FINANCIAL FEASIBILITY OF IRRIGATED FARMING: A CASE STUDY OF TUBE-WELL IRRIGATION IN MOMBASA DISTRICT

By

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Declaration

I, Michael Njoroge Thiongo, hereby declare that this thesis is my original work and it has not been submitted for a degree to any other University.

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ABSTRACT

Whereas some studies have evaluated large-scale irrigation schemes in Kenya, little economic research has been done on the Minor Irrigation projects. The decision by the Kenya Government to increase emphasis on development of Minor Irrigation Schemes necessitates studies on these particularly from the financial and economic standpoint.

Tube-wells are part of the minor irrigation development programme in Coast Province which is characterized by a general shortage of big rivers and streams. This shortage of surface water in the Province in particular and generally in the republic had been realised even during the colonial days. Government efforts have been carried out mainly by construction of tube-wells, which progressed steadily so that by the early 1970s over 80 tube-wells were being bored annually by the Kenya Government.

The substantial costs involved in this tube-well development were justified by the fact that the projects were undertaken by the Government or the Municipality for community water development. As such boring of tube-wells was restricted to the community centres only. Unfortunately most of these tube-wells especially those in Coast Province were abandoned when no personnel was available to maintain them.

A survey of the area between Gazi and Mtwapa in Coast Province in 1969 to study the distribution of tube-wells, their yields, and water quality rated this as "a good area of groundwater resources". It was recommended in this report

that some selected tube-wells which were yielding considerable quantities of good quality water should be rehabilitated and fitted with powered pumps for the purpose of irrigation and domestic water supply. This recommendation was not implemented because information was lacking concerning their financial viability as irrigation projects.

This thesis is therefore concerned with evaluation and appraisal of tube-well irrigation projects in Mombasa District to establish their financial worth. Mombasa District was selected for the study on account of the concentration of tube-wells. The focus of the thesis involved collection of primary data from a sample of 10 farms using each diesel and electric pumps.

Irrigated farming is capital and labour intensive. High initial investment capital is required to start-off a tube-well irrigation project. Because of the high costs involved in supplying irrigation water, only crops with high gross margins per hectare can be grown profitably. The study revealed that tube-well irrigated farming based on high-value horticultural crops can be a highly profitable venture if properly designed and planned. Knowledge of the important factors affecting returns is invaluable. A high degree of managerial ability, innovativeness and first-hand market intelligence and knowledge of irrigation techniques is indispensable for successful irrigation.

Inspite of the high investment and running costs involved in tube-wells irrigation projects, they are financially viable and yield high rates of return to investment and internal rates of return.

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CHAPTER I

INTRODUCTION

1.1. Place of Irrigation in Agricultural Development

The importance of irrigation in the world today cannot be overemphasized. The need for survival and the need for additional food supplies are necessitating a rapid expansion of irrigation throughout the world. Although irrigated agriculture has developed most extensively in arid regions where natural precipitation is inadequate for the production of many crops, it is becoming increasingly important in humid regions as well. Irrigation has been defined by Israelson and Hansen (1962) as the application of water to the soil for the purpose of adding water to the soil to supply the moisture essential for plant growth, providing crop insurance against short-duration drought, cooling the soil and atmosphere, thereby bringing about a favourable environment for plant growth, and washing-out or diluting the salts in the soil and softening the tillage pan. This definition does not restrict irrigation practices to the arid and semi-arid regions. In fact some of the most profitably irrigated agricultures in the world are located in areas normally thought to have sufficient rainfall (Cantor, 1967). These are areas such as Central Brazil, Central America, the West Indies, and the western part of Africa and parts of South Africa which have ample annual rainfall, but during six months of the year have practically no rainfall. Other areas have short periods of drought which necessitate irrigation, if a profitable and diversified agriculture is to be practised. Irrigation in such places is only supplemental to natural precipitation. Therefore irrigation is no longer a regional practice of arid and semi-arid zones but is becoming a basic necessity of a well-developed agriculture.

In many countries the development of agriculture is dependent on irrigation. In others, irrigation is a prerequisite to higher productivity of limited land resources, to production of high-value cash crops, and to the diversification and intensification of agriculture. All said, irrigation development can have a considerable impact on the overall economic development in terms of increased employment, increased rural incomes, and hence increased living standards which in turn stimulate the development of the internal market for industrial products. Maximum agricultural production cannot be achieved without adopting modern techniques and services such as irrigation. Even on land which has been farmed for centuries the introduction or improvement of irrigation practices can provide the exciting promise of higher yields and better living conditions for farm families.

Irrigation has converted deserts into productive agricultural lands thus attracting large habitations and new centres of life and civilization. For example, irrigation from the Nile is a source of food, life and prosperity in Egypt, whose entire cultivated area is dependent for its water supply on irrigation (Arnon, 1972). Three quarters of the cultivated area in Japan is irrigated and grows mainly rice. Other countries which have a high proportion (about two thirds) of irrigated farming area are Afghanistan, Guyana, and Taiwan. In these areas where agriculture is almost entirely dependent on irrigation, canals, dams, and wells are viewed not only as the backbone of the people's economy but also as intimately related to the very life of the people. In this regard irrigation is very much a human problem. Lack of it would mean devastation and misery for large parts of the population. Rice, which is the staple food for more than half of the world's population, is grown, except in small zones of very heavy rainfall, entirely as an irrigated crop. Similarly good quality cotton cannot be successfully grown without adequate irrigation. Fruit and vegetable production is eminently enhanced by irrigation. When there is insufficient food for people in a country and, for various reasons, it is difficult to import it, the magnitude of costs of an irrigation project may be regarded by the authorities as relatively unimportant*.

Irrigation development not only helps in increasing food production but also opens up new land frontiers to alleviate the population pressure in densely-populated areas, which is one of the development problems in many developing countries. The need to create more reliable water supplies to be able to utilize a large proportion of seasonal riverflows and reduce floods has given impetus to the construction of storage dams. Another factor contributing to this need has been that in many parts

* However, such views may not be sound from an overall economic standpoint. Food usually can be imported, so that relative long-term costs of domestic and imported supply sources should be considered.

of the world, the opportunities for developing additional water supplies through simple diversion have been exhausted (Norse, 1976). However the cost of these projects, their long gestation periods, and the relatively high foreign exchange component in their construction have caused some economic problems in using them for water-supply development in many developing countries. Their optimal use requires a high level of farm management not only for the water supplies created, but also in their utilization at farm level. The same need for optimal utilization equally applies to all water development for irrigation. An optimal water development plan should be oriented not only towards developing new water supplies, but also to increasing the efficiency of use for the presently-available water.

Strategies for the use of latent water resources will depend to a large extent on the costs of development and the potential productivity. While surface water resources have provided the base for the bulk of irrigation in most of the world's irrigated regions, groundwater has played and will continue to play an important part in irrigation development especially in areas like India, Pakistan, and parts of the Near East and Africa. Recent trends have shown a growing awareness of the utility of groundwater and technological developments in drilling and pumping have brought opportunities for their wider exploration*. Most of the world's smaller

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* These have been partially offset in recent years by increasing pumping costs reflecting the sharp advance in prices for petroleum and related energy sources.

and/or easier irrigation schemes based on river capture, especially in the developing countries, have been avoided because of the large capital requirements. Research in India has revealed that exploitation of groundwater is generally less expensive than that of surface water. However location of some groundwater resources are not known with any marked precision. Development costs have been estimated by analysing a wide range of agricultural development projects assessed and/or financed by international banks. From this it has been possible to determine the likely range of development costs for different types and sizes of irrigation projects. A general examination of these costs suggests that no economies of scale are likely to occur. The irrigation development costs per hectare have been found to increase linearly with the size of the project.

1.2. History of Irrigation

According to the indicative world plan (FAO, 1970), approximately 13 percent of the cultivable land used for annual and permanent crops in the world was under irrigation in 1963. This was approximately 180 million hectares. By 1975 this area was estimated to be about 200 million hectares, and before the turn of the century the total hectarage will have exceeded 300 million hectares. The developing countries alone command (1975) over 162 million hectares of irrigated land although almost half of it requires rehabilitation or improvement, and much of the available water-flow is underutilized. In the Indus Basin in West Pakistan and parts of

India are to be found the largest irrigation schemes in the world outside mainland China. Among the leading regions in irrigation are Asia and the Far East, North America, U.S.S.R., North West Africa, Europe, and South America. Irrigation is particularly important in the Near East where the agricultural systems are based on the Nile and the Tigris-Euphrates, and where agriculture would be impossible without irrigation.

The water resources of a country are its rivers, lakes, and springs refilled by rainfall and under-the-surface sources which usually developed millions of years ago and essentially are available for "mining". Accordingly, different types of irrigation works have been developed over the past ages, examples of which are: Percolation wells (Artesian wells and tube-wells), tanks (earthern storage areas), large storage reservoirs, pumping or lifting from rivers and lakes, weir-controlled diversion canals, trans-basin diversions, multi-purpose projects, and different combinations of all of them (FAO/UNESCO, 1973).

Percolation wells as a source of irrigation waters go back to prehistoric times and are still popular in many parts of the world. In India alone about 5 million wells are in use for irrigation. A large number of tube-wells have been installed in many areas of the world in the last 30-40 years. Tanks and storage reservoirs have been an important source of irrigation supplies for ages past - mainly in Ceylon, Continental China, and Central and Southern India. Lifting water from rivers is also an early means of irrigation for areas along the river banks. Where irrigable areas are low, lift may be necessary only in the season of low flows. During the high-flow period, in such cases, river water can flow to irrigated areas by gravity. The source of power for lifting in general may be manual, animal, thermal, or electric. Thermal power includes natural gas and petroleum.

In hilly areas, where river channels are relatively steep, it is common practice to divert streams of water into small channels taken along the hillside for purposes of irrigation. During the last 150 years, a large number of weir-controlled canals have been built in different parts of the world. These canals are based on the run of the river, with no storage. These may be 1-seasonal, supplying water for one crop season only, 2-seasonal, or perennial.

With the advance in the knowledge of hydraulics and the development in engineering techniques during the last hundred years, many large-size storage reservoirs have been built by damming the flow of rivers by masonry dams (30 to 100 meters high), concrete dams (up to 284 meters high), and earthen dams (up to 240 meters high). In conjunction with canals, these reservoirs provide irrigation to large areas (FAO/UNESCO, 1973).

1.3. Problems of Irrigation Development

In view of the breakdown, in the past, of many civilizations that were based on irrigated agriculture and the numerous cases of rapid soil deterioration in modern times (both in countries with underdeveloped agriculture and in those with the most advanced technologies), doubts are frequently expressed as to the possibility of maintaining irrigated agriculture permanently. Irrigation development has experienced both social and technical problems.

The success of irrigated agriculture depends upon the compatibility of water, land, and people (Thorne and Peterson, 1949). The world today has many abandoned irrigation projects, caused primarily by inadequate considerations of the combined uses of these resources. Many irrigation schemes particularly in Africa have met with many settlement and administrative problems. Only a few irrigation settlement schemes in Africa can be termed as successful, most others having failed outright, or having operated over a long time without recovering their costs (de Wilde, 1967). Most schemes in the early stages face the problem of selection of the right settlers. Selection of tenants who are not committed to the hard work involved in irrigation may lead to instability in the early stages of settlement. Another major problem which faces irrigation settlement schemes is the strict requirement of high-value crops in the scheme, which in many cases conflicts with the subsistence requirements of the tenants. Water sharing among settlers in a big irrigation scheme, or at times between countries, can be a major administrative problem.

Experience and research have shown unequivocally that the basic causes of the failure of crop production under irrigation are the combined and related effects of excessive salt-accumulation in the root-zone and the development of a high water-table (Thorne and Peterson, 1949). Nevertheless scientists agree that these problems are not insurmountable. The fact that good crop yields have been maintained under irrigation for a period of more than 4000 years in both Egypt and China supports the thesis that irrigation can be a permanent feature and one of the most important and productive systems of agriculture. History and research have shown that for irrigation development to be successfully maintained, there is need for a strong central government to construct and maintain extensive irrigation schemes, proper design of the system, particularly provision for adequate drainage to match the increased availability of surface water, and careful control of irrigation practices so that the persistent problems of erosion, waterlogging, salt accumulation, soil permeability and aeration, and soil depletion can be controlled.

CHAPTER II

IRRIGATION IN THE KENYAN ECONOMY

2.1. Economic Setting

Agriculture is the mainstay of Kenya's economy, contributing about 30 percent of the country's Gross Domestic Product and 60 percent of the exports by value. Nearly 90 percent of the total population lives in rural areas, some of which are densely populated.

Agricultural areas in Kenya are customarily divided into high, medium, and low-potential zones. This classification might be better replaced by the terms describing rainfall expectations such as wet, dry, and arid. Out of the country's 563,200 Kilometres^2 of dry land, nearly 25 percent (140,800 Kilometres^2) receives less than 250 millimetres of rainfall annually and is therefore termed arid or low-potential and 56 percent (315,390 Kilometres^2) receives between 250 and 500 Millimetres of rainfall, which makes it a semi-arid or medium-potential zone. The rest of the country receives over 750 Millimetres of rainfall and therefore can be classified as a high-potential zone (Criddle, 1964).

In an economic sense the greatest prospects for expansion of farming activity is in the medium and low-potential zones, which are so far not fully settled. Less than 20 percent of the potential arable land in both these zones is cultivated. Only 12 percent of all the land in Kenya is capable of crop production, but out of this total potential arable land, over 40 percent is found in the medium-potential zone. Therefore the scope and importance of these areas as an expansion zone for crop cultivation is evident.

With the present population growth rate of 3.3 percent per annum, the high-potential agricultural land has become limited, and population pressure in some parts of the country is now one of the major development problems facing Kenya. The Government has adopted a policy of extending agricultural land frontiers to cover the sparsely-populated* medium-potential zones mainly through irrigation development. Hitherto, much emphasis has been given to large-scale irrigation development, such as the following irrigation schemes: Mwea, Ahero, Perkerra, Galole and the more recent Bunyala scheme. Among these, only the Mwea scheme can be characterised as successful; the others have barely begun to show some promise after many disappointing years (de Wilde, 1967). In general, large-scale irrigation projects have a long gestation period and require large amounts of foreign exchange and domestic capital. In financial terms such projects require an estimated cost of £700 - £1000 per hectare as capital investment and running costs**. With such high development costs, efficient production of high-value crops is necessary if financial success is

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* Approximately 1.5 million people live in medium-potential zones and 0.9 million live in low-potential zones. The rest of the population (11,000,000) live in high-potential and urban areas.

** Ahero and Mwea extensions had costs of £980 and £750 per cultivated hectare respectively. Costs for the expansion of the Lower Tana scheme have been estimated at £2000 (1974 Prices) per hectare inclusive of all costs (United Nations, FAO survey of the irrigation potential of Lower Tana).

to be achieved. This in turn requires proficient management services for water supply, production, and marketing.

On the other hand, minor irrigation projects have short gestation periods and require relatively small amounts of foreign exchange and skilled personnel.

The second Kenyan five-year development plan (1970 - 1974) laid some emphasis on minor irrigation projects. A number of such projects were established in various locations, mostly in the arid parts of the country where suitable water supplies existed. In total these schemes cover more than 1000 hectares of irrigated land. During the current-plan period (1974 - 1978) minor irrigation schemes will be developed on a much wider scale than previously, primarily as a means of improving food supplies and, hopefully, obviating the need for famine relief in the arid areas. Development funds amounting to K£600,000 have been allocated for them. The initial development work for these schemes is being done by the Land and Farm Management Division of the Ministry of Agriculture. Their development will be partly on a self-help and partly on an individual basis. It is also hoped that these projects will be important locally as a source of employment and cash income.

2.2. History of Irrigation in Kenya

Irrigation work was started in Kenya in the early 1950's with the formation of the Hydraulics Department within the Ministry of Public Works (Criddle, 1964). The Department had four major Divisions, namely Community Water Supplies, Groundwater Investigations and Advice, Irrigation Systems and Dams, and Hydrology. This Ministry was charged with the duties of planning, design and construction of the irrigation projects, while the Ministry of Agriculture and Water Resources undertook the operation and maintenance of the completed projects. A joint irrigation committee composed of high level Government officials was set up and charged with the responsibility of irrigation problems of the entire country. The committee met regularly and developed policy guidelines for the national programme.

In the period between 1950 and 1960, several irrigation projects proposed by this committee were implemented. The operation of each project was put under the guidance of a local irrigation committee made up of both local and Government agency representatives. Each irrigation project had a Manager who was responsible to the Ministry of Agriculture and the advisory committees and whose duty was to organise record-keeping, maintenance and operation of equipment, distribution of water to the tenants, and advising the tenants on their farming operations. The projects which were implemented during this period included schemes such as Mwea, Ahero, Taveta and Galole all of which, except Taveta scheme*, are now under Government supervision through the National Irrigation Board. During this same period irrigation farming attracted private entrepreneurs, and several private irrigation schemes were set up mainly in Nyanza, Rift Valley, and

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* Taveta irrigation scheme was opened in 1953 and gradually developed to about 1000 hectares. But later most of the irrigated acreage was abandoned. It is now one of the minor irrigation schemes.

the Coast Province.

The major irrigation schemes set up after 1950 are shown in table 2.1. Table 2.2 shows the private and minor irrigation schemes in Coast Province.

Table 2.1 Kenya: Major irrigation schemes started after 1950, major crops, and related information.

Name of Scheme	Year of implementation	Source of Water	Hectares irrigated 1975	Main Crops	Yield per hectare kg.
Perkerra	1953	Perkerra River	582	Onions Chillies	10,600 543
Taveta	1953	Lumi River and Njoro Kubwa Springs	1,012*	Bananas Cotton	2,500 (bunches) 2,200
Mwea	1954	Thiba and Nyamindi Rivers	5,379	Rice	5,284
Galole	1958	Tana River	856	Cotton Rice Groundnuts	2,672
Ahero	1968	Nyando River	1,534	Rice	1,608
Bunyala	1969	Nzoia River	342	Rice	1,970

Source: Central Bureau of Statistics

* Most of this irrigable land was abandoned in the 1960's but at the time of writing the Ministry of Agriculture is in the process of reviving the scheme.

Table 2.2 Coast Province: Private and minor irrigation schemes, major crops, and related information, 1975

Name of Scheme	Source of Water	Area irrigated (1975) Actual	Area irrigated (1975) Potential	Main Crops	Yield per hectare
		Ha	Ha		Kg
Hewani	Tana River	30	300	Rice	1,600
Ngao	Tana River	100	500	Rice	2,500
Wema	Tana River	75	400	Maize Rice	1,800 2,250
Oda	Tana River	30	200	Rice	1,500
Ramisi Sugar Factory	Surface and Groundwater	208	1,000	Sugarcane.	45,000
Tube-wells in Mombasa	Groundwater	150	unlimited	Fruits and Vegetables	N/A
Taveta	Lumi River and Njoro Kubwa Springs	530	2,000	Bananas Cotton	2,500 (bunches) 2,200
Vanga	Umba River	300	1,500	Rice	1,600

Source: Annual reports of the Provincial Director of Agriculture, 1971/74.

The Groundwater Investigation Division also did some work on irrigation development by drilling boreholes in various parts of the settled and "native reserve" of the country where surface water supplies were either non-existent or inadequate. Table 2.3 shows the progress of drilling between 1927 and 1975.

Table 2.3 Kenya: Number of boreholes constructed between 1927 and 1975.

Year	Boreholes Drilled No.	Year	Boreholes Drilled No.
1927	5	1954	120
1930	60	1955	175
1931	50	1956	175
1932	10	1957	120
1933	7	1958	120
1936	2	1959	105
1938	20	1960	75
1939	20	1961	50
1940	90	1962	55
1941	120	1963	48
1942	30	1964	55
1943	70	1965	54
1944	55	1966	47
1945	65	1967	55
1946	100	1968	70
1947	140	1969	98
1948	160	1970	83
1949	220	1971	75
1950	255	1972	85
1951	340	1973	82
1952	250	1974	95
1953	240	1975	110

Source: Drilling Section, Ministry of Water Development, Nairobi, 1975.

It will be observed from table 2.3 that much emphasis was placed on the construction of boreholes in the 1940's and 1950's during the days of African Land Development Organization (Aldev)* with less in the 1960's. The number of boreholes constructed will however continue to steadily increase in the 1970's. Although these early drillings were based on Government efforts, the Government later encouraged in it's second Five-year Development plan (1970 - 1974) private exploitation of groundwater through a tube-well/borehole subsidy. The progress made under this tube-well programme is shown in table 2.4.

Table 2.4. Kenya: Boreholes drilled and Subsidy aid 1969/70 - 1974/75.

Item	Unit	1969-1970	1970-1971	1971-1972	1972-1973	1973-1974	1974-1975
Boreholes Drilled	No.	98	83	75	85	82	95
Successful	No.	67	64	71	75	80	87
Percentage Successful	%	68	77	95	88	98	92
Subsidy aid	K£	3,875	1,588	1,456	1,800	30,000	35,000

Source: Economic Review, 1975.

These boreholes are spread all over the country, thus having a wide range of climatological, geological, and topographical features. The results obtained from this preliminary

* "Aldev" was an organization set up by the Colonial Government to develop the "unscheduled" areas (African Land) for settlement of the landless Africans.

drilling revealed interesting information concerning the mode of occurrence of groundwater with respect to various geological formations. This information is summarized in table 2.5.

In spite of this, no systematic survey of the groundwater resources of the country has been undertaken by the Government. As such the total groundwater potential which can be exploited for irrigation purposes has not been finally determined, but the data so far available indicate that there is ample scope for considerable exploitation of such resources in several areas of the country.

Table 2.5 Kenya: Statistics of boreholes drilled between 1926 - 1932 shown according to their geological formations

Results of successful boreholes	Basement Complex	Duruma Sandstones (Terrestrial)	Jurassic System (Marine)	Kainozoic Volcanic Series	Kainozoic Sedimentary (Coastlands Marine & Terrestrial)	Kainozoic Sedimentary, Inland Lacustrine Pluviatile, & Eolean
Number	52	6	1	44	2	6
Average depth (ft)	211	240	443	310	262	251
Average depth of water from the surface (ft)	154	226	366	245	258	150
Average depth from surface to which water rose (ft)	65	74	146	154	111	101
Average yield per 24 hours (1,000 gal.)	24	28	29	32	25	40
Unsuccessful due to too saline for domestic and agricultural use (No.)	1	0	1	0	8	0
Drilled to reasonable depth but no water found (No.)	5	1	0	12	0	0
Abandoned due to drilling difficulties (No.)	8	0	0	10	0	0
Abandoned due to steam and gases (No.)	0	0	0	5	0	0
Total drilled (No.)	68	7	2	65	10	6

Source: H.L. Sikes, Underground Water Resources of Kenya Colony, 1932

2.3. Importance of Irrigation in Kenya

Although in many parts of the world irrigation development has been extended to cover even the humid and sub-humid areas, in Kenya much of the irrigation development efforts has been concentrated on the so-called medium and low-potential zones.

The main objective in concentrating efforts in these areas has been to mitigate the effect of drought and to bring security, stability, and prosperity to those areas hitherto producing only catch crops or no crops at all. Nevertheless, as modern cash inputs are successfully removing or reducing the effects of many limiting factors, even in areas of moderately adequate precipitation, there is an increasing need to consider supplementary irrigation to prevent moisture-availability from becoming the ceiling on yields. There is therefore a possible choice of two objectives in irrigation: (1) Supplemental irrigation aimed at ensuring a more or less constant level of production even during the long dry spells between long and short rains, and (2) Full irrigation designed to provide for intensification of crop production.

Among the specific advantages that may accrue from irrigation are the following: (1) Maximum growth and yield traceable not only to the supply of water itself but also to the part that moisture plays in making nutrient materials available, (2) timing of maturity of crops - particularly desirable where earliness is profitable, (3) maximum table and market quality. Quality of the harvested product is almost always inherently improved through irrigation, and (4) utilization of land. Irrigation usually affords an opportunity for fuller employment of land by ensuring double or multiple-cropping.

2.4. Legal Aspects of Water Use and Its Relation to Tube-Well Development

Kenya's first water ordinance came into force in 1929. This Ordinance was a moderately comprehensive set of laws, resting the responsibility of all surface water in the crown, and requiring the issue of a permit for the use of any amount of surface water except that required for domestic purposes. A Water Board was established to consider applications for permits. The 1929 Ordinance was modified by a number of amendments to become the 1951 Water Ordinance which is the basis of the current Kenya water laws. The abstraction of groundwater, which was not covered in the 1929 Ordinance, was carefully controlled under the 1951 Ordinance. The 1951 Ordinance was amended in 1957 and 1960. The 1960 amendment classified all the projects for water and drainage of land into four classes: (a) Private, (b) Community, (c) Public and (d) Urban.

Private projects were defined as those which concern the use of water or drainage of swamps within the limits of the land of the operator. Tube-wells fall within this class and are therefore subject to the law. The specific provision of the law governing the abstraction of water (Ministry of Agriculture and Natural Resources, Water Ordinance, 1960) states, "Any person proposing to construct any well or extend any existing well within one hundred yards of any body of surface water or to abstract water from any well so constructed or extended shall first obtain the necessary permission under the provisions of the water ordinance. The person is required to give full particulars relative to his application and to give to the Water Apportionment Board notice of his intension to construct a well, and also notify the Board when construction begins". The contractor is required to keep record of progress of the work which should include:

(1) Measurement of the strata passed through.

(2) Specimen of such strata to be preserved.

(3) Level at which water was struck.

(4) The quality of water obtained at each level and quality finally obtained and the rest level thereof.

Persons authorized by the Water Apportionment Board have access to the well at all times. The permit to extract groundwater will be given on condition that the right of the permit holder shall relate to a specific quantity of water which may be obtained with maximum lift found by the Water Apportionment Board to be reasonable or feasible at the time of granting the permit. The Water Apportionment Board may however revise both the quantity of water and the maximum pumping lift in the light of changed conditions.

Any area may be declared a groundwater conservation area if the Ministry of Water Development finds it necessary and in this case special permission to construct new wells must be obtained. The Water Apportionment Board prohibits waste of groundwater through abstracting from any well water in excess of reasonable requirements.

To avoid contamination and pollution of groundwater, wells should be sealed off in any contaminated layers. The top of the well should also be sealed between the surface casing and the internal pump column and the section of the discharge pipe.

The Water Apportionment Board reserves the right to order special measures to safeguard groundwater resources.

2.5. Statement of the Problem

A large part of the Coast Province is classified as a semi-arid zone in that the rainfall is less than 500 mm per annum, poorly distributed, and often punctuated by long dry spells. This type of rainfall regime naturally affects food production so that most of the foodstuffs in the Province have to be supplied from up-country, a distance of over 300 miles. Unfortunately, Nairobi offers a big up-country market and therefore Mombasa only gets the surplus which is usually of very low quality. Fruits and vegetables are brought to the Mombasa Market after they have been rejected in Nairobi and suffer a further loss of quality during handling and transportation (Mrabu, 1972). With the increasing population and hence demand for fresh fruits and vegetables, Mombasa cannot continue to depend on the unreliable up-country supplies. In any case the booming tourist industry at the Coast calls for more quantities and a more reliable supply of high quality fresh fruits and vegetables. There is therefore a need to increase irrigated cultivation in the Coast Province so that an all-year supply of fruits and vegetables can be assured and also to reduce the dependency of Mombasa Market on up-country supplies. This could be done by expanding minor irrigation programmes mainly through private investments in tube-wells. The Coast offers great possibility for this type of irrigation development.

The cost of boring tube-wells and installing pumping sets is however too high for an ordinary farmer. Therefore financial assistance has been provided to small-scale farmers through the World Bank's International Development Association (IDA) credit scheme which is being administered by the Agricultural Finance Corporation (AFC) in collaboration with the Ministry of Agriculture. It is also envisaged that the commercial banks will in future come forward in aid of the private investors in rural development and especially in expansion of the private investment in tube-well programmes. Whereas there has been an attempt to estimate the financial and social benefits and costs of the large irrigation projects like Mwea, no attempt has so far been made to study the economics of small-scale irrigation schemes especially those using groundwater resources in Kenya. Tube-well projects would have to be proved financially viable to be eligible for stepped-up financial assistance from the Government and commercial banks.

2.6. Objectives of the Study

The main objective of this study is to assess the financial and economic feasibility of tube-wells as a basis for crop production. By establishing their economic viability, it is hoped that attention of Government and private investors can be drawn to this method of agricultural development which has proved very successful in other countries of Asia, the U.S.A., and the Middle East. More specifically the objective is to appraise and evaluate private tube-well irrigation projects to test the hypotheses that such projects are economically-viable at the individual farm level and could contribute to the acceleration of food production in the Coastal area given credit and good extension advice.

Another related hypothesis is that such small-scale irrigation projects as tube-wells are more applicable for agricultural development, particularly in the Coast where there is no surface water but where groundwater resources are available. In testing these hypotheses the two types of the tube-wells, i.e. electric and diesel-operated systems, are studied to assess which one is more efficient and suitable for small-scale irrigated agriculture.

2.7. Location of the study area

Coast Province lies between latitudes 0° and $4^{\circ}45'$S and between longitudes 37°E and $41^{\circ}40'$E. It covers an area of 83,000 Km^2. Altitude ranges between sea level and 2,100 metres on the Taita Hills.

The climate is generally hot and humid throughout the year except on the high altitudes. Rainfall is perhaps the most important single climatic element for determining the nature of land use in most areas of the Province. On the basis of the mean annual rainfall, over two-thirds of the Province receives less than 760 mm of rainfall and is therefore unsuitable for permanent agriculture without irrigation. About half of this category receives less than 510 mm of rainfall and is therefore suitable only for range development. The remaining one-third of the Province receives over 760 mm annually and is therefore suitable for permanent agriculture. Generally rainfall decreases along the Coast from south to north and with increasing distance inland to the west. Rainfall figures higher than 1,100 mm are recorded in the area between Vanga on the Tanzania border and Takaungu in Kilifi District. Mombasa District, which is the area under study, falls within the high rainfall zone. However because of the rapid percolation of water, high ET and long dry spells, irrigation is necessary. Of greater importance is the number of years out of a hundred when these minimums are realised. Rainfall of 760 mm in 90 out of 100 years occurs for only two small areas (1) A narrow coastal belt from just south of Kilifi Town to Vanga on the southern border and (2) the high parts of Taita Hills. The rest of the area can only be certain of the 760 mm minimum in 70 - 80 years out of 100. Table 1 in appendix I shows rainfall figures in various stations in Coast Province.

Rainfall is of a bi-modal pattern with maximum precipitation occurring in the months of March to June and October to November. The pattern is uneven and rainfall appears to move in narrow bands in the direction of the prevailing monsoon winds. The long rains sometimes start in March and disappear in May or June or they may start in April and continue to June. The short rains are not dependable and may not occur at all in some parts of the Province in a very dry season.

In the light of this rainfall probability and reliability, most of Coast Province likely can benefit from full irrigation, with supplemental irrigation preferred in just a small area. Although the area covered in this study is about 700 Kilometres^2 - the area around Mombasa mainly north and south, it is estimated that over half of the total area of Coast Province is suitable for irrigation development from the soils and topographical point of view*. With a rural population of 660,000 composed of Giriama, Digo, Duruma, Pokomo, and Taita as the main tribes, irrigation development projects are not likely to experience a labour bottleneck. The urban population of 280,000 (1969 census) together with the rapidly developing tourist hotel industry and the shipchandler business will continue to provide the market for increased agricultural produce.

The study concentrates only on fruit and vegetable crops because of their rapidly growing demand all along the coastal strip especially Diani, Mombasa, Malindi and Lamu which are the chief tourist centres. The farmers practising tube-well irrigation are largely of Asian origin generally reputed for their long history of irrigated farming. The position of the study area is shown in Figure I at the end of Chapter V.

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* This estimate is given in a report on the survey of the irrigated potential of the lower Tana River Basin which was done for Kenya Government by Food and Agricultural Organization of the United Nations, Rome, 1968.

CHAPTER III

METHODOLOGY

3.1. The Data

3.1.1. Type of Data

Data were required with respect to the main vegetable crops grown by farmers utilizing the tube-well and non-tube-well irrigation systems, the cropping intensity of the two systems of irrigated farming, market channels available to the producer, and the level of fixed and variable costs, yields and prices of various fruits and vegetable crops. Fixed costs include depreciation, interest, management costs and wages for regular labour. The estimates for capital investment include costs for such items as tube-well sinking, land levelling, energization*, pump house, storage tank or stilling basin, and electrical transmission. Variable costs include wages for casual labour, costs of purchased production inputs such as seeds, fertilizers, manures, pesticides, herbicides, and fungicides, and cost of fuel, oil, and electricity.

3.1.2. Sampling Procedure

Most of these basic farm management data were gathered from a sample of 20 tube-well operated farms in Mombasa District. Mombasa District was selected purposely for this exercise on

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* Energization here refers to the use of diesel or electric power as the prime-mover of the pumps. In connection with investment, this involves the cost of the pumps and electricity installation.

account of its concentration of tube-wells for irrigation purposes. The statistical foundation of the study is based on a survey of tube-wells at the coastal strip between Gazi (in Kwale District) and Mtwapa (in Kilifi District) covering an area of 700 $Kilometres^2$ and including 446 tube-wells. This survey was carried out by Gentle (1969) with the objective of ascertaining the amount, quality, and extent of groundwater in that area. Out of these 446 tube-wells, only 50 are currently used for agricultural purposes, and the rest are used for domestic purposes. All of these 50 tube-wells were pre-surveyed to find out the cropping pattern and the acreage allocation of the various fruit and vegetable crops. The farms with a mixture of perennial crops (citrus, mangoes, coconuts, cashewnuts) and annual crops were omitted from the list to simplify the analysis. This left 40 farms which were growing annual crops only. Of these, 18 farms had electric and 22 had diesel tube-wells. From the list of each type, a sample of 10 was randomly selected for the actual survey, giving a total of 20 farms in all.

3.1.3. Data Collection

Having selected the sample and decided on the main parameters to be measured, it was necessary to consider the various ways in which such information might be obtained. The principal ways normally used by researchers for data collection are: A questionnaire approach, experimental method, observational method, or use of secondary data. The questionnaire approach may be by mail, telephone, or personal interview.

The personal interview may be self-administered or administered by an interviewer. On the other hand experimental data collection involves setting experiments in the field and controlling all the variables under the study so that the effect of one factor on the others can be tested. Certain variables may be measured before and after the experiment. The observational method of data collection involves the researcher going into the field and observing how the various activities are carried out and recording the necessary parameters, while the use of secondary data involves collection from documents (official or unofficial), tapes, pictures and microfilms.

Experimental data collection was not used because of the limited time and lack of financial resources. Instead use was made of a combination of the remaining three methods. Apart from the sample being the main source of data, some information was obtained from secondary sources, mainly from the Mombasa District Agricultural Office and the Market Manager's office at the Mwembe Tayari Auction Ring in Mombasa. Some data were obtained through personal conversation with the market foodstuffs middlemen. Technical data on husbandry practices relating to the production of various vegetables and fruits were obtained from the farmers' own estimates and were cross-checked with those in farm management District guidelines. Data on farm inputs were obtained from the farmers through the questionnaire. The prices of various farm inputs were obtained from the Kenya Farmers Association Stores in Mombasa as these are the main stockists for most of the farm inputs. Data on cost of digging wells in the area were obtained from local Arab Contractors. The prices of various sizes of pumps, engines, and electric motors were obtained from the Wiggles-worth Company in Mombasa and cross-checked with those of the Machinery Service Company, Mombasa, for consistency. Data on costs of farm electrification were obtained from the East African Power and Lighting Company, and the prices of various agricultural commodities were obtained from the Horticultural Crops Development Authority (HCDA) weekly market survey reports. These prices were cross-checked with the Market Manager's daily records for consistency. Personal observation and conversations with the farmers and the fruit and vegetable wholesalers at Mwembe Tayari Auction Ring during the period of the study also proved helpful to the author in gauging the likely magnitude of the seasonal fluctuations of fruit and vegetable prices resulting from supply and demand forces.

3.2. Technique of Analysis

Two types of analysis techniques are employed in the empirical chapters. The first one is budgeting dealing with the analysis of gross margins while the second is financial appraisal of the tube-well projects using conventional appraisal methods. In Chapter VII an average tube-well farm is synthesized using data gathered from the 20 sample farms. This was supplemented by data from other sources. The chapter details all the costs of operation of the various farm enterprises. The figures used in the budgetary and financial analyses represent a simple average of the farms studied. This synthetic farm type is believed to be sufficiently representative of the farms in the area to function in a useful analytical role. The technical unit of accounting is the acre*.

3.2.1. Budgeting

Budgeting is a method of comparing alternative economic organizations to determine and account for their relative profitability. The technique, as used in this analysis (Chapter VII), combines the components of cost and revenue for a given organization to produce a gross margin which represents the remainder of Total Revenue less Total Variable Costs. If done for a whole farm organization, the technique is termed complete budgeting but if done for a section of the farm organization it is called partial budgeting.

Although budgeting is a useful tool for choosing between enterprises, factor combinations, and technologies, and for demonstrating their comparative profitability, the technique will not automatically identify optimal levels of operation (Sturrock, 1967). In fact no attempt is made in this analysis to identify such a level, instead emphasis is focused entirely upon present organization, the economic effects of the organization, and ultimately upon policy.

The methodology of budget analysis requires that the assumption of fixed factor proportionality be made. This assumption

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* Most farmers in the rural areas have not yet gone fully metric. Thus they tend to think of the various indicators on a per acre basis, e.g. tons of manure per acre, bags of fertilizer per acre, kilograms of seed per acre, etc. The author therefore used the acre as the technical unit of accounting for convenience.

implies that over the relevant range of activity a straight-line cost function exists. Such a function presumes perfect divisibility to exist with respect to the variable inputs - that is to say there is no change in efficiency with which the inputs combine at different levels of activity. Another budgeting assumption is that of linearity of the production function. This assumption of linearity implies that all costs (other than fixed) rise in the same proportion as the quantity of output produced, if management is combining these inputs optimally. However beyond some output level - say the limit of pump capacity, expansion is impossible due to the restriction on the capacities of fixed items.

3.2.2. Financial and Economic Analyses

The gross margin analysis of all the enterprises is used to calculate the total variable costs, and these, together with the synthesized total fixed costs and total revenue per year, will form the analytical framework for the financial analysis developed (Chapter VIII). For both diesel and electric tubewells, the level of production inputs used and yield estimates are assumed to be the same and the only difference is in the cost of water.

Financial and economic analyses are techniques of appraising and evaluating projects to determine their financial or economic viability (Gittinger, 1972). Both techniques are similar in that they compare the stream of investment and production costs of the projects with the flow of benefits. However economic analysis goes further to examine the project from the standpoint of its worth to the economy or to society as a whole. On the other hand financial analysis considers the profitability of the project to the individuals or groups of people who supply capital or have enterprise interest in the project.

From this it can be said that while economic analysis is suited for public projects, financial analysis is more meaningful for private projects such as the tube-wells in this study. Financial analysis, like economic analysis, applies the discounted cash-flow methodology, but it is set-up in such a way that the elements included in the cost and benefit streams provide results that measure the return to the equity capital contributed to the project by each of the various participants - the public, corporations, or private individuals. Gittinger (1972) suggests that the use of financial analysis should not necessarily be limited to private projects, but may be applied to the costs and returns of various public entities which participate in a project. An example of such public entities is Kenya's Agricultural Finance Corporation which handles small-scale farmers' credit on behalf of the Government. Such a credit agency would be a failure as a development activity if it could not recover the funds it lends to farmers. Financial analysis must therefore be done to evaluate public - assisted projects. Financial analysis is also important when we consider the incentives associated with a proposed project investment. It would be useless to have a project which is profitable from the standpoint of the whole economy if individual farmers are unable to earn a living from their participation in that project. Timing of the returns, which the financial analysis clearly reveals, is important for individual farmers. A project which has no returns for the first five years would be useless for the individual farmer unless he has an alternative way for livelihood and the present values of future returns can warrant waiting. Financial analysis uses market prices which may include taxes and subsidies.

The market prices of farm inputs may include subsidies which are automatically accounted for as benefits to the project, but on the other hand the project may pay taxes, which are treated as a cost to the project. Adjustment for such effects would be made in an economic analysis. It is clear from the above explanation that financial analysis of a project deals primarily with the revenue - earning considerations of a project as viewed by participants. It is concerned with whether the project will be able to secure the funds it will need and be able to repay these and indeed whether the project can be considered financially viable.

3.3. Assumptions and Limitations of the Data

Mombasa District was one of the last among the medium and high potential districts to embark on the recently-introduced farm record system programme in Kenya. Therefore hardly any farmers in the area were keeping meaningful farm records at the time this study was undertaken. The author had to rely heavily on the farmers' faint memories concerning the quantities of farm inputs and prices. In some cases there was an element of inflated input levels, a fact which tended to result in over-estimation of costs. However, since the author had the advantage of having worked in the study area as a farm management extension officer, it was easier to detect such mistakes and correct the farmers in cases where there was an overestimate of inputs and output.

One major assumption made in this study is that irrigation intensity does not change appreciably with season. A constant irrigation intensity was therefore assumed throughout the year. This assumption is not strictly correct as some farmers reported that they pumped water at different rates in the dry season and in the wet season. Some farmers however continued with a full rate of irrigation even during the long rains. Even those who reduced the irrigation intensity during the long rains could not remember how often they irrigated the crops. For simplicity in calculation, a constant irrigation intensity has therefore been assumed. In view of this assumption, the diesel, oil, and electricity consumption during the long rains might be overestimated. An assumption was also made that the irrigation intensity was optimal. The yield data were estimated from either the farmers' guesses or the author's rough estimates after inspecting the crop stand. Moreover, constant repair prices were assumed over the project life. This is not realistic because repair and maintenance costs increase as the pumps become old.

Most farmers indicated that the cropping pattern and cropping intensity varied with the seasonal fluctuation of prices and/or other factors. However, for convenience in the computation of benefit and cost streams, a constant cropping pattern and intensity was assumed. It was further assumed that markets were available and that farmers were able to sell all their farm produce daily irrespective of whether the market was flooded. This was not the case, especially during the rainy season when the Mombasa Market was flooded with supplies from up-country and from the other East African partner States, mainly Tanzania. During this season some farmers had losses of well over 20 percent* on some days due to lack of a market. Such a loss was not taken into account in the computation of gross revenue. Many farmers also complained of theft of a considerable amount of farm produce.

Clearly, the foregoing assumptions and limitations do affect the validity of the study. They should therefore be borne in mind when interpreting the results.

* This figure is just a rough guess by the author. Some farmers are able to organise reliable markets and therefore do not experience this problem. It was not possible to estimate the amount of farm produce stolen by thieves and/or sold illegally by the farm workers. Many farmers particularly experienced heavy losses from bananas.

CHAPTER IV

LITERATURE REVIEW

4.1. Technical Aspects of Irrigation

4.1.1. Introduction

Irrigation is the artificial application of water to crops, either to supplement or to replace rainfall, and thus to assist in creating optimum conditions for high yields (Cantor, 1967). Water for irrigation is obtained from two general sources: Surface water and groundwater. Surface water occurs usually in the form of rivers, streams, and lakes and may be made available for irrigation by simple diversion of the streams or rivers or by using pumping equipment. Groundwater occurs below the surface of the ground in a zone in which permeable rocks are saturated with water under hyddrostatic pressure. The upper surface of this zone is called the water table. Irrigation using groundwater involves pumping from a depth of a few meters to several hundred meters except where Artesian wells exist. This source of irrigation water in most areas requires a source of power, which may be manual or by animal or mechanical means.

4.1.2. Agronomic Relationships and Plant-Water Requirements

Plants require water for growth. Water is transpired by the leaves throughout the day. The water is drawn up by roots and passed out as water vapour by leaves. This evaporation helps the leaves to remain cool. Besides the transpiration of plants, the soil also loses moisture by evaporation from its surface. The sum of these two losses of moisture from the soil is called evapotranspiration (ET) (Thorne and Peterson, 1949).

Quite recently, much to the surprise of irrigation engineers and farmers accustomed to thinking in terms of each crop having its own water requirement, an important conclusion of research in science by Penman has established the theorem, based on the simple laws of physics, that maximum water requirements for all crops must be about the same if the crops are grown on the same soil types, under the same conditions of temperature, sunshine, humidity and wind velocity, and for the same growing season (Clark, 1967). This maximum ET of green crops grown under the same climatic conditions is called potential evapotranspiration (PET) and is dependent only on the weather conditions and not on the nature of crops being grown (Thorne and Peterson, 1949). In general the PET of a field with plentiful moisture and fully covered by a green crop cannot exceed the evaporation from an extensive body of water exposed to the same weather conditions. This result permits estimates to be made of the daily water requirement to offset PET of all or any crop from climatological data. Methods have been developed for using standard weather data to estimate the irrigation needs of a crop. Such methods do not, however, take into account the possibility tbat some plants may respond to irrigation only at particular stages of growth and may tolerate very dry soil conditions at other stages.

This important finding by Penman has led to the drastic revision of all previous ideas about the economics of irrigation (Clark, 1967). Irrigating a given area at a given time of the year will use up the same amount of water almost irrespective of the crop which is being grown. Irrigators therefore should always be growing the crop which at that time of the year, and at the prices then prevailing, yields highest economic return per unit of area and per unit of time. It is important to note, however, that not all crops transpire the same amount of water per unit area over their life cycle. Different crops may have different growing seasons during which climatological conditions and hence ET may differ. Furthermore, even crops with the same growing season and thus subject to the same weather conditions may take different lengths of time to reach full leaf cover. Crops which establish a leaf canopy early have been found to utilize irrigation water more efficiently.

4.1.3. Soil - Moisture Relationship

One of the most important factors determining proper irrigation practices is the character of the soil being irrigated. In general the texture, structure, and porosity of soil determine its water-retaining and transmitting capacity (Thorne and Peterson, 1949). In turn these two capacities, together with the crop and depth of the root zone, largely govern the method of irrigation, the frequency of application, and the quantity of water that should be applied at each irrigation. The water-retaining capacity of soil, for the purpose of irrigation, is expressed as depth of water held in a given depth of soil. This is expressed in inches depth of water per foot depth of soil or millimeters of water per centimeter depth of soil.

When soil is thoroughly watered, some of the water, under the influence of gravity, drains into the lower levels and is replaced by air from the surface. When drainage virtually ceases usually after two to four days, the soil is said to be at field capacity. The roots of crops obtain water from the film of water held around the soil particles by surface tension. As this film becomes thinner and thinner, the roots find it increasingly difficult to take in water. When the roots can no longer take up water sufficiently rapidly to remain turgid, transpiration ceases and the plant wilts. The soil is said to be at the permanent wilting point. In a given soil all ordinary plants wilt permanently at the same moisture content (Thorne and Peterson, 1949). Field capacity and permanent wilting points are the two important water-retaining capacities of soils as far as irrigation is concerned.

4.1.4. Soil Moisture - Plant-growth Relationships

In recent years a great deal of attention has been paid to the effect of soil moisture on plant growth. Research work in Israel and the United States has shown that field crops grow best when the available moisture in the soil is kept at a low suction*. As the amount of moisture is depleted, the tension increases and eventually the growth and yields of crops become affected. For most crops the reduction in yield becomes significant when the available moisture is below 50 percent for prolonged

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* When moisture in the soil is at a low suction it means that the soil has a high percentage of moisture and therefore cannot absorb any more.

periods. McGillivray (1953) quotes an example where Reutlinger and Seagraves, in a pioneering study on sandy soils in North Carolina, showed that yields of tobacco (a shallow rooting crop) fell more or less linearly from 2300 to 1500 kg per hectare in response to changes in "soil moisture deficiency" over the whole growing season.

4.1.5. Water Response Functions of Crops

The yield of a particular crop depends upon the average growth of the plant over the whole length of its growing season. In other words the average growth of a plant in any period is a function of the average level of available soil moisture in that period. So if Y is the yield of a crop in a particular year and X_1, ... X_n are the average levels of available soil moisture in periods 1 to n of the life of the crop, then Y = f(X1, X2, ... X_n). This is the normal production function (Deepack Lal, 1972).

Experiments at the Wellesbourne Vegetable Research Station in England (Winter, 1967) with a rainfall of 61 cm showed that the yield of peas ceases to increase after an additional 2½ cm input of water, but for cauliflower and potatoes it goes on increasing up to 69 and 74 cm total water input respectively. Carrunthers (1968) quotes some experiments in Pakistan which in fact show a low response to water of wheat. Work and Carew (1960) give results of experiments showing increases in yield due to irrigation as high as 200 percent. Irrigation experiments at Davis, California, show that yields of shallow-rooted crops may be increased several hundred percent while deep-rooted crops may be increased from a few percent up to 50 percent. The effect of irrigation on yield is directly related to the amount of water held in the soil reservoir until maximum yield is produced. Additional water will not increase the yield. The Institute of Agricultural Research, Hindu University, Varanasi, India, conducting experiments on water requirements of crops, found that average yields of different strains of cotton and sugarcane when plotted against the amount of water they consumed, gave a linear proportion between the amount of water consumed and the total produce, provided additional manure was used (Sally, 1968). It was therefore concluded that crop yields increase with irrigation water supply within a fixed range. Higher crop response to irrigation is realised with optimum application of other inputs like fertilizers and manure. Organic manures for example modify the soil structure so that it can hold more water and air for the extra benefit of a crop. Results of experiments performed in Madras, India, indicate that the use of fertilizers increased the yield of cotton by 34 percent over that without application of fertilizer or irrigation. Irrigation alone gave a 37 percent increase, and when both fertilizer and irrigation were applied, the yield increased by 114 percent, which is over 50 percent higher than the 71 percent cumulative effect of the fertilizers and irrigation taken separately. This was found to be true through similar experiments performed in the U.S.A., Israel, and Pakistan (Sally, 1968).

4.1.6. Frequency and Rate of Irrigation

Reliable information about when plants need specified amounts of water is required to permit scientific irrigation of crops.

Most crops have two or three periods of maximum water requirement - one during the seedling stage, another during the preflowering and flowering stage, and the third during the seed formation stage (MacGillivray, 1953). Young seedlings are particularly susceptible to water tension, and growth is retarded if they are subjected to high water tension. For efficiency in water use, farmers need to be able to determine the proper time for irrigation. MacGillivray (1953) gives two criteria for this purpose: "The soil becomes depleted of soil moisture which must be replenished. The soil also becomes unable to supply sufficient moisture for maximum growth and there is cessation of plant growth followed by other indications of insufficient water - a change in colour of foliage and perhaps wilting".

Experienced farmers in developed areas determine the need for irrigation by sampling the soil with an auger and determining the approximate wetness by colour or feel. Most soils change colour between the field capacity and permanent wilting point; usually the colour is darker at field capacity and becomes lighter in colour as the moisture content approaches the permanent wilting point. The colour of foliage becomes darkgreen, often almost bluish or grayish, as the supply of moisture becomes insufficient.

The quantity of water that should be applied at each irrigation and the frequency of irrigation depends on the soil type, the crop, and the weather. The soil storage capacity, the water already held in the soil, and the rate at which water is absorbed through the soil are the principal factors in determining the quantity of water that should be applied at each irrigation. Two important characteristics of the crop which affect the frequency and the rate of irrigation are the depth of the root system, and the stage of growth in the life cycle of the crop. The rate of transpiration will vary from practically nothing at the young seedling stage during cold, cloudy weather to a maximum during hot windy weather at the time when crops are growing luxuriantly.

Each crop has a certain, rather definite, rooting habit which it will tend to follow if the soil is uniform and deep enough and equally well-moistened. On the other hand, almost any crop will develop its major root zone in the most favourable environment with regard to both nutrients and soil moisture. Considerable data have been secured to show the depth at which different crops withdraw moisture from the soil*.

4.1.7. Water Quality as Affecting Crops and Soils

Many factors are involved in any appraisal of irrigation water. Among these are: The total quantity of dissolved salts, the particular constituents and their ratios, the characteristics of the soils and the crops to be irrigated, the irrigation practices, and the climate particularly temperature and humidity (Arnon, 1972). Many authorities agree that the suitability of water for irrigation purposes depends on the effects of its total

* These data have been gathered by the US Department of Interior Bureau of Reclamation and published by the Government Printing Office as Irrigation Advisers Guide - Washington D.C. 1951.

quantity of dissolved solids on the plant and the soil. Salts may harm plant growth physically by reducing transpiration through modification of osmotic processes, or chemically by their toxic constituents (Thorne and Peterson, 1949). Salts affect soils by changing their structure, permeability, and aeration and this indirectly affects plant growth. Soils, particularly fine textured ones, have the ability to absorb certain minerals from irrigation water. If irrigation water contains more sodium than it does calcium and magnesium, a tendency exists for this sodium to replace the calcium and magnesium already in the soil. The presence of excess sodium in the soil makes the soil less permeable, so the effect of irrigation water containing an excess of sodium is to tighten or seal-up the soil.

4.2. Socio - Economic Aspects of Irrigation

4.2.1. Cost of Irrigation

The vital role of irrigation in increasing food production and as an important starting point for overall economic development has been discussed earlier. In view of this important role, the development of water resources is frequently undertaken by governments. If all costs are included in pricing such water for agricultural purposes, farmers frequently cannot afford to pay for the water. Water is therefore frequently subsidized in one form or another. In developing countries the bulk of the available water is used for irrigation.

An economic evaluation of alternative uses of water shows that agriculture is far less productive in its uses of water than are other users(Cantor, 1972). The productivity value of water in industry is frequently 100 times or more as great as for agriculture (Arnon, 1972). In the San Juan basin in Calorado and New Mexico (U.S.A.), productivity of an acre-foot (1233 m^3) of water in irrigation was estimated at $8 to $18 as compared with $1200 to $3000 when used for industrial purposes (Clark, 1967).

However, factors other than the direct financial return per unit of water used have in the past been considered to justify the existence of some expensive water-development projects. As capital is one of the scarcest resources in a developing economy, it is essential that economic and financial evaluation and appraisal of irrigation projects be done to determine the return to the scarcest resource. Capital and operating costs of providing irrigation and the returns that can be expected under different conditions vary widely. The variable factors which influence costs include: (1) The type of water supply, (2) the size of the project, (3) whether the project is government-sponsored or privately-sponsored since this may have a bearing on the interest rates or other financing aspects, (4) the climate of the area and the type of crops grown.

Costs of water for irrigation are naturally dependent on the source of supply, being generally lowest when drawn by gravity from flowing streams or springs, higher when pumped from shallow wells and streams, and highest with water pumped from deep wells and reservoirs created by constructing large-scale dams. Thus for example, in the U.S.A., studies showed stream-flow cheapest, pumping from stream next, and pumping from wells highest (Clark, 1967). The generally-accepted belief that irrigation from groundwater supply is much more expensive than that from gravity-flow canals has however been disputed by Sally (1968). Table 4.1 shows his comparison of water costs for tube-wells and canals in India based on 1968 prices. It shows tube-wells cheaper than canals after making adjustments on the construction costs for canals.

Table 4.1 India: Comparative water costs for tube-wells and canals per acre of irrigation, 1968

Crop	Based on canals		Based on tube-wells		Ratio	Adjusted ratio
	water supplied	cost per acre	water supplied	cost per acre	tube-wells to canals	tube-wells to canals *
	Ft	Rupees	ft	Rupees		
Wheat	1.2	5.8	0.9	12.7	2.2	0.5
Cotton	2.00	6.8	1.4	19.8	2.9	0.7
Sugarcane	3.5	16.5	2.4	34.7	2.4	0.7
Oilseeds	1.0	6.4	0.7	9.9	1.6	0.4
Rice	4.0	9.8	2.8	39.6	4.0	1.0
Fodder	1.0	3.8	0.7	9.9	2.7	0.7
Food Grains	1.0	6.4	0.7	9.9	1.5	0.4
Vegetables	3.0	8.3	2.1	29.7	3.7	0.9

Source: Sally H.L. Irrigation planning for intensive Agriculture. Asian Publishing House, London, 1968.

* This is the ratio of tube-wells to canals after multiplying the rates for canals by four to adjust for inflation between the time the canals were constructed (1940's) and the time the tube-wells were bored (1960's).

A report by Gibb and Partners as quoted by Criddle (1961) about the Mwea Irrigation Scheme in Kenya indicated capital costs of K£145 per acre of irrigated rice by canal system (1961 prices). More recent (1970) expansion of this scheme has cost K£700 per acre. This is evidence that the adjustment in table 4.1. was conservative.

The Agro-Economic Research Centre, New Delhi, made case studies of the Bhakra-Sarda and Betwa projects in India in 1964 (Sally, 1968). They surveyed over 40 selected villages served by canal systems and found that irrigation water rates in the Punjab had increased by 50 percent over the pre-war level. In Uttar Pradesh canal water rates were found to have gone up by 3-4 times the pre-war level. The rates were found to be far above those of tube-well supply.

The second factor that influences the cost of irrigation water is the size of the project. Costs of water per m^3 from reservoirs tend to be lower for large-scale projects. Thus for example studies in Madras, India, showed costs of water, based on construction of dams, ranging from 6-9 cents* per m^3 for small dams to 0.7 cents for the largest dams (Clark, 1967). The cost of water whether from streams, reservoirs or wells depends on the capacity of the pumps and heights of pumping, being lower for bigger capacities and shallow depths as observed in tables 4.2 and 4.3.

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* This refers to the U.S Cent.

Table 4.2 California: Cost of groundwater (1953)

Depth meters	Pump capacity Gal/min	Cost per m^3 cents
50	300	2.7
50	1200	1.7
120	300	5.9
120	1200	3.5

Source: MacGillivray J.H. Vegetable Production
New York, 1953.

Table 4.3 West Pakistan: Cost of pumping at various depths (1966)

Depth	Large Pump		Smaller pump	
	Capacity per hr	Fuel costs per m^3	Capacity per hr	Fuel costs per m^3
m	m^3	cents	m^3	cents
6	204	0.10	128	0.08
8	183	.11	99	.10
10	165	.12	90	.11
12	153	.13	78	.13
14	126	.16	66	.15
16	102	.19	51	.19
18	72	.27	33	.30
20	36	.55	9	1.1

Source: Compiled by Ghulam as quoted in Clark C. Economics of Irrigation, London - New York - Pergamon Press, 1967.

It is interesting to note that costs are lower for smaller pumps up to a depth of about 16m but apparently are much higher at depths of 20m or more. In general a diesel pump will use 0.45 kg (or 0.53 litres)of diesel per Hp per hour when raising water from 12m.

Although theoretically the cash costs should be the same regardless of who sponsors an irrigation project, government-sponsored projectshave been found to be more expensive than private projects, perhaps because only governments are willing to undertake those that are costly in both total and per m^3 terms (Clark, 1967). There appears to be substantial dis-economies of scale in government tube-well projects. In India and Pakistan - the well, powerline, and drainage all cost more per m^3/hr as the project is enlarged. This may be explained by the large overhead costs involved and the often poor water distribution and management problems encountered in such government projects. Ghulam as quoted by Clark (1967) gives costs figures seven times higher for large-scale government projects pumping 400 m^3/hr. compared to a small electric project pumping 102 m^3/hr.

Moorti and Mellor (1969) did a comparative study of costs and benefits of irrigation from State and private tube-wells in Uttah Pradesh and found that the initial investment, besides electricity transmission for State tube-well, was about 15 times the investment for a private tube-well despite the fact that the discharge of the State tube-well was only twice that of the private tube-well. The cost of water worked out to Rupees

33/1000 m^3 for State tube-wells and Rupees 22/1000 m^3 for private tube-wells. They also found that private tube-wells offered greater availability and reliability of water supply than State tube-wells, which was reflected in the higher cropping pattern and cropping intensity in the private tube-well farms. The study revealed that for almost all crops, the gross returns per hectare was higher on the private tube-well farms relative to farms irrigated by the State tube-well. Ghulam (see Clark, 1967) tries to explain this finding by stating: "When a farmer saves or borrows 6,000 - 12,000 rupees and installs a tube-well, his whole outlook on agriculture changes and he starts to view it as a business. He wants to grow more valuable crops, to apply fertilizers, and to use other modern inputs to increase his income".

The climate of an area and also the type of crops grown in an irrigation project have a bearing on the irrigation costs and benefits. In heavy rainfall areas a few acre-inches of irrigation may be enough to supplement the rainfall whereas in dry areas plant water requirement is met through full irrigation. Table 4.4 shows irrigation costs in high and low rainfall areas by electric and diesel pumps. The table shows both the capital and operating costs for both types of pumps higher in low rainfall areas with greater water table depths than in high rainfall areas. Costs for electric pumps are however lower than those of diesel pumps in both climatic zones.

Table 4.4 West Pakistan: Irrigation costs in high and low rainfall areas by electric versus diesel pumps 1963/64.

Degree of rainfall and type of pump	Depth of water table	Annual water output*	Capital costs	Annual costs per m^3	
				Fuel only	Total
	m	1,000 m^3	1,000R	Cents	Cents
Higher rainfall:					
Electric	3	236	5.4	0.17	0.29
Diesel		304	8.5	0.20	0.39
Low rainfall:					
Electric	7½	266	8.8	0.20	0.37
Diesel		317	12.0	0.25	0.47

Source: Compiled by Ghulam as quoted in Clark C. Economics of irrigation, London - New York - Pergamon Press, 1967.

Similar results were found by Moorti and Mellor (1969) in Varanasi, Uttar Prandesh, India where the running costs per ha for electric tube-wells were 40-45 percent less than those of diesel tube-wells.

In countries with a high level of agricultural production, linear programming has been used to calculate the amount of water that it is economical to apply at various price levels for water. In California for example it was found that at 1967

* Pumps averaged 2350 hr. per year at 115 m^3/hr.

farm prices, the critical price of water was 1.3 cents per m^3 of water for small farms and 1.6 cents for large farms (Clark, 1967). In the Neger of Israel, a range of 5.0 to 7.2 cents per m^3 was considered to be the marginal value product of water in field crops. The marginal productivity of irrigation water in Senapur, Ganges Valley of India was estimated by production functions at 1.7 U.S cents per m^3 during the same time period.

4.2.2. Income and Welfare Aspects of Irrigation

The benefits that accrue from irrigation are direct incomes resulting from increased crop yields and quality or may be indirect benefits resulting from increased employment, insurance against famine and reducing population pressure.

An economic analysis of alternative tube-well irrigation projects in Nadia District, West Bengal (Maji, and Sirohi, 1969) showed a benefit-cost ratio of 2.75 for deep tube-wells and 1.87 for shallow tube-wells at a 12-percent discount rate, and an internal rate of economic return of 34 percent for deep tube-wells and over 50 percent for shallow tube-wells.

In another financial analysis done for electrically operated deep tube-wells in Illambazar, West Bengal, a big difference was found in the cropping pattern between irrigated and unirrigated areas. As many as ten different types of crops, including some high-yielding varieties, were grown in the irrigated area as compared to a single crop in the unirrigated area. The intensity of cropping in the irrigated area was 157 percent as compared to 100 percent in the unirrigated area. The benefit-cost ratios for this system were quite high, as shown in table 4.5.

Table 4.5 Illambazar, West Bengal: Benefit-cost Ratios for Electrically-operated Deep Tube-wells.

Interest rate	Cost per unit of electricity			
	12 phase		18 phase	
	Daily pumping hours		Daily pumping hours	
	8	16	8	16
Percent				
5	3.0	3.7	2.6	3.2
7½	2.3	3.2	2.1	2.8
10	2.1	3.0	1.9	2.6

Source: Maji C.C. and Sirohi A.S. A case study of Financial feasibility of Deep Electrical Tube-wells, West Bengal, Indian Journal of Agricultural Economics Vol. XXVlll, No.4, 1969.

It may be observed that the lowest benefit-cost ratio is nearly 2. This indicates the high profitability of the energized deep tube-wells under study even when used only 8 hours per day and at the highest rate of interest and price of electricity tested.

In another benefit-cost analysis, private tube-well projects in Kalyanpur Block, District Kanpur, West Bengal, the intensity of cropping for the tube-well farms increased 54 percent over the unirrigated farms. The employment of human labour per ha increased from 100 days before tube-well irrigation to 149 days after irrigation. This increase in labour demand was the cumulative effect of cropping pattern, intensity of cropping, and adoption of high yielding varieties of crops as a result of availability of assured water (Maji and Sirohi, 1969).

Although the economic and financial aspects of any investment must be considered carefully before a final decision is taken, many Governments in recent years have found themselves compelled to embark, for social and other non-technical reasons, on both large-scale and small-scale irrigation schemes which may not have appeared stictly economic in bankability terms.

Irrigated land can support a larger population than unirrigated land. For instance Mwea irrigation scheme in Kenya supports a population of 2944 persons per square Kilometer and the peasants are reported to have a higher standard of living than most others in the rest of the country (Moris and Chambers, 1975). Population absorption and employment generation have been and are likely to remain major objectives of settlement projects in Tropical Africa. One of the major recommendations to the Kenya Government of a Parliamentary Select Committee on unemployment in 1970 was an urgent expansion of irrigation. The International Labour Office mission which visited Kenya in 1972 quoted National Irrigation Board figures of four jobs created by every hectare of land irrigated (UNDP/ILO team, 1972). In 1964, the number of days worked annually on the Mwea rice irrigation scheme by both family and hired labour averaged 220 man-days per acre of paddy. On 24 peasant farms of between 4 and 8 acres in neighbouring Nyeri District, average labour input was 76 man-days per acre. By 1971 there were 19,000 people supported by the Mwea irrigation scheme of 10,652 acres. This was a man-land ratio of 1.8. A linear programming study in Pakistan revealed that the provision of irrigation water on a small farm of given area has a highly significant effect in increasing both the demand for labour and its marginal productivity (Clark, 1967).

The amount of water for which a farmer can find renumerative use depends on the price of his products and the inputs, and also the cost of obtaining the water, which normally differs from country to country and even from District to District. Even where the economic and financial feasibility of irrigation has been accurately confirmed, there is a need for frequent re-evaluation and re-appraisal as changes in prices of the main investment items and farm inputs and of farm produce occur. Superior technology may also improve the yields and quality of the crops and this should be taken into account.

CHAPTER V

IRRIGATION FARMING IN MOMBASA DISTRICT

5.1. Crop-Water Requirement

Basic water requirement data for Kenya is limited. However Pereira and his associates at EAAFRO* - Muguga and the National Agricultural Laboratories in Nairobi have made considerable progress towards assembling these data (Criddle, 1964). They have found little variation in potential water requirements of crops. This is explained by the relatively uniform temperatures and lengths of day-light throughout the year in Kenya. The differences in temperatures and humidity from the Coast to the hinterland counteract the effect of elevation on crop-water requirement.

These findings also agree with recent theories by Penman who changed all the previous ideas of each crop having its own water requirement. As noted previously, he has proposed that all crops have the same water requirement if they are grown under similar conditions of solar radiation, sunshine hours, air temperature, and humidity and have the same growing period.

5.2. Methods of Irrigation Practised in Mombasa District

For economical and efficient distribution of irrigation water the operator must at all times have complete control of the water as it flows from the head ditch onto the land. This is

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* East African Agricultural and Forestry Research Organization.

true, whatever method of irrigation is used. When uncontrolled streams of water are turned into the fields, waste, inefficiency, and uneven distribution are almost certain to result. This can be averted by the use of relatively simple equipment which provides a means of distribution and control of water. Irrigation water is applied to land by three general methods namely:

(1) Surface application by flooding.

(2) Sub-surface or with furrows in which the surface is wetted little if any.

(3) Sprinkling, in which the soil surface is wetted as much as it is by rainfall.

The surface and sub-surface methods are further subdivided as follows:

(a) Surface application:

(i) Uncontrolled or wild flooding.

(ii) Flooding controlled with corrugations, borders, and basins.

(iii) Furrows.

(b) Sub-surface application:

(i) Controlled by lateral supply ditches.

(ii) Uncontrolled irrigation through excess application of water to adjacent or higher lands.

Irrigation methods vary in different parts of the country and even on different farms within a community because of differences in soil topography, water supply, the crops grown, and the custom. Close-growing crops such as lucerne, clover, and pastures are normally irrigated by use of borders and basins.

Forages and some vegetable crops are all suited to flood irrigation by borders and basins. Row crops generally are irrigated by furrows. Any one or a combination of several methods may be best suited to one farm. Although sprinkler irrigation is used by a few farmers whose farms are very uneven, the most widespread method of irrigation in Mombasa is by flooding, especially basin flooding and furrow irrigation. The soils are not particularly suited for this method of irrigation because they are mainly wind-blown sands. Sandy soils usually have too high an intake of water. In view of this they are best irrigated by over-head means, but this method is far more expensive than flood irrigation. The essential requirements for flood irrigation are sufficiently smooth land of very gentle gradient, preferably flat (Turk, 1960). Where flood irrigation is being carried out there must be complete control of the water and the farmer must know the amount of water his layout is capable of applying. Uncontrolled irrigation leads to overwatering, inefficient water-use, and hence poor crop returns.

Flood irrigation is generally the simplest and cheapest method of applying water. However it has its own disadvantages in that it requires constant attention as regards maintaining levels and smoothness. More skilled labour is required to apply water evenly and to avoid waste through excessive runoff than for most other methods. The canals require constant cleaning and maintenance. The one great advantage of a flood scheme is that it is very flexible. If necessary it can be adjusted easily by enlarging the volume of water to increase the acreage irrigated or to irrigate the lands more quickly than originally designed.

Row or furrow irrigation is probably the cheapest method of obtaining efficient irrigation. It is suitable only for crops which can be planted in rows sufficiently far apart to allow furrows to be made between the rows. Each row may have a furrow serving it, or where the rows are fairly close together, one furrow may serve two rows of plants. Irrigation water is run between the crop rows. The size of the stream is varied according to the gradient and soil texture. For flat gradients, long runs, and sandy soils, large flows of water 0.01 to 0.03 cusecs* are used (Turk, 1960). In any case the ideal stream is of such a size as to run to the end of the furrow with inflow just equalling the infiltration in the furrow. Row irrigation is the most common method used to irrigate the banana crop in Mombasa, for example.

Basin flooding is widely used in irrigating fruit trees and vegetables on flat topography. Basins are flat areas surrounded by low ridges or dikes. They may be square, rectangular, or irregular in shape and may vary in size from 6 ft^2 to an acre depending on the soil texture and the size of the irrigating stream. The more porous and sandy the soil is and the smaller the irrigating stream, the smaller should be the basin for efficient irrigation. Where vegetables are irrigated, each basin

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* Cusecs means cubic feet per second and 0.01 to 0.03 is equivalent to 3.75 to 11.25 gallons per minute.

is made and levelled independently of the others. The basins are filled with water to a depth of 2 to 6 inches depending on the soil type and the crop. Sandy soils require more water because the infiltration rate is higher.

Water from the source is led through the main canal, the size of which depends on the size of flow and the size of the irrigating system. From the main canal the water is diverted into an intricate canal system which distributes it throughout the farm. The most common means by which this is done is with open ditches or laterals. The ditches are generally permanent features and commonly follow boundary lines, fences, and edge of fields. They are frequently earth ditches which may suffer from excessive losses owing to seepage and evaporation, especially in arid regions or in areas of porous or sandy soils. Leading from the permanent open ditches are the field ditches which may or may not be ploughed in at the end of the growing season. Water is delivered through the field ditches by means of check structures or turnouts. They usually consist of metal or wooden fixtures, though they may be merely gaps cut in the ditch bank. From the field ditches water is led into supply ditches and finally into individual basins one at a time by cutting a gap in the levees surrounding the basins. This method of irrigation does not allow heavy mechanization. It requires much human labour with a high degree of skill for adjusting the flow of water to avoid over-watering or under-watering.

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5.3. Sources of Irrigation Water

The major source of irrigation water in the Coast Province is surface water in the form of rivers and streams. The other source is groundwater which has not been fully exploited to date.

5.3.1. Surface Water

The largest river in the Coast Province is the Tana River which rises in the southern slopes of Mount Kenya and flows into the Indian Ocean. The minimum flow of this river at Garissa (where it enters Coast Province) is estimated to be 1.8 million acre feet* per year or 56 percent of the mean annual flow of 3.3 million acre feet (Criddle, 1964). Except for minor uses upstream, present stream uses are limited to about 5,000 acre feet annually at Galole, and small flood benefits to numerous villages along the lower Tana. Such villages include Wema, Hewani, Oda, and Ngao, all of which have recently been taken over by the Ministry of Agriculture as part of the Minor Irrigation Scheme Development programme. Practically, however, all water of the Tana River flows unused to the sea.

With control of the river, a large part of the flow could be put to beneficial use. According to Gibb's report as quoted by Criddle (1964), about 370,000 acre feet would need to be diverted annually for irrigation of some 93,000 acres above the

* An acre-foot (43,560 gallons) is the amount of water required to cover one acre of land flooded to a depth of one foot.

Seven Forks dam. It was also estimated that even in a low-water year the net available water in the lower Tana should be 1.7 million acre feet, sufficient to irrigate not less than 300,000 acres of highly productive land along the river.

Athi-Galana River, which is the second largest stream, has its headwaters north and south of Nairobi* and runs through the Coast Province into the Indian Ocean. The river runs through arid portions of the area and receives water from much of the catchment only during and following heavy rainstorms. In the dry season, the flow of the river generally drops to some 20 cusecs or less near the mouth. The flood waters could be stored and used to irrigate several thousand acres of good land adjoining the river a few miles upstream from its mouth.

Umba River is a relatively small stream heading in the Kasigao mountain and running southward, reaching the Indian Ocean at Vanga near the Kenya-Tanzania border. At present several small diversions from natural flow are made from the river for the irrigation of rice fields north of Vanga. With its minimum flow of 50 cusecs, this river could be used to irrigate over 3,000 acres of land of suitable quality and topography available a few miles upstream. However, as has been said in an earlier chapter, the development and utilization of these waters for irrigation purpose is expensive, running from £500 to £800 per ha at present-day costs. Their development would require

* The Nairobi and Ruiru Rivers from the north of Nairobi join the Athi River from the southern hills at Ol Doinyo Sapuk in Machakos District.

the sustained investment of substantial foreign financial and manpower resources over several years.

5.3.2. Groundwater Source

All the minor irrigation projects in Mombasa District are based on groundwater supplies, but such resources of the Coast Province and the country as a whole have not been fully exploited. Evidence suggests vast resources which could be used to open up the arid areas or supplement rainfall where no surface water exists. A large proportion of the water in Coast Province is obtained from boreholes and open wells. Most of these pumping schemes are developed initially for domestic requirements which help to justify the high costs usually incurred in projects of this nature where the acreages irrigated are relatively small compared to canal irrigation. Occasionally the quantity of water available is considerable and a reasonable acreage can be irrigated. Pumping from boreholes and wells is always a matter to be watched, as the tendency is to pump in excess of the rate of natural replenishment. Usually it is not advisable to pump at more than 60 percent of the tested capacity (Turk, 1960).

Undue lowering of groundwater results in higher pumping lifts and sometimes prohibitive pumping costs. Wells may need to be deepened and pumps lowered in order to obtain sufficient quantities of water. The extent of irrigation pumping from groundwater supplies should therefore be determined on the basis of thorough, long-time investigations of the quantity of annual inflow or re-charge to groundwater streams, basins, or reservoirs. Essential decisions concerning development of groundwater supplies for irrigation should, according to Israelson and Hansen (1962), be based on:

(1) The availability, quality, and depth of water.

(2) The trend of the water table - whether it is stable, rising, or declining and whether the development of groundwater is likely to bring about withdrawals of water seriously in excess of the natural recharge.

(3) Legal or natural protection of groundwaters against excessive depletion.

(4) Cost of operation, i.e. whether the prospective production under irrigation will bring enough returns to pay the increased costs of irrigation farming.

(5) Land requirements - whether the land is physically suitable for irrigation from the standpoint of contour, productivity, crop suitability, and water - holding ability.

5.3.3. Advantages and Disadvantages of Using Groundwater

The advantages of using groundwater are numerous. It is often available at or near the point of use and consequently does not require a complex distribution network. Although it is generally considered more expensive than direct river diversion, this method frequently is considerably cheaper than surface storage of water by dams and is usually easier to develop. There is less fluctuation in supply than may be the case with stream flow. Groundwater also tends to be freer from a soluble mineral load than surface water. It is particularly suited in regions for which surface waters are adequate for irrigating only relatively small areas, for areas isolated from streams, and for providing stand-by or supplemental facilities. In arid areas where no perennial rivers flow, as in a large portion of Coast Province, the development of groundwater resources may be the only practical solution to the problems of water supply. Furthermore, since groundwater is available in controlled quantities, its use for irrigation purposes forms an effective anti-waterlogging measure.

The use of groundwater is not without its problems, however. Sometimes it is available only at an excessive depth or in inadequate quantities. Occasionally it may be of poor quality because, although usually unpolluted and relatively free of sediment, it is often highly mineralised. In some circumstances it may prove more expensive than surface water because it requires expenditure of energy for pumping while surface waters can flow by gravity or, at times, even be used to produce energy. Most important is the fact that there is a finite amount of groundwater available in any one area, so that if extraction exceeds infiltration, the reserve of water accumulated over prior years will sooner or later become exhausted.

5.4. <u>Hydrogeology and Groundwater Potential of Coast Province</u>

Gregory (1921) as quoted by Gentle (1968) was the first to attempt to relate the geology of the Coast Province to its groundwater resources. He showed how rainfall is related to runoff, evaporation, and groundwater re-charge. By exploratory drilling he discovered some freshwater wells very near the seashore. He explained this by saying that the sea floor is permeable and therefore fresh water wells can occur near the shore by virtue of the fact that fresh water floats on the salt water.

Supporting Gregory's report, Sikes (1932) wrote, "there are aquifers that transmit potable water through the Pleistocene coral limestone and coral breccia. This water floats on top of the sea water which penetrates through the sands, sandstones and sandy shales on which the coral rests. Wells on the Coastal Strip, where the catchments are suitable, sometimes strike the aquifers carrying this water, but wells sunk at random frequently miss them and reach salt water which had percolated from the sea". The report by Sikes further shows that this fresh water is usually only a shallow layer on top of the sea water, and overpumping or deepening such wells may result in an increase in salinity by admixture with the underlying salt water.

Miles (1951), as quoted by Gentle (1968), carried out a survey in the Likoni area of Mombasa and showed that a high-level fresh water-table feeds the water-table in the coral formation. He concluded that a continous removal rate of 500,000 gal. per day could be maintained from an area of 550 acres even during the dry season without detrimental effect on groundwater supply or its quality. This suggests a good recharge of groundwater to this area which had formerly been classified by Sikes as a marginal area of groundwater resources.

Gentle (1968) reports that abstraction of water from the north mainland up to Mtwapa totals 1.1 million gal. per day.

Analysis of two wells in this area showed that water of good quality at high rates of pumping is available. He concludes that careful siting of wells, using resistivity technique*, should make it possible to obtain more good quality water. In the southern parts of Mombasa, a total of 2.6 million gal. per day was extracted from a group of 13 tube-wells during Gentle's hydro-geological survey. This gave an average yield of 200,000 gal. per tube-well. Thus high rates of pumping likely can be maintained in the Southern Coastal plain. Figure I shows the distribution of high, medium, and low-yielding wells in Coast Province.

Research done between 1930 and 1968 has laid a useful foundation both relating to the physical aspects of dams and tube-wells and to groundwater availability and quality which should greatly facilitate the planning and implementation of future groundwater development projects. However it must be pointed out again that groundwater resources have not yet been explored fully and the total potential is still not known.

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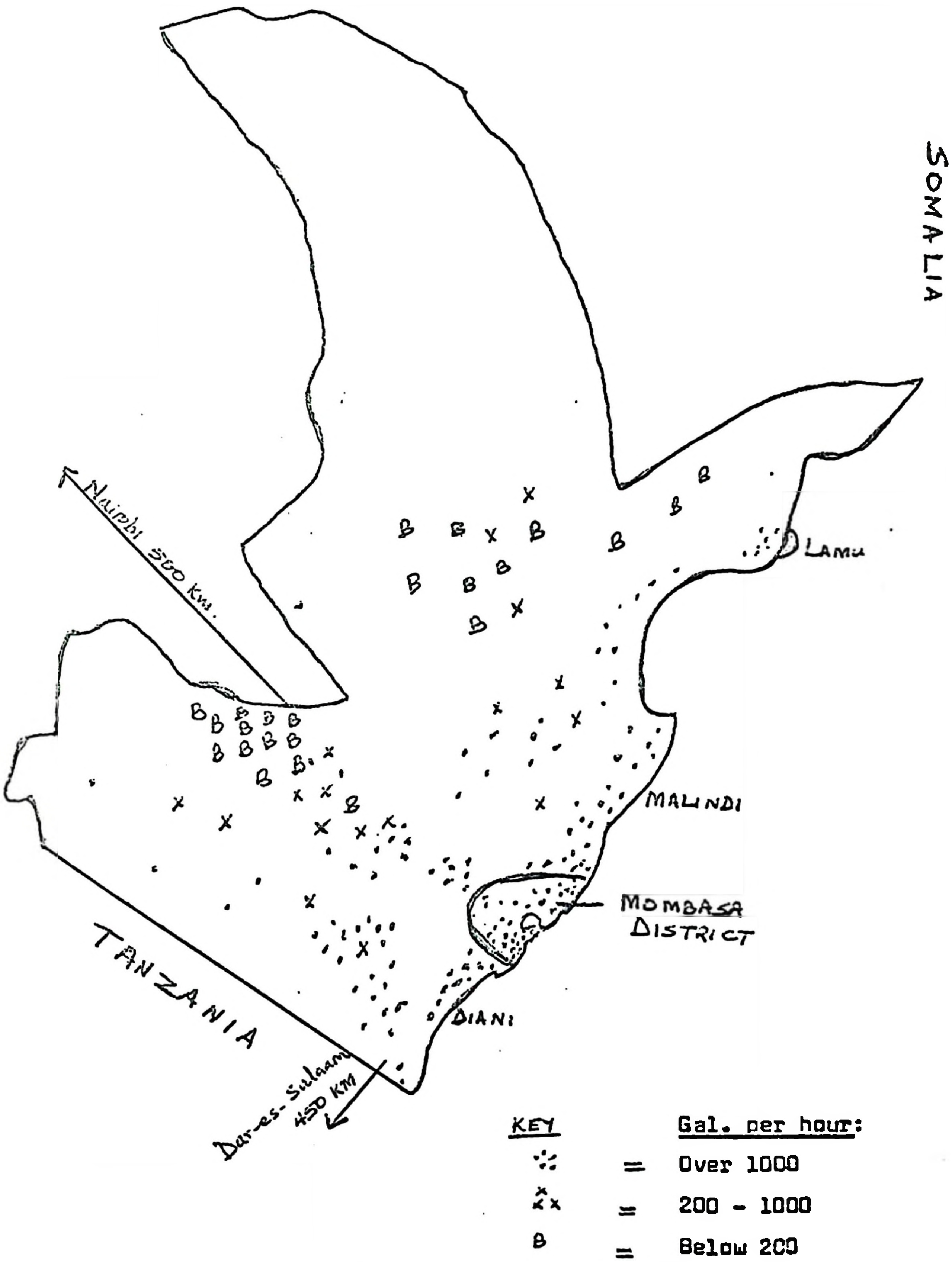
* This technique is based on the fact that electric conductivities of various rock types are poor, though they are, in fact, perfect insulators when quite dry. Their resistivity is a function of the nature of the rock material itself, percentage of moisture content in the materials, and chemical properties and ionisation factors of the soluble salts in the materials. Dense rocks with few voids, little moisture, and negligible quantities of salts have a high electrical resistivity. The resistivity of different strata varies inversely with the moisture content of the material.

Figure 1: Coast Province: Distribution of boreholes and tube-wells.



CHAPTER VI

THE TUBE-WELL IN MOMBASA

6.1. Classification of Tube-wells

The tube-wells in Mombasa can be divided into three categories: Dug wells, bored wells, and drilled wells. This classification is based on the method of construction and is related to the size of the tube-well.

6.1.1. Dug Wells

This class contains the largest number of wells in Mombasa District. Dug wells are frequently used as a source of water supply for the home, ranches, and for irrigation purposes. They are dug where the water table is reasonably close to the surface, although some may involve a depth of up to 100 ft. Dug wells are usually excavated by hand, using a pick and shovel. The loose material is hoisted to the surface and the hole is followed down with well-cribbing where the formation will not stand by itself. The well is lined with rock, concrete, brick, or metal depending on the cost and availability of material. Dug wells are usually between 6 to 12 ft in diameter and 40 to 90 ft in depth.

6.1.2. Bored Wells

These wells are often bored in soft unconsolidated materials by means of an auger turned by hand or diesel power. The size of the hole may vary from 2 to 30 inches in diameter. The auger is turned in the hole until loaded, then pulled out and cleaned. The drilling rods used to suspend and rotate the auger are usually made of wood or hollow steel and may be any lengths from 3 to 30 ft. Casing is required as soon as the well reaches the water table. Perforated pipe or a drive point and screen are attached at the bottom of the string of casing and is driven into the water-bearing beds or the casing is perforated all round by means of perforating tool.

6.1.3. Drilled Wells

There are two types of drilled wells:

(1) Percussion drilled wells and (2) hydraulic rotary wells.

(a) Percussion Drilled Wells

These are also of two types depending on the type of equipment used: (1) Driven wells and (2) Cable-tool wells.

(i) Drilled Wells

These are the simplest form of percussion wells. They are necessarily shallow and of small diameter because of the difficulty in driving large pipes to great depth; in consequence they are used to develop small water supplies for domestic or ranch use. They are adapted to soft, granular, formations which are easily penetrated by the pipe. Difficulties in driving the pipe through boulders and other obstacles limit such wells to shallow depths usually between 100 - 150 ft.

(ii) Cable-tool wells

These are drilled with a portable drilling outfit, usually powered with a petrol or diesel engine. Wells drilled with the cable-tool equipment are usually over 150 ft deep.

(b) Hydraulic Rotary Wells

These are wells of wider diameter and greater depth drilled with a rapidly rotating bit. The diameter ranges from 24 in. to 60 in. and the depth to over 150 feet.

For all types of wells the yield is influenced by the diameter of the well. For example a 12 in. diameter well will produce 10 to 15 percent more water than a 6 in. diameter well, all other factors being equal, while a 48 in. diameter well will produce 20 to 35 percent more water than a 12 in. well (Tolman, 1953). Most shallow wells in Mombasa have high yields of water owing to their large diameters.

6.2. Characteristics of Tube-Wells in Mombasa

Nearly all tube-wells in Mombasa are dug with manual labour. Most of the drilled and bored wells (boreholes) are found in other Districts, usually on ranches. Drilling and boring of the wells is done by gazetted drilling contractors who are appointed by the Government, while digging of the open wells (dug wells) is done by local Arab contractors. Table 6.1 shows the characteristics of the tube-wells in the study. It will be observed from this table that the depth ranges from 40 - 90 ft and the diameter from 6 - 12 ft. All the wells have a shallow soft layer ranging between 5 and 15 ft and a deeper rocky layer. It was not possible to get detailed data on salinity, therefore this has simply been described by the terms sweet and slightly salty. Sweet water in this case means water that is close to river water in salt content. All of these wells were dug manually.

Table 6.1 Mombasa District: Characteristics of Tube-Wells

Well Number	Depth				Diameter of well	Nature of water flow	
	of well	of water	of rock			Regular	Seasonal
			soft	hard			
	ft						
Wells with slightly salty water:							
1	65	4	0	65	9	x	
2	45	5	5	40	10	x	
3	50	6	10	40	12	x	
4	65	7	5	60	8		x
5	90	5	15	75	8	x	
6	70	3.5	8.5	61.5	7	x	
7	50	4	10	40	8		x
8	40	4	6	36	10	x	
9	80	4	12	68	6	x	
10	70	5	14	56	7	x	
11	68	4	9	59	12	x	
12	70	4.5	10	60	12	x	
13	65	4	15	50	7	x	
14	60	3	15	45	8	x	
15	70	4	13	57	8	x	
16	60	3.5	6	54	12	x	
17	90	8	15	75	10	x	
18	60	9	12	48	7	x	
Wells with sweet water:							
19	75	10	9	66	9		x
20	70	12.5	7	63	10	x	
Average	66	5.4	8.8	57	9		

Source: Survey results.

6.3. Legal Procedure of Tube-Well Construction

The large-diameter shallow wells in Mombasa have not in the past been subjected to a long application procedure for obtaining permission for construction. The farmers could dig these wells anywhere in their farms at their own discretion. In recent years, however, the Ministry of Water Development has strengthened its Groundwater Investigation and Drilling Division which now requires that all proposed wells be applied for with an application fee of K.Shs.100. The application passes through the District Agricultural Committee for recommendation and later to the Ministry of Water Development for approval. For large-diameter shallow wells, the local contractors take the contracts. Local knowledge and experience of these contractors often gives a useful lead as to the probable success of the tube-wells and therefore a prior geophysical survey is not necessary. However there are cases where dug wells fail to strike water or there is a high inflow of sand thus causing well failure. For small-diameter deep tube-wells, the Ministry of Water Development carries out a geophysical survey and selects the tube-well site using the modern electrical resistivity method. The Ministry then appoints a gazetted drilling contractor, who is required to follow all the necessary instructions as follows:

(1) Drilling on the exact site.

(2) Diameter of the well and depth must be exact.

(3) Taking measurements of strata passed through and sending the specimens to the Ministry.

(4) Taking measurements of level at which water is struck and sending water specimens to the Ministry.

(5) Pumping tests must be done properly, 24 hours being the standard pumping test time.

If the tube-well was intended for irrigation or livestock purposes and it happens to fail, then the Ministry of Water Development meets 75 percent of the construction costs and the applicant pays only 25 percent of the costs. However if the tube-well becomes successful, the applicant pays all the construction costs. A full hydro-geological knowledge in the District and the country as a whole is essential because lack of it leads to uncertain prospects of striking water and the Ministry incurs a considerable loss due to well failures. However, with improvement in the modern electrical resistivity method, it is hoped that well failures will be minimised.

6.4. Utilization of the Tube-wells

6.4.1. Frequency and hours of pumping

The extent of utilization of the tube-wells generally is measured in terms of the total number of hours run throughout the year, determined by the daily pumping time and the frequency of irrigation.

All the farmers in the sample were found to irrigate each plot every third or fourth day so as to maintain the moisture at field capacity. Pumping is done for 7 to 10 hours and one-third or a quarter of the farm is irrigated every day in rotation. It was not possible to obtain data on the distribution of working hours by months for the two types of pumps, but the diesel pumps were reported to have a poorer performance than the electric ones. The number of pumping hours per year depends on the daily pumping hours and to a lesser extent on the frequency of breakdowns of the pumps. The average daily pumping time was 9 hours, with pumping usually done some time between 7.00 a.m. to 12.00 a.m. and 2.00 p.m. to 9.00 p.m.

6.4.2. Irrigable capacity or culturable command area

The best indicator regarding utilization of tube-wells is the extent of the area irrigated in a year known as "Culturable command area" or irrigable capacity (Chowdhury, 1971). A great divergence may occur between the amount of water pumped out in a season and the amount that actually reaches the fields for useful purposes. This divergence is influenced by the nature of the soils, which determines the amount of water lost through seepage, and the climatic conditions, which determine the water loss through evaporation. It was found that the acreage irrigated by each tube-well in the sample, known as its irrigable capacity, is limited to a great extent by the size of the farms and less so by the capacity of the tube-well. In fact 70 percent of the farmers interviewed indicated that they could expand the irrigated acreage if more land were available. Although the irrigable capacity of a tube-well is difficult to assess correctly, it is generally felt by most farmers that a tube-well of 10 ft diameter fitted with a pump of 3 in. suction and 3½ in. delivery pipe will have enough discharge to irrigate 30 - 35 acres in one season. Thus it is apparent that most of the tube-wells in Mombasa are underutilized.

The irrigable capacity of a tube-well is governed by the rate of discharge per hour, the type of land to be irrigated, and the nature of the crops to be irrigated. The discharge rate per hour for a particular size of engine and pump is often given by the manufacturers but this rate is rarely achieved in practice.

6.5. Costs of the Tube-Well Projects

6.5.1. Construction Costs

The cost of sinking tube-wells in Mombasa depends on the diameter, depth of the well, and the geological formations encountered. All the wide-diameter shallow wells are dug by local Arab contractors through hand work. Through personal communication with those contractors, the author was able to estimate the costs of the tube-well construction. One group of contractors based their charges on the geological structure encountered and another group had a uniform charge of Shs.60 to 70 per ft depending on the distance of the well from the town. These are labour costs only and the owner of the tube-well has to provide the building materials - stones, cement, and sand. Table 6.2 shows the construction costs of the tube-wells in the study.

6.5.2. Cost of Pump-shed and Storage tank/Stilling basin

To provide the engine and pump with protection against weather and thieves, all tube-wells are covered with pump-sheds. All the tube-wells under study were provided with suitable sheds of various sizes, varying from simple open sheds thatched with coconut leaves to stone-walled sheds with corrugated iron roof.

Table 6.2 Study area: Construction costs of Tube-wells

Well Number	Pipe Length	Strainer Length	Total Depth	Cost of Pipe & Strainer	Cost of Sinking	Total Cost
	ft	ft	ft	K. Shs.	K. Shs.	K. Shs.
1.	65	4	69	280	7,800	8,080
2.	45	5	50	215	5,850	6,065
3.	50	6	56	235	7,850	8,085
4.	65	7	72	300	6,500	6,800
5.	90	5	95	395	9,500	9,895
6.	70	3.5	73.5	300	7,000	7,300
7.	50	4	54	220	6,000	6,220
8.	40	4	44	190	5,000	5,190
9.	70	5	75	310	6,900	7,210
10.	68	4	74	290	10,676	10,966
11.	70	4.5	74.5	305	10,990	11,295
12.	65	4	69	280	6,175	6,455
13.	60	3	63	260	6,000	6,260
14.	70	4	74	320	7,000	7,320
15.	60	3.5	63.5	265	9,400	9,675
16.	90	8	98	410	9,000	9,410
17.	60	9	69	330	7,800	8,130
18.	75	10	85	350	9,200	9,550
19.	70	12.5	82.5	345	8,900	9,245
Average	66	5.5	71	298	7,757	8,055

Source: Survey Results

All have either storage tanks or stilling basins which help to "break" the force of water pumped from the well before it is led into the field. The stilling basins are also used for washing the vegetables and fruits before packing. The costs of the pump-sheds and storage or stilling basins are shown in tables 6.3 and 6.4.

6.5.3. Cost of Land-Levelling, Field Channels, and Land Rent

A major disadvantage of flood irrigation is that it requires a considerable investment in land-levelling and subsequent constant attention to maintain the levels and smoothness. More skilled labour is required to apply water evenly and to avoid waste through excessive run-off and water-logging in fields which are not completely level. The cost of land-levelling depends on the gradient and nature of the field, i.e. whether the land has ant-heaps, hollows, and high spots. The land must be levelled in such a way as to allow water to flow slowly from the tube-well into the fields. The field channels can be permanent, semi-permanent, or temporary. Permanent and semi-permanent channels require frequent cleaning-out due to luxuriant growth of weeds within the channels. Semi-permanent channels are ploughed in after 3 - 4 years, but temporary channels are ploughed in after the end of the crop season. The annual canal maintenance cost has been estimated at Shs.1000.

Land is usually rented to the tube-well operators by landlords on a monthly basis. Although a few farmers operate tube-wells on their own farms, this study has assumed a monthly rent of land for all the sample farms. The land rent, the costs of

Table 6.3 Electric Tube-wells: Cost of pump-shed, Storage tank/stilling basin, hand tools, levelling and land rent.

Costs*						
Well Number	Pump-shed and meter board	Storage tank or Stilling basin	Sprayers, hand tools and wheel-barrows	Levelling and distribution channels	Land rent	Totals
K. Shs.						
1	2,000	1,000	4,800	2,500	-	10,300
2	3,100	1,500	4,800	3,000	2,400	14,800
3	2,800	2,000	4,800	6,000	6,000	21,600
4	2,500	2,000	4,800	4,200	3,600	17,100
5	2,200	2,000	4,800	5,600	4,200	18,800
6	1,500	1,500	4,800	1,500	3,000	12,000
10	1,800	1,200	4,800	2,250	3,600	13,650
12	1,800	1,200	4,800	2,600	6,000	16,400
13	2,000	1,200	4,800	2,025	4,200	14,225
15	2,000	1,200	4,800	1,800	2,400	12,200
Average	2,170	1,510	4,800	3,679	3,900	15,137

Source: Survey data

* All costs based on 1975 prices.

** Where a dash appears, the overall average of Shs.3,900 was used in computing costs.

Table 6.4 Diesel Tube-wells: Cost of pump-shed, storage tank/stilling basin, hand tools, levelling and land rent

Well number	Costs*					
	Pump-shed	Storage tank or stilling basin	Sprayers Hand tools and wheel-barrows	Levelling and distribution channels	Land rent **	Totals
	K.Shs.					
7	3,500	2,000	4,800	6,000	4,800	21,100
8	3,000	1,800	4,800	5,250	6,000	20,850
9	3,300	2,300	4,800	6,150	4,200	20,650
11	2,800	1,600	4,800	1,800	-	11,000
14	2,000	1,500	4,800	700	2,400	11,400
16	3,600	2,000	4,800	4,800	-	15,200
17	3,200	1,900	4,800	5,000	-	14,900
18	3,000	2,400	4,800	5,500	-	15,700
19	3,800	2,600	4,800	6,000	-	17,200
20	2,500	2,200	4,800	900	1,500	11,900
Average	3,070	2,030	4,800	3,679	3,900	16,190

Source: Survey results

* All costs based on 1975 prices.

** Where a dash appears, the overall average of Shs.3,900 was used for computing costs.

land-levelling, and of constructing field channels for the tube-wells are shown in the tables 6.3 and 6.4.

6.5.4. <u>Energization of the Tube-Wells</u>

Tube-wells in Mombasa are powered with diesel engines or electric motors. The diesel engines use light diesel oil (LDO) or high speed diesel (HSD) as fuel and supply power to the pumps, whereas the electric motors convert electric power into mechanical energy to operate the pumps for lifting water. Using such diesel engines as prime-movers of the pumps is termed dieselisation and the use of electric motors as prime-movers of pumps is termed electrification of the wells. In the early years most of the tube-wells in Mombasa were run with diesel engines and pumps, but in recent years the urban areas has gradually encroached on the rural area, resulting in increased rural electrification. Quite a number of farmers having had a disappointing experience with the old diesel engines and pumps, and believing that electric pumps are probably cheeper and more convenient to run than the diesel pumps, have changed from the latter to the former, and many more have already submitted their applications to the East African Power and Lighting Company for electricity supply*. The costs involved in this change are discussed at the end of the chapter.

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* Electricity supply is the responsibility of the East African Power and Lighting Company, but the applicant is required to pay for power connection from the nearest power line. Electricity supplies are provided by means of overhead or underground lines at 415 volts, three-phase, four-wire 50 c.p.s. alternating current.

Table 6.5 Sample Farms: Cost of engines and pumps

Well Number	H.P	Year of Purchase	Expected life	Size of pump: Delivery pipe	Size of pump: Suction pipe	Make of engine	Cost of engine & pump and installation
Electric pumps							
			Years	in	in		K. Shs.
1	5	1973		2	2.5	Not applicable	10,000
2	12	1974		2	2.5		20,000
3	20	1974		3	3.5		27,000
4	20	1975		3	3.5		27,000
5	15	1975		2.5	3		23,000
6	10	1964		2.5	3		17,000
10	10	1967		2.5	3		17,000
12	7	1972		2.5	3		15,000
13	7.5	1970		2.5	3		15,000
15	7.5	1966		2.5	3		15,000
Average	11.4		10-15				18,650
Diesel pumps							
7	24	1969		3	3.5	Ruston	24,000
8	20	1965		3	3.5	Ruston	18,000
9	28	1970		3	3.5	Ruston	24,000
11	12	1971		2	2.5	Lister	12,000
14	8	1963		1.5	1.75	Lister	10,000
16	24	1966		3	3.5	Ruston	22,000
17	24	1969		3	3.5	Ruston	22,000
18	20	1972		2.5	3	Ruston	18,000
19	30	1972		2.5	3	Ruston	18,000
20	6	1969		1.5	2	Lister	10,000
Average for Diesel pumps	19.5		10-12				17,800
Average for Sample	15.5						18,200

Source: Wigglesworth Company

Three types of diesel pumps are used in Mombasa: Ruston pumps, Lister pumps, and deep-well turbine pumps; and two types of electric pumps - jet pumps and submersible pumps are common. The sample showed that Ruston pumps and Lister pumps were the most common and ranged in size from 8 to 30 Hp. Table 6.5 shows the prices of different sizes of engines and electric motors and pumps for the sample farms. The initial cost of electric pumps is much higher than that of diesel pumps.

6.5.5. Cost of Running the Tube-Wells

Tube-wells are operated by the owner-cultivators whose opportunity cost has been used in assessing management cost. No other expenditure is incurred by the operation of pumps except the cost of diesel or electricity, lubricating oil, and repair and maintenance costs. Table 6.6 and 6.7 show the cost of running the diesel and electric pumps under study in the year 1975. All the diesel engines in the sample use light diesel oil (LDO), popularly known as crude oil, which is the cheapest type of diesel in the market. The farmers reported that although this light diesel oil was comparatively much cheaper than the high speed diesel (HSD), it made the diesel engines breakdown more frequently resulting in increased repair and maintenance costs.

As would be expected, the annual cost of power is directly proportional to the acreage irrigated for both diesel and electric tube-wells. It is also observed that diesel pumps are more expensive than electric pumps. Diesel engines lose a considerable amount of power with age and therefore more diesel and oil has to be used for the same power output as the engine gets older.

Table 6.6 Sample Farms: Annual cost of operating diesel pumps, 1975

Well Number	Amount per year		Cost per year			Total	
	Diesel	Oil	Diesel	Oil	Total	Pumping time	Area irrigated
	Drums*	Litres	K.Shs.			Hours	Acres
7	72	600	15,275	3,300	18,575	2,900	15
8	48	480	10,224	2,640	12,864	2,700	14.5
9	72	720	17,892	3,960	21,852	3,155	15
11	24	300	5,112	1,535	6,647	2,500	6
14	12	120	2,555	894	3,539	2,670	2.5
16	95	840	20,448	4,620	25,068	3,120	18.2
17	96	900	20,442	4,914	25,363	3,465	20
18	96	720	20,448	3,960	24,408	3,300	25.7
19	120	1350	25,560	6,600	32,160	2,950	33
20	24	252	4,952	1,320	6,312	2,600	5.6
Average	66	637	12,506	3,363	17,678	2,941	14.9

Source: Survey results

Table 6.7 Sample Farms: Annual cost of operating electric pumps, 1975

Well Number	Electricity		Total	
	Amount used	Cost	Pumping time	Area irrigated
	Kw. Hrs.	K.Shs.	Hours	Acres
1	34	3,000	3305	5
2	55	4,200	3212	6
3	100	7,800	2950	15
4	120	9,360	3312	10.5
5	90	7,080	3570	14
6	30	2,700	2750	3
10	60	4,800	3800	7
12	41	3,540	2900	6
13	44	3,960	3290	4.5
15	38	3,360	3000	4
Average	61.2	4,980	3131	7.5

Source: Survey results

* 1 drum contains 200 litres.

Electric pumps are on the other hand fairly constant in power output and the pump capacity does not appreciably decrease with age. Diesel pumps also require bigger pump-sheds than electric pumps with the same power output.

To derive the greatest advantage from tube-wells, pumps must be maintained in good running condition. Breakdowns occur from time to time in both types of pumps although a higher frequency was reported for diesel pumps. Diesel pumps require regular maintenance. The operator must therefore have some technical experience in operation of diesel engines and also be able to perform minor repairs if the pump is to run throughout the year without major breakdowns. Bearings, bush shafts, and belts are the items that need regular replacement. Electric motors on the other hand can give several months of trouble-free service with minimum maintenance. The only major problem with electric pumps is in short-circuiting which burns out the motor. The exact cost of repairs for these pumps was not available, but most farmers guessed that these costs would run to Shs.5,000 on the average for diesel pumps and Shs.3,000 for the electric pumps. A few farmers reported that unavailability of spare parts and qualified mechanics results in considerable waste of pumping time.

6.6. Cropping Pattern and Cropping Intensity

Irrigation involves a considerable amount of investment and working capital. It is therefore imperative that high-value cash crops must be grown for irrigation projects to be successful. The types of crops grown and their market values are important factors which largely influence the profitable use of irrigation water. In the light of Penman's most important finding that all crops use the same amount of water under the same climatic conditions and within the same growing period, experienced farmers grow only the most valuable crops at any particular time. The cropping pattern in Mombasa is much influenced by the availability of good-quality water, assured market, market price of the crop during that season, enough labour during that season and crop rotation requirements. The cropping pattern of the sample farms is shown in table 6.8.

As shown, no rigid cropping pattern exists. A tube-well farm may have as many as 10 different crops in one season and probably as few as 3 crops in another season depending on the above-mentioned factors. Many farmers however have tried to maintain a fairly constant number of crops for purposes of risk aversion.

Table 6.8 Sample Farms: Cropping Pattern

Tube-Well No.	Bananas	Pawpaws	Brinjals	Tomatoes	Chinese Spinach	Chillies	Okra	Sweet Pepper	Sweet Melons	Cucumber
	Acres									
1.	-	1	½	1	-	-	-	-	-	-
2.	-	2	1½	-	0.5	1	-	-	-	-
3.	4	2	1	2	1	2	2	-	-	-
4.	3	2	1	-	1	1½	-	-	-	1
5.	8	3	1	-	1	-	-	-	-	-
6.	-	-	1	-	1	-	0.5	-	-	-
7.	6	3	2	-	2	-	-	-	-	-
8.	4	2	1½	2	2	-	2	4	-	-
9.	5	3½	2	-	1	-	1	2	-	-
10.	1½	2	1½	-	0.5	½	-	-	-	-
11.	-	1	1	-	2	1	-	-	-	-
12.	-	1½	1	-	1.5	1½	-	-	-	-
13.	-	2	1	-	1	-	-	-	-	-
14.	-	1	½	-	1	-	-	-	-	-
15.	1	1	-	-	1	½	-	-	-	-
16.	3	-	1	2	-	2	3	-	6	-
17.	10	2	2	-	-	1	2	1	-	-
18.	4	4	1	3	2	2	-	2	5	2
19.	6	5	-	7	-	3	3	2	-	5
20.	-	-	2	2	-	-	1	-	-	-
Total	55½	38	22½	19	18.5	16	14.5	11	11	8

Source: Survey Results

The cropping intensity in the tube-well farms is higher than that of non-tube-well farms. All the seasonal crops can be grown twice or thrice in a year due to the availability of water. Of special interest is the chinese spinach (mchicha) which, with a good supply of water and manure, can be grown as many as 8 times in one year. A major contrast in both the cropping pattern and the cropping intensity is found in the neighbouring farms where irrigation is not practised. In these farms the cropping intensity is restricted. Most farmers grow either maize or cassava in the long rains intercropped with widely-spaced cashewnuts or coconuts. In the short rains they may grow either another maize crop or cowpeas if the rains are enough. These short rains are, however, hardly enough for a crop in some years, in which case farmers end up with only one crop per year. Another striking difference between irrigated and non-irrigated farming is found with the perennial crops, bananas and pawpaws. Unirrigated bananas take 18 months to produce the first crop while irrigated bananas start to yield after 11 to 13 months. Table 6.9 shows the relative cropping intensities for irrigated versus unirrigated crops.

Brinjals, pawpaws, and chinese spinach are the most popular crops as shown in table 6.10 based on percentage of farmers who grow them. However, in terms of total acreage (table 6.8) the order is bananas, pawpaws and brinjals. This is a reflection of the high demand for these vegetables in both the Mombasa and export markets.

Table 6.9. Study area: Cropping intensity

Name of crop	Crops per year		Intensity of cropping for irrigated relative to unirrigated crops (Column 2 x 100) ÷ Column 3
	Irrigated No.	Unirrigated No.	
Chinese Spinach	8	3	266
Brinjals	2	1	200
Chillies	2	1	200
Cucumbers	2	Not grown	-
Okra	2	Not grown	-
Sweet melons	2	Not grown	-
Sweet peppers	2	1	200
Tomatoes	2	1	200
Bananas	Perennial	Perennial	-
Pawpaws	Perennial	Perennial	-

Source: Survey results.

Table 6.10 Sample Farms: Horticultural crops grown

Name of Crop	Farmers who grow	
	No.	%
Brinjals	18	90
Pawpaws	17	85
Chinese spinach	15	75
Bananas	12	60
Chillies	11	55
Okra	8	40
Tomatoes	7	35
Sweet pepper	6	30
Cucumber	3	15
Sweet melons	3	15

Source: Survey results.

6.7. Labour Requirements and Costs

A major disadvantage of flood irrigation is that it requires constant attention in maintaining levels and smoothness. More semi-skilled labour is required for applying water evenly. Although many tube-well farmers in Mombasa are fond of casual labour and piece work, which they argue is more efficient than regular labour, they nevertheless prefer to maintain a few permanent labourers who have gained some skill in irrigation work. Table 6.11 shows the number of permanent and casual labourers employed in each sample farm. An average of 3.7 permanent labourers and 6.9 casual labourers are employed per farm of 11.5 acres. Family labour amounts to an average of 1.4 per farm but this is mainly used for supervision. The total labour thus averages 12 adults per farm, or about one adult per acre.

Many farmers reported a shortage of labour in the wet season especially in April and May when the casual labourers prefer to work in their own plots. The shortage of labour during this season affects mostly farmers who are far from Mombasa Town. These farmers sometimes have to pay slightly higher casual wages to attract labour. Casual labour is on the average more expensive than permanent labour if hired full-time. It amounts to Shs.213 per labourer per month as compared to Shs.197 for permanent labour. Family labour has been treated as the management and is therefore valued at a high opportunity cost. Most of the tube-wells are operated by Indians who have at one time been building contractors earning fairly high incomes. The management has therefore been costed at Shs.1,000 per month. Although

K. Shs.4,[illegible] is an underestimation of the opportunity cost of a contractor, it is taken as a compromise between a farmer and a manager. Family labour is composed of the farmer himself and his sons above 15 years old, since Indian women do not work on the farm. The annual cost of family labour amounts to K. Shs.10,[illegible] and that of permanent labour to K. Shs.8,740.

Table 6.11 Tube-well Farms: Labour requirement and cost

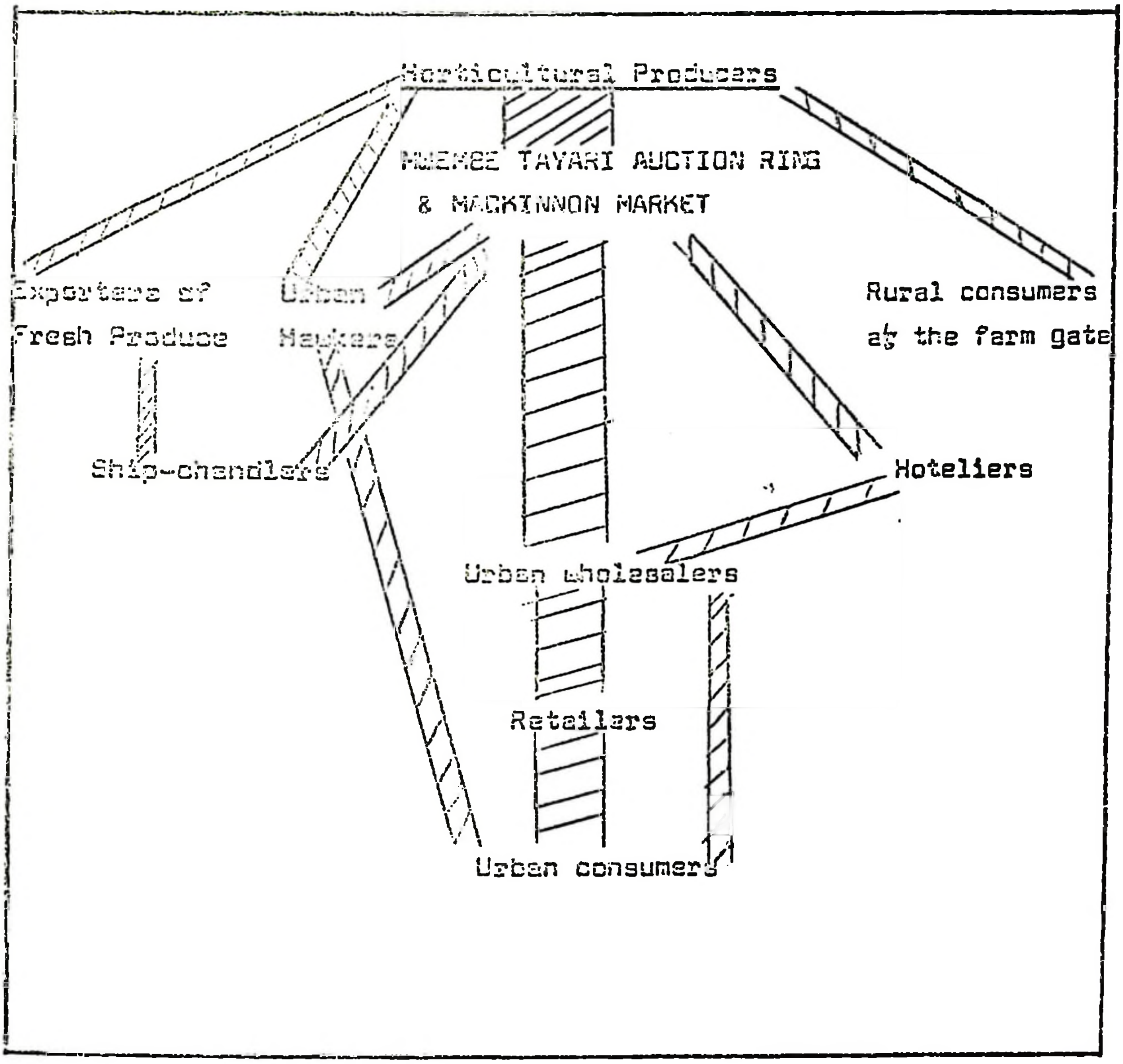
Tube-well No.	Labourers				Acreage	Wages for Labour	
	Casual	Permanent	Family	Total		Permanent per month	Casual per day
	No.				Acres	K.Shs.	
1	2	4	0	6	5	300	9.80
2	3	4	2	9	6	200	8.00
3	8	6	2	16	15	200	7.00
4	10	2	2	14	10.5	190	7.50
5	7	5	2	14	14	190	7.00
6	0	4	1	5	3	190	7.00
7	10	3	2	15	15	180	7.00
8	8	3	1	12	14.5	210	7.00
9	9	4	1	14	15	180	7.00
10	7	4	1	12	7	200	7.00
11	3	2	1	6	6	180	7.00
12	4	3	1	8	6	200	7.00
13	2	2	1	5	4.5	200	7.00
14	2	2	2	6	2.5	200	7.00
15	3	3	1	7	4	200	7.00
16	18	4	2	24	18.2	180	7.00
17	15	5	2	22	20	190	7.00
18	12	6	1	19	20.7	200	7.00
19	15	7	1	23	33	180	7.00
20	2	1	1	4	5.6	165	6.00
Average	6.9	3.7	1.4	12	11.5	196	7.10

Source: Survey results

6.2. Transport and Marketing Costs of Fruits and Vegetables

Transport costs are an important item of total costs. Most farmers prefer to sell their farm produce in the Mwembe Tayari wholesale market as they feel they can get a better price. All the farmers in the study have either farm vehicles or handcarts to transport the vegetables to the market. Although Mwembe Tayari wholesale market is the main outlet of the vegetables and fruits grown in Mombasa and Coast Province as a whole, other minor marketing channels exist for specialised horticultural producers, especially those with irrigation facilities. Figure 2 shows the main market channels for fruits and vegetables in Mombasa District. Ship-chandlers and fresh fruit and vegetable exporters require high-quality produce which must be supplied regularly. All the farmers interviewed complained of high transport costs but agreed that they obtained higher prices in the market than they would have received had they sold their farm produce at the farm gate. Transport costs have been covered in this study by annual running and maintenance costs of farm vehicles estimated at Shs.12,700. They therefore are assumed not to vary with the size of the enterprise. The marketing system necessitates the use of the farm vehicle every day. The annual costs of transport are shown in table 6.12. Market cess is collected for all produce entering the wholesale market on a container basis, but it was difficult to determine the total amount of cess because some farmers sometimes got away without paying by giving small tips to the cess collectors.

Figure 2: Major Channels* for Fruits and Vegetables in Mombasa District, 1975



Source: Survey results

* Size of flow diagram indicates the relative importance of the channel.

Table 6.12 Assumed cost of Transport to the Market

Tube-well No.	Make and model of the vehicle	Current value of the vehicle	Expected life	Annual cost of the vehicle*
		K.Shs.	Years	K.Shs.
1	1972 VW Microbus	60,000	10	11,865
2	1970 3-ton Bed Ford	50,000	10	18,615
3	1968 Peugeot Pickup	30,000	10	10,037
4	1970 Morris Pickup	32,500	10	13,687
5	1975 Datsun Pickup	52,000	10	11,534
6	Handcart	300	15	2,190
7	1970 Peugeot Pickup	36,000	10	17,337
8	1970 3-ton Bed Ford	61,000	10	27,740
9	1972 3-ton Bed Ford	66,500	10	27,740
10	Handcart	300	15	2,190
11	1974 Mazda	39,650	10	11,315
12	1973 Peugeot Pickup	49,500	10	7,665
13	Handcart	300	15	2,190
14	Handcart	300	15	2,190
15	Handcart	300	15	2,190
16	1974 Land Rover	65,000	15	26,280
17	1973 Datsun	41,000	10	18,980
18	1973 3-ton Bed Ford	68,250	10	16,425
19	1973 Peugeot	47,200	10	22,630
20	Handcart	300	15	2,190
Average		35,012		12,749

Source: Survey results

* This cost includes the running and maintenance, and the estimated annual depreciation.

6.9. Comparison of Alternative Tube-Well Systems (Diesel Tube-Wells versus Electric Tube-Wells)

Comparisons of the two alternative tube-well systems - diesel and electric - is shown in table 6.13. The performance of the two systems can be judged by two indicators: (1) Annual hours of operation, (2) Acre-inches of water pumped per year. The second, though a better indicator of performance, has not been used for comparison in this study because sufficient data on the rates of discharge were not available. The annual hours of operation of the tube-wells were calculated by multiplying the daily working hours by the number of days per year that the pumps were operated. Since most farmers could remember the number of days in the year 1975 when the pumps were cut of order, it was easy to determine the number of days of operation.

Total average annual cost of operation per acre of irrigation is 16 percent lower with electric pumps than with diesel pumps. The cost of the electric connection was charged over a 20-year period but in reality this should be charged over a longer period because electric poles last longer than 20 years. The average cost per hour of operation works out to Shs.8.3 for diesel pumps, and Shs.3.5 for electric pumps. This big difference in cost can be explained by the fact that the diesel pumps in the study are much larger than the electric pumps (electric pumps being only a little over half the size of diesel pumps). However the average cost of power per acre irrigated is 44 percent cheaper for electric pumps than diesel pumps. This suggests that the cost of electricity per unit of power is cheaper than

Table 6.13 Investment and operating costs of Diesel and Electric operated pumps in the sample farms

Item	Unit	Type of pump		Electric in relation to diesel
		Diesel	Electric	%
Wells in sample	No.	10	10	
Average size of prime movers	H.p	19.8	11.4	58
Investment				
Engine and pump installation	Shs.	18,200	18,600	
Pump-shed and storage tank	"	5,100	3,680	
Electric connection	"		13,905	
Total initial investment	"	23,300	36,185	
Annual operating costs				
Cost of fuel, lubricants and electricity	"	17,687	4,960	
Depreciation (or Amortization)	"	1,826	2,492	
Repairs and maintenance	"	5,000	3,000	
Total operating costs	"	24,513	10,472	
Performance				
Time worked per year	Hours	2,941	3,131	
Area irrigated per season	Acres	14	7.5	50
Average operating cost:				
per hour of operation	Shs.	8.30	3.50	42
per acre irrigated	"	1,628	1,380	84
Average cost of power per acre irrigated	Shs.	1,183	664	56
Initial cost of pump per unit of horsepower	Shs.	929	1,632	175

Source: Computed from survey results.

the cost of diesel for the same power output. The initial cost of electric pumps is however much higher than that of diesel pumps per unit horsepower. As the figures in the table show, a 20-Hp diesel pump costs nearly the same as an 11-Hp electric pump.

These observations however give only a general idea of the total operating costs at a particular level of operation. They do not indicate how cost components would behave at lower or higher levels of operation. At the present level of operation of the two systems, the farmer can save Shs.248 per acre irrigated annually by investing in an 11.4-Hp electric pump rather than a 19.8-Hp diesel pump. The electric pump however requires a high initial investment due to the electric connection which may offset the difference in operating costs of the two systems.

All the farmers interviewed favoured electric pumps for their convenience in operation and non-requirement of high technical skill. Operation of the electric pump just involved "Switching on and off" the switchboard, whereas it is not easy to start a diesel pump without previous experience.

CHAPTER VII

ENTERPRISE PROFITABILITY

7.1. General Introduction

Horticultural farming with irrigation is both capital and labour intensive. Because of the high costs involved in supplying irrigation water, only the most valuable crops can be grown profitably.

In order to secure satisfactory returns from irrigation farming, the farmers must have knowledge of the important factors affecting returns. They must also be proficient managers capable of taking advantage of every opportunity to secure increased returns from their crops. For successful irrigation farming, experience in irrigation work is essential. Farmers must know when to irrigate. This is important because expensive water may be wasted through over-watering. Secondly, it is essential than the farmer have a high degree of managerial ability and be able to accept new ideas and innovations. Response in yields due to irrigation is only realised at high levels of complementary inputs such as fertilizers and manures. Without good husbandry practices money spent on irrigation would be money lost in the drain. Successful irrigation also requires that a farmer have first-hand market intelligence so that he can make quick decisions on types of crops to grow, how much of each crop to grow, and in what seasons to grow them. The aim should be to grow crops that have the highest return per acre-inch of water applied. Although the Horticultural Crops Development Authority in Kenya has been collecting weekly prices and disseminating them through the press and radio to help growers, wholesalers, retailers, and consumers in decision-making and to even-out price fluctuations, the most successful irrigation farmers have always had to get first-hand information on the supply and demand of the various horticultural crops.

Good irrigation farmers stagger the planting dates of various crops in such a way that the crops mature at different times. This is one of the advantages of using irrigation water. In this way the farmers get a regular income by maintaining a constant supply of produce.

In this chapter the production costsof the important fruits and vegetables have been estimated and gross margins calculated. An analysis of the composition of the costs of production can give some idea as to what changes may be made on a particular farm to improve its economic prospects. Gross margins have been calculated for 10 different crops which were predominant in the sample farms and which were grown as pure stands. The analyses in this chapter also provide the framework for the profitability appraisal discussed in the next chapter.

The production costs and input levels are fairly accurate in the author's opinion as field observations were made during the planting of some of the crops. The farmers were also willing to discuss these costs. The input levels are considered average (not too high and not too low) as compared to the horticultural guidelines and recommendations for Mombasa District. For example manure levels of up to 30 tons per acre are recommended for most vegetable crops, but most farmers indicated that they used only up to 20 tons of manure per acre. In the estimation of yields, on the other hand, much guess-work had to be done. The yield figures used here are just average. Much higher yield figures than the ones used in this analysis have been reported under coastal conditions.

The cost of water accounts for the largest proportion of total variable costs. The annual cost works out to Shs.1517 per acre for Diesel pumps and Shs.1096 for Electric pumps. The higher figure for diesel pumps has been used in the calculation of the gross margins. This annual cost includes cost of fuel, lubricants, maintenance, and repairs.

Only casual labour costs have been included in the gross margin analysis. It must however be pointed out that in several cases it was difficult to distinguish between casual and permanent labour. Permanent labour was taken as that labour employed for actual irrigation work, that is distribution of water and maintenance of canals, and casual labour was taken as that labour employed to do the peak-period operations such as planting, weeding, spraying, and harvesting. Sometimes some of the permanent labour was called to help on the major peak-period operations, hence the difficulty in correctly assessing the casual labour costs.

The prices used in the calculations of gross revenues of the crops are the average market wholesale prices published or recorded by HCDA at the beginning and middle of every month. Although it is customary to use farm-gate prices in gross margin analysis, these prices have not been used because all the farmers interviewed indicated that they sold their produce in the wholesale market where they could bargain higher prices. Transport and other market costs have not been included in the total variable costs because these have been treated as fixed overhead costs. Transport cost has been treated as an overhead cost because the farm vehicle is used for transporting the vegetables to the market and also for domestic and pleasure purposes. It was therefore difficult to assess the transport cost for each vegetable crop, hence its omission in the gross margin analysis. Seasonal fluctuation of prices was observed especially in the wet season of April to June and the dry season July to March. These prices are shown in Table 4, appendix I. Monthly prices of fruits and vegetables weighted by marketings were used in the calculation of gross margins.

In this study no attempt was made to determine the additional production of crops due to irrigation. For comparison, however, gross margins for the unirrigated crops in Mombasa were obtained from the Ministry of Agriculture Farm Management District guidelines and these data are given in Table 3, appendix I. Also no attempt was made in this study to determine the returns at an optimum level of irrigation.

The gross margins for the ten vegetable crops are outlined in tabular form in tables 7.1 to 7.10. Although pawpaws, tomatoes, brinjals, and bananas have very high gross margins per acre, they do not have a stable market. They are subject to greater price fluctuations. Farmers cannot therefore expand the acreage of these crops beyond a certain level because they may face marketing problems. Bananas and tomatoes for example are from time to time in oversupply in the Mombasa market. These commodities are supplied to the Mombasa market from upcountry growers and from other parts of East Africa. The farmers therefore choose to include in their cropping patterns other less profitable crops such as chillies and sweet pepper.

Double cropping has been assumed for all annual crops, and therefore the total production costs relate to the total costs per year. Similarly the yield figures relate to annual yields from the assumed two crops.

7.2. Gross Margins for crops grown in the sample

Table 7.1 Gross Margin for Bananas

Type of Operation	Cost per Acre 1st Year	2nd Year	3rd Year
	K.Shs.	K.Shs.	K.Shs.
Land Preparation			
Ploughing and harrowing	150	0	0
Digging planting holes using Casual Labour (50 mandays)	350	0	0
Digging of Irrigation canals	150	0	0
Planting Materials			
Cost of seedlings @ 1/= per seedling assuming plant population of 538 per acre	538	0	0
Fertilizer Application			
100 kg. Double Superphosphate	200	0	0
100 kg. Sulphate of Ammonia	90	90	90
F.Y.M. 3 lorry loads (7 tonners)	600	0	0
Planting and Manure Application (25 mandays)	175	0	0
Weeding 4 times (40 mandays)	280	280	280
Pest Control			
Dipping planting materials	50	0	0
2 sprays with Roger E or DDT	100	100	100
Harvesting and Packing	70	70	70
Total annual costs	2,753	540	540
Returns			
Yields	1,000 bunches	2,500 bunches	3,000 bunches
Value of produce @ Shs.8/= per bunch	8,000	20,000	24,000

Average annual returns $= \frac{8,000 + 20,000 + 24,000}{3}$

= Shs.17,333

Average annual costs of establishment $= \frac{2753 + 540 + 540}{3}$

= Shs.1278

Annual cost of water per acre (Diesel tube-wells) = 1517

Total costs per acre = 1278 + 1517

= Shs.2795

Gross Margin = 17, 333 - 2795

= Shs.14,538

Source: Survey results.

Table 7.2 Gross Margin for Brinjals

Type of Operation	Cost per Acre
Land preparation	K.Shs.
(a) Ploughing and Harrowing	150
(b) Digging Irrigation canals	150
Nursery preparation and seedling raising	100
Planting using casual labourers (5 mandays)	35
Weeding (10 mandays)	70
Fertilizer application - 200 kg. Sulfate of ammonia	180
F.Y.M. 20 tons	600
Disease and Pest control	100
Harvesting and Packing (20 mandays)	140
Total annual costs	1525
Total annual costs (assuming double crop)	3050

Returns

Yield = 10,000 kg. per acre

Output for double crop = 20,000 kg. per acre

Value @ 1/= per kg. = 20,000

Total production costs per acre = Shs.1,516 + 3050

= Shs.4,566/=

Gross margin per acre = Shs.20,000 - 4566

= Shs.15,433/=

Source: Survey results.

Table 7.3 Gross Margin for Pawpaws

Operation	Cost per Acre 1st Year	2nd Year	3rd Year
	K.Shs.	K.Shs.	K.Shs.
Land preparation			
(a) Ploughing and Harrowing	150	0	0
(b) Digging irrigation canals	150	0	0
Nursery preparation and seedling raising	130	0	0
Planting (10 mandays)	70	0	0
Weeding (40 mandays)	280	280	280
Fertilizer application	500	200	200
F.Y.M. (10 tons)	300	300	300
Harvesting and Packing (15 mandays)	105	105	105
Total annual costs	1,685	885	885

Average annual costs = 1,685 + 885 + 885 Shs.

= Shs. $\frac{3,454}{3}$

= Shs.1,151

Returns

Yields = 50,000 fruits per year

Value @ -/50 = Shs.25,000

Total production costs per acre = Shs.1,516 + 1,151

= Shs.2,668

Gross margin per acre = Shs.25,000 - 2,668

= Shs.22,331

Source: Survey results

Table 7.4 Gross Margin for Chinese Spinach (Mchicha).

Operation	Cost per Acre Per Season	Per Year*
	K.Shs.	K.Shs.
Land preparation		
(a) Ploughing and harrowing	150	150
(b) Digging irrigation canals	150	150
F.Y.M. Application (10 lorry loads (10 tons each)	2,000	2,000
Planting (3 mandays)	21	210
Weeding and thinning (50 mandays)	350	3,500
Pest control	100	1,000
Harvesting and bundling (15 mandays)	105	1,050
	2,876	7,910
Returns		
Yield per acre per season	= 10,000 bundles	
Value @ -/20 per bundle	= Shs.2,000	
Total returns assuming 10 crops per year	= Shs.20,000	
Total production costs per acre	= Shs.7,910 + 1,516	
	= Shs.9,426	
Gross margin per acre	= Shs.20,000 - 9,426	
	= Shs.10,575	

Source: Survey results

* Land preparation, digging of irrigation canals and manure application is done once a year, but all the other operations are done 10 times a year, therefore the costs per year are 10 times more than the costs per season.

Table 7.5 Gross Margin for Okra (Ladies Fingers)

Operation	Cost per Acre
	K.Shs.
Land preparation	
(a) Ploughing and harrowing	150
(b) Digging Irrigation canals	150
Nursery preparation and seedling raising	160
Planting (5 mandays)	35
Fertilizer application - 100 kg. Double Super-phosphate	180
100 kg. Sulphate of Ammonia	90
F.Y.M. 20 tons	600
Disease and pest control	200
Harvesting	200
Total annual costs	2,115
Total annual costs (assuming double crop)	4,230

<u>Returns</u>

Yield	= 8,000 kg. per acre
Output for double crop	= 16,000 kg. per acre per year
Value @ 1/= per kg.	= Shs.16,000
Total production costs	= Shs.4,230 + 1,516
	= Shs.5,746
Gross margin per acre	= Shs.16,000 - 5,746
	= <u>Shs. 10,254</u>

Source: Survey results

Table 7.6 Gross Margin for Chillies

Operation		Cost per Acre
		K.Shs.
Land preparation		
(a) Ploughing and harrowing		150
(b) Digging Irrigation canals		150
Nursery preparation and seedling raising		100
Planting (15 mandays)		105
Weeding (20 mandays)		140
Fertilizer application	100 kg. double super phosphate	180
	50 kg. sulphate of Ammonia	45
	F.Y.M. 20 tons	600
Disease and pest control		160
Harvesting (20 mandays)		140
	Total costs	1,720
Total annual costs (double crop)		3,440

Returns

Yield	= 4,000 kg. per acre
Annual yield (double crop)	= 8,000 kg. per acre
Value @ 1/50 per kg.	= 12,000
Total production costs	= Shs.3,440 + 1,516
	= Shs.4,956
Gross margin per acre	= Shs.12,000 - 4,956
	= Shs.7,044

Source: Survey results

Table 7.7 Gross Margin for Tomatoes

Operation		Cost per Acre
		K.Shs.
Land preparation		
(a) Ploughing and harrowing		150
(b) Digging Irrigation canals		150
Nursery preparation and seedling raising		100
Planting (7 mandays)		70
Weeding		160
Fertilizer application	100 kg. double super phosphate	180
	200 kg. sulphate of ammonia	180
	F.Y.M. 20 tons	600
Disease and pest control		400
Staking and pruning		1,200
Picking and packing		200
Total costs		3,390
Total annual costs (double cropping)		6,780
Returns		
Yield	= 15,000 kg.	
Annual yield (double cropping)	= 30,000 kg.	
Value @ -/80	= Shs.24,000	
Total production costs	= Shs.6,780 + 1,516	
	= Shs.8,296	
Gross margin per acre	= Shs.24,000 - 8,296	
	= Shs.15,703	

Source: Survey results

Table 7.8 Gross Margin for Sweet Melons

Operation	Cost per Acre
	K.Shs.
Land preparation	
(a) Ploughing and harrowing	150
(b) Digging Irrigation canals	150
Nursery preparation and seedling raising	80
Weeding	100
Fertilizer application 100 kg. double superphosphate	180
200 kg. sulphate of ammonia	180
F.Y.M. 20 tons	600
Disease and pest control	170
Harvesting and packing	210
Total costs	1,855
Total annual costs (double cropping)	3,710
Returns	
Yield	= 10,000 kg.
Output for double cropping	= 20,000 kg.
Value @ -/80 per kg.	= Shs.16,000
Total production costs	= Shs.3,710 + 1,516
	= Shs.5,226
Gross margin per acre	= Shs.10,653

Source: Survey results

Table 7.9 Gross Margin for Sweet Pepper (Cupsicums)

Operation		Cost per Acre
		K.Shs.
Land preparation		
(a) Ploughing and harrowing		150
(b) Digging Irrigation canals		100
Nursery preparation and/seedling raising		50
Planting		50
Weeding		50
Fertilizer application	100 kg. double superphosphate	180
	200 kg. sulphate of ammonia	180
	F.Y.M. 20 tons	500
Disease and pest control		100
Harvesting and packing		100
	Total costs	1,460
Total annual costs (for double crop)		2,920
Returns		
Yield	= 8,000 kg.	
Output for double cropping	= 16,000	
Value @ -/80 per kg.	= Shs.12,800	
Total production costs	= Shs.2,920 + 1,516	
	= Shs.4,426	
Gross margin per acre	= Shs.12,800 - 4,426	
	= Shs.8,373	

Source: Survey results

Table 7.10 Gross Margin for Cucumbers

Operation	Cost per Acre
	K.Shs.
Land preparation	
(a) Ploughing and harrowing	150
(b) Digging Irrigation canals	100
Nursery preparation and seedling raising	80
Planting	35
Weeding	100
Fertilizer application 100 kg. double superphosphate	180
200 kg. sulphate of ammonia	180
F.Y.M.	600
Disease and pest control	290
Harvesting and packing	252
Total costs	1,967
Total annual costs (double cropping)	3,934
Returns	
Yield	= 12,000 kg.
Output for double cropping	= 24,000 kg.
Value @ -/80 per kg.	= Shs.19,200
Total production costs	= Shs.3,934 + 1,516
	= Shs.5,450
Gross margin per acre	= Shs.19,200 - 5,450
	= Shs.13,749

Source: Survey results

Table 7.11 Sample farms: Total Gross Margins

Tube-Well No.	Crop	Acreage	Gross Margin	
			Per acre	Total
			1,000 Shs.	
1	Pawpaws	1	22.3	22.3
	Brinjals	½	15.4	7.7
	Tomatoes	1	16.0	16.0
	Sweet Melons	1	7.7	7.7
	Total			64.4
2	Pawpaws	2	22.3	44.7
	Brinjals	1½	15.4	23.1
	Chillies	1	7.2	7.2
	Mchicha	½	10.6	5.3
	Total			80.3
3	Bananas	4	14.5	58.2
	Pawpaws	2	22.3	44.7
	Brinjals	1	15.4	15.4
	Tomatoes	2	16.0	32.0
	Okra	2	10.3	20.5
	Chillies	2	7.2	14.5
	Mchicha	1	10.6	10.6
	Total			195.9
4	Bananas	3	14.5	43.6
	Pawpaws	2	22.3	44.7
	Brinjals	1	15.4	15.4
	Chillies	1½	7.2	10.9
	Mchicha	1	10.6	10.6
	Cucumber	1	13.7	13.7
	Total			138.9

Table 7.11 continued

Tube-Well No.	Crop	Acreage	Gross Margin	
			Per Acre	Total
			1,000 Shs.	
5	Bananas	8	14.5	116.3
	Pawpaws	3	22.3	66.9
	Brinjals	1	15.4	15.4
	Mchicha	1	10.6	10.6
	Total			209.2
6	Brinjals	1	15.4	15.4
	Okra	½	10.3	5.1
	Mchicha	1	10.6	10.6
	Total			31.1
7	Bananas	6	14.4	87.2
	Pawpaws	3	22.3	66.9
	Brinjals	2	15.4	30.7
	Mchicha	2	10.6	21.1
	Total			205.9
8	Bananas	4	14.5	58.2
	Pawpaws	2	22.3	44.7
	Brinjals	1½	15.4	23.2
	Tomatoes	2	16.0	32.0
	Okra	2	10.2	20.5
	Mchicha	2	10.6	21.1
	Sweet Pepper	1	7.7	7.7
	Total			207.2
9	Bananas	5	14.5	72.7
	Pawpaws	3½	22.3	78.6
	Brinjals	2	15.4	30.9
	Okra	1	10.2	10.3
	Mchicha	1	10.5	10.6
	Sweet Pepper	2	7.7	15.3
	Total			218.4

Table 7.11 continued

Tube-Well No.	Crop	Acreage	Gross Margin	
			Per acre	Total
			1,000 Shs.	
10	Bananas	1½	14.5	21.8
	Pawpaws	2	22.3	44.7
	Brinjals	1½	15.4	23.1
	Mchicha	½	10.6	5.3
	Chillies	½	7.2	3.6
	Total			98.5
11	Pawpaws	1	22.3	22.3
	Brinjals	1	15.4	15.4
	Chillies	1	7.2	7.2
	Mchicha	2	10.6	21.2
	Total			65.1
12	Pawpaws	1½	22.3	33.5
	Brinjals	1	15.4	15.4
	Chillies	1½	7.2	10.8
	Mchicha	1½	10.6	15.8
	Total			75.5
13	Pawpaws	2	22.3	44.7
	Brinjals	1	15.4	15.4
	Mchicha	1	10.6	10.6
	Total			70.7
14	Pawpaws	1	22.3	22.3
	Brinjals	¼	15.4	3.9
	Mchicha	1	10.6	10.6
	Total			36.8

Table 7.11 continued

Tube-Well No.	Crop	Acreage	Gross Margin	
			Per acre	Total
			1,000 Shs.	
15	Bananas	1	14.5	14.5
	Pawpaws	1	22.3	22.3
	Chillies	½	7.2	3.6
	Mchicha	1	10.6	10.6
	Total			51.0
16	Bananas	3	14.5	43.6
	Brinjals	1	15.4	15.4
	Tomatoes	2	16.0	32.0
	Okra	3	10.3	30.7
	Chillies	2	7.2	14.5
	Sweet Melons	6	10.7	64.3
	Total			200.5
17	Bananas	10	14.5	145.3
	Pawpaws	2	22.3	44.6
	Brinjals	2	15.4	30.8
	Okra	2	10.2	20.5
	Chillies	1	7.2	7.2
	Sweet Pepper	1	7.6	7.6
	Total			256.5
18	Bananas	4	14.5	58.2
	Pawpaws	4	22.3	89.3
	Brinjals	1	15.4	15.4
	Tomatoes	3	16.0	48.0
	Chillies	2	7.2	14.5
	Mchicha	2	10.6	21.1
	Cucumber	2	13.7	27.5
	Sweet Melons	5	10.7	53.6
	Sweet Pepper	2	7.6	15.3
	Total			342.9

Table 7.11 continued

Tube-Well No.	Crop	Acreage	Gross Margin	
			Per acre	Total
			1,000 Shs.	
19	Bananas	6	14.5	87.2
	Pawpaws	5	22,3	111.7
	Tomatoes	7	16.0	112.0
	Okra	3	10.2	30.7
	Chillies	3	7.2	21.7
	Cucumber	5	13.7	68.7
	Sweet Pepper	2	7.6	15.3
	Total			447.4
20	Brinjals	2	15.4	30.9
	Tomatoes	2	16.0	32.0
	Okra	1	10.2	10.2
	Total			73.1

Source: Computed from survey results.

Table 7.12 Summary

Tube-Well No.	Total Gross Margins
	1,000 Shs.
1	64
2	80
3	196
4	139
5	209
6	31
7	206
8	207
9	218
10	99
11	65
12	76
13	71
14	37
15	51
16	201
17	257
18	343
19	447
20	73
	3,070

Average gross margin per farm Shs.153,500

Average gross margin per acre* Shs.13,300

* Based on average farm size of 11.5 acres.

CHAPTER VIII

APPRAISAL AND EVALUATION OF THE TUBE-WELL PROJECTS

8.1. Review of the Analytical Techniques

The conventional investment criteria used in project appraisal and evaluation are: Payback period, net present worth, rate of profitability, benefit-cost ratio, and internal rate of return. One or a combination of these can be used to assess the worthiness or profitability of a project.

The first criterion - payback or recoupment period does not take into account the discount rate and is therefore a rough means of judging the profitability of an investment. It shows the number of years which are required to accumulate earnings sufficient to cover the cost of the project. A project with a payback period of 5 years is better than one of 10 years. Bierman and Smidt (1966) feel that, although this criterion is not much defended in the literature, it is an easy inexpensive device for dealing with risk and they call it "a quick crude rule of thumb". However this criterion has two major weaknesses as a measure of investment worth. It fails to take into consideration earnings after the "break-even" period and therefore tends to favour quick-yielding projects without taking into account their overall rate of return. For example a machine may continue to operate for many years after its initial cost is covered. These later years also determine the profitability of the machine, an element which is ignored in the criterion. It also fails to take into account the differences in the timing of the proceeds or receipts. For example the investors would prefer a £1,000 project with a payback period of 5 years and with receipts of £300 annually in the first 3 years and £50 annually in the last 2 years rather than a similar size project with the same payback period but with receipts of £100 annually in the first 3 years and £350 annually in the last 2 years. The earlier the benefits are received the earlier they can be reinvested or consumed, and hence, the more valuable they are. This criterion is however quite a good indicator where early capital recovery is emphasized because of financial constraints. It is used in cases of risky investments - risky owing to technological progress, commercial, and/ or political uncertainties.

The other investment criteria are based on the discounted principle commonly applied to Agricultural projects. Discounting "reduces" the future benefits and costs stream to their present worth. There are four investment criteria which use this discounted principle: Net present worth, profitability rate or rate of return to investment, benefit - cost ratio, and internal rate of return.

Net Present Worth is the most straight-forward discounted cash flow measure of project worth. It is simply the present worth of the cash flow stream. Although it may be computed by finding the difference between the total discounted present worth of the benefits stream less the total discounted present worth of the cost stream, it is easier and normal practice to compute it in the form of discounted (net) Cash flow. Depreciation costs are not deducted from the gross returns or benefits of the project because the analytical technique automatically takes care of the return of capital in determining the worth of the project (Gittinger, 1972). One advantage of the net present worth (N.P.W.) measure as compared with the other discounted measures is that it makes no difference at all as to what point in the computation process the netting out of benefits and costs takes place, whether it is done at the middle of the project life or at the end of the project life the difference is the same. The formal selection criterion for the net present worth measure of project worth is to accept all projects with a positive net present worth when discounted at the opportunity cost of capital. The fact that net present worth is an absolute and not a relative measure imposes a serious drawback because no ranking of acceptable alternative projects is possible using this criterion. A small highly-attractive project may have a smaller net present worth than a large marginally-acceptable project. In this case the investor may select the smaller attractive project which is less risky. Another limitation of this criterion is that it cannot be applied unless there is a relatively satisfactory estimate of the opportunity cost of capital.

Profitability Rate or Rate of Return on Investment is a discounted measure which compares discounted benefits with all the discounted project costs. Depreciation costs are also included in the calculation of project costs. Interest cost on capital is however not included in project costs because this is taken care of by the discounting factor (Gittinger, 1972). Computation of the profitability rate involves the calculation of "annual equivalent" of revenues and costs by dividing the total discounted present revenues and costs by the number of years over the production period. The annuity concept aims at revealing what would be the acceptable constant costs and benefits over the project life. The sum of the discount factors for a period "n" is termed the annuity factor. Gittinger (1972) refers to annuity as "How much £1 received annually from the 1st year to the nth year is worth today". Profitability rate or rate of return on investment has a major weakness in that it considers return on invested capital only and therefore favours projects with low capital investment. A project may require low investment capital but very high operating, maintenance, and production costs i.e. very high out-of-pocket costs. Such a project may appear more profitable on account of its high rate of return on investment than another project requiring an equal amount of investment and out-of-pocket costs (added) in which the investment takes the greater portion of the total project costs.

Benefit-Cost Ratio is the ratio of project benefits to project costs. This criterion is one of the most widely used in project appraisal and evaluation especially for economic analysis. This parameter provides some indication of the economic merits of a project. It has much popular appeal since it gives an immediate indication of the "degree" of desirability of the project (Kuiper, 1971). A project with a benefit-cost ratio of well above unity is considered economically justified if the discount rate used truly reflects the risk involved in the project. A ratio of exactly one shows that the project is marginal. The absolute value of the benefit-cost ratio varies depending on the interest rate or discount rate chosen. The higher the discount rate, the smaller is the resulting benefit-cost ratio; and if a high enough discount rate is used on a project the ratio is likely to be driven down to less than one in which case the investor cannot recover the investment. The benefit-cost ratio is computed by comparing the discounted present worth of net benefits with the discounted present worth of project costs (investment plus out-of-pocket costs). A major weakness of the benefit-cost ratio is that it discriminates against projects with relatively high gross returns and high operating costs even though these may be shown to have a greater wealth-generating capacity than alternative projects which have higher benefit-cost ratios.

Another discounted measure of project worth is the internal rate of return, also called the marginal efficiency of investment of a project (Gittinger, 1972). It is the interest or discount rate which would render the discounted present value of a project's expected future marginal yields exactly equal to the investment and out-of-pocket costs of the project. Kuiper (1971) defines it as that discount rate which renders the project a benefit-cost ratio of 1.0. Whereas in the consideration of the benefit-cost ratio one assumes a certain rate of interest or discount, in the case of internal rate of return calculation one tries to measure the rate of discount or the earning power of the project. The internal rate of return has the advantage of not being affected by the assumed interest rate of the project and therefore it is completely independent of the external interest rates (Kuiper, 1971). Internal rate of return (IRR) is a useful measure of project worth and is widely used by the World Bank in both economic and financial analysis of projects. It represents the average earning power of the money used in the project over the project life. When the "IRR" is used in financial analysis of projects it is termed Internal financial rate of return (IFRR) to distinguish it from internal economic rate of return (IERR) used in economic analysis of projects. The formal selection criterion for the internal rate of return measure of project worth is to accept all projects having an internal rate of return above the opportunity cost of capital, which in our tube-well projects is the interest rate on borrowed capital. The minimum acceptable internal rate of return is often termed the "cut off rate" and is normally set slightly above the opportunity cost of capital or interest rate*.

Although this subject of determining project worth has been treated by many authors, each author recommending a different criterion for different types of projects, Gittinger (1972) feels that there is no one best technique for estimating project worth, though some techniques are better than others and some are especially deficient. This is why all the available tools for appraising the profitability of tube-wells in Mombasa have been used in this study.

* For example while the World Bank lends at 9½%, it's cut-off rate is about 12 - 15%. This implies that only those projects with an IRR of 12 - 15% and above would qualify for a loan.

8.2. Some Assumptions and Considerations in Project Appraisal

Depreciation

The method used to depreciate the fixed assets in this study is the straight line method adopted from Yang (1965). Yang suggests two possible ways of depreciating fixed assets, one on the basis of wear and tear and the other on absolescence. Depreciation due to wear and tear is determined by the ratio of actual number of hours the machine is used to the number of hours determined by the manufacturers. In this case annual depreciation cost is variable, depending on the amount of use made of the machine. Depreciation by absolescence is determined by the useful life of the machine in which case the annual depreciation is a fixed sum. The first step in calculating the annual depreciation cost is to determine the total depreciable amount of the fixed assets. In Mombasa, diesel and electric pumps can be operated for 15 to 20 years but breakdown and repair costs become increasingly more from the 10th year. In fact some tube-well farmers operate the pumps for over 20 years but in that case the pumps would not have any trade-in value. Experience gained by the dealers shows that the useful life of engines and pumps under the coastal conditions is about 10 years if the pumps are used everyday for a maximum of 10 hours*. At the 10th year the engines and pumps would still have a salvage value of about 10 percent. Thus the pumps and engines have been depreciated at a fixed amount for 10 years on an absolescence basis. The well,

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* This information was obtained through personal communication with the staff of Wigglesworth Company and Machinery Service - Mombasa.

the pump-shed, and the storage tanks have a useful life of 30 years. So at the end of 10 years these assets still have a high salvage value which for purposes of this study was assumed to be 50 percent of the initial cost of these assets. Farm vehicles have also been depreciated for 10 years on a straight-line obsolescence basis leaving 10 percent salvage value at the 10th year. The annual depreciation costs of the main fixed items are shown in Table 7, appendix I. These costs have been used in computation of the profitability rate.

Discount Rate

The choice as to which discount rate to use in project analysis is not an easy matter. Controversy exists on whether to use the opportunity cost of capital, or the borrowing or lending rate as the discount rate. Gittinger (1972) suggests that, for benefit-cost ratios or net present value calculations, the most appropriate rate is the opportunity cost of capital - that rate which will just result in all the capital in the economy being invested if all possible projects were undertaken which yielded that much or more return. Kerr (1966) also holds similar views and states, "In agricultural projects where loan rather than equity capital is employed, the opportunity cost of capital may be more appropriate. This could be taken as the farmer's personal discount rate, the rate of interest at which he is prepared to invest". In Kenya, where many channels are open for private investment at varying rates of return, it would not be easy to decide outright what the opportunity cost of the farmer's own capital is. Farmers may invest their capital in commercial banks at a savings rate of 5 percent, in the East African Building Society at 8 percent interest, in Government Bonds at 11 percent interest or simply in a grocery at a much higher rate of return. Thus it is clear that the choice of this rate is bound to be personal and subjective.

FAO Lecture notes on agricultural project analysis (FAO, 1969) state that the discount rate should be the interest rate at which loans or investments are undertaken in the economy. The interest or discount rate is here defined as the market price for lending and borrowing. Billings (1971) suggests that in a situation where the rates of return to alternative investments are not known, one alternative would be to use the rate of interest on loans.

The discount rate used in this analysis is the interest rate on borrowed capital. Since the tube-well projects in Mombasa are private projects, most of the investment funds are likely to come from private sources. Most farmers do not have their own capital and therefore they rely much on borrowed capital from the lending institutions such as the Agricultural Finance Corporation (AFC), the Cooperative Bank of Kenya, the Commercial Banks, etc. The A.F.C. and the Co-operative Bank of Kenya charge an interest of 9½ percent while the commercial banks are currently charging 10 percent interest. The author has chosen 10 percent as the discount rate for this analysis because it is from the commercial bank sources that tube-well construction loans are more likely to come.

Cost of Land

Determining a proper value to place on land in an agricultural project is often difficult because this is governed by the market situation of a country or project area, the level of development of the project area, and the land tenure system. In socialist countries, for example, where land belongs to the state and thus cannot enter into money transaction between individuals, the cost of land to an agricultural project would be the net value of production of that land if it were used for another purpose such as a National Park. In areas where land changes ownership through financial transactions, the economic considerations are the sole determinants of land values, but this would assume a perfect land market, which rarely occurs in practice. The cost of land for an irrigation project to be started in an arid zone is low whereas land in a highly-developed high-potential zone is more expensive. Land speculation also inhibits the establishment of a perfect market.

Gittinger (1972) suggests three alternatives for determining the value of land for the purpose of economic and financial analysis of a project. One alternative is to value the land at its purchase price, entering the cost of land purchase as a lumpsum capital item incurred one time only at the beginning of the project. This is the simplest approach, but it assumes that the land market is relatively competitive and open and the purchase price is close to an equilibrium price in a perfect market. This is the best approach especially where financial analysis of a project is done.

In the area of study most of the farms belong to absentee landlords who prefer to rent the land instead of selling it. Another alternative is to value land at it's rental cost and enter it into the project costs year by year as the project proceeds. This is the alternative used in this analysis. Out of the 20 farms studied in the sample 18 farmers indicated that they were paying annual rents for the land, and only two owned the land. Land rent is therefore a good alternative of valuing land especially for financial analysis. Valuing land at it's opportunity cost or the net value of production foregone is good in economic analysis where land is owned by the public.

Length of Project Period

The cut-off point of this project was decided from the technical-life point of view. As mentioned earlier under depreciation, the useful life of pumps in Mombasa is 10 to 20 years, with operation and maintenance costs of the pumps becoming increasingly higher after the 10th year. So 10 years has been taken as the average technical life of the pumps. The well may have a useful life of 30 to 40 years after which it may collapse. Gittinger (1972) suggests that a convenient way of establishing the period of analysis of a project is to use the technical life of the major investment item. In a tube-well project one alternative would be to take the well as the major investment item and replace the pumps when they have become too old. The other alternative is to take the pumps as the major investment items and close down the project when the pumps have become too old, in which case the well would still have a fairly high salvage value at the end of the project period. This second alternative has been used to determine the cut-off point of the tube-well projects in the study.

Salvage Value

Although the technical life of the project has been assumed to be 10 years, most of the major investment items could not have been used up at the end of 10 years. The engines and pumps can be sold to scrap dealers at a price referred to as salvage value in this analysis. The salvage values of the main investment items are given in Table 7, appendix I. These salvage values are treated as a benefit to the project in the last year of the project.

Capital Investment and Out-of-Pocket Costs

Capital investment in private tube-well projects is incurred once at the beginning of the project life in year "zero". Out-of-pocket costs include fuel or electricity, purchased inputs and repair, and maintenance of the pumps. These costs are shown in tabular form in table 8.1. It is observed from this table that the annual out-of-pocket costs for the tube-well projects are higher than the initial investment costs. These high out-of-pocket costs are due to the large working capital required for the operation of the pumps and the production costs of horticultural crops.

Table 8.1 Sample Farms: Summary of investment, Annual costs and Annual benefits

Item	Source of data	Amount K. Shs.
Investment		
Construction costs	Table 6.2 last column	8,055
Pump-shed Storage tank, Hand tools and levelling	Table 6.3 and 6.4 column 2, 3, 4, and 5	12,868
Engines and pumps	Table 6.5 last column	18,200
Farm vehicles	Table 6.12 5th column	35,012
Total		74,885
Annual costs		
Land rent	Table 6.3 and 6.4 6th column	3,900
Operating the pumps	Table 6.6 6th column	17,680
Repairs and maintenance of pumps	Page 90	5,000
Clearing canals	Page 82	1,000
Transport	Page 100	12,750
Permanent labour	Page 97	8,748
Family labour	Page 97	16,800
Farm inputs (plus casual labour)	Tables 7.1 - 7.10	44,800
Total		116,200
Annual benefits		
Gross output	Table 7.12	198,400*

* This figure is equivalent to the total average gross margin of Shs. 153,500 in table 7.12 plus the total for farm inputs (plus casual labour) of Shs. 44,800 as shown above.

8.3. Analysis Results

8.3.1. Payback Period

It is observed from table 8.2. that the payback period or recoupment of the tube-well projects is very short. The initial investment which is incurred in year zero* is Shs.75,000 and the out-of-pocket costs amount to Shs.116,200, thus the total costs that year amount to Shs.191,200 and the benefits accruing that year amount to Shs.198,400. Thus practically all the initial investment in the tube-well projects can be recouped in about one year. This short payback period is due to two reasons. One is the fact that the initial investment in a private tube-well project is not very big. Secondly the horticultural crops grown under irrigation have fairly high gross returns.

8.3.2. Rate of Return on Investment Capital

In calculation of the return to capital investment or profitability rate a discount rate of 10% has been used as discussed earlier in this chapter. The annual equivalents of costs and benefits have been computed by dividing both the sum of the discounted costs and benefits by 10 which is the economic life of the project. This gives the average annual costs and benefits. The profitability rate or return on investment is then obtained by dividing the difference between the annual equivalent of revenues and the annual equivalent of costs by the present value of investment.

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* Year zero is here taken to mean the beginning of the project.

$$\text{Profitability rate} = \frac{\text{Annual equivalent of revenue} - \text{Annual equivalent of cost}}{\text{Present value of investment}}$$

The profitability rate for the tube-well projects works out at [illegible] percent. This means that the return on the investment is 60 percent over and above a 10 percent rate of return. Since in the calculations of annual costs depreciation costs were included and since the annual equivalent of revenue is greater than the annual equivalent of costs, the investment has returned in interest payments at least as much as the 10 percent rate of interest in each year. The total rate of return on capital is therefore 70 percent. Table 8.3 and 8.4 show that the rate of profitability of the project falls when the costs and revenues are discounted at a higher rate.

Table 8.2 Profitability rate calculated from future values of costs and benefits discounted at 10 percent

Year	Future Nominal Values			Discount Factor at 10%	Present Values		
	Investment	Annual Costs*	Annual Benefits		Investment	Annual Costs	Annual Benefits
	K. Shs. '000				K. Shs. '000		
0	75			1.00	75		
1		116	198	0.909		105.4	180.0
2		116	198	0.826		95.6	163.5
3		116	198	0.751		87.1	148.7
4		116	198	0.683		79.2	135.2
5		116	198	0.621		72.0	123.0
6		116	198	0.564		65.4	111.7
7		116	198	0.513		59.5	101.6
8		116	198	0.467		54.2	92.5
9		116	198	0.426		49.4	84.3
10		116	210	0.386		44.8	81.0
	75	1,160	1,992	6.144	75	713.5	1,221.9

Average annual benefits = $\frac{\text{Total discounted benefits}}{10} = \frac{1221.9}{10}$

= 122.2

Average annual costs = $\frac{\text{Total discounted costs}}{10} = \frac{713.5}{10}$

= 71.4

Profitability rate = $\frac{\text{Average annual benefits} - \text{Average annual costs} \times 100}{\text{Present value of investment}}$

= $\frac{122.2 - 71.4}{75} \times 100$

= 68%

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* Annual costs exclude interest on capital.

Benefits in the 10th year include salvage value.

Table 8.3 Profitability rate calculated from future values of benefits and costs discounted at 15 percent

Year	Future Nominal Values: Investment	Future Nominal Values: Annual Costs	Future Nominal Values: Annual Benefits	Discount Factor at 15%	Present Values: Investment	Present Values: Annual Costs	Present Values: Annual Benefits
	K. Shs. '000				K. Shs. '000		
0	75	-	-	1.00	75	-	-
1		116	198	0.870		100.9	172.3
2		116	198	0.756		87.7	149.7
3		116	198	0.658		76.3	130.3
4		116	198	0.572		66.4	113.3
5		116	198	0.497		57.7	98.4
6		116	198	0.432		50.1	85.3
7		116	198	0.376		43.6	74.4
8		116	198	0.327		37.9	64.7
9		116	198	0.284		32.9	56.2
10		116	210	0.247		28.6	51.8
	75	1,160	1,992	5.019	75	582.1	993.5

$$\text{Average annual benefits} = \frac{\text{Total discounted benefits}}{10} = \frac{993.5}{10}$$

$$= 99.4$$

$$\text{Average annual costs} = \frac{\text{Total discounted costs}}{10} = \frac{582.1}{10}$$

$$= 58.2$$

$$\text{Profitability rate} = \frac{\text{Average annual benefits - Average costs} \times 100}{\text{Present value of investment}}$$

$$= \frac{99.4 - 58.2}{75} \times 100$$

$$= 54.9\%$$

$$= 55\%$$

Table 8.4 Profitability rate calculated from future value of benefits and costs discounted at 30 percent

Year	Future Nominal Values: Investment	Future Nominal Values: Annual Costs	Future Nominal Values: Annual Benefits	Discount Factor at 30%	Present Values: Investment	Present Values: Annual Costs	Present Values: Annual Benefits
	K. Shs. '000				K. Shs. '000		
0	75	-	-	1.00	75	-	-
1		116	198	0.769		89.2	152.3
2		116	198	0.592		68.7	117.2
3		116	198	0.455		52.8	90.1
4		116	198	0.350		40.6	69.3
5		116	198	0.269		31.2	53.3
6		116	198	0.207		24.0	53.0
7		116	198	0.159		18.4	31.5
8		116	198	0.123		14.3	24.4
9		116	198	0.094		10.9	18.6
10		116	210	0.073		8.5	15.3
	75	1,160	1,992		75	358	611.9

$$\text{Average annual benefits} = \frac{\text{Total discounted benefits}}{10} = \frac{611.9}{10}$$

$$= 61.2$$

$$\text{Average annual costs} = \frac{\text{Total discounted costs}}{10} = \frac{358}{10}$$

$$= 35.8$$

$$\text{Profitability rate} = \frac{\text{Average annual benefit} - \text{Average annual costs} \times 100}{\text{Present value of investment}}$$

$$= \frac{61.2 - 35.8 \times 100}{75}$$

$$= 34\%$$

8.3.3. Benefit-Cost Ratio

Horticultural farming is, as discussed in the last chapter, a capital intensive venture involving high annual production costs per acre, and in some cases much higher than the initial investment costs. Thus a better criterion for determining the real project worth would be one that shows the return on total capital employed on the project-investment costs and total out-of-pocket costs.

Benefit-cost ratio is a better criterion for judging the private tube-well projects because it compares the total discounted benefits with the total discounted costs (Investments plus out-of-pocket costs). It is observed from table 8.5 that after discounting all the future nominal costs and benefits at 10 percent, the benefit-cost ratio of the tube-well projects works out to 1.6. Any benefit-cost ratio greater than 1 means that the project earns at least 10 percent in its economic lifetime after the investment capital and all other costs have been recovered. The tube-well projects are therefore profitable because they yield benefits over one and half times the total sum of capital employed (investment, production, and operation costs) even after allowing an interest cost of 10 percent. This 10 percent interest cost ensures that all the project costs are fully recovered if the benefit-cost ratio works out to 1 or over.

Although this criterion is recommended for appraisal and evaluation of public projects, many economists have in the past used it to establish the economic worth of private projects as well. Maji and Sirohi (1969) in their study of electrically-operated deep tube-wells in West Bengal did a benefit-cost analysis and found that even at low utilization of tube-wells (8 hours a day) the benefit-cost ratio of tube-well installation was as high as 3.0, 2.3, and 2.1 at discounting rates of 5 percent, 7.5 percent, and 10 percent respectively. At higher levels of tube-well utilization the benefit-cost ratio was higher. Mellor and Moorti (1969) in their comparative study of costs and benefits of irrigation from state and private tube-wells in Uttar Pradesh also found high benefit-cost ratios - 1.8 and 1.9 for state and private tube-wells respectively at a 12 percent rate of discount. These are consistent with the high profitability of investment in tube-well projects as found in this analysis.

8.3.4. Net Present Worth

The net present worth of the tube-well projects in this study works out to K.Shs.465,800 after discounting the future costs and benefits at 10 percent. The 10 percent discount rate ensures that the investment capital and operating and production costs are fully recovered at the end of 10 years, and the project will still earn an extra K.Shs.465,800. Therefore all the capital borrowed from the banks at 10 percent interest rate can be repaid and the farmer will remain with a net balance of this amount in terms of the present value of future incomes.

Table 8.5 Benefit-cost ratio and net present worth calculated from present and future value of costs and benefits

Year	Future Nominal Values			Discount Factor 10 %	Present Values		
	Investment	Annual Costs°	Annual Benefits		Investment	Annual Costs	Annual Benefits
	K. Shs. '000				K. Shs. '000		
0	75	-	-	1.00	75	-	-
1		110	198	0.909		100.0	180.0
2		110	198	0.826		90.9	163.5
3		110	198	0.751		82.6	148.7
4		110	198	0.683		75.1	135.2
5		110	198	0.621		68.3	123.0
6		110	198	0.564		62.0	111.7
7		110	198	0.513		56.4	101.6
8		110	198	0.467		51.4	92.5
9		110	198	0.426		46.9	84.3
10		110	198	0.386		42.5	76.4
	75	1,100	1,980		75	676.1	1,216.9

Benefit-cost ratio = $\frac{\text{Total discounted benefits}}{\text{Total discounted costs (investment + Annual costs)}}$

$$= \frac{1216.9}{676.1 + 75} = \frac{1216.9}{751.1}$$

$$= 1.619$$

$$\approx 1.6$$

Net present worth = (1216.9 - 751.1) X 1000

= Shs. 465,800

° Annual costs include out-of-pocket costs (production costs, family and permenent labour, transport) and cost of land. Depreciation costs are not included.

8.3.5. <u>Internal Rate of Return</u>

The internal rate of return as defined earlier in this chapter is that rate of discount which makes equal the total discounted benefits and the total discounted costs i.e. it gives a net discounted cash flow or net present worth of zero. The IRR is also that discount rate which gives a benefit-cost ratio of exactly 1. Table 8.5 shows that at a discount rate of 10% the Net present worth of the projects is Shs.465,800 and the benefit-cost ratio is 1.6. At a 20 percent discount rate the net present worth falls to K.Shs.293,000 and the benefit-cost ratio falls to 1.5. At a 100 percent discount rate the net present worth or net discounted cash flow falls to Shs.14,000 and the benefit-cost ratio is 1.074. It is therefore clear that we would have to discount the benefit and cost streams at a discount rate slightly over 100 percent in order to arrive at a net discounted cash flow of zero and a benefit cost ratio of 1. It will be observed from table 8.10, which summarizes tables 8.5 to 8.9, that every 10-percent increase of the discount rate up to 50 percent reduces the benefit-cost (B/C) ratio by about 0.07. However, over the large range from 50 to 100 percent, the decrease per 10-percent increase of the discount rate is about 0.05. Thus a discount rate of 115 - 120 percent likely would be required to reduce the B/C ratio from 1.074 to exactly 1, so that the IRR likely falls in this range. These results showing the high earning power of capital invested in private tube-well projects are supported by Mellor and Moorti (1969) in their study of tube-well projects in Uttar Pradesh India in which they got an internal rate of return of well over 50 percent for private shallow tube-well projects.

It is therefore evident that in bankability terms the private tube-well projects at the existing level of performance in Mombasa are highly attractive for investment because they would more than pass all the financial feasibility tests at the going interest rate charged by the banks. It is however worth noting that irrigation is an art which not many people have mastered. In the area of study 18 farmers out of a sample of 20 were Indians who claimed to have acquired the art from their forefathers. These Indians are considered to be of a lower social class in the Indian Community however profitable farming is. The findings of this study are also subject to the limitations and assumptions discussed in chapter three and the beginning of this chapter*

* The estimated 20 percent loss of farm produce due to seasonal fluctuation of supply and demand was not taken into account. Many farmers also complained of considerable loss of farm produce through theft and/or through illegal sale of the produce by farm workers.

Table 8.6 Benefit-cost Ratio and Net Present Worth Calculated from Future benefits and Costs Discounted at 20 percent

Year	Future Nominal Values			Discount Factor at 20%	Present Values		
	Investment	Annual Costs	Annual Benefits		Investment	Annual Costs	Annual Benefits
	K. Shs. '000				K.Shs. '000		
0	75	-	-	1.000	75	-	-
1		110	198	0.833		91.6	164.8
2		110	198	0.694		76.3	131.4
3		110	198	0.579		63.7	114.6
4		110	198	0.482		53.0	95.4
5		110	198	0.402		44.2	79.6
6		110	198	0.335		36.8	66.3
7		110	198	0.279		30.7	55.2
8		110	198	0.233		25.6	46.1
9		110	198	0.194		21.3	38.4
10		110	198	0.162		17.2	32.1
	75	1,110	1,980		75	460.8	829.1

$$\text{Benefit-cost ratio} = \frac{\text{Total discounted benefits}}{\text{Total discounted costs + investment}}$$

$$= \frac{829}{536}$$

$$= 1.546$$

B/C ratio = 1.5

Net present worth = (829 - 536) x 1000

= <u>Shs.293,000</u>

Table 8.7 Benefit-cost ratio and net present worth calculated from future benefits and costs discounted at 30 per-cent

Year	Future Nominal Values			Discount Factor at 30%	Present Values		
	Investment	Annual Costs	Annual Benefits		Investment	Annual Costs	Annual Benefits
	K. Shs. '000				K. Shs. '000		
0	75	-	-	1.00	75	-	-
1		110	198	0.769		84.6	152.3
2		110	198	0.592		65.1	117.2
3		110	198	0.455		50.0	90.1
4		110	198	0.350		38.5	69.3
5		110	198	0.269		29.6	53.3
6		110	198	0.207		22.7	40.9
7		110	198	0.159		17.5	31.5
8		110	198	0.123		13.5	24.4
9		110	198	0.094		10.3	18.6
10		110	198	0.073		8.0	14.5
	75	1,100	1,980		75	339.9	611.9

$$\text{Benefit-cost ratio} = \frac{\text{Total discounted benefits}}{\text{Total discounted costs + investment}}$$

$$= \frac{611.9}{339.9 + 75}$$

$$= \frac{611.9}{414.9}$$

$$= 1.475$$

B/C ratio = 1.5

Net present worth = (611.9 - 414.9) x 1000

= K.Shs.197,000

Table 8.8 Benefit-cost ratio and net present worth calculated from future benefits and costs discounted at 50 per-cent

Year	Future Nominal Values			Discount Factor at 50%	Present Values		
	Investment	Annual Costs	Annual Benefits		Investment	Annual Costs	Annual Benefits
	K. Shs. '000				K. Shs. '000		
0	75	-	-	1.00	75	-	-
1		110	198	0.667		73.4	132.1
2		110	198	0.444		48.8	87.9
3		110	198	0.296		32.6	58.6
4		110	198	0.198		21.8	39.2
5		110	198	0.132		14.5	26.1
6		110	198	0.088		9.7	17.4
7		110	198	0.059		6.5	11.7
8		110	198	0.039		4.3	7.1
9		110	198	0.026		2.7	5.1
10		110	198	0.017		1.8	3.4
	75	1,100	1,980		75	216.3	388.6

Benefit-cost ratio $= \dfrac{\text{Total discounted benefits}}{\text{Total discounted costs + Investment}}$

$= \dfrac{388.6}{216.3 + 75}$

$= \dfrac{388.6}{291.3}$

$= 1.334$

B/C ratio $= 1.3$

Net present worth $= (388.6 - 291.3) \times 1000$

$=$ <u>Shs.97,000</u>

Table 8.9 Benefit-cost ratio and net present worth calculated from future benefits and costs discounted 100 percent

Year	Future Nominal Values			Discount Factor at 100%	Present Values		
	Investment	Annual Costs	Annual Benefits		Investment	Annual Costs	Annual Benefits
	K. Shs. '000				K. Shs. '000		
0	75	-	-	1.00	75	-	-
1		110	198	0.500		55	99.0
2		110	198	0.250		27.5	49.5
3		110	198	0.125		13.6	24.7
4		110	198	0.0625		6.8	12.4
5		110	198	0.0312		3.4	6.2
6		110	198	0.0156		1.7	3.1
7		110	198	0.0078		0.9	1.6
8		110	198	0.0039		0.5	0.8
9		110	198	0.00195		0.2	0.4
10		110	198	0.00097		0.1	0.2
	75	1,100	1,980		75	109.3	197.8

Benefit-cost ratio $= \dfrac{\text{Total discounted benefits}}{\text{Total discounted costs + Investment}}$

$$= \frac{197.8}{109.3} + 75$$

$$= \frac{197.8}{184.3}$$

$$= 1.074$$

B/C ratio = 1.1

Net present worth = Shs.14,000

Table 8.10 Benefit-cost ratios and net present value at different discount rates

Discount rate %	Net present worth	B/C ratio	Amount of reduction	
			Direct	Per 10-percent increase in discount rate
	K.Shs. '000			
10	465.8	1.619	0.073	0.073
20	293.3	1.546	.072	.072
30	197.0	1.474	.140	.070
50	97.0	1.334	.260	.052
100	15.0	1.074		

Source: Summary of Tables 8.5 to 8.9.

6.4. The effect of Changing Prices and Interest Rate on the Profitability of the Tube-Well Projects

In the financial analysis of the tube-well projects in this study we have established their financial worth by assuming constant prices of farm inputs and farm produce over the economic life time of the projects. Certainly this assumption is unrealistic because these prices cannot be expected to remain constant for a period of 10 years especially in the present-day world inflation trend. Unfortunately, in all agricultural projects it is a difficult task to predict the changes in commodity prices over the lifetime of a project, however short it may be. Gittinger (1972) suggests that the best general guide to future prices is those of the past decade or so. But in a situation where prices have been gradually increasing in the past decade it could rightly be assumed that this trend will increase into the next decade or so. It is customary in project appraisal to test the sensitivity of the various measures employed to judge the project worth. The idea is to test if the project would still pass the profitability or financial viability tests if slight changes occurred in the economy. The question posed is; Would the earning power or earning capacity of the project be changed by unexpected results in the project? These measures are usually tested for price and yield sensitivity and for changes in interest rate on capital.

Sensitivity on yield is usually done on a project where a new cropping pattern is being proposed and the agronomic information is based mainly on experimental trials. As explained in the previous chapter the yields used in this analysis have been underestimated and therefore if any sensitivity analysis has to be done with respect to yield changes then it must be based on higher yield estimates. For the purpose of this study, however, we shall stick to the yield estimates used in the initial calculations.

Sensitivity analysis with respect to output prices could also be done for these tube-well projects, but in the gross margin analysis we have used weighted average market prices to determine the gross output per acre. For example tomatoes prices for the years 1975-76 used in this study fluctuate between 60 cents per kg. in the peak harvest season to Shs.2.00 per kg. in the off-season as shown in Table 4 appendix I. A weighted averaged prices of 80 cents per kg. has been used in calculation of the gross revenue per acre of tomatoes. Weighted average prices have been used to estimate the gross revenues of all the crops in the study. No allowance has been made for an increase in the prices of farm produce. Depending on long-run supply developments for horticultural crops, prices for these items may remain about the same on the average or may rise, reflecting general inflation. To be conservative with respect to the merits of the tube-well projects, no change has been made from the prices in the initial analysis.

For input prices on the other hand we can safely assume that they will rise gradually over the project lifetime. The main farm input prices expected to rise are those for fuel and oil, electricity, seed, fertilizers and manures, fungicides, pesticides, and labour costs. It must be pointed out here that it is difficult to predict the future price trends of these farm inputs individually with any degree of accuracy. For instance most of the farm input prices have over the last 5 years risen tremendously due to the world oil situation. We cannot rely on the assumption that this past trend will continue into the next 10 years at the same rate. Tables 5 and 6 appendix I show how the prices of some of the farm inputs have increased in the last 5 years. Most of the input prices have increased at the rate of about 20 percent annually. For our purpose we assume a steady 10 percent annual increase in total annual variable cost over the project life versus constant output prices and hence constant annual benefits over the same time period. The effect of the changes in annual costs is shown in tables 8.11 to 8.15. Table 8.16 shows the sensitivity of the projects at different discount rates assuming constant annual costs and output prices and Table 8.17 shows the sensitivity of the project at different discount rates assuming a 10 percent annual increase in annual costs. It will be observed from these tables that the profitability of the tube-well projects is not sensitive to small changes in the discount rate. For example the benefit-cost ratio of the projects changes by 0.1 between discounting rates of 10 and 30 percent and the net present worth is still positive even at 100 percent discount rate. After allowing a 10 percent annual increase on costs, the indicators of the financial viability of the tube-well projects are still positive at discounting rates as high as 100 percent.

Table 8.11 Benefit-cost ratio and net present worth at a 10 percent discount rate after allowing 10 percent annual increase on costs.

Year	Future Nominal Values: Investment	Annual Costs	Annual Benefits	Discount Factor at 10 %	Present Values: Investment	Annual Costs	Annual Benefits
	K. Shs. '000				K. Shs. '000		
0	75	-	-	1.00	75	-	-
1		110	198	0.909		100.0	180.0
2		121	198	0.826		99.9	163.5
3		132	198	0.751		99.1	148.7
4		143	198	0.683		97.7	135.2
5		154	198	0.621		95.6	123.0
6		165	198	0.564		93.1	111.7
7		176	198	0.513		90.3	101.6
8		187	198	0.467		87.3	92.5
9		198	198	0.424		84.0	84.4
10		209	198	0.386		80.7	76.4
	75	1,980			75	927.7	1,216.9

Benefit-cost ratio $= \dfrac{\text{Total discounted benefits}}{\text{Total discounted costs + investment}}$

$$= \frac{1216.9}{927.7 + 75} = \frac{1216.9}{1002.7}$$

$$= 1.213$$

$$\simeq 1.2$$

Net present worth $= (1216.9 - 1002.7) \times 1000$

$$= \text{Shs. } 214,200$$

Table 8.12 Benefit-cost ratio and net present worth at 20 percent discount rate, allowing 10 percent annual increase on costs.

Year	Future Nominal Values			Discount Factor at 20%	Present Values		
	Investment	Annual costs	Annual Benefits		Investment	Annual Costs	Annual Benefits
	K. Shs. '000				K. Shs. '000		
0	75	-	-	1.000	75	-	-
1		110	198	0.833		91.6	164.8
2		121	198	0.694		84.0	131.4
3		132	198	0.579		76.4	114.6
4		143	198	0.482		68.9	95.4
5		154	198	0.402		61.9	79.6
6		165	198	0.335		55.3	66.3
7		176	198	0.297		52.3	55.2
8		187	198	0.233		43.6	46.1
9		198	198	0.194		38.4	38.4
10		209	198	0.162		33.9	32.1
	75				75	606.3	829.1

Benefit-cost ratio = $\frac{\text{Total discounted benefits}}{\text{Total discounted costs + investment}}$

$= \frac{829.1}{603.3 + 75}$

$= \frac{829.1}{678.3}$

$= 1.2$

Net present worth = (829.1 - 678.3) x 1000

= Shs. 150,800

Table 6.13 Benefit-cost ratio and net present worth calculated at 30 percent discount rate and allowing 10 percent annual increase on costs.

Year	Future Nominal Values			Discount Factor at 30 %	Present Values		
	Investment	Annual costs	Annual Benefits		Investment	Annual costs	Annual Benefits
	K. Shs. '000				K. Shs. '000		
0	75	-	-	1.000	75	-	-
1		110	198	0.769		84.6	152.3
2		121	198	0.592		71.6	117.2
3		132	198	0.455		60.0	90.0
4		143	198	0.350		50.0	69.3
5		154	198	0.269		41.0	53.3
6		165	198	0.207		34.2	41.0
7		176	198	0.159		30.0	31.5
8		187	198	0.123		23.0	24.4
9		198	198	0.094		18.6	18.6
10		209	198	0.073		15.3	14.6
	75				75	428.2	611.9

$$\text{Benefit-cost ratio} = \frac{\text{Total discounted benefits}}{\text{Total discounted costs + investment}}$$

$$= \frac{611.9}{428.2 + 75}$$

$$= \frac{611.9}{503.2}$$

$$= 1.21$$

$$\text{Net present worth} = (611.9 - 503.2) \times 1000$$

$$= \text{Shs. } 108{,}700$$

Table 8.14 Benefit-cost ratio and net present worth calculated at 50 percent discount rate and allowing 10 percent annual increase on costs.

Year	Future Nominal Values			Discount Factor at 50 %	Present Values		
	Investment	Annual costs	Annual Benefits		Investment	Annual Costs	Annual Benefits
	K. Shs. '000				K. Shs. '000		
0	75	-	-	1.000	75	-	-
1		110	198	0.667		73.4	132.1
2		121	198	0.444		53.7	87.9
3		132	198	0.296		39.1	58.6
4		143	198	0.198		28.3	39.2
5		154	198	0.132		20.3	26.1
6		165	198	0.088		14.5	17.4
7		176	198	0.059		10.4	11.7
8		187	198	0.039		7.3	7.1
9		198	198	0.026		5.1	5.1
10		209	198	0.017		3.6	3.4
	75				75	255.7	388.6

Benefit-cost ratio $= \dfrac{\text{Total discounted benefits}}{\text{Total discounted costs + investment}}$

$= \dfrac{388.6}{255.7 + 75} = \dfrac{388.6}{320.7}$

$= 1.21$

Net present worth $= (388.6 - 320.7) \times 1000$

$=$ Shs. 68,000

Table 8.15 Benefit-cost ratio and net present worth calculated at 100 percent discount rate and allowing 10 percent annual increase in costs.

Year	Future Nominal Value			Discount Factor at 100 %	Present Values		
	Investment	Annual costs	Annual Benefits		Investment	Annual Costs	Annual Benefits
	K. Shs. '000				K. Shs. '000		
0	75	-	-	1.000	75	-	-
1		110	198	0.500		55.0	99.0
2		121	198	0.250		30.3	49.5
3		132	198	0.125		16.5	24.8
4		143	198	0.0625		8.9	12.4
5		154	198	0.0312		4.8	6.2
6		165	198	0.0156		2.6	3.1
7		176	198	0.0078		1.4	1.5
8		187	198	0.0039		0.7	0.8
9		198	198	0.00195		0.4	0.4
10		209	198	0.00097		0.2	0.2
	75				75	120.8	198.9

$$\text{Benefit-cost} = \frac{\text{Total discounted benefits}}{\text{Total discounted costs + investment}}$$

$$= \frac{198.9}{120.8 + 75} = \frac{198.9}{195.8}$$

$$= 1.01$$

$$= \text{Shs. } 2,200$$

Table 8.16 Sensitivity of the profitability rate, benefit-cost ratio and present worth of Tube-well projects at different discount rates.

Criterion	Discount rate					
	10%	15%	20%	30%	50%	100%
Profitability rate %	69	55		34		
Benefit-cost ratio	1.6		1.5	1.5	1.3	1.1
Net present worth Shs. '000	465		293	197	97	14

Source: Summary of Tables 8.2 to 8.9

Table 8.17 Sensitivity of benefit-cost ratio and net present worth of the Tube-well projects with 10 percent annual increase of annual costs at different discount rates.

Criterion	Discount rate				
	10%	20%	30%	50%	100%
Benefit-cost ratio	1.2	1.2	1.2	1.2	1.0
Net present worth Shs'000	214.2	150.8	108.7	68	2.2

Source: Summary of tables 8.11 to 8.15

CHAPTER IX

SUMMARY AND CONCLUSIONS

9.1. Resumé of the Study and Findings

Although the two largest rivers in Kenya run through the Coast Province, much of the area is characterised by a general lack of permanent rivers so that there is little scope for irrigation development using river water. The search for an alternative source of water to reduce the whims of nature is inevitable. A large portion of the Province lies in the medium and low-potential zone, and water development for irrigation purpose is considered as the best alternative for agricultural development in this area. Tube-wells as a source of irrigation water is beginning to receive some recognition in Kenya generally and more so in the coastal strip. The Government has laid more emphasis on development of minor irrigation schemes in its current development plan. Emphasis has mainly been focused on the development of tube-wells in semi-arid areas for irrigation and livestock purposes through the tube-wells subsidy. The 40 percent subsidy on all individual tube-wells in the marginal areas will greatly encourage their construction in the future and therefore increase the total irrigable acreage under the minor irrigation development programme.

The objective of this study is to assess the benefits reaped by farmers through tube-well irrigation. The study was confined to Mombasa District which has the greatest concentration of tube-wells. Ten tube-wells operated with diesel pumps and another 10 operated with electric pumps were selected for study.

The techniques of budgeting and financial appraisal were used in assessing the financial worth of the tube-well projects. This study of the operation of the tube-wells and the benefits reaped by the cultivators reveals that the tube-well development can bring substantial financial and social benefits. Construction costs and installation of the pumps were found to be the main investment items in the tube-well development but annual operation and maintenance costs are much higher.

The tube-wells in the study were found to be under-utilized, pumping being done for an average of 8 hours per day. The main reason for this is the small size of the plots being irrigated. For example a 24 H.p diesel pump fitted with a 3-inch suction and 3½-inch delivery pipe was used to irrigate an average of 30 - 35 acres per day. Such a pump could irrigate up to 50 acres if land were available and water distribution system improved. However such big pumps were necessary because they would be expected to lose some power as they became older.

The cropping pattern, though not rigid, was found to have increased among the tube-well farms. The main factors influencing the cropping pattern were found to be: An assured market, relative market price of the vegetables in any particular season, and the availability of labour. As a result of availability of assured irrigation water, some farmers grew as many as 9 different types of vegetables with brinjals, pawpaws, Chinese spinach, and bananas being the leading crops. The cropping intensity was also found to increase through double cropping.

The study also reveals that irrigated farms have a high labour requirement, employing at least one man per acre for 8 hours a day throughout the year. Therefore tube-well irrigation development would be one way of reducing the unemployment problem, assuming that adequate land and markets for the output were available.

The study also reveals that horticultural farming using tube-well irrigation in Mombasa District is a profitable venture if high value crops are grown. Experience in irrigation work is essential for successful irrigation, and a high degree of managerial ability and first hand market intelligence is also required.

Comparison of the two systems of irrigation - electric and diesel - has shown that the electric system is cheaper and more convenient in operation and maintenance. Electric pumps costs are shown to be 15 percent lower than diesel pumps at a particular level of operation. The extent of rural electrification is however minimal, power lines passing only along the main-roads. Therefore only a few farms along these roads have been able to shift from diesel to electric pumps.

The financial appraisal of tube-well irrigation projects has revealed that the capital invested in these projects can be recouped in one year. The financial viability of these projects has been established. With a profitability rate of 68 percent, benefit-cost ratio of 1.6, and an internal rate of return of over 100 percent, the suitability of tube-well projects as investment projects in Mombasa cannot be questioned, provided the farmers have the necessary management and irrigation skills.

Even at higher rates of interest charged on the investment capital, tube-well projects have been found to be quite attractive. They are even likely to remain highly attractive investment projects in the foreseeable future inspite of input price increases.

9.2. Policy Implications and Recommendations

Much has been written and talked about by economists and politicians on the problem of Government policy with regard to settlement of the landless, self-sufficiency in foods, and unemployment. Although the Government has been vague in regard to the time when settlement would be complete, the objective remains to develop and open-up all irrigable land in Kenya. Kenyan irrigation planning has been characterised by emphasis on large-scale surface irrigation projects and, although these have been shown to ease-out the main development problems, expansion of such projects is becoming difficult in view of their large foreign capital requirement in the present inflationary trend. Emphasis now is and will continue to be on small-scale irrigation projects involving a village or just a small group of people. The 1975-76 drought, which claimed many lives of people and animals in various parts of the country, gave added urgency to small-scale irrigation development. Such development in most of the areas will involve exploitation of the groundwater resources. In view of the potential benefits of tube-well projects, a tube-well investment programme should be planned in various parts of the country where no permanent rivers or streams exist. These programmes should aim mostly to support and encourage small groups of people and even private investors in small and large diameter tube-wells, powered where possible, by electricity. Energisation of all open wells that have been abandoned or left to the local governments for domestic purposes should be started so that greater quantities of water could be pumped for domestic as well as irrigation purposes*.

The development of a tube-well programme will also call for improved extension service. In view of the fact that irrigation is an advanced technology, more training pertaining to proper irrigation methods and agronomic aspects of the crops should be organised for both the extension staff and farmers. The training would involve teaching agro-business and demonstrations of the use of modern record-keeping. The development of the tube-well programme will also call for accelerated registration of land in Coast Province to provide farmers with title deeds which they could offer as security for credit purposes.

The emphasis on smaller group or even individual irrigation projects is explained here from the agronomic view-point. Wells which provide controlled water adequately, reliably, and when and where it is needed, have been found to be more popular than seasonal canals that may have major distribution problems. Highly-controlled water allocation, geared to optimal cropping systems, is not in general possible with a large-scale distribution system, which for efficient water use might imply centralised decisions on cropping patterns and timing of cultivation

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* A large number of such wells in the Coast Province were dug by the Ministry of Natural Resources and later handed over to the Local Government County Councils or abandoned when nobody was available to care for them.

and water release. To the individual farmer there are great gains to be derived from private control of irrigation water. And a private tube-well system would of course economise in direct absorption of Government administrators. The farmer can organise his cropping pattern according to his preference, expected returns, water, capital, and labour availability. For smaller and private irrigation projects in Mombasa District and along the Coast, emphasis should be on development of horticultural farming to cope with the rapidly growing tourist industry which earns Kenya a substantial amount of foreign exchange.

To accomplish these objectives the Government may have to review the farm credit system. The Agricultural Finance Corporation, which has been the main Government lending institution, in collaboration with the Farm Management Division of the Ministry of Agriculture should step-up efforts to recruit more farmers to take credit for tube-well development. In view of the large initial investment required in tube-well projects the size of the small-scale loan available to small-scale farmers should be reviewed to enable private tube-well investors to borrow enough capital for such projects*. A tube-well trial programme with selected African farmers would have to be started and if it works satisfactorily, then the programme could be extended to other farmers. This would also test the price-response in the market place.

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* Small-scale loans are those not exceeding Shs.15,000 which are given to small-scale farmers (3 - 25 acres). Such loans would not be sufficient for the initial investment in a tube-well project.

9.3. Conclusions and Further Research Needs

This study has revealed that irrigation farming using groundwater is highly viable, given the required management and irrigation skills. Although the initial investment cost in tube-wells and the pump-sets is high, the project yields quick returns and can pay off the investment in one year if profitable horticultural crops like bananas and spinach are grown. Tube-well projects should be found attractive by the lending institutions because of their short pay-back periods and high rates of profitability and internal rates of return. These findings, however, should be substantiated by more comprehensive studies in this respect in different parts of the Province and the country at large and also over successive years. The Government should embark on an expansion programme in those areas where positive tube-well results have been obtained and an extensive trial programme with a few of the better African farmers in various areas that appear suitable.

In the course of this study a number of areas have been identified which would appear to offer fruitful future research opportunities. For example it would be of interest to study the optimum size of a tube-well project as regards the pumping capacity and the efficiency of water distribution in the field.

Another area of research would be the economics of tube-wells in range lands where the Government is investing in water supplies, particularly dam construction, for human and livestock consumption. Studies on the optimum level of irrigation should also offer a fruitful research opportunity. This would mainly involve determining the optimum pumping time for various types and sizes of pumps in relation to their working life. The critical timing of irrigation under various soils and agro-climatic conditions is also a needed area of research. Not only is the quantity of water important in influencing the crop yield and hence the returns, but also the timing of application at different stages of plant growth.

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Appendix I

Table 1 Coast Province: Mean annual rainfall for various stations arranged by Physiographic Regions

Physiographic Regions and Rainfall Stations	Mean Annual Rainfall	Height above Sea Level	Mean Rainy Days	Years on Record
	mm	m	No.	No.
THE COASTAL PLAIN				
Vanga	1,118	13	44	31
Gazi	1,375	6	54	31
Tiwi	1,290	10	50	20
Mombasa (old observatory)	1,175	15	46	76
Takaungu	1,125	5	48	25
Kilifi	941	3	37	44
Malindi	1,047	3	41	69
Witu	1,081	10	42	35
Lamu	889	10	35	58
Faza	876	8	34	41
THE FOOT PLATEAU				
Lunga Lunga	882	60	34	15
Kikoneni	787	60	31	30
Baricho	734	70	28	15
Marafa	856	60	33	30
THE COASTAL RANGE				
Shimba Dev. Scheme	1,270	250	50	14
Shimba Hills Mrere	974	400	39	17
Kwale	1,079	400	42	55
Mazeras	1,029	150	40	56
Chonyi	1,181	250	46	24
Ganze	856	200	33	20

Table 1 Continued

Physiographic Regions and Rainfall Stations	Mean Annual Rainfall	Height above Sea Level	Mean Rainy Days	Years on Record
	mm	m	No.	No.
THE NYIKA PLATFORM				
Ndavaya	759	300	30	18
Kinango	822	300	32	22
Mariakani	868	200	32	26
Samburu	598	300	23	33
THE PLATEAU AND REMNANT HILLS				
Kasigau-Rukinga	684	600	25	15
Macknnon Road	692	350	27	47
Bura	952	1,200	30	26
Wudanyi	1,316	1,500	51	52
Voi	497	900	19	22
Taveta ziwani	416	1,200	20	29

Source: Ministry of Land and Settlement, Kenya.
Agricultural Land Potential in Kwale, Mombasa and Kilifi (Unpublished) - 1971.

Table 2 Major Horticultural crops grown in Mombasa District, 1975

Crop	Area	Proportion irrigated
	Ha.	
Coconuts	2,100	None
Cashewnuts	1,600	Do
Vegetables*	300	Over half
Mangoes	240	20%
Citrus	100	Half
Bananas	93	Do
Pawpaws	50	80%
Pineapples	15	All

Source: District Agricultural Officer's Annual Report, 1975.

* Brinjals, Tomatoes, Chinese Spinach (Mchicha), Chillies, Okra, Sweet Pepper, Sweet Melons, Cucumber.

Table 3 Mombasa District: Gross Margins of some selected Horticultural Crops grown without irrigation

Crop	Annual Yield	Price per Unit	Total		
			Returns	Variable costs	Gross Margin
	Per acre		Per acre		
		K.Shs.			
Tomatoes	10,000 kg	0.80	8,000	2,240	5,760
Paupaws	22,000 fruits	0.25	5,500	981	5,519
Bananas	1,000 bunches	8.00	8,000	2,603	5,397
Brinjals	6,000 kg	1.00	6,000	1,375	4,625
Okra	5,200 kg	1.00	5,200	1,965	3,225
Sweet Melons	6,000 kg	0.80	4,800	1,705	3,095
Cucumber	6,000 kg	0.80	4,800	1,867	2,933
Cupsicums	5,000 kg.	0.80	4,000	1,360	2,740
Chillies	2,500 kg	1.50	3,750	1,570	2,180
Spinach	24,000 bundles	0.20	4,800	2,726	2,074

Source: Farm Management Guidelines for Coast Province
Ministry of Agriculture, Coast Province, 1974.

Table 4 Mombasa Market: Average monthly vegetable prices, 1975

Type of Vegetable and unit of sale	Item	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Cooking Bananas per bunch	Supply	L	L	N	N	H	H	H	N	N	N	N	N
	Demand	H	H	H	H	H	L	L	L	N	N	N	N
	Price in K.Shs.												
	Minimum	12	12	11	10	7	5	5	7	7	8	10	10
	Maximum	20	21	19	18	12	12	13	14	13	12	12	12
	Frequent	15	15	13	12	8	8	8	9	8	8	9	9
Tomatoes per 20 kg. box	Supply	L	L	L	L	L	H	H	H	N	N	N	L
	Demand	H	H	H	H	H	L	L	L	N	N	N	H
	Price in K.Shs.												
	Minimum	25	25	30	28	25	20	15	16	18	18	22	22
	Maximum	40	45	50	44	30	25	20	18	22	27	30	32
	Frequent	25	30	35	30	26	22	16	16	20	22	25	25
Brinjals per kg.	Supply	L	L	L	L	L	L	N	N	N	N	N	N
	Demand	H	H	H	H	H	L	L	N	N	N	N	N
	Price in K.Shs.												
	Minimum	2.00	2.00	1.50	1.80	1.60	1.30	0.80	0.70	0.60	0.60	0.80	1.00
	Maximum	3.50	3.00	2.50	2.60	2.50	2.00	1.50	1.20	1.00	1.00	1.50	1.60
	Frequent	2.50	2.00	2.00	2.00	2.00	1.50	1.00	1.00	0.80	0.70	1.00	1.20
Green Chillies per kg.	Supply	L	L	L	L	L	L	N	N	N	N	N	N
	Demand	H	H	H	H	H	N	L	L	N	N	N	N
	Price in K.Shs.												
	Minimum	1.80	1.80	2.00	2.00	1.50	1.50	1.00	1.00	1.00	1.00	1.00	1.00
	Maximum	2.50	2.50	3.00	3.00	2.50	2.00	1.50	1.50	2.00	2.00	2.00	2.00
	Frequent	2.00	2.00	2.50	2.50	2.00	1.80	1.50	1.20	1.30	1.50	1.50	1.50

Table 4 Continued

Type of Vegetable and unit of sale	Item	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Okra per kg.	Supply	L	L	L	L	L	L	N	N	N	N	N	N
	Demand	H	H	H	H	H	H	N	N	N	N	N	N
	Price in K.Shs.												
	Minimum	1.50	1.50	1.50	1.80	1.50	1.20	1.00	0.80	0.80	0.80	1.00	1.00
	Maximum	2.50	2.50	3.00	3.50	3.00	2.00	1.50	1.50	1.50	0.50	1.50	1.50
	Frequent	2.00	2.00	2.00	2.00	2.00	1.50	1.00	0.80	0.80	0.80	1.00	1.00
Chinese Spinach (Mchicha) per bundle	Supply	L	L	L	L	N	N	H	H	H	N	N	N
	Demand	H	H	H	H	H	N	N	N	N	N	N	N
	Price in K.Shs.												
	Minimum	0.20	0.20	0.20	0.20	0.20	0.20	0.15	0.15	0.20	0.20	0.20	0.20
	Maximum	0.35	0.35	0.35	0.30	0.30	0.30	0.20	0.20	0.30	0.30	0.30	0.30
	Frequent	0.30	0.30	0.30	0.25	0.20	0.20	0.15	0.15	0.20	0.20	0.20	0.20
Pawpaws per doz.	Supply	L	L	L	N	N	N	N	N	N	N	N	N
	Demand	H	H	H	H	H	N	N	N	N	N	N	N
	Price in K.Shs.												
	Minimum	12	12	15	10	10	8	6	6	6	8	10	10
	Maximum	15	18	20	15	12	10	10	10	10	12	12	12
	Frequent	12	15	15	12	10	8	6	6	6	8	10	10
Sweet Melons per kg.	Supply	N	L	L	L	L	N	N	N	N	N	N	N
	Demand	N	H	H	H	H	H	H	H	H	H	H	H
	Price in K.Shs.												
	Minimum	1.50	1.50	1.50	1.50	1.50	1.00	0.80	0.80	0.80	0.80	0.80	0.80
	Maximum	2.60	2.50	3.00	2.50	2.50	2.00	1.50	1.00	1.00	1.00	1.50	1.50
	Frequent	2.00	2.00	2.00	2.00	2.00	1.50	1.00	0.80	0.80	0.80	1.00	1.00

Table 4 Continued

Type of Vegetable and unit of sale	Item	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Sweet Pepper per kg.	Supply	L	L	L	L	L	N	N	N	N	N	N	N
	Demand	H	H	H	H	H	H	H	H	H	H	H	H
	Price in K.Shs.												
	Minimum	1.50	1.50	1.50	1.50	1.50	1.00	0.80	0.80	0.80	0.80	0,80	0.80
	Maximum	2.50	2.00	2.00	2.50	2.50	1.50	1.00	1.00	1.00	1.00	1.00	1.00
	Frequent	1.80	1.50	1.50	1.50	1.50	1.00	0.80	0.80	0.80	0.80	0.80	0.80
Cucumber per kg.	Supply	N	L	L	L	L	N	N	N	N	N	N	N
	Demand	H	H	H	H	H	H	H	H	H	H	H	H
	Price in K.Shs.												
	Minimum	1.50	1.50	1.50	1.50	1.50	0.80	0.80	0.80	0.80	0.80	1.00	1.50
	Maximum	2.50	2.50	2.50	2.50	2.00	1.50	1.50	1.50	1.50	1.50	1.50	2.00
	Frequent	2.00	2.00	2.00	1.50	1.50	0.80	0.80	0.80	0.80	0.80	1.20	1.50

Source: Mwembe Tayari Wholesale Market

Supply - demand notations are as follows:

Supply: H - Overflooding of market
N - Normal
L - Not enough to meet demand

Demand: H - All available was purchased
N - Normal
L - Some remained unsold

Table 5 Fertilizer Prices at KFA Shop, Mombasa

Type of Fertilizer	1973	1974	1975	1976	Average annual increase
	K.Shs.				
TSP	60	70	90	125	[illegible]
Double superphosphate	45	50	72	90	[illegible]
Single superphosphate	33	37	50	60	[illegible]
Sulphate of ammonia	30	33	45	60	[illegible]
ASN	49	53	70	90	[illegible]
CAN	49	53	70	90	[illegible]
Urea	80	85	110	150	[illegible]
Diammonium phosphate	74	85	110	150	[illegible]

Source: KFA Mombasa

Table 6 Diesel Prices in Mombasa

Year	Price per 200 litre drum
	K.Shs.
1970	60
1971	75
1972	82
1973	125
1974	175
1975	180
1976	213

Table 7 Annual depreciation of Main Tube-Well Investment items

Fixed Asset	Original cost	Expected life	Salvage value in the 10th year	Depreciable amount	Estimated annual deprecia-tion
	K.Shs.	Years	K.Shs.		
Tube-well	8,055	30	4,030	4,020	130
Engine and pump	18,950	10	1,895	17,055	1,700
Pumpshed storage tank or stilling basin	4,390	30	2,195	2,200	70
Farm vehicle	35,012	10	3,500	31,500	3,150
Spraying pumps	1,800	5	NIL	1,800	360
Wheel barrows	600	15	200	400	30
Cultivating tools	1,000	15	300	700	70

Source: Survey results

Appendix II

Questionnaire for the Analysis of Financial Feasibility of Tube-Well Irrigation in Mombasa District

I am a member of staff of the Ministry of Agriculture in Mombasa. You must have heard about the drought that has occurred in various parts of the country particularly in Machakos and Kitui areas where many people have died of starvation. The Ministry of Agriculture therefore wants to take a positive action to help these drought-stricken areas including some parts of Coast Province mainly through Irrigation Development. This will involve tube-well development where there are no permanent rivers. I am therefore seeking information concerning tube-well irrigation. You have been selected purposively to supply this information because of your past experience which I am sure you would like to share with other farmers. I would therefore be grateful if you could answer the following questions:-

QUESTIONS

Date of visit ....

1. Name of the farmer ....

   Ward or Location ....

   Age ....

   Formal Education ....

   Caste ....

   Country of origin ....

2. How long have you operated a tube-well? ....

   ....

3. Have you gone for any training concerning the operation of a tube-well ....

   ....

4. If such a course is started in the local F.T.C. would you sacrifice some of your time to attend it?

   ....

5. What is the acreage of your farm? ....

   ....

6. Do you own the farm or you have leased it from a landlord?

   ....

   How much is the lease? ....

7. Has the farm got a title deed? ....

8. How did you develop interest in irrigation? ....

   ....

   ....

9. Do you work full time in the farm or you are a part time farmer? ....

10. How often does the Agricultural Extension Agent visit you?
....

11. Does he offer you advise on the technical aspects of tube-well operation? ....
....
....
....

12. What is the size of the tube-well?
Depth ....
Diameter ....

13. Who bores the tube-wells? ....
By what means - Manual labour or Machine? ....
....

14. What are the costs of boring the well per foot at different depths? ....
....

15. Is the flow of water regular or seasonal? ....

16. If seasonal, when is the water at the lowest level?
....
At the highest level? ....

17. Is the water sweet or salty? ....
If salty, does the water affect the growth of some crops?
....

Which crops have you failed to grow with this water?

....

....

....

....

18. What is the type of the well?

Dug well .... Drilled well ....

Bored well .... Driven well ....

19. Cost of building the well: ....

Cost of sinking ....

Cost of lining ....

Other costs ....

20. Does the cost of boring wells in different areas of the District differ? ....

21. What is the cost building the pump house ....

Storage tank ....

22. What is the size of your pump and engine in H.P.?

....

23. Did you buy it new or second hand? ....

24. How much did it cost? ....

25. When did you buy it? ....

26. How efficiently does the pump work? ....

....

How often does it break down? ....

....

27. When do you contemplate to replace it? ....

....

28. How much diesel do you use per unit of operation?

or per irrigation day? ....

Which type of diesel? ....

What is the cost of the diesel? ....

29. How has the escalating price of oil in the last two years affected irrigation using dieselized tube-wells?

....

....

....

30. How many times do you irrigate per crop? ....

Per week ....

per growing season ....

31. How many hours do you pump water?

(hours that the pump is in working condition)

Per day ....

Per week ....

or per month ....

32. Do you have a water tank? ....

What are the measurements of the tank? ....
(hence the volume)

Time it takes to fill it ....

33. How do you decide when to irrigate and how much water to apply.

34. Do you pump water throughout the year or only during the dry season? ....

If throughout the year, how often do you pump the water during the rainy season? ....

during the dry season? ....

35. Is the well-water used for any other purpose apart from irrigation on the farm e.g. selling water to neighbours?

....

....

36. Is the engine used for other purposes e.g. lighting the house ....

....

37. How many hours can the pump work per week? ....

(allowing for breakages) per month ....

per year ....

38. How much do you spend on repairs and lubricants?

Per week ....

Per month ....

Per year ....

39. Do you think you are under-utilizing or over-utilizing the pump ....

40. What is the average life of the pump? ....

41. What guarantee do you get from the dealers? ....

....

42. Do you use single phase line or three phase line for electric pump? ....

43. How much did it cost you to connect the single phase?

.... three phase ....

44. How much do you pay for electricity according to electric units used per month? ....

How have the electricity prices changed over the last 5 years? ....

How has it affected irrigation using electrified tube-wells?

....

45. Do you have your own transport for transporting vegetables to the market or you hire transport?

....

46. If there is a farm vehicle, is the vehicle used for other purposes apart from farm activities? ....

....

What is the model? ....

Make .... Cost of vehicle ....

Cost of running and maintenance? ....

47. If there is no farm vehicle how do you transport your vegetables to the market? ....

....

How much does it cost to transport? ....

48. How many people are employed on the farm?

Casual labourers? ....

Wages paid - cash, in kind e.g. food? ....

Permanent labourers ....

Wages paid - cash, in kind e.g. food, houses, insurance, bonuses, etc. ....

49. How many members of your family work full time on the farm?

Adults ....

Children ....

50. Do you use/have you ever used farm credit?

If yes - what is/was the source of credit?

....

51. Under what terms do/did you take the credit?

Interest rate ....

Grace period ....

Repayment schedule ....

52. For what purpose do/did you take the credit?

For Farm investment? ....

Working capital? ....

Both ....

What proportion of the investment and working capital is your own (not borrowed)

....

53. Where do you invest the farm income?

Into industry? ....

Back into the farm? ....

Both ....

54. What is the proportion of total farm income do you invest

into industry? ....

into the farm? ....

55. In general what problems do you find in irrigation farming?

....

....

....

....

Is seasonality of rainfall an advantage or disadvantage to irrigation farming?

....

....

whether the pumps and spare parts are readily available

....

....

whether other inputs like fertilizers, manures, seeds etc., are readily available ....

....

whether the required labour is readily available

....

....

whether a lot of technical know-how and experience is required ....

....

whether crop pests are a menance ....

....

56. Given more resources - land, labour and capital would you increase the irrigated area or leave it as it is?

....

....

57. What is the possibility of selling irrigation water to your neighbours?

....

....

58. List the various crops that you grow: -

Crop	Acreage
1	....
2	....
3	....
4	....
5	....
6	....
7	....
8	....
9	....
10	....

59. Do you grow the same crops every season?

Yes/No. ....

If no, which crops do you grow in what season?

....

60. Which factors influence your decision as to which crops to grow?

(a) Availability of assured market?

....

(b) Current price of the product?

....

(c) Availability of water (Rain water or pumped water)

....

(d) Labour availability?

....

(e) Rotation requirement?

....

(f) Availability of capital?

....

(g) Others? ....

61. Do you allocate the same acreage to each crop every season?

Yes/No ....

If no, which crops do you allocate the biggest acreage?

....

....

....

62. Which factors influence your decision in acreage allocation?

(a) Assured market?

....

(b) Current price of the produce?

....

(c) Labour availability?

....

(d) Rotational requirements?

....

(e) Availability of water - Rain water or pumped water?

....

(f) Capital availability?

....

(g) Others? ....

6J.

Costs of Inputs of Various Crops

Name of Crop

	1	2	3	4	6	7
Seed rate (kg. of seed/acre						
Spacing						
FYM application rate						
Cost						
Cost of Pest and Disease control - Pesticide cost 1 2 3 4 5						
Total						
LABOUR EXPENSES Operation Ploughing and harrowing - Mandays Digging distribution Channels - Mandays Manure/Fertilizer application - Mandays Nursery preperation and Maintenance - Mandays Planting or transplanting - Mandays Weeding - Mandays Staking and training - Mandays Spraying - Mandays Harvesting cleaning and packaging - Mandays						
Total						

64. Who does the verious operations?

....

....

How do you organise the marketing of fruits and vegetables?

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Which kinds of customers do you have?

Private households ....

Hotels and Restaurants ....

Institutions e.g. Schools ....

Hospitals ....

Mwembe Tayari vegetable wholesellers ....

On farm sales ....

Shipchandlers ....

Urban hawkers ....

Exporters of fresh produce ....

65.

TYPE OF VEGETABLE		JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
1. Powpaw	Quantity sold												
	Price												
2. Tomatoes	Quantity												
	Price												
3.	Quantity												
	Price												
4.	Quantity												
	Price												
5.	Quantity												
	Price												
6.	Quantity												
	Price												
7.	Quantity												
	Price												