Influence of Water Management Structures on Household Food Security Status among the Smallholder Farmers in Kilifi Sub-county, Kenya

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Authors' contributions

This work was carried out in collaboration between the two authors. Author JMC designed the study, wrote the protocol and the first draft of the manuscript, managed the literature searches and analyses of the study. Author EMM proofread the manuscript. Both authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Inadequate quality-water is a major hindrance to rural development and food security in arid and semi-arid areas of Kenya. Technologies that can promote water harvesting and conservation are, therefore, instrumental in increasing resilience in recurring droughts and enhancing food security in these dry lands. A study was carried out in Kilifi sub- County in the coastal areas of Kenya one of the areas where food insecurity incidences are prevalent. The study aimed at assessing the influence of water management structures on food security status among smallholder farming communities. Non experimental design using descriptive survey was adopted for the study. Data was analyzed using descriptive statistics and logistic regression to measure the contribution of water harvesting structures and irrigation to food security status. Water harvesting structures examined were: contour terraces, water pans, trash lines, boreholes, and unploughed strips. The results indicated that 80% of the respondents were food insecure. The respondents who adopted boreholes and unploughed strips were 2% food secure while those who adopted water pans and

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trash lines were 4% food secure respectively. Additionally, those who adopted contour terraces were (8%) food secure compared to other water harvesting structures. There was a significant (P=0.05) positive relationship between the water management structures and food security This implies that contour terraces, water pans, water harvesting structures being economical, possession of title deed and land size are some of the most significant issues affecting food security in Kilifi Sub-county. To further enhance the understanding of food security and improve food insecurity status in Kilifi Sub-county, adoption of water harvesting structures should be promoted by all stakeholders.

1. INTRODUCTION

Water scarcity is a global concern which typically threatens the sustainability of smallholder farmers' livelihoods and food security [1]. The problem of water scarcity is growing as more and more people put ever increasing demands on the limited supplies [2] more so in dry areas where rainfall is limiting. Dry land technologies that promote improved management of water resources are, therefore, paramount in promotion of food production in dry areas which experiences limited and highly variable precipitation [3].

Agriculture is the main economic activity in sub-Saharan Africa (SSA) supporting over 67% of the population. According to World Bank [4], 60% of the population above depends on rainfed agricultural practices which generate 30-40% of the country's Gross Domestic Product. However, these areas receive erratic- poorly distributed rainfall [5,6]. Most of these areas are also prone to high surface runoff and poor water infiltration leading to low water availability in crop rooting zone [7], poor crop root distribution and helath, soil erosion and evaporative losses which leads to poor crop production, food insecurity and societal poverty [4,5,8]. Another study by Dudal [9] reported that water management structures has become an integral part of land use and receives support within a social and economic environment which is conducive to the maintenance and improvement of soil capital. According to Morgan [10], the ultimate aim of water management structures is to obtain the maximum sustained level of production from a given area of land whilst maintaining soil loss below a threshold level which theoretically permits the natural rate of soil formation to keep pace with the rate of soil erosion.

According to Troeh et al. [11], in Ethiopia the primary principals of controlling soil erosion include reducing raindrop impacts on the soil, reducing runoff volume and velocity and increasing the soils resistance to erosion. The function of terraces in dry areas is to retain runoff and increase water available for plant growth. A study by Schwab et al. [12] in Ethiopia reported that a conservation technique may be regarded as successful if it reduces the rate of soil loss to less than 20 percent of the rate without conservation and to less than 10t ha^{-1} $year^{-1}$ which is the commonly accepted as a tolerable ' rate of erosion.

In Kenya, more than three-quarters of land is arid and semi arid with 3.2 million of the population documented as food insecure [13,14]. Eighty five percent of this population also derives their livelihood from rainfed subsistence agriculture [4] in farms averaging 0.2-3 ha which are either individually or family owned. Since the rainfall is normally unreliable in these dry lands, agricultural production which plays a major role in improving food security, can be improved by adoption of new farming technologies that can promote improved soil and water management as well as provision of required plant nutrients [13,14,15]. The water management technologies help in maximizing the limited water supply in the soils, chemical processes in the soils, minimizing water loss through erosion, runoff and evaporation and improving overall soil physical, chemical and biological processes hence improved crop growth and production [3,16,17].

In soil and water management activities, the terms water conservation (WC), water harvesting (WH) and water management (WM) are very close in meaning and quite often used interchangeably. However, the National Soil and water Conservation Program (NSWCP) in the Soil and Water Conservation branch (SWCB) in the ministry of Agriculture in Kenya, explains the three terms as follows [18]. Water Conservation (WC) is defined as prevention of surface flow of excess rain, by prolonging the time for infiltration, thereby, increasing the amount of water stored in

soil profile while Water harvesting (WH) is defined as the collection and concentration of run off for productive purposes. Water management (WM) on the other hand is a broad term that encompasses the regulation, control, use, conservation and harvesting of water in agriculture. It may also refer to the efficient or economical management of available water in agriculture. Soil and water management can technically be achieved through either water harvesting or employment of the barrier and cover approach [19]. Water harvesting involves establishment of structures such as water pans, check dams, farm ponds and roof top water harvesting among others [20]. Barrier approach manages runoff and soil erosion rates by means of contour- aligned barriers such terraces, stone bunds, strips, trash lines or hedgerows [21]. On the other hand, cover approach entails employment of practices that improves water retention in the soil [19].

Despite its close vicinity to Indian Ocean, Kilifi South Sub-County is one of the dry areas in Kenya that experience erratic and unpredictable rains leading to droughts and recurring food insecurity [22]. This leads to over reliance on government food aid. To address this constraint a number of water manangement structures have been developed and introduced to farmers by the Ministry of Agriculture (MOA) and other nongovernmental organizations. They include: contour terraces, water pans, trash lines, boreholes and unploughed strips. Water pans and boreholes have also been introduced to create opportunities for drip irrigation development which is believed to be a means for livelihood improvement in many households. However, despite the new technologies or structures economic viability and potential in improving agricultural productivity and livelihoods [23,5], the adoption of the water harvesting structures by farmers have been low. Many of the small scale farmers in the sub county have also remained poor, food insecure and depended on food aid for their survival. The study, therefore, aimed at evaluating the influence of water management structures on food security status among smallholder farming communities of Kilifi South Sub County.

2. RESEARCH METHODOLOGY

2.1 Research Area

Kenya has 47 counties and one of them is Kilifi County which has several sub-counties namely, Ganze, Kaloleni and Magarini. Kilifi sub-county comprises Bahari, Chonyi and Kikambala divisions. The sub-county was chosen from other sub-counties because of the magnitude of food insecurity whose causes have not been researched on or documented. The sub-county lies between 2º 20' South, and 26º 5' East covering an area of 7,500 km^2. It is both arid and semi-arid, with erratic and unreliable rainfall. Most of the areas are generally hot and dry leading to high rates of evaporation. This combined with unreliable rainfall limit intensive land use and related development activities. It experiences two main rainfall seasons in a year. The long rains start from April to June, with a peak in May while the short rains falls from October to December. The rainfall pattern is influenced by the district's proximity to the Indian Ocean, relatively low altitudes, high temperatures and wind. The majority of the farmers are small-scale farmers with low investment for agricultural production [24]. According to recent population census G.o.K [25], the Sub-county has a total of 25 074 inhabitants comprising of 6 784 households who practice farming.

2.2 Research Design

Kothari [26] defined a research design as the arrangement of conditions for collection and analysis of data in a manner that aims to combine relevance to research purpose with a keen interest on procedure. The study adopted non experimental design using descriptive survey which is a method of collecting information by interviewing and administering questionnaire to a sample of individuals.

2.3 Target Population

The target population of this study was the accessible rural households of Kilifi Sub county. According to Kenya Bureau of statistics population Census [27], the sub county has a total population of 25 074 inhabitants comprising of 6 784 accessible rural households spread across Bahari, Chonyi and Kikambala divisions.

2.4 Sample Size and Sampling Procedure

2.4.1 Sample size

A sample is a smaller group or sub-group obtained from the accessible population [28]. Cochran [29] provides a simplified formula for sample sizes leading to 256 households but 6

households were used for piloting leaving 250 households for the study.

$$n = \frac{Z^2 pq}{d^2}$$

Where

- n = the desired sample.
- Z = the standard normal deviate at the required confidence level.
- p = the proportion in the target population estimated to have characteristics being measured.
- q = 1-p
- d = the level of statistical significance set.
- n = $(1.96)^2(0.05)(0.05)/(0.005)^2 = 384$

2.4.2 Sampling procedure

Sampling refers to a selection of a representative sample from a target population to be used in a study to give desired characteristics about the population. This study used systematic random sampling which involved drawing every n^{th} household in the population starting with a randomly chosen household in each of the villages in the three divisions. The nth household was the 5th household. The respondents were the head of the household or any available adult.

2.5 Research Instruments

The main data collection instruments that were used in this study included the questionnaire. This was used for the purpose of collecting primary quantitative and qualitative data. Additionally, the questionnaires were used for the following reasons: its potentials in reaching out to a large number of respondents within a short time, able to give the respondents adequate time to respond to the items, offers a sense of security (confidentiality) to the respondent and it is objective method since no bias resulting from the personal characteristics [30]. The questionnaire was divided into the main areas of investigation except the first part which captures the household characteristics of the respondents. Other sections were organized according to the major research objectives.

2.6 Piloting of the Instruments

A pilot study was conducted as a technique of testing the validity of the data collection instruments especially the questionnaire and the interview schedules. In this study, a sample of 6 respondents was selected for piloting out of the target population. Piloting helped to identify any unforeseen limitations that could adversely affect the results of the findings of research.

2.7 Validity and Reliability of the Instruments

To validate the questionnaire, after supervisors input, a panel of three competent officers from the sub county agricultural offices were requested to assessed the relevance and quality of the questionnaire and their recommendations were also incorporated in the final questionnaire. The final questionnaire was then administered to a few identical respondents who were not included in the main study and the answers evaluated. After two weeks the same questionnaire was administered to the same group and re evaluated. Thus, test –retest method was used. The consistency in the answers provided assurance of reliability of the instrument.

2.8 Data Collection and Analysis

Household heads or adult representatives provided information on water harvesting structures, their advantages, possession of title deeds and land size. Data on household food security was collected based on self-report in reference to the Experience-based Method [31]. The Statistical Package for Social Sciences (SPSS version 20.0) was used to run descriptive statistics to present the quantitative data in form of tables based on the major research questions. Subsequent analysis was done which involved assessing the relationship between the factors influencing food security using multiple regression. Multiple regression measures the relationship between the categorical dependent variable and independent variables which are usually continuous by estimating probabilities [32].

The regression equation is y= a+ B_1X_1 + B_2X_2 + B_3X_3 + B_zX_z + e where z is the number of independent variables, y is the dependent variable, a is the constant and the Xs are independent variables. The Bs are listed in a column of coefficients. The study used Adjusted R Squared of 0.691. That is, 69 percent of a change in the dependent variable can be explained by changes in the independent variables. Before running statistical analysis, variables were examined for the presence of stochastic trends using normality test in order to

confirm whether data conforms to ordinary least squares (OLS) assumptions. Using the P-P plots of regression, the data were found to be normally distributed.

According to [33], identifying an appropriate food security measure is a difficult issue as not all aspects of food security can be captured by any single outcome measure. This is because the subsistence production is harvested piecemeal and is neither measured nor recorded. In order to avoid this difficulty; most analyses depend on measuring food consumption. Food security can be analyzed in terms of food availability as compared with requirements [34]. They further reported that the net food available after selling the surplus to the market is a function of domestic production at household level. Food security at household level is best measured by food calorie intake [35]. In order to cater for the measurement limitations mentioned by [36,37] and [38], the study adopted food security index which is constructed using FAO calorie intake approach. It helped to determine the food security status of each household based on the food security using the Recommended Daily Calorie Required approach. Households with daily calorie intake equal or higher than the recommended daily calorie were treated as food secure and those below the recommended daily calorie were food insecure. To get the average daily calorie intake of each household; daily calorie intake of each individual was multiplied by its household size. The following formula was adopted:

Food security index Z_n = [Household's daily per capita calorie availability (A) / Household's daily per capita calorie requirement (B)]

Food security index $(Z_n) = \dfrac{Y_n}{R}$

Where

Z_n is food security index of nth household.

Y_n is the actual daily calorie intake of the nth household.

R is the Recommended Daily Calorie Required by n^{th} household.

Food security index ≥ 2060 = food secure household while food security index < 2060 = food insecure household. The 2060 kcal was used because the Daily Recommended Calorie Requirement for Kenya is 2060 kcal [39]. The daily food (carolie) requirement was estimated by

grouping household members into different age groups (Table 1). Total household calorie requirement was then obtained by multiplying total number of adults in each household by the 2060 kcal. Total energy requirements for children were converted to adult equivalent using conversion scale in Table 1.

Table 1. Recommended daily energy intake and conversion factor

Age category (years)	Average energy allowance per day	Conversion factor
<6	750	0.29
7-15	1200	0.51
16-30	1500	0.71
31-50	2350	0.98
51+	2200	0.90

Source: Kenya National Bureau of Statistics [32]

Daily calorie intake was obtained by converting data on food consumed (maize, cowpeas, sorghum and cassava) by every household per week into kilograms and equating using the information in Table 2.

Table 2. Cereal equivalent conversion ratios

Food crop	Calorie/kg	Milling ratio	Maize equivalent ratio
Maize	3590	0.85	1.00
Cowpeas	3640		0.92
Sorghum	1350	0.65	0.40
Cassava	1490	0.85	0.40

Source: Okigbo [33]

3. RESULTS AND DISCUSSION

3.1 Types of Water Harvesting Structures Adopted and Their Advantages to the Farmers

Analysis of the effects of water harvesting structures on food security status indicated that households which adopted contour terraces were more food secure (8%) compared to other water management structures (Table 3). Households using water pans and trash lines were 4% food secure while households using boreholes and unploughed strips were 2% food secure respectively. The higher food security status in households that adopted contour terraces can be attributed to reduction of slope length by contour terraces leading to reduced slope gradient, velocity of runoff and soil erosion rates hence improved water infiltration, less soil degradation and improved crop yields [40]. This findings are

similar to those of [41], who found that increase in using rainwater harvesting structures are significant in the improvement of food security status.

The study revealed that although a contour terrace was the technology adopted by households in the area more than the other water management technologies the level of adoption was low. Contour terraces were adopted by 35% of the respondents, water pans (12%), Trash lines (34%), boreholes (8%) and unploughed strips (12%). The low adoption of the water management technologies can be attributed to poor education levels, land tenure systems, and social status of the people in the study area. According to [42], poor adoption and maintenance of introduced technologies can be attributed to site speficity of socio-economic and biophysical factors. The actual and long term financial profitability of the technologies influences the process of accepting and replication [43]. Additionally, poverty levels, age, education levels, frequency of extension agent visits in the area and land tenure also plays a great role in determining the level of technology adoption [44,45,46]. On the other hand, the low levels of adoption of water management technologies in the study area seems to contradict studies by [1], who stated that several water harvesting structures employed in Kenya to improve crop production purposes have shown a high degree of success.

The study identified that 46% of the respondents reported that WHS were simple to install and operate and 30% of respondents reported that they were convenient and finally 24% of the respondents reported that WHS were economical. Analysis of the effects of the advantages of WHS on food security status indicated that 1% food secure respondents

reported WHS are simple to install and operate. 8% food secure respondents reported that WHS were convenient and finally, 11% food secure respondents reported that WHS are economical.

The relationship between contour terraces and household food security was positive and significant (P=0.01) at 5% significant level (Table 4). The relationship between the dependent variable and independent variables was strong (R^2=0.691). This can be attributed to the ability of contour terraces to improve soil and water management hence improved crop establishment, growth and yields. Similar trends of increased crop production hence alleviation of poverty and enhancement of food security after adoption of water management structures has been reported in South Africa by [47].

The relationship between water pans and food security was positive and significant (P=0.03). The relationship between the dependent variable and independent variables was strong (R^2=0.691). The coefficient of water pans was positive indicating that there was a correlation between water pans and food security. This shows that use of water pans contributes to farmer's ability to alleviate food insecurity. The ability of water pans to improve food security status can be attributed to the role of water pans in rain water harvesting, harnessing runoff, reducing soil erosion and ensuring water conservation to be used during times of scarcity [48]. According to [49] the water management structures are economical because they aid in provision of water at the point of consumption hence reducing operational costs and living expenses. The money that would have been invested in sourcing the water during periods of scarcity is, therefore, diverted to other basic needs such as food leading to reduced food insecurity.

Table 3. Types of water harvesting structures adopted, their advantages and land size

Adoption of WHS	Sample	Percentage	Food insecure	Food secure
Types of WHS adopted				
Contour terraces (Fanya juu)	96	35	27%	8%
Water pans	30	12	8%	4%
Trash lines	77	34	30%	4%
Boreholes	19	8	6%	2%
Unploughed strips	27	12	10%	2%
Total	**250**	**100**	**80%**	**20%**
Advantages of WHS				
Simple to install and operate	116	46	45%	1%
Convenient	65	30	22%	8%
Economical	69	24	13%	11%

Table 4. Logistic regression on types of water harvesting structures as determinants of food security

Variables	Coefficients (*B*)	Std error	t	p-values
Contour terraces	63.74	2.40	1.95	0.01
Water pans	31.85	4.62	1.75	0.03
Trash lines	28.39	9.07	1.38	0.07
Boreholes	12.06	18.95	1.08	0.09
Unploughed strips	10.81	24.66	1.07	0.07
Advantages of water management structures				
Convenient	9.73	25.05	1.04	0.03
Economical	8.81	28.91	1.09	0.05

$R^2=0.691, F=1.731, df=6$

The relationship between water management structures being convenient and food security status was significant (P=0.03). The relationship between the dependent variable and independent variables was strong ($R^2=0.691$). They are flexible and can be built to meet almost any requirements. Their construction and maintenance are not labour intensive. According to [50], they uses simple and flexible technologies that are easy to maintain.

The relationship between water management structures being economical and food security was significant (p=0.05). The relationship between the dependent variable and independent variables was strong ($R^2=0.691$). They are economical in the sense that they provide water at the point of consumption and operating costs are negligible. These findings agree with a study conducted by of [51]. The increase of crop production was enhanced by improvement of soil fertility, high soil moisture and control of soil erosion.

4. CONCLUSIONS AND RECOMMENDA-TIONS

Soil and water management technologies practiced by small scale farmers in Kilifi sub county were contour terraces, water pans, trash lines, boreholes and unploughed strips. Contour terraces was widely adopted and practiced followed by trash lines, water pans, unploughed strips and boreholes was least. Water management structures were found to significantly improve food security in the study area with household that practiced contour terraces being the most food secure (8% food secure).The influence of water management structures to food security was also found to be significantly (P=0.05). It can, therefore, be concluded that the household heads who adopted contour terraces and water pans were more food secure. Additionally, the household heads who reported that water management structures are efficient and economical are more food secure.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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