ABRJ
American Based Research Journal
ISSN Online (2304-7151)

https://www.abrj.org/
Impact Factor 2.30

Assessing Crorelation of Socio-Economic Effects of Solar Powered Boreholes In Kenya, Case of Buuri ; Meru County

Author Details: Odula Barasa Elias
Kenya School of Government – Lower Kabete, Nairobi, Lecturer elias.odula@ksg.ac.ke

Abstract
Agriculture plays an important role in Kenya's economic development. About 85 per cent of Kenya's population is dependent on Agriculture for their livelihood. Agriculture contributes about 35 per cent of our GDP. It provides a sizeable amount of employment and is a major source of foreign exchange. Besides, it serves the growing market for the goods and services produced by other sectors as well as producing the food and primary materials on which successful growth in other sectors largely depend. Increasingly, demand for data and research on agriculture and ways of boosting yields and maximize on the potential for agriculture has been necessary. The study has therefore examined the socio-economic effects of utilizing solar-powered boreholes for irrigation water among crop-farmers in Kenya. A case of Buuri Sub-county, Meru County. More specifically the study has set out to established solar-powered boreholes effects on crop yield, determined how solar-powered boreholes have affected Agricultural income of crop farmers and established how income from crop farming using water from solar-powered boreholes have affected spending habits among crop farmers. Theories that have been used in this study include Oasis Theory and Johnstone and Mellor Theory. The study has adopted a descriptive research design. The target population of the study was 137 crop farmers in Buuri Sub-County, Meru County. Data collection was done through use of questionnaires constructed on a 5-point Likert scale. Questionnaires were tested for validity and reliability.Data was also analyzed using descriptive statistics which includes frequency, percentages, mean and standard deviation and inferential statistics which includes regression and correlation analysis and data presented in tables and figures accompanied by relevant discussions.
Keywords*: Assessing, correlation,socio-economic effects, solar powered boreholes ,kenya*

INRODUCTION

According to a report by CDC Investment Works (2020), about two-thirds of people living in rural areas in developing countries live off smallholder farming. They have limited access to markets and inputs, and they are exposed to constant risks. The yields of African smallholder farmers trail world averages by about 50 per cent, which means that Africa contributes to global agriculture output below its potential. Despite all of these constraints, they still manage to produce food both for themselves and for substantial part of the urban population.

In Kenya for instance, most farmers are historically dependent on the two rainy seasons each year for crop growth. Prolonged reliance on this rain patterns has however resulted in consistent disappointments lately, majorly as a result of climatic changes currently being experienced globally. Rain has become undependable and largely unpredictable. (Epicentre Africa, 2016).

The inability by farmers to predict rain patterns has consequently contributed to massive crop failures and food shortages, with government relief efforts doing little to mitigate the situation. One of the key challenges for smallholder farmers in many regions is access to water. In Kenya, for example, only 3 per cent of Kenyan farmers use the irrigation techniques needed to become more productive (CDC Investment Works, 2020).

It is as a result of these challenges that most farmers have opted to explore alternative sources of water for crop irrigation such as rivers, water pans and boreholes.

These alternative sources of water often come with the need for pumping to get the water where it is needed. Electricity and fuel-powered generators have for long periods been the only available alternatives, but their expensive running costs make them untenable for profit-oriented crop farming. This has seen the emergence of solar-powered boreholes as an attractive game-changer, especially given the abundance of solar energy in Africa and Kenya. Research shows that Nairobi experiences an average of 6.8 hours of sunshine per day, Garissa 8.5 hours, with Lodwar getting a staggering 9.8 hours of sunshine each day (Wikipedia).

This is abundantly available free source of energy that can be tapped to power boreholes and provide invaluable water for domestic use, watering animals and crop irrigation.

One of the main advantages of the solar-powered boreholes is that they only incur the initial costs of installation and do not have recurring running costs unlike when electricity and diesel-powered engines are used. Calculations show that with a 18KVA generator, a farmer would be spending up to Ksh. 980,000 (assuming the generator runs 8 hours daily) annually on fuel, service and maintenance and associated loses due to breakdowns. (Epicentre Africa, 2016).

Research further indicates that lack of sustainable water sources for farming significantly impacts farmers' livelihoods since it directly links to pre-harvest loss.

In Meru County and by extension Sub-Saharan Africa, agricultural productivity is principally rain-reliant. However, rainfall has proved to be highly variable. Most of the drier parts of Kenya's central highlands, eastern Kenya, continue to experience high unpredictable rainfall patterns, persistent dry-spells/droughts coupled with high evapotranspiration (2000–2300 mm year^{-1}). Generally, the total amount of rainwater is enough; however, it has been reported to be poorly redistributed over time with 25% of the annual rain often falling within a couple of rainstorms; as a result, crops suffer from water stress, often leading to complete crop failure. The situation is exacerbated by a poor rain-water harvesting practice, with water pans, dams and water tanks all underutilized.

It is this phenomenon that has prompted governments to explore alternative routes to water supply particularly in the Arid and Semi-Arid (ASAL) areas to boost food security through irrigation and livestock keeping. Ground water

Up to 89% of the households in Meru County practice agriculture and 63% of all enterprises owned are within the agriculture sector (Meru County Socio Economic Indicators baseline survey, 2016).

Meru County is endowed with rich agricultural land cutting across all agro-ecological zones. Out of the total agricultural land, 37% is high potential, 15% is medium potential and 48% is low potential. Despite these favourable conditions, only 24% of those practicing farming in Meru County use irrigation. This can largely be attributable to insufficient water supply for irrigation and the erratic rainfall patterns.

The drier parts of the County – parts of Buuri, Tigania West, Tigania East and Igembe - with vast land resources, are more adversely affected by drought. Development of irrigation infrastructure in these areas would boost food production and improve food security in the County– Water is a big challenge despite availability of fertile land.

According to a joint report done by Kenya Food Security Steering Group **(KFSSG)** and the Meru County Secretariat in 2018, Meru County has a wide range of agro-ecological livelihood zones and untapped water for irrigation which support the production of a variety of crops such as mangoes, citrus, coffee, maize, beans, bananas, pigeon peas, cow peas and horticultural crops. The area which is potential for irrigation is 81,262 ha with only 2,131 ha under irrigation. Irrigated agriculture is mainly practiced by farmers in mixed farming livelihood zone, near river sources where the water flow is more consistent and reliable. (**KFSSG** and the Meru County Secretariat, 2018)

By using solar power, the boreholes have been quite helpful in remote areas with no access to the power grid. They are also sustainable since their cost of running and maintenance is low.

Meru County makes for a good target for the study given the fact that until recently, borehole-sustained agriculture remained relatively low, with only a few privately-owned boreholes serving irrigation purposes. During the first five years of devolution in Meru County, the county managed to sink 17 boreholes, with few – if any – of these targeting crop irrigations. However, from 2017 to date, the county has committed enormous investments into water, with at least 180 boreholes already sunk, the bulk of this in the dry but arable parts of the county. The idea has been to stimulate crop irrigation, with agriculture being the core driver of economy for the county (Up to 89% of the households in Meru County practice agriculture – Meru County Socio Economic Indicators baseline survey, 2016).

Little or no research has since been conducted to assess the short-term effect of these boreholes on the incomes and livelihoods of crop farmers in the county, and it is on this basis that this study is pegged. Accordingly, this study proposes to investigate the effect of these solar-powered boreholes on crop irrigation practices, yields and incomes, with the intention of advising water investment policy in the county.

Statement of the Research Problem.

Agriculture in Kenya forms the largest source of livelihood and also the largest contributor of Kenya's Gross Domestic Product (GDP). (Kenya country profile; Library of Federal Research Division). However, most crop farming is reliant on rainfall which is erratic in most regions if the country. Kenya has over seven million small scale farmers who depend indirectly or directly on cash crop farming for livelihood. (Urban Article on agriculture January 2, 2020 by Ammanulah). Of these, majority rely on rainfall. Currently, most farmers have adopted advance in agricultural practices which include mechanisation, better farming practises, technology and innovation to help improve the crop yields and subsequent improvement of their income. With this in mind it is important to acknowledge the efforts made by the farmers towards becoming self-reliant by increasing their incomes and subsequent spending/saving from improved agricultural practices.

Justification of the Study

The study focuses on the Social-Economic effects of Solar-Powered boreholes among crop farmers in Kenya, a case of Buuri Sub-county in Meru County. With the dynamic nature of Agriculture, this study will serve to inform the farmers on how to establish whether solar-powered boreholes have an effect on crop yields. This will aid the crop-farmers in the organization to come up with the policy guidelines on strategy implementation involving active participation of corporate leadership. On the other hand, the study will assist the crop farmers understand how solar-powered boreholes have affected their Agricultural income in Buuri Sub-county, Meru County. Additionally, the crop farmers will be informed of how income from crop farming using solar-powered boreholes have affected spending habits among crop farmers. Lastly, the study aims at contributing to the existing wealth of knowledge in this area and serve as a reference point for future researchers interested in this line of study.

Research questions,

i) How have the solar powered boreholes affected productivity of crop farming?

ii) How have the solar powered boreholes affected the economic status of the crop farmers?

iii) How has the income from crop farming among the farmers affected their spending habits?

Research Objectives

The main objective of the study is to Assessing correlation of socio-economic effects of solar powered boreholes in Kenya,case of Buuri ; Meru county

Specific objectives.

i) Examine whether the solar powered boreholes have effect on crop yield.

ii) Assess how the solar powered boreholes have affected the agricultural income among crop farmers in Buuri sub county.

iii) To explore the relationship of how income among crop farmers in Buuri Subcounty have affected their spending habits.

LITERATURE REVIEW

An Overview of Crop Irrigation

In general, the amount of irrigation systems in Africa is quite modest comparing to other countries of the world, with the exception of Egypt and Sudan. In Asia 32.4 percent of the total cropland is under irrigation and in Africa it is only 6.1 percent (Schoengold et al., 2005), but in Sub-Saharan Africa the percentage is even lower, 3.5 percent of the total cropland is irrigated (McLean et al., 2006). Further on, the irrigation costs are doubly so high compared to other continents and the topography of the landscape is irregular which complicates irrigation constructions (Paarlberg, 1999).

To meet the population growth the agriculture in the developing countries needs to produce more crops per litre of water (FAO, 1997). According to Richard MacLean and Joachim Voss, cereal production accounts for more than the half of the irrigated land in Africa (McLean et al., 2006) and globally, 31 percent of the total agriculture area is irrigated (Rijsberman, 2001). It is well documented that irrigated land leads to increased agricultural productivity, irrigated areas are 2.5 times more productive comparing to rain-fed agricultural areas (Stockle, 2001).

One of the benefits of irrigation systems is that the farmers have the possibility to decide when they need the water, instead of depending on when and if the rain-falls come. In Asia, the yields have increased 100-400 percent after irrigation (Schoengold et al., 2005). To have in mind, in the developing countries many irrigation systems are inefficient and lose about 60 percent of the water that is transported (United Nations, 2002).

Some researchers argue that traditional furrows lose up to 80 percent of the water through leakage and evaporation before it reaches the field (Huggins, 2000). About 85 percent of the total water withdrawals in Africa are used by agriculture and in the semi-arid regions the percentage is somewhat higher. In those areas the water that is used for irrigation represents a major part of the water resources (FAO, 1997). For example, in Tanzania, the total water withdrawals are estimated for the year 2002 to be 5142 million m3. The agriculture sector consumes 4624 million m3 of which 4417 m3 is used for irrigation and livestock takes 207 million m3. Finally, the domestic sector uses 493 million m 3 (ICID, 2006)

International Water Management Institute (IWMI) argues that during an average rainfall year, rain-fed agriculture evaporates 20 percent of the rainwater, comparing to 3-6 percent of irrigated lands. Rain-fed agriculture consumes a big quantity of water, because of its large area, that could instead be used to river runoff. But rain-fed agriculture is common, for example in Sub-Saharan Africa about 95 percent of the total cereal area originates from that kind of agriculture, and is very important for those people that live in rural areas that do not have access to irrigated land (Rijsberman, 2001).

Irrigated area in Sub-Saharan Africa totals a bit more than 7 million hectares, and about twice that when including northern Africa; individual country areas range from almost none in Lesotho to nearly 3 million hectares, nearly a fifth of the total for Africa, in Egypt. A striking difference between Africa and the world as a whole is that African countries withdraw less than half as much water per capita as does the world in general (241 cubic meters per year [m3 /year] compared with 599 m3 /year). This reflects the fact that African countries irrigate only about 6 percent of their collective cropland, compared with a world average of about 18 percent. (Svendsen et al., 2009)

African countries have less renewable water per unit area and a higher population density than the world as a whole. They have a higher percentage of the population engaged in agriculture (more than half the economically active population) with a slightly smaller average farm size (a little more than one hectare per agricultural worker). They withdraw only a quarter as much water for human uses as does the world as a whole, and the irrigated share of their cropland is less than one-fourth of the world average. (Svendsen et al., 2009)

According to FAO (Food and Agriculture Organization), the population growth in sub-Saharan Africa is estimated to be over 3 percent per year (FAO, 1997). Furthermore, the world population has doubled since 1960 and about 78 million people are added to the world population each year (Dungumaro et al., 2002). At the same time food production has only increased 2.5 per year in Sub-Saharan Africa (FAO, 1997). To deal with future food supplies, the development of irrigation system is high on the political agenda. International Water Institute (IWMI), estimates that 29 percent more irrigated land will be required by the year 2025 (Rijsberman, 2001).

Closer home in Kenya, figures on land under irrigation have also been on the rise, with the shrinking land size and swelling urban population calling for need for greater agricultural productivity. In 2018, total area equipped for irrigation for Kenya was 151,000 hectares. Total area equipped for irrigation of Kenya increased from 26,000 hectares in 1969 to 151,000 hectares in 2018 growing at an average annual rate of 3.73% (Knoema, 2020)

Influence of Irrigation on crop yields

Irrigation is one of the major inputs of agriculture which plays an important role in its development. It provides an opportunity for the increase in quantity of agricultural production. Therefore, irrigation is the major invariable component for agricultural development. Irrigated agriculture is one of the most critical human activities sustaining civilization. The current world population of 7.7 billion people is sustained in a large part by irrigated agriculture. USDA statistics show that 17% of cultivated crop land in the United States is irrigated. (Mueller, N. D. et al. 2012)

An analysis published in Nature shows that yield increases of 45–70% are possible for most crops through improved nutrient management and increased use of irrigation. (Mueller, 2012)

On average, irrigated crop yields are 2.3 times higher than those from rain-fed ground. These numbers demonstrate that irrigated agriculture will continue to play an important role as a significant contributor to the world’s food supply. (Gewin,2012)

The period from 1965 to present is marked by a massive increase in irrigation in Nebraska. In 1966 there were 3 million irrigated acres while in 2002 there were 8 million acres. Over this time the area devoted to corn in the state of Nebraska was constant at a little over 9 million acres. This period also marked the largest increase in yields in both irrigated Nebraska and non-irrigated Illinois. This yield increase is often attributed to the “green revolution” of better fertilization

methods along with improved varieties and crop protection chemicals. The reality is that the green revolution started as early as the turn of the century and started to take off in the

1930’s. The large yield increases seen since the 1960’s was the mainstreaming of the yield increasing technologies due to increased farm investment. (Michael,2010)

It was studied in a long-term experiment on chernozem soil, the effect of crop irrigation on the yield of maize in an extremely dry year in 2007. The yield increment due to irrigation was 3100-4000 kg ha-1 in monoculture, 1700-2300 kg ha-1 in biculture and 1900-2600 kg ha-1 in triculture, respectively. Without irrigation, 40 thousand plants ha-1 proved to be optimal in all crop rotations, while maximum yields were obtained at plant densities of 40-60-80 thousand plants ha-1 in mono-, bi- and triculture under irrigation, respectively. Under irrigated conditions, the optimum fertilizer dosages were N180-240+PK, N120+PK and N60-120+PK in monoculture, biculture and triculture, respectively. By optimizing the agrotechnical factors, 10-11 t ha-1 yield can be realized on chernozem soil irrespective the crop year effect. (Gewin, 2012)

Influence of Irrigation on farmers' agricultural income

A study carried out in Shebedino, Southern Ethiopia provides evidence as to whether or not irrigation use has brought significant changes on household farm income and asset holding. The estimation result provided a supportive evidence of statistically significant effect of irrigation use on farm income and asset holding of household measured in Ethiopian Birr.

It has been found, that on average, participation in irrigation use has increased annual household farm income by 19,474.8 birr for participant households than non-participant households which is significant at 1% level. Similarly, it had increased their physical asset holding which is measured in Ethiopian birr valued 27,502.4 ETB at 1% statistically significance level. The finding of this study was consistence with Kinfe et al., (2012), Bernard (2012), Ayele (2013), Dereje and Desale (2016) and Woldegebriel, (2015).

A study by JBIC in 2001 estimates that paddy rice yield increases from 16 to 35% where access to irrigation is available. As a result, productivity in the Mekong Delta doubles from 4.5 tons/ha in 1975 to 9.5 tons/ha in 1990 and food outputs escalate from 16 million tons in 1986 to 34 million tons in 1999 (JBIC, 2001).

Irrigation facility increases the crop production and intensity of crop in higher rate. Farmers use improved variety of crops. What is more, the irrigation induced increase in farm yield promotes the use of high-yielding varieties, fertilizers and multiple cropping, resulting in a higher farm output. Assured by the stable output, the farmers will be motivated to increase investment for better seeds and other input factors, thus enabling further improvement of farm productivity. The stable water supply also enables the diversification of crops as well as the switching from staples to higher-value, market-oriented produces. Farmers switch from drought-resistant plants to water-tolerant ones which promise higher price and better marketability.

Influence of irrigation on the spending power of farmers

Irrigation brings changes in socio-economic status such as education, high living standard, per capita income and other indicators of civilization of people. Employment is higher in irrigated area where there is higher production, higher income, higher expenditure and higher saving (Dhakal, 1990).

The irrigation induced increase in farm output also stimulates demand for farm labour, thus enhances the employment opportunities in the rural areas and reduce migration to urban areas. Increased investments expand the farm size resulting in the demand for additional labour force, offering landless labourers a stable source of income. This changes the rural wage structure and lessens the pressure of migration to urban areas. Additionally, higher farm yield enables a reduction in food price.

This allows better access to food for all, but particularly beneficial to landless and subsistence families which normally spend more than half of their income on food (Bhattarai ,2002). This is particularly true for rice, taking into consideration the concentration of supply chain in the world rice market and the volume of irrigation investment into rice projects (Jones 1995). irrigation system plays the catalyst role in changing the whole socio-economic situation of the commune and benefiting households with better welfare conditions (Lipton,2003, Bhattarai,2002, Hussain and Hanjra 2004). The increase in production resulted higher food sufficiency status, higher use of agriculture inputs such as fertilizer, hybrid seeds, insecticides, pesticides as well as modern agriculture tools such as tractor, power tillers and threshers. To acquire all these, the farmers need to spend more, and with the assurance of a stable income stream, they are more assured in making bigger investments in agriculture.

Furthermore, thanks to the stable farm output, the farming households are less vulnerable to external shocks such as food price or natural disasters. Especially for households whose subsistence income level relies heavily on farming to overcome poverty, their vulnerability to external shock is among the main reasons for them to fall back into poverty trap. On the whole, access to irrigation provides farming households with a better-off condition to achieve higher and more sustainable source of income (Dhakal, 1990).

The Oasis Theory

The Oasis Theory was defined by Australian-born archaeologist Vere Gordon Childe [1892-1957], in his 1928 book, The Most Ancient Near East. He argued that at the end of the Pleistocene (The growth of large ice sheets, ice caps, and long valley glaciers was among the *most significant events* of the time**)**, North Africa and the Near East experienced a period of desiccation, a period of an increased occurrence of drought, with higher temperatures and decreased precipitation. That aridity, he argued, drove both people and animals to congregate at oases and river valleys; that propinquity (close relationship) created both population growth and a closer familiarity with plants and animals. Communities developed and were pushed out of the fertile zones, living on the edges of the oases where they were forced to learn how to raise crops and animals in places that were not ideal.

Johnstone and Mellor Theory

The approach adopted here is to examine the interrelationship between Agriculture and Industrial development and to analyze the nature of agricultural role in the process of economic development.

Diversity among nations in their physical endowment, cultural heritage and historical context precludes any universally applicable definition of the role that Agriculture should play in the process of economic growth. Nevertheless, certain aspects of Agriculture's role appear to have a high degree of generality because of special features that characterize the agricultural sector during the course of development.

Two important and related features distinguish the Agricultural sector in an undeveloped country and its role in the process of economic growth. First, in virtually all underdeveloped economies agriculture is an existing industry of major proportion, frequently the only existing industry of any consequence. Typically, some 40 to 60 per cent of the national income is produced in agriculture from 50 to 80 per cent of labour force is engaged in agricultural production.

Conceptual framework

Earp and Ennett (1991) define a conceptual framework as "a diagram of proposed causal linkages among a set of concepts believed to be related to a particular public problem. Conceptual Framework is a set of concepts that are placed within a logical and sequential design. It represents less formal structure and used for studies in which existing theory is inapplicable. In this study the conceptual framework will be derived from the research variables and will seek to show the relationship between the independent and dependent variables. The conceptual framework below attempts to explain the relationship between the independent variables and the dependent variable.

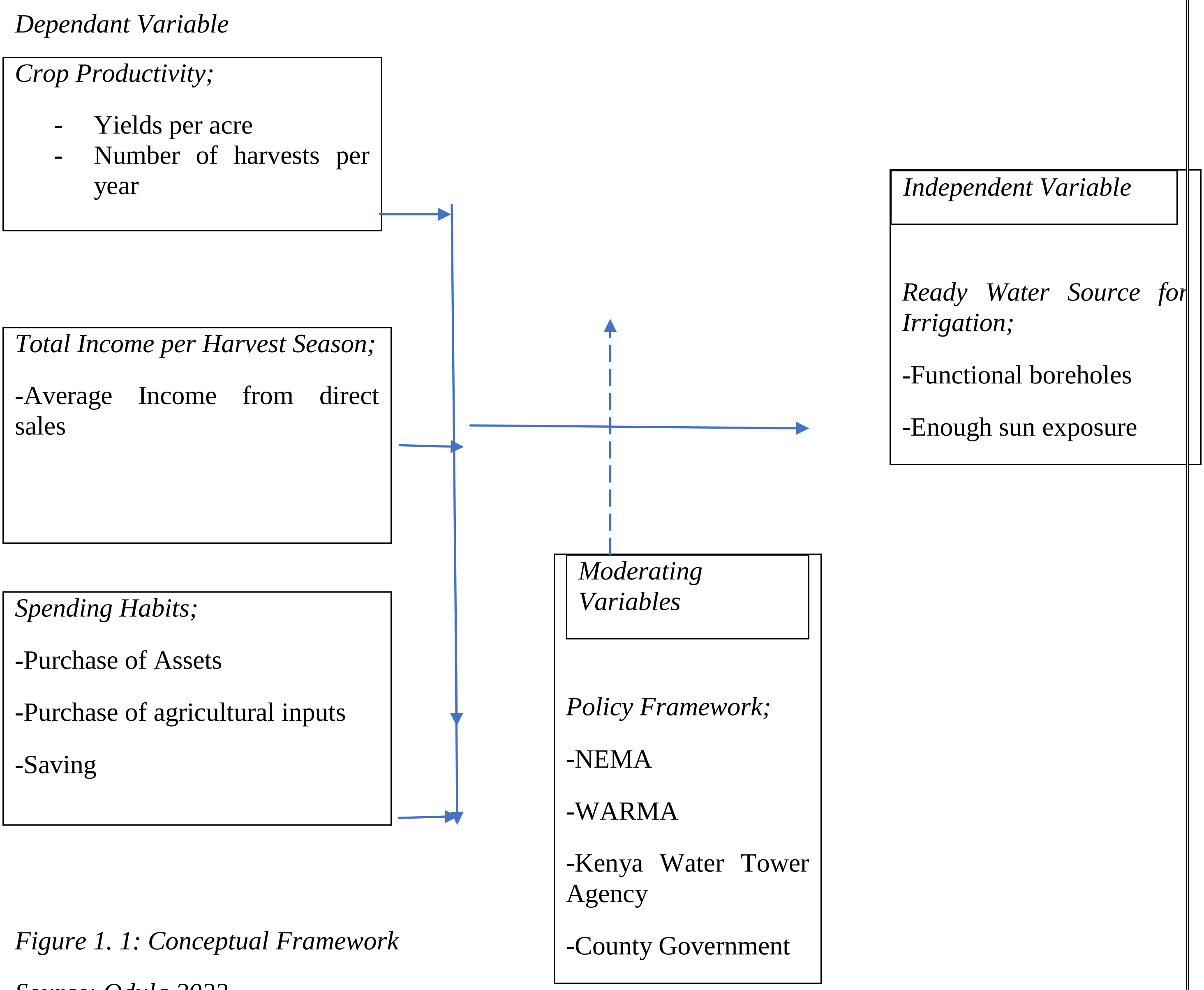

Figure 1. 1: Conceptual Framework

Source: Odula 2022

RESEARCH METHODOLOGYAND DESIGN

Research Design

A research design is a blue print for fulfilling the objectives of the study. Although there are numerous research designs; the study will employ a descriptive research design. This is because the design is well structured with clearly stated research questions. Descriptive survey research design will be adopted as it will enable the researcher generalize the findings to a large population. The study will utilize quantitative approach in the collection of data. According to Kothari (2009), the approach enables data to be systematically collected and analyzed in order to provide a descriptive account of the questions under study.

Target Population

A population is a complete group of entities sharing some common set of characteristics. A target population is the complete group of specific population elements relevant to the research project (Cooper & Schindler, 2003; Zikmund, 2003). The target population for this study will be the crop-farmers in Buuri sub-county Meru county.

In consideration of the size of the target population, the study will employ census approach where all the 123 crop-farmers will form the study respondents. Population Census is unique in that it provides the possibility of examining small and special population groups, and acquiring information on small geographic units. The census approach is justified since according to Orodho (2009), data gathered using census contributes towards gathering of unbiased data representing all individuals' opinions in the study population on a study problem. The census approach is also justified since according to Field (2006) results obtained from a census are likely to be more representative accurate and reliable than results obtained from a population sample and thus census assists in generalization of research findings.

Data Collection Instrument

The study employed the use of questionnaires as the main tools for collecting data. According to Kothari (2006), a questionnaire is the best tool for the researcher who wishes to acquire the original data for describing a population. Questionnaires will enable a researcher to reach a large sample within a short time. The questionnaire will be composed of short structured closed ended statement constructed on a 5-point Likert scale.

Validity of instruments

Brains and Manheim (2011) asserted that validity was the extent to which a concept, conclusion, or measurement is well-founded and corresponds precisely to the real world. In other words, the validity of a measurement tool such as a questionnaire is said to be the degree to which that tool measures what it claims to measure. The study sought to determine the content validity of the research instrument.

Reliability of Instruments

Reliability is said to be the extent to which a measurement gives results that are consistent. When reliability is upheld, then the research instrument should collect similar data when administered to different sampled populations exhibiting related characteristics. The study will employ Cronbach alpha (α) coefficient to test the reliability of the research instrument. The Cronbach's reliability coefficient above 0.70 in the questionnaire will be considered as an indication that the items on the questionnaire are reliable.

Data Analysis

The primary data was collected from the respondents was analyzed, summarized, and interpreted accordingly with the aid of descriptive (Frequencies, percentages, means and standard deviations) as well as inferential (Pearson product moment correlation coefficient) statistics. The findings presented in the form of tables and discussions thereof. The following multiple regression model was adopted.

$$\mathbf{Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \varepsilon}$$

Where:

Y representing Strategy Formulation
B_0 represents model Constant
X_1 Stands for Resource Allocation
X_2 Stands for Communication
X_3 Stands for Leadership
X_4 Stands for Stakeholders' Involvement
X_5 Stands for Strategic Decision Making
ε Represents Error term
β_1, β2, β_3, β_4, β_5, β_6 Represents regression coefficients for independent variables

DATA ANALYSIS, PRESENTATION AND INTERPRETATION

Table 4.1: Highest Level of Education of Respondents

	Frequency	Percent
None	47	38.2
Primary	31	25.2
Secondary	40	32.5
University/ College	5	4.1
Total	123	100.0

Source: Odula 2022

The findings revealed that 38.2% of the respondents had no education, 32.5% had attained secondary level education, and 25.2% had attained primary level education, while 4.1% had reached the university / college level. This shows that majority of the respondents who participated on the study were learnt enough to understand and give reliable information on the subject matter.

4.2.2: Age Bracket of the Respondents

The study sought after the respondents' age bracket. Their responses were presented in Table 4.2. below.

Table 4.2: Age Bracket of the Respondents

	Frequency	Percent
18-24 yrs.	21	17.1
25-35 yrs.	35	28.5
36-50 yrs.	41	33.3
51 yrs. and above	26	21.1
Total	123	100.0

Source: Odula 2022

From the results, 33.3% of the respondents were aged between 36-50 years, 28.5% were aged between 25-35 years, 21.1% were 51 years and above, while 17.1% were aged 18-24 years. The results implied that all the relevant ages were represented and therefore the results were reliable.

4.3 Farming Practices

The researcher further required the respondents to indicate the duration that they have been practicing rain fed agriculture. The findings are presented on Table 4.3.

Table 4. 3: Duration Having Practiced Rain Fed Agriculture

	Frequency	**Percent**
0-2 yrs.	6	4.9
3-5 yrs.	20	16.3
6-10 yrs.	30	24.4
10 yrs. & above	67	54.5
Total	**123**	**100.0**

Source: Odula 2022

From the study results, 54.5% of the respondents indicated that they have been practicing rain fed agriculture for 10 years and above, 24.4% indicated for 6-10 years, 16.3% indicated for 3-5 years while 4.9% indicated for 0-2 years.

4.4: Crop Productivity

The study sought to establish whether the solar powered boreholes have effect on crop yield. The respondents were also asked to indicate the extent that the following affect crop productivity in Kenya. The results are as shown on Table 4.4.

Table 4.4: Extent of Crop Productivity Effects

	Not at all F (%)	Low extent F (%)	Moderate extent F (%)	Great extent F (%)	Very great extent F (%)
Acreage	16 (13.0)	14 (11.4)	19 (15.4)	68 (55.3)	6 (4.9)
Number of harvests per year	4 (3.3)	29 (23.6)	33 (26.8)	36 (29.3)	21 (17.1)

Source: Odula 2022

The findings show that 55.3% of the respondents indicated that yields per acre affect crop productivity in Kenya to a great extent, 15.4% indicated to a moderate extent, 13.0% indicated not at all, 11.4% indicated to a low extent, and 4.9% indicated to a very great extent. This implies that yields per acre affect crop productivity in Kenya to a great extent. These findings are in line with Gewin (2012) who said that on average, irrigated crop yields are 2.3 times higher than those from rain-fed ground. These numbers demonstrate that irrigated agriculture will continue to play an important role as a significant contributor to the world's food supply.

Also, 29.3% of the respondents indicated that the number of harvests per year affect crop productivity in Kenya to a great extent, 26.8% indicated to a moderate extent, 23.6% indicated to a low extent, 17.1% indicated to a very great extent, while 3.3% indicated not at all. This implies that the number of harvests per year affect crop productivity in Kenya to a great extent. This is in line with Hussain and Hanjra (2004) who stated that the increase in production resulted higher food sufficiency status, higher use of agriculture inputs such as fertilizer, hybrid seeds, insecticides, pesticides as well as modern agriculture tools such as tractor, power tillers and threshers. To acquire all these, the farmers need to spend more, and with the assurance of a stable income stream, they are more assured in making bigger investments in agriculture.

4.4.1: Ready Water Source for Irrigation

The researcher required the respondents to indicate the extent to which the aspects of functional boreholes and sun exposure affect the availability of water for irrigation. The responses were as shown in Table 4.5.

Table 4.5:Effect of functional boreholes and sun exposure on availability of water for irrigation

	Not at all F (%)	Low extent F (%)	Moderate extent F (%)	Great extent F (%)	Very great extent F (%)
Functional boreholes	4 (3.3)	19 (15.4)	12 (9.8)	56 (45.5)	32 (26.0)
Enough sun exposure	17 (13.8)	13 (10.6)	18 (14.6)	37 (30.1)	38 (30.9)

Source: Odula 2022

From the findings, 45.5% of the respondents indicated that functional boreholes affect water availability for irrigation among crop farmers in Kenya to a great extent, 26.0% indicated to a very great extent, 15.4% indicated to a low extent, 9.8% indicated to a moderate extent while 3.3% indicated not at all. This implies that functional boreholes affect availability of water for irrigation among crop farmers in Kenya to a great extent. These findings are in line with FAO (1997) who stated that about 85 percent of the total water withdrawals in Africa are used by agriculture and in the semi-arid regions the percentage is somewhat higher. In those areas the water that is used for irrigation represents a major part of the water resources.

Moreover, 30.9% of the respondents indicated that enough sun exposure affects availability of water for irrigation among crop farmers in Kenya to a very great extent, 30.1% indicated to a great extent, 14.6% indicated to a moderate extent, 13.8% indicated not at all, and 10.6% indicated to a low extent. This implies that enough sun exposure affects availability of water for irrigation among crop farmers in Kenya to a very great extent.

4.4. Duration Having Practised Crop Farming Depending on Solar Powered Boreholes

Further, the respondents were asked to indicate how long they have been practicing crop farming depending on solar powered boreholes. Their responses were presented in Table 4.6.

Table 4.6: Duration Having Practised Crop Farming Depending on Solar Powered Boreholes

	Frequency	Percent
0-1 yrs.	16	13.0
2-3 yrs.	43	35.0
4-5 yrs.	31	25.2
6 yrs.	33	26.8
Total	123	100.0

Source: Odula 2022

As per the results, 35.0% of the respondents indicated that they have been practicing crop farming depending on solar powered boreholes for 2-3 years, 26.8% indicated for 6 years, 25.2% indicated for 4-5 years, and 13.0% indicated for 0-1 years. This concurs with Gewin (2012) who described that in 1966 there were 3 million irrigated acres while in 2002 there were 8 million acres. Over this time the area devoted to corn in the state of Nebraska was constant at a little over 9 million acres. This period also marked the largest increase in yields in both irrigated Nebraska and non-irrigated Illinois. This yield increase is often attributed to the green revolution of better fertilization. This conforms to Schoengold et al. (2005) who noted that one of the benefits of irrigation systems is that the farmers have the possibility to decide when they need the water, instead of depending on when and if the rain-falls come. In Asia, the yields have increased 100-400 percent after irrigation.

4.4.3: Size of Farming Land Utilized in Acres

Moreover, the respondents were asked to indicate the size of farming land utilised in acres. Their responses were as shown in Table 4.7.

Table 4. 7: Size of Farming Land Utilized in Acres

	Frequency	Percent
< Or equal to 0.99	28	22.8
1- 3.99	20	16.3
4-6.99	64	52.0
7 & above	11	8.9
Total	123	100.0

Source: Odula 2022

The results revealed that 8.9% of the respondents had indicated that they utilised 7 acres and above, 52.0% had indicated that they utilised 4-6.99 acres, 16.3% had indicated that they utilised 1- 3.99 acres, while 22.8 % had indicated that they utilised less than or equal to 0.99 acres. These findings are similar to those of Michael (2010) who noted that the reality is that the green revolution started as early as the turn of the century and started to take off in the 1930's. The large yield increases seen since the 1960's was the mainstreaming of the yield increasing technologies due to increased farm investment.

4.4.4: Farm Yields of 90 Kg Bag disposed per acre of Land (Rain Fed Agriculture)

The respondents were also required to indicate the number of farm yields of 90 kg bag per piece of land (rain fed agriculture) that they used. The results were displayed on Table 4.8.

Table 4.8: Farm Yields of 90 Kg Bag disposed per acre of Land (Rain Fed Agriculture)

	Frequency	Percent
0-5	9	7.3
11- 15	27	22.0
16- 20	61	49.6
21 & above	26	21.1
Total	123	100.0

Source: Odula 2022

The findings show that 49.6% of the respondents indicated that they disposed 16-20 farm yields of 90 kg bag per acre of land (rain fed agriculture), 22.0% used 11- 15 farm yields of 90 kg bag per acre of land, 21.1% disposed 21 farm yields of 90 kg bag per acre of land and above, while 7.3% disposed 0-5 farm yields of 90 kg bag per acre of land But rain-fed agriculture is common, for example in Sub-Saharan Africa about 95 percent of the total cereal area originates from that kind of agriculture, and is very important for those people that live in rural areas that do not have access to irrigated land.

4.4.5: Farm Yields of 90 Kg Bag disposed per acre of Land (Irrigation Agriculture)

Further, the study sought to find out the farm yields of 90 kg bag per acre of land (irrigation agriculture) that the farmers disposed. Their responses were as tabulated in Table 4.9

Table 4.9: Farm Yields of 90 Kg Bag disposed per acre of Land (Irrigation Agriculture)

	Frequency	Percent
0-5	13	10.6
6- 10	3	2.4
11- 15	10	8.1
16- 20	79	56.9
21 & above	27	22.0
Total	123	100.0

Source: Odula 2022

The outcomes revealed that 56.9% of the respondents indicated that they disposed 16-20 farm yields of 90 kg bag per piece of land (irrigation agriculture), 22.0% had disposed 21 farms had utilized and above, 10.6% had utilized 0-5, 8.1% had utilized 11-15, and 2.4% had utilized 6- 10. This is in line with Paarlberg (1999) who states that irrigation costs are doubly so high compared to other continents and the topography of the landscape is irregular which complicates irrigation constructions.

4.5: The Farmer's Ability to Spend from the Income using Solar Powered Technology Agriculture

The researcher asked the respondents to indicate how much they were able to spend from the income using solar powered technology agriculture. Their responses were a shown in Table 4.10.

Table 4.10: The Farmer's Ability to Spend from the Income using Solar Powered Technology Agriculture

	Frequency	Percent
Enough	21	17.1
High	96	78.0
Extremely high	6	4.9
Total	123	100.0

Source: Odula 2022

As per the study results, 78.0% of the respondents indicated that they highly spent from the income using solar powered technology agriculture, 17.1% indicated they spent enough, while 4.9% indicated they spent extremely high from the income using solar powered technology agriculture. These findings are in relation to Bhattarai et al. (2002) who stated that irrigation facility increases the crop production and intensity of crop in higher rate. Farmers use improved variety of crops. What is more, the irrigation induced increase in farm yield promotes the use of high-yielding varieties, fertilizers and multiple cropping, resulting in a higher farm output. Assured by the stable output, the farmers will be motivated to increase investment for better seeds and other input factors, thus enabling further improvement of farm productivity. The stable water supply also enables the diversification of crops as well as the switching from staples to higher-value, market-oriented produces. Farmers switch from drought-resistant plants to water-tolerant ones which promise higher price and better marketability.

4.5.1: The Farmer's Ability to Save from the Income using Solar Powered Technology Agriculture

Further, the respondents were asked to indicate how much they were able to save from the income using solar powered technology agriculture. Table 4.11 shows the outcomes.

Table 4.11: The Farmer's Ability to Save from the Income using Solar Powered Technology Agriculture

	Frequency	Percent
Extremely low	12	9.8
Low	26	21.1
Enough	18	14.6
High	51	41.5
Extremely high	10	8.1
Nothing	6	4.9
Total	123	100.0

Source: Odula 2022

The findings show that 41.5% of the respondents indicated that they saved highly, 21.1% indicated that they had low savings, 14.6% indicated that they had enough savings, 9.8% indicated that they had extremely low savings, 8.1% indicated that they had extremely high saving, while 4.9% indicated that they had not saved. This is consistent with Lipton et al. (2003) who note that increased investments expand the farm size resulting in the demand for additional labour force, offering landless labourers a stable source of income.

This changes the rural wage structure and lessens the pressure of migration to urban areas. Additionally, higher farm yield enables a reduction in food price.

Findings are in line with FAO (1997) who stated that about 85 percent of the total water withdrawals in Africa are used by agriculture and in the semi-arid regions the percentage is somewhat higher. In those areas the water that is used for irrigation represents a major part of the water resources.

Moreover, 30.9% of the respondents indicated that enough sun exposure affects solar powered boreholes among crop farmers in Kenya to a very great extent, 30.1% indicated to a great extent, 14.6% indicated to a moderate extent, 13.8% indicated not at all, and 10.6% indicated to a low extent. This implies that enough sun exposure affects solar powered boreholes among crop farmers in Kenya to a very great extent. This concurs with Rijsberman (2001) who argued that rain-fed agriculture consumes a big quantity of water, because of its large area, that could instead be used to river runoff. But rain-fed agriculture is common, for example in Sub-Saharan Africa about 95 percent of the total cereal area originates from that kind of agriculture, and is very important for those people that live in rural areas that do not have access to irrigated land.

4.6 Total Income per Harvest Season

The research aimed to determine how the solar powered boreholes have affected the agricultural income among crop farmers in Buuri Sub County. The researcher required the respondents to indicate the extent that the following affect total income per harvest season in Kenya. The findings are displayed on Table 4.12

Table 4. 4: Extent of Total Income per Harvest Season Effects

	Not at all F (%)	Low extent F (%)	Moderate extent F (%)	Great extent F (%)	Very great extent F (%)
Average Income from direct sales	25 (20.3)	26 (21.1)	24 (19.5)	48 (39.0)	0 (0.0)

Source: Odula 2022

The results revealed that 39.0% of the respondents indicated that the average income from direct sales affect total income per harvest season in Kenya to a great extent, 21.1% indicated to a low extent, 20.3% indicated not at all, and 19.5% indicated to a moderate extent. This implies that the average income from direct sales affect total income per harvest season in Kenya to a great extent. This concurs with Dhakal (1990) who noted that especially for households whose subsistence income level relies heavily on farming to overcome poverty, their vulnerability to external shock is among the main reasons for them to fall back into poverty trap. On the whole, access to irrigation provides farming households with a better-off condition to achieve higher and more sustainable source of income.

4.6.1 Spending Habits

The study sought to establish how income among crop farmers in Buuri Sub County has affected their spending habits. The researcher further required the respondents to indicate the extent that the following affect spending habits in Kenya. Table 4.13 shows the results.

Table 4. 5: Extent of Spending Habits Effects

	Not at all F (%)	Low extent F (%)	Moderate extent F (%)	Great extent F (%)	Very great extent F (%)
Purchase of Assets	0 (0.0)	6 (4.9)	16 (13.0)	77 (62.6)	24 (19.5)
Purchase of agricultural inputs	0 (0.0)	0 (0.0)	9 (7.3)	75 (61.0)	39 (31.7)
Saving	0 (0.0)	11 (8.9)	21 (17.1)	69 (56.1)	22 (17.9)

Source: Odula 2022

The findings revealed that 62.6% of the respondents indicated that purchase of assets affect spending habits to a great extent, 19.5% indicated to a very great extent, 13.0% indicated to a moderate extent, while 4.9% indicated to a low extent. This implies that purchase of assets affects spending habits to a great extent. Moreover, 61.0% of the respondents indicated that purchase of agricultural inputs affects spending habits to a great extent, 31.7% indicated to a very great extent, while 7.3% indicated to a moderate extent. This implies that the purchase of agricultural inputs affect spending habits to a great extent. Further, 56.1% of the respondents indicated that saving affects spending habits to a great extent, 17.9% indicated to a very great extent, 17.1% indicated to a moderate extent, while 8.9% indicated to a low extent. This implies that saving affects spending habits to a great extent. This is in line with Paarlberg (1999) who noted that furthermore, thanks to the stable farm output; the farming households are less vulnerable to external shocks such as food price or natural disasters. On the whole, access to irrigation provides farming households with a better-off condition to achieve higher and more sustainable source of income.

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The studies found that majority of the farmers have been practicing rain fed agriculture for 10 years and above. The researches also found that majority of the farmers have been practicing crop farming depending on solar powered boreholes for 2-3 years. Moreover, most of the farmers utilised 4-6.99 acres and above. The study found that most of the farmers used 16-20 farm yields of 90 kg bag per acre of land (rain fed agriculture) and (irrigation agriculture). The study also found that the farmers highly spent from the income using solar powered technology agriculture, and saved highly.

In regards to ready water source for irrigation, the study found that functional boreholes and enough sun exposure affect water availability of water for irrigation among crop farmers in Kenya to a great extent.

In relation to crop productivity, the research found that yields per acre affect crop productivity in Kenya to a great extent. The study also found that the number of harvests per year affect crop productivity in Kenya to a great extent.

On the total income per harvest season, the study found that the average income from direct sales affect total income per harvest season in Kenya to a great extent. On the spending habits, the study found that purchase of assets affects spending habits to a great extent. The study also found that the purchase of agricultural inputs affects spending habits to a great extent. Moreover, the study found that saving affects spending habits to a great extent.

Conclusions

The study concluded that purchase of agricultural inputs takes up a big percentage of their savings whereas it is a prudent move and important but the cost incurred is too high to realize a sense of agricultural economic growth. The study also deduced that in efforts to mainstream the use of solar power for water pumping at community level, focus has been on the reduction in recurrent costs associated with water supply and consequent payback period for solar water systems compared to alternatively powered systems.

Recommendations

Farmers' cooperatives, water user associations, irrigation associations and similar organizations for water distribution have a long-standing history in many countries with an irrigation history. There is need to support such structures to create bottom-up user organization and to engage representatives of irrigation water users in decision-making processes. In order to come to sustainable solutions, these associations have to go beyond their direct purpose and reach out to form partnerships with the private sector (financiers, suppliers and service providers) and water authorities (e.g., to guarantee groundwater monitoring).

That, it is important that water departments are well informed about new developments, such as solar pumps, modern irrigation technologies and mini-grids. They play a crucial role in advising farmers on these issues, developing policies to support farmers, especially smallholders and marginalized groups, and promoting sensible technological developments. There are great opportunities for improving (ground) water monitoring through solar pumps coupled with online data management systems and mobile applications, but these opportunities need to be seized by irrigation departments or other official bodies.

The increasing number of suppliers for solar-powered irrigation equipment makes it difficult for consumers to select the appropriate and reliable product. A structured local supply industry with standardized equipment (at least in the data supplied to the customer) will help consumers, as will a certification scheme for national suppliers, who would have to undergo a transparent qualification procedure to become certified.

Instilling a sense of ownership of the water point should be done prior to, during and after the installation of the systems. Failure to do this often leads to high prevalence of vandalism and theft as well as over-reliance by the community on donor assistance. There is also need for communities to be trained on system management with the option of additional guidance and supervision after the installation of the borehole (e.g. 6 months) before they are left to run it.

Solar panels should be regularly cleaned with water and a soft sponge to reduce soiling losses that arise due to accumulation of dust and other particles like bird droppings on the panels. Equipping companies should provide communities with solar panel cleaning poles and brushes.

Reference

i. Adams, W.M., Potanski,T.& Sutton, J.E.G.(1994) î The Indigenous Farmer-Managed Irrigation in Sonjo, Tanzania; in The Geographical Journal,no.1,vol.160,pp.17-32.

ii. Barker, Randplph. & van Koppen, Barbara.(1999) water Scarcity and Poverty. International Water Management Institute.

iii. Connelly, James .& Smith, Graham.(2003) Politics and The Environment, From Theory To Practice.Routledge, London and New York.

iv. Dungumaro, Esther.W.& Madulu, Ndalahwa,F.(2002) ì Public Participation in Integrated Water Resources Management: the Case of Tanzania, 3rd WaterNet/Warsafa Symposium in Water Demand Management for Sustainable Development, Dar es Salaam, October 30-31.

v. Economic and social research foundation.(1997) ì A framework for a national irrigation policy and the economic and social implications for future irrigation development programmes in Tanzaniaî, Policy dialogue series, No. 006

vi. Environmental cell unit, irrigation section.(2001) initial environmental examinations for Mkombozi, Mwungano and Endamajeki irrigation schemes in Babati district, Arusha region, Dar es Salaam

vii. FAO.(1997) irrigation potential in Africa: A basin approach, FAO Land and Water Development Division, Rome.

viii. FAO.(2006) what is water worth in agriculture 21, published March 2006.Cited 2006- 05-26, http://www.fao.org/ag/magazine/0603sp1.htm FAO.(2005) îLand and Water Development Divisionî. Cited 2006-05-26 http://www.fao.org/ag/agl/aglw/aquastat/countries/tanzania/index.stm

ix. Farm Radio Network.(2000). ìVoices Newsletter. Cited 2006-05-26, http://www.farmradio.org/english/publications/voices/v2000jan.asp

x. Hassler, Bjˆrn.(2005) ì The Myth of Sustainable Development-Environmental Policy, Practice, and Incentives in the Baltic Sea Regionî, Sweden, Huddinge, Sˆdertˆrn University College. 29

xi. Huggins, C. (2000) Rural Water Tenure in East Africa, A comparative Study of Legal Regimes and Community Response to Changing Tenure Patterns in Tanzania and Kenya, Nairobi, Kenya, African Centre for Technology Studies.

xii. International Commission on Irrigation and Drainage.(2006) Cited 2006-05-26, http://www.icid.org/cp_tanzania.html

xiii. Juma, T. (2004) Politicians behind Babati land disputes. Cited 2006-05-27 http://www.ipp.co.tz/ipp/mirror/2004/08/24/19330.html

xiv. Lankford, Bruce.(2002) Irrigation, Livelihoods and River Basinsî in; Ladder Working Paper, no.14

xv. Lankford, Bruce.(2004) Irrigation improvement projects in Tanzania; scale impacts and policy implications, UK, Norwich, School of Development Studies, University of East Anglia.

xvi. Lankford, Bruce.(2002) ì Irrigation Livelihood Trends in River Basins-Implications for Policyî, 3rd WaterNet/Warsafa Symposium in Water Demand Management for Sustainable Development, Dar es Salaam, October 30-31.

xvii. MacLean, Richard.& Voss, Joachim.(2006) î Allocation of Water Resources in Africa: Potential for Moving Waterî. Cited 2006-05-26 http://www.idrc.ca/en/ev-31102-201-1-DO_TOPIC.html

xviii. Maganga, Faustin.P.(2003) ì Incorporating customary laws in implementation of IWEM: some insights from Rufiji River Basin, Tanzania; in Physics and Chemistry of the Earth, no.28, pp. 995-1000.

xix. Mutayoba, W.N.(2002) ì Management of Water Resources in Tanzania Through Basin Management, 3rd WaterNet/Warsafa Symposium in Water Demand Management for Sustainable Development, Dar es Salaam, October 30-31.

xx. National Website of the United Republic of Tanzania.(2006). Cited in 2006-05-26 www.tanzania.go.tz/census/districts/babati.htm Ubwani, Zephania.(2002) î Babati land Conflictî. Cited 2006-05-26 www.ntz.info/gen/b00625.html

xxi. United Nation. (2002) î UN Calls on World Leaders to commit to a Sustainable Future at Upcoming Johannesburg Summitî, UN press release, Cited 2006-05-17, www.globalpolicy.org/socecon/confrnce/2002/0813un.htm

xxii. Ostrom, Elinor.& Gardner, Roy.(1993) ì Coping with Asymmetries in the Commons: SelfGoverning Irrigation Systems Can Work; in The Journal of Economic Perspective, no.4,vol.4,pp.93-112. 30

xxiii. Ostrom, Elinor.(1990) Governing the Commons, The Evolution of Institutions for Collective Action, Cambridge University Press, United Kingdom.

xxiv. Paarlberg, Robert.L.(1999) ìPolitics and Food Insecurity in Africa; in Review of Agriculture Economics, no.2,vol.21, pp.499-511.

xxv. Palamagamba, John.Kabudi.(2005) Challenges of legislation for water utilization in rural Tanzania: drafting new lawsî, International workshop on African Water Laws: Plural Legislative Frameworks for rural Water Management in Africa, Johannesburg, January 26-28

xxvi. Quinn, Clarie.H.(2002) Review of CPR Institutions in 12 Villages in Semi-Arid Tanzania, UK, York, Centre for Ecology, Law and Policy Environment Department University of York.

xxvii. Rijesberman, Frank.R.(2001) ì Balancing Water Uses: Water for Food and Water for Nature, The International Conference on Freshwater, Bonn

xxviii. Sandstrˆm, K.(1995) Forest and Water-Friends or Foes? Hydrological implications of deforestation and land degradation in semi-arid Tanzania, Kanaltyckeriet, Motala.

xxix. Schoengold, Katarina.& Zilberman, David.(2002) The Economics of Water, Irrigation, and Development, United States, Barkley, Department of Agriculture and Resource Economics, University of California.

xxx. Sandstrˆm, K, 1995, Forest and Water- Friends or Foes? Hydrological implications of deforestation and land degradation in semi-arid Tanzania, Kanaltryckeriet i Motala. Juma,

xxxi. Thomas.(2004) Politicians behind Babati land disputes. Cited 2006-05-27 http://www.ipp.co.tz/ipp/mirror/2004/08/24/19330.html MacLean, Richard.& Voss, Joachim.(2006) î Allocation of Water Resources in Africa: Potential for Moving Water. Cited 2006-05-26 http://www.idrc.ca/en/ev-31102-201-1- DO_TOPIC.html