# MODERN TECHNOLOGY AND SUSTAINABLE IRRIGATION OF SMALL SCALE DRY-LAND FARMING IN KITUI COUNTY, KENYA

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## ABSTRACT

*The Purpose of this study was to investigate the influence of technology on sustainable irrigation of small scale dry land farming in Kitui Central District, Kitui County, Kenya. The study sought to establish the extent to which adoption of new irrigation technology, gravity free flow irrigation and access to access to credit has influenced sustainable irrigation of small scale dry land farming. Descriptive survey research design was adopted. A sample of 150 participants was randomly selected from 1540 small-scale dry land irrigation farmers in the district. Data was collected using questionnaires and an interview schedule. Descriptive and inferential statistical procedures, including Pearson's correlation coefficient and one way ANOVA were used to analyze quantitative data. Qualitative data was analyzed by daily briefs, categorization into themes and narrations of respondents' quotations and verbatim explanations. The findings revealed that irrigation of intensive, small scale dry-land farming yields statistically significantly higher farm outputs from a 2-acre dry-land farm than the natural rain-fed small scale dry-land farm of similar acreage at 95% confidence interval. The study recommended that farmers and County governments should adopt both indigenous and new technologies that are supportive to the development and growth of small scale dry land farming. Further studies should be done on the relationship between training and sustainable irrigation of small scale dry land farming to ensure successful artificial agricultural productivity from the Arid and Semi Arid Lands (ASALs) of Kenya.*

**Key words:** Irrigation technology, gravity free flow, access to credit, dry-land farming

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## 1. Introduction

Sustainable irrigation is defined pragmatically by (Abrams, 1998) as "when the irrigation scheme continues to work overtime after the initial donor support has been withdrawn." Sustainable irrigation, in this study, refers to the ability of small scale farmers to continue practicing irrigation farming effectively for intensive crop production in the dry land region of Kitui County after the initial donor support is withdrawn. That is why Parry- Jones, Reed and Skinner (2001) defined sustainable small-scale irrigation dry-land farming as involving the notions of minimal external support, village-level financing and the continuation of beneficial service overtime, long after the withdrawal of donor support. Sustainable irrigation of small scale dry land farming in the ASALs like Kitui County could only be achieved by irrigation technology.

The World Food Summit of 1996 defined sustainable irrigation of small scale dry-land farming as "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life." Sustainable irrigation of small scale dry-land farming also focuses on the adoption of new irrigation technology, gravity free flow irrigation and access to credit. The food insecure population in the world is increasing at an alarming rate (Gabre-Madhin, 2009). In the year 2000, about 830 million people in the world were food insecure, but in 2011, this figure had gone up to 925 million (Jamah, 2011).

Sub-Saharan Africa is the home of nearly 240 million chronically food insecure population, which makes 25% of the total population living in the developing countries (Jamah, 2011). But agricultural production is declining significantly in Africa (Gabre-Madhin, 2009). In 1995, over one-third of the African continent's grain consumption depended on food imports (Aileen, 2003) and each year, some 30 million people require emergency food aid. In the year 2000, food aid in Africa amounted to 2.8 million tonnes (Slater, Peskett, Ludi and Brown, 2007). It is significant to note that the adoption of rain-fed dry-land farming has failed to attain sustainable food production in the sub-Saharan Africa (Gabre-Madhin, 2009). Africa needs a sustainable irrigation technology for agricultural food production in order to improve in its agricultural food production to a level that can sustain the high population growth rate (Slater, *et al.,* 2007).

In Kenya, the agricultural sector supports livelihoods of about 80% of the 41 million people (Government of Kenya [GoK]: *Population Census*, 2009). The sector also accounts for 25% of Kenya's Gross Domestic Product (GDP) and it is the second largest after the service sector. Small-scale farmers account for over 75% of the total agricultural output and about 50% of the marketed agricultural produce (GoK, 2009). Initiation and management of irrigation schemes in Kenya is delegated to the National Irrigation Board (NIB) by the Ministry of Water and Irrigation (MWI) which is legally mandated by the government to manage all irrigation related resources on behalf of the Government of the Republic of Kenya (GoK, 2009).

The board, which was established through the Irrigation Act of 1966 (CAP 347) of the Laws of Kenya, is also subject to the State Corporations Act (CAP 446) that guides the operations and functions of all Public Sector Corporations (Kinyua, 2004). The latest NIB policy on irrigation foregrounds the normalization of operations; provision of infrastructure for the existing irrigation schemes; restarting of the stalled irrigation schemes through farmers' sensitization and capacity building; initiation of long term sustainability of irrigation schemes through self-owned activities which eschew the trap of dependency on external support; increasing farmers' participation in irrigation management; expanding irrigation development through assessments and developing new irrigation schemes (GoK, 2009).

One of the challenges facing irrigation is the availability of freshwater, which is associated with global climate change. Karl, Melillo and Peterson (2009) argued that agriculture uses roughly 70% of the total global freshwater supply and so, the agricultural sector is adversely influenced by the global climate change. The global climate change influences the small-scale irrigation dry-land farming worldwide due to the increased variability in precipitation and competing demands for fresh water supply, which challenge the capacity to maintain output (Slater, *et al.*, 2007).

Other irrigation technology-related constraints influencing small-scale farming in ASALs include: high cost of equipment, their repair and maintenance, especially the motorized pumps (Baker, 2005). Similarly, there is no collateral to safeguard loans either from the government Agricultural Finance Corporation (AFC) or from commercial banks in small scale irrigation farming (Karl, *et al.,* 2009). However, income gains from small-scale irrigation agriculture are impressive (Omiti, Otieno, Nyanamba and Mccullouch, 2009).

On average, a small-scale farmer on 2-3 acre-land of rain-fed agriculture makes less than Kshs. 60,000 gross income annually, which contrasts with Kshs. 100,000 from an equivalent unit of land under irrigation, for Kshs Snow peas and French beans, Kshs. 34,000 for Kale and Kshs. 45,000 for onions (Omiti *et al,* 2009). But less than 50,000 hectares of land are used for small-scale irrigation which pales in comparison with the estimated small-scale irrigation potential of 300, 000 hectares as well as the 80, 000 hectares total irrigation area in Kenya (Omiti et al, 2009). Kitui Central District is in a central hilly part of Kitui County, one of the driest Counties in Kenya (GoK, 2010, *Kenya Vision 2030*).

In Kitui Central District, the main agricultural land use utilizes the unreliable short-rains (Christian and Mbuthia, 2008). The rainfall pattern is bi-modal but erratic and unreliable within the range of 500 mm to 700 mm annually (Vasudevan and Gichohi, 2008). Rain-fed food production is unreliable, except among the farmers who grow crops such as millet, sorghum, green grams and cowpeas. Thus, there is rampant food insufficiency in the district (Vasudevan and Gichohi, 2008). Small scale irrigation of dry-land farming is dominant in the rural regions surrounding the Kitui County headquarters, along the Kalundu and Nzeeu river banks and by isolated cases of farmers who use water from their shallow wells for irrigation (Christian and Mbuthia, 2008). It is against this background that this study sought to establish the extent to which technology influences sustainable irrigation of small scale dry-land farming in Kitui Central District, Kitui County, Kenya.

## 1.1 Statement of the problem

Although there has been low small scale irrigation in Kenya as revealed in the introduction, its contribution to the national income, employment, sustainable irrigation of small scale dry-land farming and nutrition is recognized worldwide (Jamah, 2011). For example, the increasing demand for staple food and income generated from small scale irrigation agriculture in Africa is currently at Kshs. 12,000 billion annually (Jamah, 2011). This shows that there is untapped food production and income generation potential from small scale irrigation farming. With relevant government policy support, small scale irrigation of dry-land farming is capable of solving not only food and income insufficiency, but may also create employment opportunities for many people (Christian and Mbuthia, 2008).

In spite of the foregoing knowledge, sustainable irrigation of small scale dry-land farming has not been addressed in Kitui Central District (Vasudevan and Gichohi, 2008). In the *Kenya Vision 2030* policy paper, it was convincingly projected that Kenya would have attained an economically viable agricultural production which would be sustainable and commercially competitive in the global market by the year 2030 (GoK, 2010). However, three years down the line in 2012, there was no significant impact of its implementation in Kitui Central District.

Consequently, rural poverty and food insecurity persist with the decrease of food aid and donor funding from the World Food Programme (WFP), the World Bank and International Monetary Fund (IMF) respectively (Christian and Mbuthia, 2008). There are approximately 93,000 people in Kitui Central District (GoK, *Population Census*, 2009). This population still depends on relief food aid to meet the deficit from the rain-fed agriculture. (Christian and Mbuthia, 2008). Although small scale irrigation of dry-land farming can be sustainable and has potential to supply surplus for commercial purposes, it has not been adequately adopted in the district. This is why this study investigated the influence of technology on sustainable irrigation of small scale dry-land farming in Kitui Central District, Kitui County, Kenya.

## 1.2 Objective of the study

The objective of the study was to establish the extent to which adoption of new irrigation technology has influenced sustainable irrigation of small scale dry land farming.

### 1.3 Hypothesis of the study

The following Null Hypothesis was tested:

**Ho:** There is no significant difference between the treated mean values of technologically irrigated dry-land 2-acre farm yields and the control mean values of rain-fed dry-land 2-acre farm yields at 5% significance level.

**$H_1$:** There is significant difference between the treated mean values of technologically irrigated dry land 2-acre farm yields and the control mean values of rain fed dry-land 2-acre farm yields at 5% significance level.

## 2. Literature Review

Kenya is already utilizing the low-cost technology for small-scale irrigation defined in this study as irrigation on small plots where farmers have the major control and influence and under which farmers use any level of technology that they can effectively operate and maintain (Meinzen-Dick, 2007). Many different technologies and techniques are used for water collection and distribution for small-scale irrigation in Kenya, including rainwater harvesting, bucket irrigation, gravity fed sprinkler and drip, treadle and pedal pumps, rope and washer, motorized pumps, wind-power and construction of small earthen dams (Meinzen-Dick, 2007).

Inexpensive simple gravity and pump sprinkler systems for horticultural crops have been extremely profitable investments. Their numbers are growing fast in high-potential areas such as on the slopes of Mt. Kenya where commercialization of horticultural crops for domestic and international markets is in full swing. However, the spread of this technology to cover most of the estimated potential irrigation area is limited by physical conditions and increasing competition for water. Techniques focused on keeping water in the field, distributing it more efficiently, achieving better soil moisture retention are typically less expensive than management strategies or system modifications (Evans, 1998). Field practices are techniques focused on keeping water in the field, distributing it more efficiently, achieving better soil moisture retention (Verhallen, *et al.,* 2003). When traditional field practices fall short of expectations and the management strategies and systems modifications discussed below are out of reach, the field practices of dry-land farming are another avenue to explore. Examples of dry-land farming field practices include: chiselling of extremely compacted soils; furrow diking to prevent runoff; and land levelling for more even water distribution (Verhallen, *et al.,* 2003).

In order for dry-land farming to be feasible for farmers, it must be accompanied by financial incentives like conservation easements, which involve the transfer of development and/or land use rights to a government agency or non-profit providing tax benefits or direct payment for retirement of the land (Kromm and White, 1990). Management strategies allow the irrigator to monitor soil and water conditions to ensure water is delivered in the most efficient manner possible (Evans, 1998). By collecting this information, farmers can make informed decisions about scheduling, the appropriate amount of water for a particular crop, and any system upgrades that may be needed (Anderson and Heimlich, 2000).

The methods include: measuring rainfall, determining soil moisture, checking pumping plant efficiency, and scheduling irrigation (Evans, 1998). Farmers have to rely on a number of factors to monitor soil moisture, including temperature and humidity, solar radiation, crop growth stage, mulch, soil texture, percentage of organic matter and rooting depth. The government of Queensland (2002) in Australia has done an effective job of compiling a fact sheet on a variety of irrigation scheduling tools, including the associated pros, cons, and costs of each (Anderson and Heimlich, 2000). When pumping plants are running at their most efficient, water gets delivered to the plant without being wasted (Evans, 1998). A pump in need of repair or adjustment cannot only waste water but also cost money (Anderson and Heimlich, 2000). The management strategies described above allow for the correct amount of moisture to be delivered to the plant. When combined with system upgrades, farmers can maximize the amount of water savings and the efficiency of their land (Verhallen, et al., 2003). While this is not an automatic replacement for a dam, there could be an opportunity for removal or the ability to delay construction of a new barrier depending on the size of the diversion (Kromm and White, 1990).

Monitoring the water needs of crops in the most efficient manner possible requires technological upgrades that also require an initial outlay of capital (Evans, 1998). In addition to the cost of implementing these system upgrades, there may be training required to integrate new computer systems and others (Verhallen, et al., 2003). System modifications, often the most expensive of the three categories, require making changes to an existing irrigation system or replacing an existing system with a new one (Evans, 1998).

One typical system modification that allows for the most efficient delivery of water is the addition of drop tubes to a centre pivot system and the retrofitting of a well with a smaller pump (Evans, 1998). Replacement irrigation systems include: installing drip irrigation, micro sprinklers, or solid set systems, or constructing a tail water recovery system (Kromm and White, 1990). Many farms still use inefficient irrigation techniques like travelling gun, and centre pivot, which apply more water than crops require (Bureau of Reclamation, 1996). Modern irrigation technologies such as drip irrigation, micro sprinklers and solid set systems can deliver water much closer to the actual plant and achieve much greater water efficiency (Evans, 1998). These irrigation tools are the most efficient in terms of delivering water to crops. They use the latest technologies to determine the exact amount of water a crop needs in order to grow and delivers the water directly to the plant. However, they often prove most efficient when used with vegetable and fruit tree crops and less so with dense grain crops (Verhallen, et al., 2003).

Low horsepower (LHP) diesel pumps are also very popular among farmers who can afford them: the pumps are not inexpensive, typically selling for Kshs. 50,000- Kshs.70,000 for 3-5 HP pumps (Meinzen-Dick, 2007). There has been no revolution in pump technology in small-scale irrigation in Kenya due to the expensive cost of acquiring the motorized pump. Pump breakdowns are major problems: farmers are not trained to maintain pumps and do not know the spare parts for these pumps (Meinzen-Dick, 2007). Irrigation small scale dry-land farmers do not have collateral to safeguard loans either from the government-run AFC or commercial banks (McIntyre et al., 2009). Overall, the government has put a lot of effort into crop and livestock research, but much less effort has gone into support for agricultural engineering and improvement of sustainable small-scale irrigation. Thus, knowledge and capacity for technology development and application is lacking. Overall, there remains little national awareness of innovative, lower-cost technologies (Baker, 2005).

## 2.1 Theoretical framework

This study is based on the Janssen and Anderies (2007) after Irrigation Management Transfer (IMT) viability theoretical framework for a sustainable dry-land farming irrigation scheme. The broad objective of IMT is to increase irrigation performance while reducing constraints on public budget. It is a strategy to improve economic conditions by reducing the role of the state or its agents through privatization and empowerment of local communities.

The underlying principle is to encourage farmers and local communities to take responsibility for the management of local resources, thereby limiting external interventions to the provision of information and institutional support services that enhance efficient resource allocation (Janssen and Anderies, 2007). Janssen and Anderies (2007) define viability as the ability of the irrigation scheme to generate sufficient income to satisfy the household income expectations of the irrigators and to cover basic operational and maintenance costs of the irrigation infrastructure, while not mining the natural resources (soil and water). Janssen and Anderies (2007) also postulates that although income expectation may differ widely across cultures and among individuals, it is much related to the relative role irrigation plays in the income functions of individual irrigators. Janssen and Anderies (2007) have developed their Irrigation Scheme's Viability Theoretical Framework from International Water Management Institute's global studies on sustainable dry-land farming irrigation schemes (Svendsen, 1994; Brewer *et al.*, 1999).

These studies, however, have only stressed on getting the right sustainable dry-land irrigation process along with the favorable technical, legal and institutional conditions' viability; while, Janssen and Anderies (2007) have emphasized on the fact that dry-land irrigation scheme's viability after IMT will further depend on the costs of sustainable self-management and reliance of the farmers on their sustainable irrigation.

### 2.1.1 Conceptual framework

Conceptual framework is a graphical/narrative of relationships of the study variables-network where the independent variables network with moderating/ intervening ones, while the outcome, also called dependent variable, is the output (Orodho, 2005). *This is shown in Figure 1.*

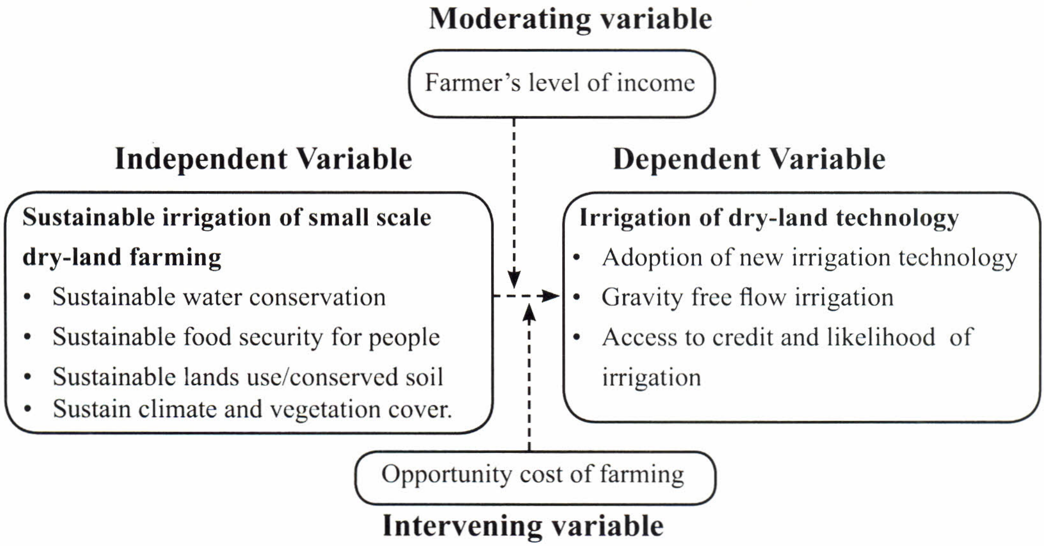


*Figure 1: Conceptual framework for sustainable irrigation of small scale dry-land farming technology*

Access to irrigation technological support services like (extension services and inputs) is often restricted in dry-land agricultural management. Rural communities, however, have proven capable of tackling extreme livelihood conditions deriving from dry-land degradation, including through reforestation and irrigation activities. Providing Credit is one of the best ways of encouraging rural population to take an interest in environmentally sound activities. Smallholder dry-land farmers, using irrigation, often face difficulties in obtaining credit due to lack of collateral.

## 3. Research Methodology

A descriptive survey research design was adopted for this study. The target population was all the 1540 small-scale dry-land irrigation farmers in Kitui central district (Christian & Mbuthia, 2008). The small-scale farmers were grouped into three clusters - Kalundu and Nzeeu river banks and those using shallow wells. From each cluster a sample proportional of 10% of the population was selected using simple random sampling to give 76, 61 and 13 a total of 150 small-scale farmers respectively. According to Mugenda and Mugenda, (2003), 10% is given as the minimum sample size representing the target population. A questionnaire and an interview guide were used for data collection. The instrument was pretested by means of a pilot study.

In the pilot study, the questionnaire was administered on a random sample of ten small scale irrigation agriculture farmers who did not participate in the actual study and reliability was determined using a split-half method. During data collection, the questionnaire was personally administered to 103 farmers as well as face-to-face interview with 47 of the selected farmers who were not able to fill in the questionnaire independently. The filled-in questionnaire was collected before leaving each of the selected farmers. The Statistical Package for Social Sciences (SPSS) was used to analyze the resultant information to produce frequencies, percentages. For additional analysis, Pearson's correlation coefficient and one way ANOVA techniques were used by employing the quantitative approach which involved descriptive and inferential statistical procedures. Qualitative data was analyzed by daily briefs, categorization into themes and narrations of respondents' quotations and verbatim.

## 4. Discussion of the Findings

The study sought to establish the extent to which irrigation technology had influenced sustainable irrigation for small scale dry-land farming in Kitui Central District in Kenya. The selected small scale irrigation dry-land farmers were asked to rate the following indicators of the level of influence of the farmers' irrigation technology on sustainable small scale dry-land farming: adoption of sustainably efficient irrigation technology, gravitational free water flow, convenient and sustainable irrigation and access to credit to secure sustainable irrigation technology equipment.

As was revealed in literature, inexpensive simple gravity and pump sprinkler systems for horticultural crops are extremely profitable investments. However, the spread of this technology to cover the estimated potential irrigation area is limited by physical conditions and increasing competition for water. The research also examined irrigation field practices, that is, the techniques focused on keeping water in the field, distributing it more efficiently, achieving better soil moisture retention, as shown in Figure 4.1(Verhallen, *et al.,* 2003).

**Source:** Copyright © Verhallen, Fisher, and Shortt (2003) Irrigation Conservation Practices.

*Figure 2: Land that has been levelled and furrow irrigation for feasible dry-land farming*

When traditional field practices fall short of expectations and the management strategies and systems modifications discussed below are out of reach, the field practices of dry-land farming are another avenue to explore. Examples of Dry-land farming field practices include: The chiselling of extremely compacted soils, furrow digging to prevent runoff, land levelling for more even water distribution (Verhallen, et al., 2003). The adoption of planned use of technologies can also help people exchange experiences, find common ground for decisions and actively participate in and guide development activities (Ado, 2009).

The irrigation small scale dry-land farmers were asked to use a 5-point likert rating scale ranked from 1-to-5 as **(SA)** Strongly Agree = 1; **(A)** Agree = 2; **(N)** Neutral = 3; **(D)** Disagree = 4 and **(SD)** Strongly Disagree = 5. The responses were grouped together then coded and analyzed. After data analysis, the results were presented in tabular form. The distribution of farmers by influence of irrigation technology on irrigation of small scale dry-land farming was given as shown in Table 1

*Table 1: Distribution of farmers by irrigation technology influence on sustainable irrigation of small scale dry-land farming.*

| | Frequency distributions by 5-point rating scale values | | | | | |
|---|---|---|---|---|---|---|
| **Irrigation technology indicators for dry-land farming** | **SA** | **A** | **N** | **D** | **SD** | **Total** |
| Adoption of sustainably efficient irrigation technology | 110 | 18 | 8 | 12 | 2 | **150** |
| Gravitational free water flow for sustainable irrigation | 111 | 32 | 3 | 3 | 1 | **150** |
| Access to credit for sustainable irrigation technology tools | 79 | 51 | 7 | 13 | 0 | **150** |
| **Cumulative sum of the 3-indicators' frequency** | **300** | **101** | **18** | **28** | **3** | **450** |

As shown in Table 1, the majority (401) of the cumulative sum of the total 450 of the 3-indicators' frequency responses from the selected irrigation small scale dry-land farmers, agreed that irrigation technology influenced the sustainable irrigation of small scale dry-land farming in Kitui Central District.

The interpretation was that irrigation technology negatively influenced sustainable irrigation of small scale dry-land farming in Kitui Central District. The summary of the study results in Table 1 were used with the 5-point scale rater and tabulated as shown in Table 2, where **($x$)** = Scale Values in 5-point numerical values of likert scale ranked as $x = (1,2,3,4,5)$, and **($fx$)** = Sum of product of Cumulative Sum of Frequency and the 5- Scale Values **($x$)** = (1,2,3,4,5).

*Table 2. Responses on the influence of irrigation technology sustainable irrigation of small scale dry-land farming.*

| **5 point ratings** | **No. of farmers** | **(*x*)** | **(*fx*)** | **Percentage** |
|---|---|---|---|---|
| Strongly agree | 300 | 1 | 300 | **66.7** |
| Agree | 101 | 2 | 202 | **22.4** |
| Neutral | 18 | 3 | 54 | **4.0** |
| Disagree | 28 | 4 | 112 | **6.3** |
| Strongly disagree | 3 | 5 | 15 | **0.6** |

As shown in Table 2, 89.1 per cent of the 150 farmers (most of the respondents) had strongly agreed that irrigation technology had influence on sustainable irrigation of small scale dry-land farming in Kitui Central District, Kenya. Only 6.9 per cent (of the respondents) had strongly disagreed, including all those who had strongly disagreed and disagreed that the gender stereotyped roles had influence on sustainable irrigation of small scale dry-land farming, while 4% of the respondents were undecided.

The mean calculated was $\sum fx/\sum f = 683/450 = 1.52$. Therefore, the calculated mean was in between likert scale point values of 1 and 2, where 1 – represented strongly agreed and 2 represented agreed which when combined for purposes of this study stood for strongly agreed. Thus, the findings of the study were interpreted to have indicated that the majority of the sampled dry-land irrigation farmers were in agreement that the farmers' inadequacy in adoption of the irrigation technology negatively influenced sustainable irrigation of small scale dry-land farming in Kitui Central District.

The study findings were similar to the information from literature reviewed, which confirmed that sustainable agricultural development is based less on material inputs (seeds and fertilizers) than on the people involved in their use (Okoro and Amaechi, 2008). Investments in scientific and material inputs for agricultural production bear little fruit without parallel investments in people. To this end, communication technologies are powerful tools for informing people and providing them with the knowledge and skills they need to put agricultural science and production inputs to best use (Mbah, 2008).

To test the study hypothesis, the sampled farmers' responses to the questionnaire and the interview guide item number 19, were interpreted, analyzed and presented as shown in Table 3, which presents the two sets of 2-acre farm annual yields from the irrigation and the rain-fed small scale dry-land maize farming. The two levels of ANOVA were treated-irrigation small scale dry-land farm 90 kg annual outputs of dry maize and the control was the rain-fed small scale dry-land farm 90 kg annual outputs of Maize. The treated case was assumed to be the mean values of the 2-acre 90 kg annual yield from the 5 class intervals of 30 farmers each from the total sample size of the 150 farmers who were grouped according to responses on the yields from the irrigation small scale dry-land maize farm outputs. The control case was assumed to be the mean values of the 2-acre 90 kg annual yield from the 5 class intervals of 30 farmers each from the total sample size of the 150 farmers who were grouped according to responses obtained from the rain-fed small scale dry-land farm 90 kg annual outputs of maize.

The mean values of the 2-acre 90 kg annual yield from the 5 classes of 30 farmers each from the 150 farmers grouped into class intervals of 30 farmers on the two sets of yield of 150-150 responses (treated irrigation = 150 responses of 90kg bag yields) and the (control rain-fed = 150 responses of 90kg bag yields). Of both the treated- irrigation technology and control- rain-fed small scale dry-land maize farming five 2-acre 90 kg annual yield mean values for each of the five-30 member class interval of 10 classes of the selected irrigation small scale dry-land maize farmers were calculated and presented as in Table 3.

*Table 3. Distribution of farmers by the five-30 member group mean values from the 150*

| *Irrigation 2-acre 90 kg yields each 30 farmers* | *Rain-fed 2-acre 90 kg yields each 30 farmers* |
|---|---|
| 11 | 9 |
| 10 | 7 |
| 12 | 8 |
| 14 | 11 |
| 13 | 10 |
| **Total = 60** | **Total = 45** |
| **Grand Total = 105** | |

The Correction Factor CF= (Grand total)$^2$ /N = 105$^2$/10 = 1102.5; The total sum of squares = sum ($X^2$i) - Correction Factor = $11^2+10^2+12^2+14^2+13^2+9^2+7^2+8^2+11^2+10^2$ - Correction Factor = 1145-1102.5 = 42.5; The treatment sum of squares = {[(Irrigation total)$^2$/n +(Rain-fed total)$^2$/n)]- Correction Factor} = {[60$^2$/5 + 45$^2$/5] - 1102.5} = 1125-1102.5 = 22.5.

The results are set out in the ANOVA Table 4 in which there are three sources of variation, as the Treatment, Error and Total. Since there are two treatments, T, there is T-1 = 1 DF (degrees of freedom) for treatments and as there were T = 10 observations total there were 10-1 = 9 total DF. The error DF is obtained by subtraction 9-1 = 8. The SS calculated above are then put in the Table 4, and the error SSE is obtained by subtraction of the treatment sum of squares = 22.5 from the total sum of squares = 42.5 as [(42.5-22.5)] = 20.0. The MS is calculated as the SS/DF = 22.5/1 = 22.5 and the error MSE is calculated as the SSE/error DF = 20.0/8 = 2.5.

The F is calculated as the MS/MSE = 22.5/2.5 = 9.0. Using the Critical Significance Level ($\alpha = 0.05$) and the between treatment F ($df_1$= 2-1 =1) and within treatment ($df_2$=10 – 1 = 9) degrees of freedom calculated to find the Critical Value of ($F_{(1,9)critical}$) using a Critical Value Table as shown in (Appendix V p.76) if $\alpha = 0.05$, $df_1 = 1$ and $df_2 = 9$ then $F_{(1,9)critical}$ = 7.209 compared to calculated F value = 9.000, as shown in Table 4.

*Table 4. Analysis of variance table for comparison of rain-fed and irrigation yields*

| Source | DF | SS | MS | F value | $F_{(1,9)critical}$ at ($\alpha = 0.05$) |
|---|---|---|---|---|---|
| Treatment | 1 | 22.5 | 22.5 | 9.000 | 7.209 |
| Error | 8 | 20.0 | 2.5 | | |
| **Total** | **9** | **42.5** | | | |

On condition that the Null Hypothesis is rejected if the calculated F value is greater than or equal to the F (1, 9) critical where the critical value is at (1,9) degrees of freedom in which ($df_1$=1) is between treatment degrees of freedom and ($df_2$= 9) is within treatment degrees of freedom. Therefore, if $F \geq F$ (1, 9) critical, there is a significant difference and the calculated F value = 9.000 is a significant result.

The Null Hypothesis is accepted if the calculated F value is less than the critical value - $F < F$ (1,9) critical there is no significant difference and the calculated F value is a non-significant result. According to the Critical $F_{(1,9)}$, Table Value = $F_{(1,9)critical}$ = 7.209 compared to the calculated F value = 9.000: it was concluded that the null hypothesis shows that there is no significant difference between the treated mean values of irrigation dry-land 2-acre farm yields by using technology and the control mean values of rain-fed dry-land 2-acre farm yields was rejected at 5% significance level since the $F_{(1,9)critical}$ = 7.209 is less than the calculated F value = 9.000 at $\alpha = 0.05$.

Interpretation of the study findings above, implies that irrigation of small scale dry-land farming yields statistically significant higher farm outputs from a 2-acre dry-land farm on intensive small scale farming than the natural rain-fed small scale dry-land farm outputs from the similar 2-acre dry-land intensive farming would do at 95% confidence interval. This is in part explained by the fact that rain-fed small scale dry-land farming utilizes the natural unreliable and poorly distributed rainfall in Kitui County where Kitui Central District is located.

Hazell (2006) had noted that although small scale dry-land farmers needed enhanced access to arable land, appropriate technology and key farm inputs like seed, fertilizer and access to credit, these key farm inputs might not be the end of the road map to attaining the effective, efficient and reliable improved irrigation dry-land agricultural productivity. Therefore, the farmers' limited access to modern irrigation technology is among the key barriers to improving agricultural productivity.

The majority of the sampled irrigation small scale dry-land farmers (89.1 per cent)had strongly agreed that irrigation technology had influence on sustainable irrigation of small scale dry-land farming in Kitui Central District. However, from the literature review, sustainable agricultural development is not only based on material inputs but also on the people involved in their use (Okoro and Amaechi, 2008). In other words, investments in scientific and material inputs for agricultural production bears little fruit without parallel investments in people (Mbah, 2008).

## 5. Recommendations

The study recommends that the Ministry of Agriculture and policy makers should formulate policy on irrigation and technology that is supportive to the development and growth of small scale dry-land farming. The policy should provide incentives that promote small scale dry-land farming establishments. These would include access to the market, access to credit, transport and the general provision of the required infrastructural facilities that could help in enhancing sustainable irrigation of small scale dry-land farming in most of the arid and semi-arid lands.

On the appropriate use of irrigation technology, the agricultural extension officers should develop sensitization programs for small scale dry-land farmers covering appropriate irrigation technology, economical irrigation farming practices and sustainable water supply in the irrigation of small scale dry-land farming. This is because the farmers would have a broad range of options for adoption of appropriate irrigation technology and irrigation farming practices.

In agricultural economic terms, however, there must be adequate research to support the fact that the measurement of profit supersedes the measurements of cost in the application of the irrigation technology in the arid and semi-arid regions.

### 6. Conclusions

Sustainable irrigation of small scale dry-land farming could be obtained by enhancing own irrigation technology through adoption of improved, affordable and regional appropriate farming technologies. The new farming methods could be achieved through improved access to irrigation technologies. This has indirectly been exerting higher influence on sustainable irrigation of small scale dry-land farming in the ASAL region of Kitui Central District in Kenya. The study findings revealed that access to farm inputs would enhance higher amounts of farm outputs.

Availability of water for irrigation, legal rights to water and competitive alternative water uses, were noticed as factors to consider in enhancing supportive and sustainable irrigation of small scale dry-land farming programme that would change most of the arid and semi-arid lands to green with adequate agricultural produce.

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