive and where a cheap and copious supply of water is readily available. The method of flooding is usually used where there is low initial cost of preparing the land for irrigation. However, heavy losses of water coupled with soil erosion often more than offset the advantage of low initial cost of preparing the land for irrigation.

Bed or Border Method

In this method the entire area is laid out into series of flat beds with channels running in between two series. The beds are irrigated through these channels. Water is let into each bed until the bed is

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[3] *Ibid.*, Ch. XI, p. 555.

soaked to the desired degree, it is then cut off and let into the next bed, and so on, until the entire field is covered. This method is more suitable for high value crops. In many parts of India it is usually followed in raising vegetable crops. It ensures uniform application and results in higher efficiency in the use of water. It is suitable for crops both planted in rows or broadcast. It has a high initial cost but a lower maintenance cost.

Basin Method

This method is suitable for small plots of land and for high value crops. It is commonly used in India for irrigating fruit trees. A small embankment is erected around the trunk of a tree at a distance of one to two feet, depending on the area to be irrigated around the plant, and the quantity of water to be impounded. It requires level land and is suitable to most types of soils. It has a high initial cost, low maintenance cost, and is efficient in the use of water.

Furrow Method

This method is commonly practiced wherever crops are grown in rows. The land is prepared into ridges and furrows and the water is let into the furrows. This method has distinct advantages over other methods, because it wets only a part of the surface, thus reducing evaporation losses. The stems of plants do not come in direct contact with water as in the case of the bed method. Water is efficiently used in this method as compared with other methods.

Subsurface Irrigation

In this method water is directed into a series of ditches or into perforated or porous pipes laid underground. The plan is to raise the water table so that the plants can obtain water through capillary movement. It is very efficient in the use of water as loss due to evaporation is practically negligible. It does not hinder cultivation. It is, however, open to the danger of converting the soil into saline or alkaline condition and spoiling the neighbouring lands through seepage. The high initial cost has limited its use.

Overhead or Sprinkler Irrigation

In sprinkler irrigation water is conveyed under pressure from a main pipeline into lateral pipelines. The water is discharged through nozzles or sprinklers mounted on risers connected to the lateral pipes. The sprinkler nozzles may be single or double, revolving, or stationary. Each sprinkler head applies water to a circular area. The spacing between the lateral pipes and the position of sprinkler heads is adjusted to provide an overlap and to have a uniform coverage. The rate of application of water is determined by selecting the proper combination of nozzles. This method reduces the loss due to percolation and run-off and obviates the need for levelling the land.

The overhead or sprinkler method is most suited to areas with uneven topography. It ensures uniform distribution of water and does not hinder cultivation. Both the initial costs and maintenance and repair costs are high. It requires a dependable and constant supply of water, free from silt and suspended matter, and can be advantageously used in the case of high value crops. It renders levelling of land unnecessary and reduces the loss of water to a minimum. An important advantage is that water soluble fertilizers can be applied through sprinklers.

In India not much work regarding the utility of sprinkler irrigation has been done. Preliminary studies have indicated that it results in saving of water but the cost of irrigation is exhorbitant. The Indian Council on Agricultural Research has recently sanctioned a scheme for investigating the economics of this, compared with other systems.

In the villages selected for study, only the flood and bed methods prevail.

Water Lifts

In case of canal and tank irrigation the water is made available to the low lying areas through gravitational force. But in case of well irrigation, water has to be lifted from the well before it is made available to the plants. This necessitates the use of water lifting equipment. Various kinds of equipment ranging from the most primitive picota (a kind of water lift used in India) to the highly developed electric pumps are in use in the selected villages.

Picota

This device makes use of the principle of the lever with a suspended fulcrum and a counterweight. It consists of a long horizontal pole mounted on a vertical pillar near the well. The longer end of the beam carries a bucket hung by a rope, and the shorter end carries a counter-balancing weight which helps in easing the labor required for lifting the bucket from the well. The lift is generally worked by one man but additional help is rendered in many ways in reducing the strain. It is suitable for lifts up to about 15 feet. The size of the bucket may be small or big depending upon the quantity of water to be lifted and the labor available for working the lift. The quantity of water lifted varies according to the size of the bucket, and the depth of the well. In the selected villages, the average capacity of the bucket is 5 gallons with a range from 4 to 7 gallons. The average quantity of water lifted per hour is 1,295 gallons with a variation from 768 to 1,560 gallons.

Moht

The moht (a kind of water lift used in India) consists of a large semicircular leather bag with a wide mouth at one end and the other end transformed into a hose; with both ends open. The leather bag, when full and ready for raising, becomes U shaped. The main pulley rope is fastened to the mouth or the wider end of the leather bag, and taken over a pulley mounted at the top of the frame on the well. A smaller or tail rope is tied to the other (bottom) end of the leather bag and passed over a small roller fixed at the base of the frame on the well, and connected with the open end of the main pulley rope. With the forward movement of the bullocks, the leather bag is pulled up, and when it reaches the top of the well, the tail end of the rope is pulled taut, the hose straightens, and empties the leather bag. The operation is automatic but a tug may help in completely emptying the leather bag. Generally, a pair of bullocks are sufficient to work the lift for drawing water from a depth of 20 to 30 feet. For greater depths the use of two to three pairs of bullocks is not uncommon. The joint end of the pulley rope and the tail rope is fastened to the bullocks' yoke. As the bullocks walk forward, the leather bag is raised. When they walk the entire length of the rope, the hose straightens and empties the leather bag. With the backward movement of the bullocks, the leather bag is lowered down into the well and fills up with water. The forward walk of the bullocks is down a ramp with a gentle or steep slope. Therefore, it is really the weight of the bullocks, and the weight of the driver who sits on the rope on the downward movement, that constitutes the power. Cases are also numerous where two ramps, one a steep one, and the other with a gentle slope, are provided to avoid the backward movement of the bullocks. At the end of the steeper ramp, the bullocks are unyoked, and they turn back to walk up along the other ramp in a natural manner. After unyoking the bullocks, the driver walks back to the well with the pulley rope in his hand and again hitches the rope to the bullocks' yoke for the next downward journey. Mohts are commonly used where the depths are greater, but their use at lower depths are also not uncommon. The quantity of water lifted depends upon the depth of the well and the size and condition of the leather bag because leakage due to wear and tear is very high. In the selected villages, the average capacity of the leather bag is 38 gallons with a range from 24 to 42 gallons. The average quantity of water lifted per hour is 2,099 gallons with a range from

1,760 to 2,634 gallons.

Persian Wheel

This water lift is also devised for the use of animal power. The bullocks move in a circle around a vertical pole, which connects them through a transverse pole and rotates with their movement. The circular motion is transformed into a vertical motion through a bevel arrangement which rotates a vertical wheel or drum carrying an endless chain of buckets. The revolving movement of the drum raises the buckets filled with water on one side and empties them into a container as they come to the top, and lowers them on the other side to fill again with water. When the water level goes below the level of the lowest bucket, the work is stopped. Work is resumed after the water level raises sufficiently high so as to allow the buckets to completely dip into the water. The quantity of water lifted depends upon the size and the soundness of the buckets, the quality of the bullocks, and the ratio between the two cog wheels at the bevel. The average quantity of water lifted by this method in the selected villages is 392 gallons per hour with a variation from 102 to 682 gallons.

Pump

The advancement of science has greatly enhanced the substitution of mechanical power for human and animal power. The alternatives for the traditional heavy labor-consumptive water lifts in vogue would be the various kinds of power driven pumps. The availability of cheap electric power in more and more villages of India has greatly enhanced the use of pumps for irrigation purposes. The constant efforts of the Agricultural Departments coupled with the aid of demonstration by the manufacturing companies have made the farmers more conscious of the advantages of pumps over other types of water lifts. As a result, the present conditions are more propitious for increasing the use of pumps than in the past, and indications are that they will be even better in the future.

Pumps can advantageously be used in places having copious supply of water. The initial capital investment in the installation of a pump is high. It would be possible to obtain adequate returns on the investment only if the area under command is sufficiently large enough for a wide scope of intensive cultivation of valuable crops. In case of deeper wells, the animal drawn lifts may prove futile and the only resort would be to the mechanically operated pumps.

The pumps lift more quantity of water per unit of time than other types of water lifts. Since the areas served by pumps are large, the cost of irrigation is spread over a large area and the cost of irrigation per unit of land is considerably lower than in the case of other water lifts. The quantity of water lifted by pumps varies with the depth of the well, the horse power and efficiency of the engine.

It is evident from Table II that picota, moht and pump are the commonly used water lifts, whereas the use of Persian wheel is quite restricted. The area irrigated in case of picota is an average of 0.88 acres with a range from 0.20 to 3.90 acres; the average in case of pumps is 3.20 acres with a variation from 0.78 to 8.50 acres. The area to be irrigated and the quantity of water to be lifted often sets a

TABLE II

NUMBER OF DIFFERENT TYPES OF WATER LIFTS USED BY SELECTED FARMERS AND THE AVERAGE AREA IRRIGATED BY EACH TYPE OF LIFT. BANGALORE DISTRICT, INDIA. 1959-60

Types of water lifts	No. of lifts used	Average area irrigated per lift in acres	Range in acres
Picota	28	0.88	0.20 to 3.90
Persian Wheel	4	2.05	0.85 to 3.18
Moht	26	2.33	0.50 to 7.25
Pump	24	3.20	0.78 to 8.50

limit for the type of equipment to be used. The picota water lift is advantageous where the quantity of water to be lifted and the area to be irrigated are small. The pump water lift would be advantageous where the quantity of water to be lifted and the area to be irrigated are large.

Units of Measurement of Water

Following are the common units of measurements used for measuring water:

(1) Cursec

(2) Acre-inch or acre-foot

(3) Gallons per hour

Cusec

Cusec is the quantity of water flowing at the rate of one cubic foot per second.

Acre-inch or Acre-foot

Acre-inch denotes the quantity of water that will cover one acre of surface one inch deep. Twelve acre inches of water forms one acre-foot. A cusec of water flowing for one hour supplies approximately one acre-inch.

Gallons Per Hour

When the quantity of water supplied is small, it is usually expressed in terms of gallons per hour. The quantity of water lifted by picota, moht, Persian wheel, etc. are all expressed in terms of gallons per hour.

In this study the gallon is the unit used in measuring water at the village level. At the compilation stage, the quantity of water is converted into acre-inches. An acre-inch of water contains 27,154 gallons.

Measurement of Water According to Different Lifts

Following are the methods used in measuring water according to different lifts.

Picota

The average capacity of the bucket in gallons is determined by working the lift a number of times and measuring each time the quantity of water raised per lift and then calculating the average. Similarly, the number of times the bucket is lifted per hour is determined by working the lift for a number of hours and computing the average. This is determined separately for each bucket of every individual farmer. By recording the time of operation of the lift for irrigating a particular plot, the quantity of water used for irrigation is calculated by multiplying the time of operation of the lift in hours, by the average quantity of water lifted per hour.

Moht

The average capacity of the moht in gallons, and the number of lifts per hour are determined in the same way as in the case of picota. By noting the time of operation of the lift, the quantity of water used for irrigating a particular plot is calculated. This is done by multiplying the time of operation in hours by the average capacity of the moht in gallons.

Persian Wheel

For the Persian wheel the quantity of water lifted per revolution of the entire chain of buckets is determined by measuring the amount of water lifted per revolution. This is repeated a number of times and the average quantity of water in gallons lifted per revolution of the entire chain of buckets is determined. Similarly, the average number of revolutions per hour are determined. Depending upon the time taken in hours, the quantity of water used for irrigating a particular plot is calculated.

Pump

In the selected villages the pumps used are of the capacity of 3 and 5 H. P. (horse power). The quantity of water used for irrigating a particular plot is estimated by recording the time of operation of the pump and using the following formula which was obtained from the engineers.

1. For 3 H. P. pump $Q = \frac{5,940}{H}$ gallons per minute

2. For 5 H. P. pump $Q = \frac{10,725}{H}$ gallons per minute

where

Q = quantity of water lifted per minute

and

H is the height given by $H = H_s + H_d + \frac{20}{100}(H_s + H_d)$

H_s represents the static suction head

H_d represents the static delivery head

Q multiplied by the time in minutes gives the total quantity of water lifted during a particular period.

V Notch

In case of tank irrigation 90° V notches are used for measuring the water. V notches are placed at such points in the canals where the velocity of water is negligible or considerably reduced. The height of water flowing through the V notches is recorded in inches and the quantity of water flowing through it is calculated by the formula $Q = 1.922\ H^{5/2}$ gallons per minute, where Q is the quantity of water and H is the height in inches of water flowing through the V notch (calculated from $Q = 2.56\ H^{5/2}$ cusecs per second, H being the height in feet).

CHAPTER III

PREPARATION OF DATA FOR ANALYSIS

Various factors are required to be considered for the calculation of the cost of irrigation. They are:

(1) Depreciation and repairs of wells

(2) Depreciation and repairs of equipment

(3) Human labor

(4) Bullock labor

Depreciation and Repairs of Wells

Wells have been classified as (1) permanent, (2) semi-permanent, and (3) temporary wells based on the estimated duration of their use. Wells with an estimated life of 25 years or less are included under temporary wells, those with an estimated life between 25 to 50 years fall under semi-permanent wells, and the rest with an estimated life of above 50 years are categorized as permanent wells.

The depreciation of the wells has been calculated by the straight line method. The original cost of construction has been divided by the total number of years of expected life of each well, respectively, which gives the depreciation of wells per year. In cases where the repair charges have exceeded 10 per cent of the original investment, it has been considered as an addition to the capital investment and is added to it. From this total amount, the depreciation per year is worked out. The actual repair charges in the particular year (less than 10 per cent of the original investment in each case) are added to the depreciation charges, and the total is divided by the area in gunthas irrigated by the well, which gives the depreciation of the wells per guntha.

Depreciation and Repairs of Equipment

The area irrigated by each type of equipment is first determined. The original cost of the equipment is divided by the total expected life of the equipment in years, to give the depreciation per year. To this is added the repair charges during the year. The total charge for irrigating with this equipment is divided by the area irrigated, in acres, to give the depreciation per acre. In cases where the repair charges exceeded 10 per cent of the original cost of the equipment, it has been considered as an addition to the capital, and included in the original cost for calculating the depreciation.

Human Labor

Labor is assessed in terms of man-days of eight hours each. Each day of woman and child labor is converted into 0.66 and 0.50 man-day, respectively.

Family labor has been valued as the annual servants who, in turn, have been valued according to the terms of contract between the owner and the annual servants. The terms of contract are usually on a yearly basis. It may be in the form of cash or in the form of food, clothing and cash. For calculation purposes, the payments in kind are converted into cash based on the prevailing rates in the respective villages and added to the amount paid in cash. From the total amount thus obtained, the wages per work hour are determined. The value of labor is calculated on the basis of number of hours worked.

Hired labor has been valued for men, women and children separately at the prevailing daily average rates in the respective villages.

Bullock Labor

Bullock labor, both owned and hired, has been valued at the prevailing rates for hire of bullocks in the respective villages on an eight hour day basis.

The valuation of both bullock and human labor have been done in terms of rupees and naye paise (different demoninations of Indian currency).

Cost of Irrigation

Table III shows the average cost of irrigation by different lifts in the selected villages, irrespective of the crops raised. The table shows that the average cost of irrigation is approximately the same for picota and moht, slightly lower for Persian wheel, and lowest for pumps. The average cost of irrigation by pumps is less than half of any other type of water lift used.

Cost of Irrigation of Potatoes

The cost of irrigation not only varies according to the type of water lift used, but also according to the crops grown. It is intended to study whether it pays to irrigate, and if so, how much? In order to

TABLE III

AVERAGE COST OF IRRIGATION IN RUPEES PER ACRE, BY TYPES OF WATER LIFTS, IRRESPECTIVE OF CROPS, IN THE SELECTED VILLAGES OF BANGALORE DISTRICT, MYSORE STATE, INDIA
1959-60

Type of water lift	Average cost of irrigation in rupees and naye paise per acre
Picota	142.75
Moht	148.85
Persian Wheel	124.01
Pump	58.02

determine the extent to which it pays to irrigate, it is essential to find out the relation between the cost of irrigation and the additional returns obtained by it. Hence, to establish the relationship between the cost of irrigation and the additional returns obtained thereon, it would be necessary to find the rate of increase in yield per unit quantity of water applied, and also the rate of its increase in cost per unit.

Since an acre-inch has been taken as the unit of water, the relationships are to be established in terms of the increase in yield per acre-inch of water and also the increase in cost thereon.

As the cost of irrigation also varies according to the type of water lift used, it is essential that the cost of irrigation be determined separately for each type of water lift. Therefore, two separate dot charts were prepared, one for moht and the other for pump in the irrigation of potatoes. Regression equations of the type $Y = a + bx$ were fitted to each of them by the least squares method as shown in Charts 1 and 2. The equations obtained for the two types of water lifts were as follows:

Moht $Y = 33.3367 + 6.17\ X$

Pump $Y = 22.11 + 0.7431\ X$

Tests of significance for b were carried out for both the equations by t test and it was found that it was significant at .01 level in case of moht and 0.05 level for pump.

Since the relationship of acre-inches of water to cost is linear, the marginal cost (cost per unit) becomes a straight line parallel to the X axis and will be the same for every unit of input. Hence the marginal cost of the acre-inches of water in these cases can be taken as the price

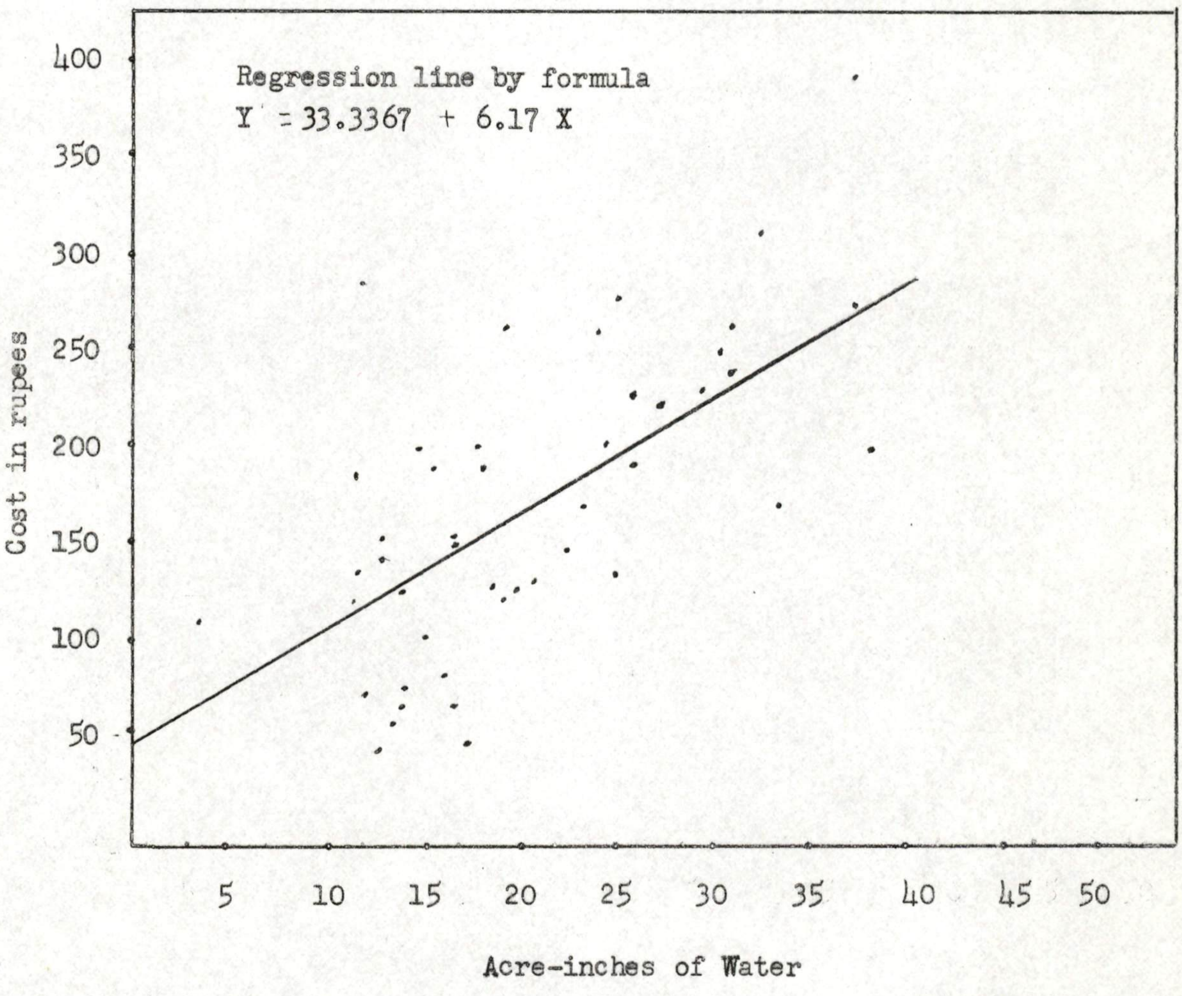

Figure 1. Cost of irrigating the Simla variety of potatoes with the moht water lift, by inches of water used per acre. Selected villages, Bangalore District, India. 1959-60.

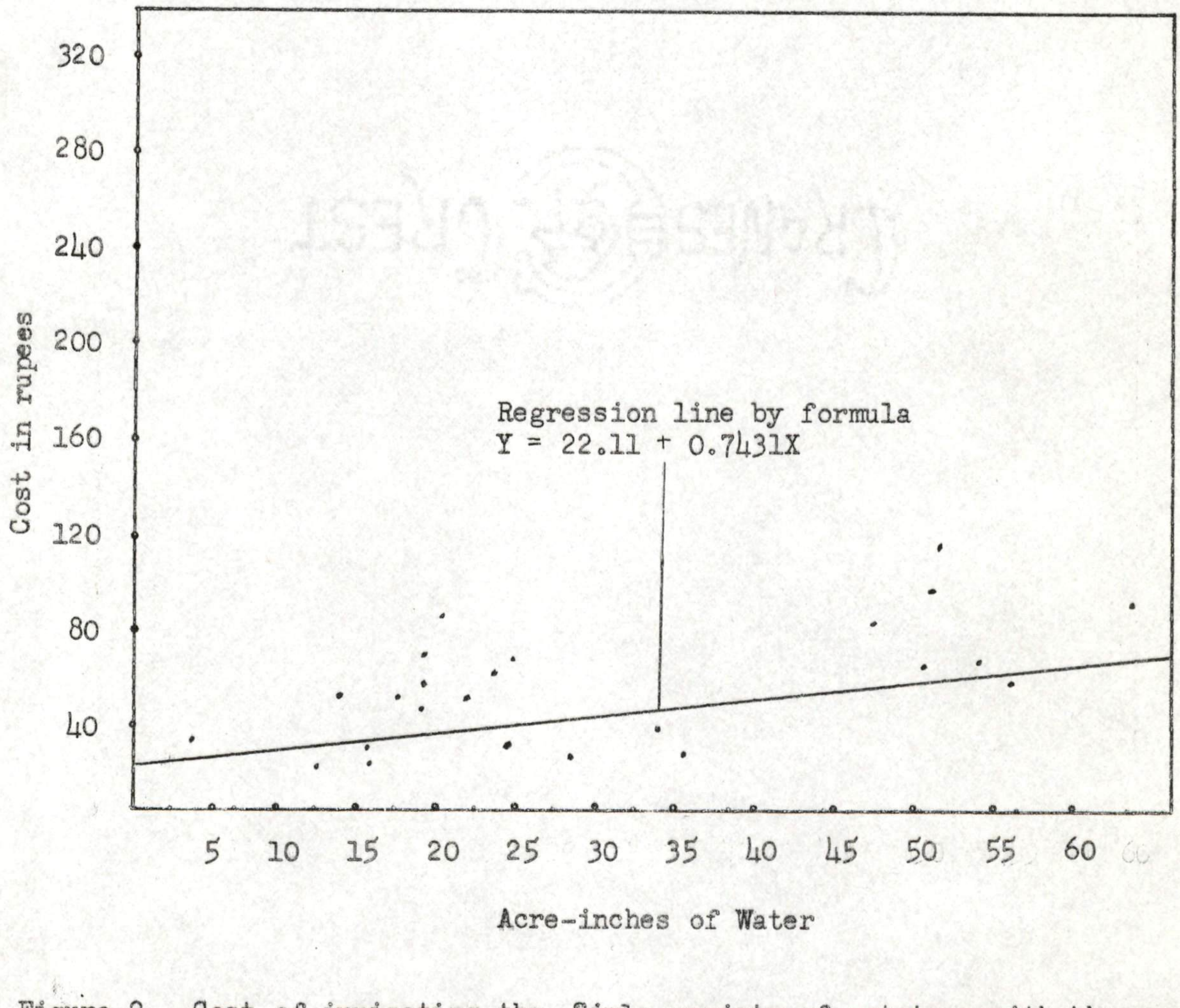

Figure 2. Cost of irrigating the Simla variety of potatoes with the pump water lift, by inches of water used per acre. Selected villages, Bangalore District, India. 1959-60

of the input per unit. The marginal cost of irrigation by moht would be Rupees 6.17 and by pump it would be Rupees 0.7431 respectively.

Assumptions Made in the Study

Following are the assumptions made in the study:

(1) There was little seasonal variation in yield.

(2) Rain water as well as irrigation water had almost the same effect on yield.

(3) There were only small differences in soil fertility among fields.

(4) There was little climatic variation among the selected villages that might cause changes in yield.

(5) There was little variation in the cultural practices that would affect yield.

(6) There was little variation among farms in the distance travelled by water.

Though the above factors varied slightly among farms, observations indicated that the variations were not large enough to cause significant changes in yield.

CHAPTER IV

ANALYSIS AND RESULTS OF THE STUDY

I. RELATION BETWEEN INPUTS AND CROP YIELDS

Manures and Fertilizers

An attempt was made to determine the effect of manures and fertilizers on potato yields. The compost and the artificial fertilizers were purchased at different rates by the individual farmers, probably because of the varying quality of the manures. The total purchase value of the different manures and fertilizers used by each farmer was calculated and included in the analysis.

Separate dot charts were prepared to show the relationship between the compost, fertilizers and yield in two different varieties of potatoes. The dot charts (Figures 3 and 4) did not show any appreciable relationship.

One of the reasons why the manures and fertilizers did not show any marked relationship to yield was probably that manures and fertilizers used by individual farmers varied in their ingredient contents to a considerable degree, i. e. they were nonhomogeneous. The nonhomogeneity of the manures and the fertilizers obscured the relationship between them and yield. Probably better results could have been obtained, had the manure and the fertilizer samples used by each farmer been chemically analyzed, and the ingredient contents shown by the tests included in the analysis for determining relationships to yield.

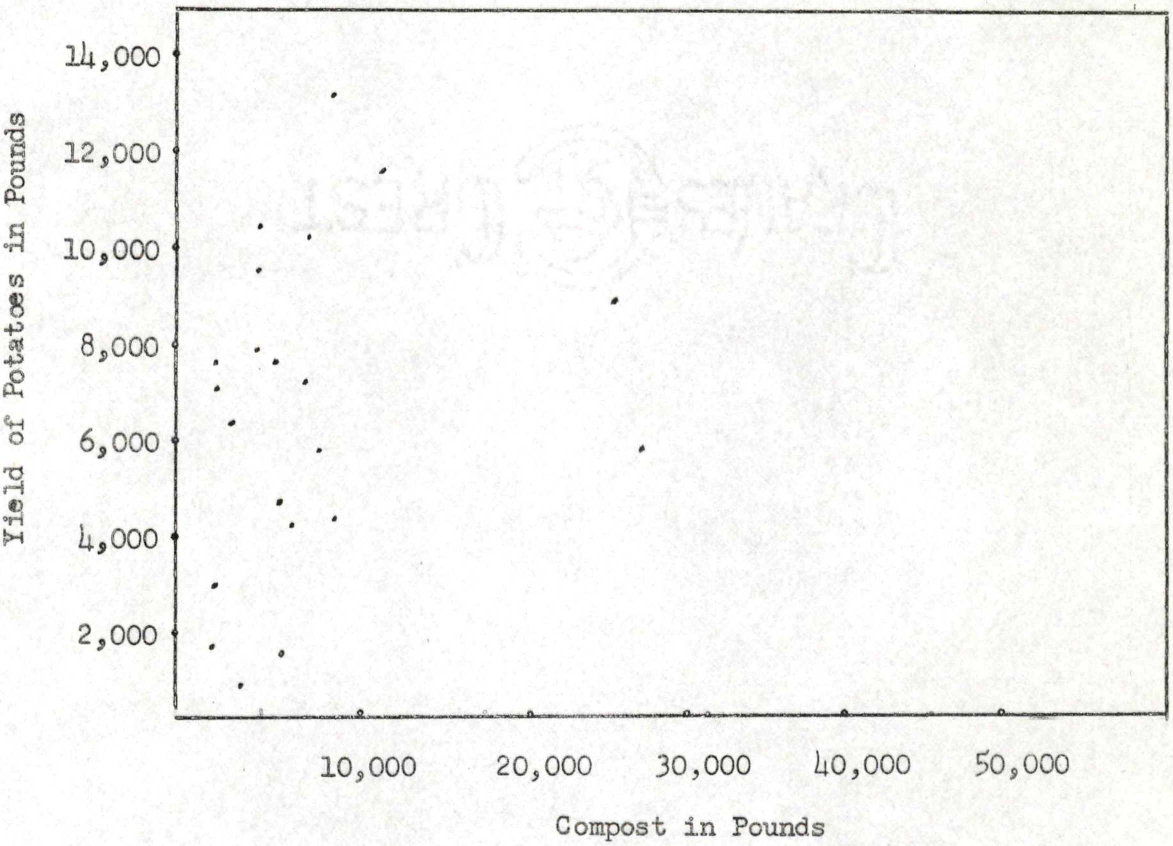

Figure 3. Relationship between compost and yield of Rickets variety of potatoes of selected farmers, Bangalore District, India. 1959-60.

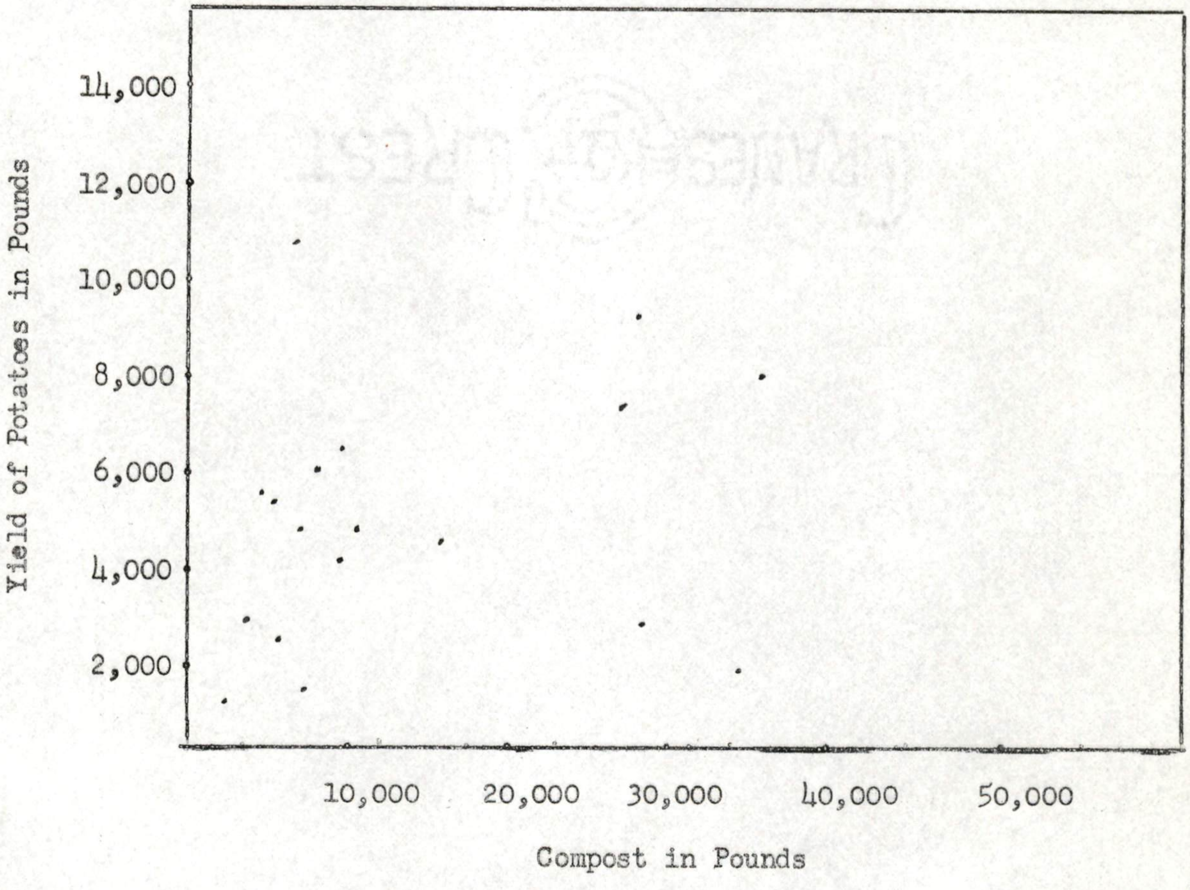

Figure 4. Relationship between compost and yield of Simla variety of potatoes of selected farmers, Bangalore District, India. 1959-60.

Since the exact amounts of nitrogen, phosphorous, and potassium in the compost and the various fertilizers used by these farmers were not known, an attempt was made to use estimates for these ingredients.[1] The following regression equation was used for finding the relationships between the independent variables (the various ingredients) and the dependent variable (yield of potatoes), among the farms studied:

$$\log Y = \log a + n \log N + p \log P + k \log K$$

where

N = Nitrogen   P = Phosphorous   K = Potassium

Y represents the yield of potatoes

a is the value of the dependent variable when the value of the independent variables are zero

n is the regression coefficient of nitrogen

p is the regression coefficient of phosphorous

k is the regression coefficient of potash

The logarithms used were the natural logarithms.

This analysis of the separate estimates of applications of the ingredients, N, P, and K explained just 2 per cent of the variation in yield.

Acre-inches of Water

The relation of acre-inches of water to yield was computed for

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[1] The estimated amount of each ingredient (nitrogen, phosphorous and potassium) of compost or fertilizer approximated the mid-point of a range for that fertilizer, as presented in the Appendix.

three crops, viz. (1) Ragi, (2) Garlic and (3) Potato.

In case of ragi the regression equation $Y = a + bX + cX^2$ was used to explain the relation between acre-inches of water and yield. The R^2 value obtained was 0.05, which was very low.

For garlic the regression equation $\log Y = \log a + b \log X$ was used and the R^2 value obtained was 0.0007, which means that water did not explain the variation in yield to any considerable extent.

The regression equation $\log Y = \log a + b \log X$ was used in case of potatoes for two varieties, Simla and Rickets. For Rickets the R^2 value obtained was low, viz. 0.014. However, for the Simla variety the R^2 value obtained was 0.1408, which means that about 14 per cent of the variation in yield was associated with variation with irrigation water. The equation obtained for Simla variety was as follows:

$$\log Y = \log 7.6067 + 0.3731 \log X$$

<u>The Maximum Profit Point in the Application of Irrigation Water</u>

The maximum profit point was derived as follows:

(1) $Y = a X^b$ Cobb Douglas function

(2) $\log Y = \log a + b \log X$

(3) $\frac{dy}{dx} = \frac{Px}{Py}$ maximum profit point

where the elasticity of production is less than one, i. e. in stage II of the production function and the price of Y covers the variable cost.

(4) $\frac{dy}{dx} = Y \left(\frac{b}{x}\right)$

(5) From (3) $Y \left(\frac{b}{x}\right) = \frac{Px}{Py}$

(6) From 1 substituting for Y

$$aX^{b} \left(\frac{b}{X}\right) = \frac{Px}{Py}$$

(7) Rewriting $abX^{b-1} = \frac{Px}{Py}$

(8) Solving for x

$$X^{b-1} = \frac{Px}{ab \cdot Py}$$

log of both sides

$$(b-1) \log X = \log \left[\frac{Px}{ab \cdot Py}\right]$$

(9) $\log X = \log \left(\frac{\frac{Px}{ab \cdot Py}}{b-1}\right)$

(10) $X = \text{Antilog} \left(\frac{\log \left(\frac{Px}{ab \cdot Py}\right)}{b-1}\right)$

where X is the quantity of irrigation water to be applied to get maximum profit.

Px = cost of irrigation water per acre-inch

a is the value of Y intercept in the equation log Y = log a + b log X

b is the regression coefficient of water

Py is the price of Y, i.e. potatoes per 100 pounds

The price of X (Px) was Rs. 6.16 per acre-inch in case of moht and Rs. 0.7431 in case of pump which represented the factor cost in the case of the two equipments, respectively. The price of potatoes was Rs. 16.00 per 100 pounds of potatoes. The maximum profit point obtained by using the above factor and product prices and using the above equation was 25 acre-inches with the moht lift and more than 60 acre-inches with the pump lift, which means that cost of irrigation was not a limiting factor. However, factors other than cost of irrigation may have limited production where the pump lift was used.

Maximum profit point can also be determined graphically. The estimated values of yield at different levels of water application were calculated and given in Table IV. The production function

$$\log Y = \log 7.6067 + 0.3731 \log X$$

was plotted as shown in Figure 5. The line representing the ratio of the price of input and the price of output (Px/Py) was drawn. The point at which the line is tangential to the production function is the maximum profit point. The maximum profit point as determined graphically was approximately 25 acre-inches for moht.

The other way of determining the maximum profit point is by comparing the marginal cost with marginal returns. The factor cost is calculated at each level and the marginal cost is worked out. Similarly, the total returns at each input level are worked out. The level of input most profitable to employ is that at which the additional returns (value of the additional product) just equals the cost of the additional input.[2]

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[2] C. E. Bishop and W. E. Toussaint, Introduction to Agricultural Economic Analysis. John Wiley and Sons, New York, 1958. p. 41.

TABLE IV

ESTIMATED YIELD OF SIMLA VARIETY OF POTATOES AT DIFFERENT LEVELS OF APPLICATION OF WATER WITH MOHT WATER LIFT IN SELECTED VILLAGES, BANGALORE DISTRICT, INDIA, 1959-60

Water in Acre-inches	Estimated yield in 100 lbs.
5	14.00
10	16.50
15	20.50
20	23.20
25	25.50
30	27.20
35	28.50
40	30.00
45	31.50
50	32.50
55	33.50
60	35.00

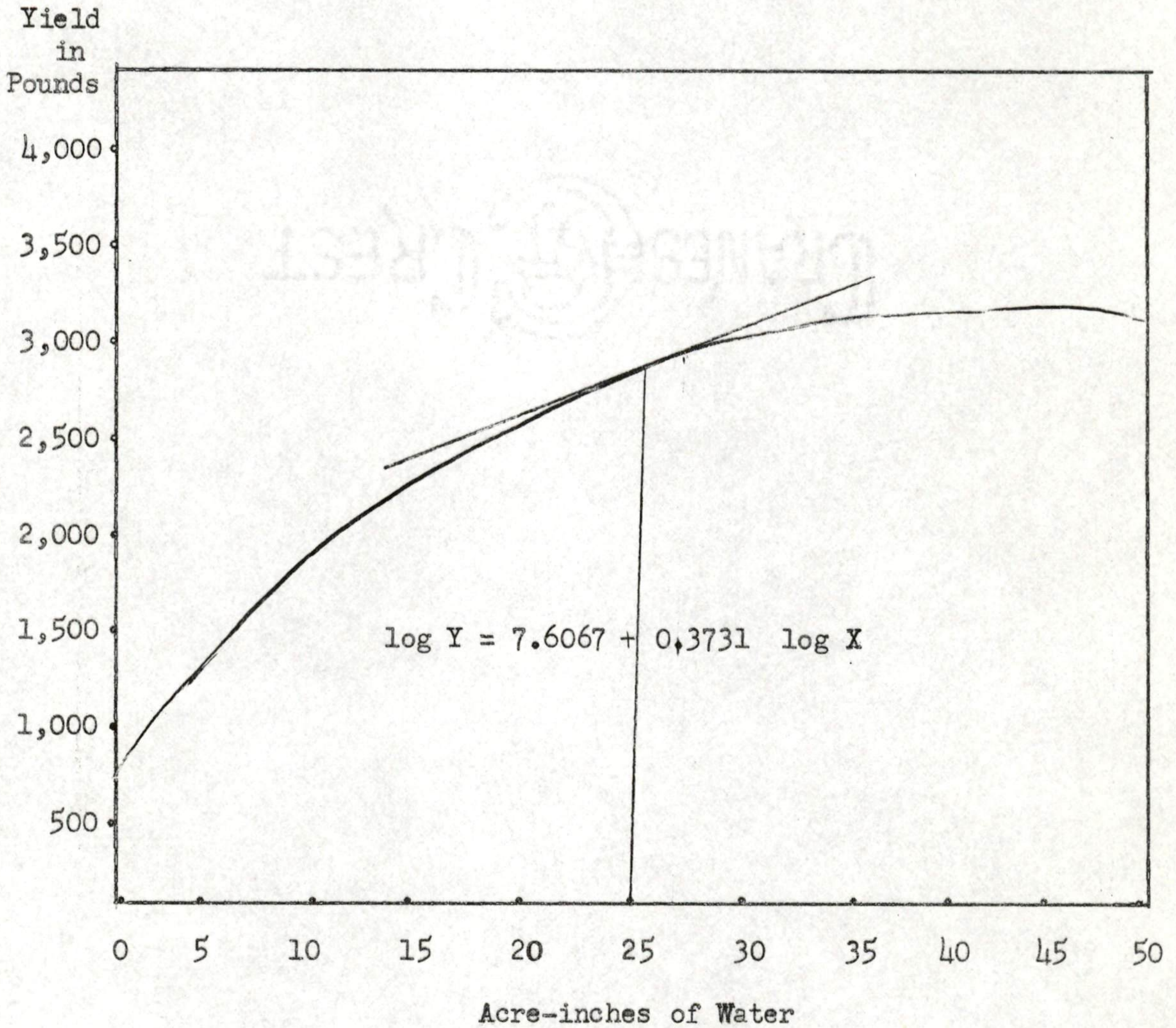

Figure 5. Relationship of acre-inches of water to yield of potatoes and the determination of maximum profit point for irrigation with moht water lift in the selected villages, Bangalore District, India. 1959-60.

In Table V it is shown that it paid to irrigate with a moht up to some point between 25 and 30 acre-inches of water. The profit at this point was maximum.

TABLE V

DETERMINATION OF MAXIMUM PROFIT POINT BY COMPARING MARGINAL COSTS AND MARGINAL RETURNS WITH MOHT WATER LIFT IN SELECTED VILLAGES, BANGALORE DISTRICT, INDIA, 1959-60

Water in acre-inches x	Estimated yield in 100 lbs. Y	Cost of X @ Rs. 6.16 per acre-inch	Estimated returns @ Rs. 16.00 per 100 lbs. potatoes	Marginal cost for each input unit of 5 acre-inches	Marginal returns for each input unit of 5 acre-inches
5	14.00	30.80	224.00		
				30.80	40.00
10	16.50	61.60	264.00		
				30.80	64.00
15	20.50	92.40	328.00		
				30.80	43.20
20	23.20	123.20	371.20		
				30.80	36.80
25	25.50	154.00	408.00		
				30.80	27.20
30	27.20	184.80	435.20		
				30.80	20.80
35	28.50	215.60	456.00		
				30.80	23.80
40	30.00	246.40	480.00		
				30.80	24.00
45	31.50	277.20	504.00		
				30.80	16.00
50	32.50	308.00	520.00		
				30.80	16.00
55	33.50	338.00	536.00		
				30.80	24.00
60	35.00	369.60	560.00		

CHAPTER V

USEFULNESS OF THE RESULTS

The results obtained in the study apply to the total number of acre-inches of water that could be applied to potatoes for maximizing profit. In this study, the total rainfall and irrigation water was used in the analysis. The average expected rainfall during the particular growing season would need to be deducted from the total acre-inches to determine only the amount of irrigation water that would be profitable. This can be done for each growing season. The results can be used to greater extent if similar results were available for all of the crops that may be grown on each farm.

In this study, the results apply to farms with a limited supply of water. However, as an average, on the farms included in the analysis the limited supply of water was beyond the amount needed to reach the point where the additional returns just equalled additional costs.

The latter situation will not always exist. In any study designed to analyze the economics of use of irrigation water, either of three conditions will exist or need to be assumed in India, i. e. unlimited supply without a cost, unlimited supply with a cost and a limited supply with a cost.

I. UNLIMITED SUPPLY OF WATER WITHOUT ANY COST

When there is an unlimited supply of water without any cost associated for getting it, then it pays to irrigate up to the extent where the total physical product would be at a maximum. The production function, $\log Y = \log a + b \log X$, which is known as the Cobb Douglas function, was used in this study. This function does not lend itself to total diminishing yields. However, functions of the type $Y = a + bX + cX^2$ and $Y = a + bX + cX^2 + dX^3$ do allow for total diminishing products.[1] They can be used, depending upon the circumstances, where the input level for maximum physical product has to be determined.

II. UNLIMITED SUPPLY OF WATER WITH A COST

When the supply of water is unlimited, and a cost is associated for obtaining it, then it pays to irrigate as far as the additional returns pay for the additional cost. We can visualize two types of cases: (1) where the cost is fixed and does not vary with the quantity of water used, (2) the cost varies according to the volume of water used.

Canal irrigated areas of India, where the water cess (amount charged for the use of irrigation water) is based on the number of acres irrigated and not on the volume of water used, fall under the first category. In such cases, it will not pay to irrigate if the additional returns due to irrigation do not cover the fixed water cess. If it pays to irrigate, then it pays the farmer to irrigate up to the point where the total physical product would be at a maximum. This will be true where

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[1]Earl O. Heady and others. Resource Productivity, Returns to Scale, and Farm Size. Iowa State College Press, Ames, Iowa. 1956. pp. 9-10.

there is no variable cost associated with the use of input or no variable harvesting cost associated with the yield.

In some cases, the amount of irrigation water that can be used economically varies with the kind of crop grown, such as paddy, sugarcane, wheat, etc. These form the latter type of cases where there is unlimited supply of water and the cost varies according to the volume of water used. In such cases, if the selection involves finding just one crop out of the many that can be grown, then it can be determined by preparing budgets and comparing the total returns and the total irrigation cost involved up to the point where additional returns just cover additional costs for each crop, and selecting the crop which gives the maximum total net returns (i.e. the difference between the total returns and the total irrigation cost up to the marginal point). If the farmer desires some diversity rather than complete specialization, then he should choose one or more additional crops ranking next in order in total net returns (up to the point where the marginal returns just equal to the marginal costs).

III. LIMITED SUPPLY WITH COST

If the selection involves one of the many crops that can be irrigated, then budgets should be prepared for each crop as stated above. By comparing the data, the net returns due to the available level of irrigation can be determined for each crop. The crop that yields the maximum net returns for the amount of irrigation water available, should be selected.

When the quantity of water available is limited and the choice involves growing of a number of crops which use different levels of irrigation water, then the limited supply of that water should be distributed to the crops so that the last additional acre-inch of water will give the same net returns from each crop. (This principle applies when the resource used, such as irrigation water, can be applied in small units.)

CHAPTER VI

SUMMARY

Irrigation occupies a prominent place in the predominantly agricultural countries. Since water is often a scarce resource in crop production, its proper allocation is highly important. In India, agricultural production can be substantially increased by properly allocating the available scarce resources.

The Indian government contemplates increasing agricultural production by increasing irrigation potentialities, use of manures and fertilizers, enhancing research activities and developing the proper means of disseminating research results, etc. Increasing the irrigation potentialities has been considered as one of the most important factors of increasing agricultural production. With the increase in the irrigation potentialities, the knowledge of the economic levels of water application for accomplishing the ends in view becomes all the more important. Though water is scarce in India, examples are numerous where it is extravagantly used. This has resulted in problems arising out of water logging and has thrown large areas out of cultivation. In some cases, the manner in which water is charged is defective, and partly responsible for its extravagant use. Suitable methods of levying water cess have to be developed so that water is used judiciously.

Research can be focused on important water use problems from the individual farmer's objectives or from the nation's viewpoint. The present study is based on maximizing the net returns to the scarce water resource from the individual farmer's point of view.

It is observed from the study that a very small percentage of variation in yield is associated with the variation in the quantity of water used in case of ragi and garlic. The results show that about 14 per cent of the variation in yield in case of Simla potatoes is associated with the variation in the use of water.

The cost of irrigation also varies with the type of water lift used. Hence, cost of irrigation for the two types of water lifts, moht and pump, were estimated by regression analysis in case of potatoes. It was observed that it paid to irrigate potatoes (Simla variety) up to 25 acre-inches with a moht lift and more than 60 acre-inches with a pump lift.

The results obtained can be used in a number of ways. Proper decisions can be made for the use of irrigation water for maximizing net returns to farmers depending on the nature of the availability of irrigation water, cost of irrigation, etc.

The use of water can be economized by following the proper methods of irrigation. Research also needs to be conducted on the economics of sprinkler irrigation under Indian conditions. Some of the water lifts used at present are heavy labor consumptive, resulting in higher cost of irrigation. They need to be substituted by other mechanical devices which reduce the cost of irrigation.

Limitations of the Study

The conclusions reached in the study have some limitations. The type of sample used in the study was a purposive one and thus limits the application of the results. The response of yield to water has been worked out for the total quantity of water used. This limits the direct application of the conclusions reached in the study. Before arriving at any conclusions regarding the quantity of irrigation water to be applied, the estimated rainfall during the growing season has to be deducted from the total acre-inches. It is also observed that the factors other than the ones included in the study also varied and thus limit the applicability of the conclusions.

Need for Further Research

Further research needs to be done by adopting proper sampling procedures so that the results of the study can be used as guides for action by farmers.

Since the yield responses will differ at various levels of fertilization, research has to be accomplished for determining the profit points for water input at various levels of fertilization. As water and fertilizers are often complementary factors, the optimum combination of these inputs for maximization of profits also need to be determined.

Research needs to be conducted, not only for determining the application of input levels for a particular enterprize, but also it needs to be directed toward the proper allocation of scarce water resource among the alternate crop enterprizes. India has tremendous potentialities for increasing her agricultural production by proper allocation of scarce resources. This has been neglected in the centuries past for various reasons. With the dawn of independence she has been making great strides for the economic betterment of her people through a series of Five-Year Plans. She has considerably increased her irrigation potentiality and any research conducted in the economic use and proper allocation of water will contribute significantly to its economic development.

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APPENDIX

PERCENTAGES OF NITROGEN, PHOSPHOROUS AND POTASH CONTENTS OF DIFFERENT MANURES AND FERTILIZERS USED

Name of manure and fertilizer	Nitrogen N_2	Phosphoric Acid P_2O_5	Potash K_2O
		Percentages	
Farmyard manure	0.3-1.1	0.3-0.54	0.4-1.1
Groundnut cake	6.5-8.8	1.4	-
Superphosphate	-	14-21	-
Ammonium sulphate	20.5	-	-

Source. Yagna Narayan Aiyer. Field Crops of India. The Bangalore Printing and Publishing Company. Fifth Edition. 1958.