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Analysis of Diet Diversity and Child Stunting in Households Practicing Smallholder Irrigation in Kenya

Karanja L., Karumba M., Opondo M., Macharia E., Kiriro M., Kipruto S., Mburu J., Musavi E., Ntwiga J. and Njeri M.

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By

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List of Acronyms and Abbreviations

ATE	Average Treatment Effects
ATET	Average Treatment Effect on Treated
CIDU	County Irrigation Development Unit
HDDS	Household Diet Diversity Score
MDD	Minimum Dietary Diversity
MDD-W	Minimum Dietary Diversity in Women
PSM	Propensity Score Matching

Definition of Terms

Stunting is a measure of growth retardation in children as a result of chronic or long-term deprivation in the quantity and quality of diets. It is diagnosed by capturing the height and age and assessing these against a reference height and age from a reference population. Stunting is classified as height for age (HAZ) < –2 SD of the WHO Child Growth Standards median. (WHO 2010. Nutrition Landscape Information System)

Wasting is a measure of acute malnutrition resulting in thinness. It is usually due to a recent infection or insufficient food intake or both and often leads to impaired functioning of the immune system. It diagnosed by capturing weight and height and assessing these against the weight and height of a reference population. Wasting is classified as weight for height (WHZ) < –2 SD of the WHO Child Growth Standards median. (WHO 2010. Nutrition Landscape Information System)

Underweight is a composite indicator of both impaired weight and height. It is measured by capturing weight and age and assessing these against the weight and age of a reference population. Underweight is classified as weight for age (WAZ) < –2 standard deviations (SD) of the WHO Child Growth Standards median, (WHO 2010. Nutrition Landscape Information System).

Food Poor refers to households and/or individuals whose monthly expenditure for food consumption per adult is less than Ksh1,954 in rural and peri-urban areas, and less than Ksh2,551 in core-urban areas. (Economic Survey 2018).

Absolute Poor: refers to households and/or individuals whose monthly consumption expenditure per adult is less than Ksh 3,252 in rural and peri-urban areas, and less than Ksh5,995 in core-urban areas. (Economic Survey 2018).

Wealth Quintile: this is a measure of inequality that divides a population into five equal groups of 20 per cent each based on the expenditure distribution ranking from the lowest to the highest. The ideal scenario is that, in a normally distributed population if perfect equality exists, each quintile is expected to control 20 per cent of the total expenditure. (KIHBS 2015/2016 – Basic Report on Well-Being in Kenya).

Household: Is defined as (i) Person or a group of people living in the same compound (fenced or unfenced); (ii) Answerable to the same head; and (iii) Sharing a common source of food and/or income as a single unit in the sense that they have a common housekeeping arrangement (That is share or are supported by a common budget). (KIHBS 2015/16 – Labour Force, Basic Report).

Improved Sanitation: Human waste disposal facilities that are considered improved/adequate include: connection to main sewer, septic tanks, ventilated improved pit latrine, pit latrine with slab and composting toilets.

Household Diet Diversity Score: HDDS is the number of food groups consumed by a household over a given reference period. It reflects the economic ability of a household to access a variety of foods and household food security. More diversified household diet is correlated with increased caloric and protein adequacy. HDDS can be measured via 12 food groups or 16 food groups

12 food groups: Cereals; white tubers and roots; vegetables; fruits; meat; eggs; fish and other seafood; legumes; nuts and seeds; milk and milk products; oils and fats; sweets; spices, condiments and beverages.

16 good groups: Cereals; white roots and tubers; Vitamin A rich vegetables and tubers; dark green leafy vegetables; other vegetables; Vitamin A rich fruits; other fruits; organ meat; flesh meats; eggs; fish and seafood; legumes, nuts and seeds; milk and milk products; oils and fats; sweets; spices, condiments, beverages.

Body Mass Index: is an index of the body's weight by height calculated as weight in kilograms divided by the square of height in metres squared (kg/m^2).

Table of Contents

List of Acronyms and Abbreviations vii

Definition of Terms iv

Abstract vii

1 Introduction 1

2 Irrigation Policy Progress 5

2.1 Scope of small holder agriculture in Kenya 5

2.2 Overview of Policy and Programmes in Irrigation 5

2.3 What is the Unmet Policy and Legislative Agenda in Small-Holder Irrigation? 7

2.4 An Overview of Irrigation Programmes 8

2.5 Governance of Irrigation Initiatives 11

3 Literature Review 13

3.1 Irrigated Agriculture and Household Diet Diversity 13

3.2 Irrigated agriculture and stunting 15

4 Methods and Study Data 17

4.1 Conceptual Framework 17

4.2 Analytical framework 18

5 Results and Discussion on Means and Proportions Comparison 23

5.1 Descriptives, Means and Comparison 21

5.2 HDDS Regression Results by Irrigation Practice 26

6 Conclusion and Recommendation 29

6.1 Conclusion 29

6.2 Recommendations 29

References 31

Annex 1: Key policy documents 34

Annex 2: Irrigation and household dietary diversity Inverse-probability-weighted regression with adjustment 35

List of Figures

Figure 1: Timeline of irrigation development 7
Figure 2: Irrigation-nutrition conceptual framework 18
Figure 3 Distribution of height-for-age Z-scores 22
Figure 4: HDDS 12 food groups by irrigating agriculture 23

List of Tables

Table 1: Proportion of irrigated land by category in Kenya 2
Table 2: Key smallholder irrigation projects to support food and nutrition security in the Big Four agenda 9
Table 3: Size of analytical samples from KIHBS 2015/16 dataset 21
Table 4: Means and proportions comparison of irrigating and non-irrigation households 23

Abstract

Stunting can be caused by several interacting factors. Conversely, irrigated agriculture has been identified as a likely contributor to reducing under-nutrition as it has potential to increase household income, ensure consistent food production and improve household diets. The study used data from the Kenya Integrated Household Budget Survey (KIHBS) 2015-16 with a focus on children aged 6 to 59 months from irrigating and non-irrigating agriculture-practicing households. Regression analysis through Average Treatment Effects (ATE) was applied to identify the effect of treatment (irrigation) on the potential outcomes (household diet diversity and stunting). Matching techniques were applied to account for demographic and socio-economic confounders.

The key finding is that practicing irrigation increases the chances of having a higher diet diversity at the household level by 8.6 per cent. Further, children in households practising irrigation have slightly lower stunting incidence (26.6%) compared to non-irrigating households (27.9%). There is, however, low engagement of women in community nutrition programmes, implying decision-making may not be in favour of women in irrigating homes. Further, there is low nutrition education and messaging in community programmes.

To ensure that irrigated agriculture translates to improved nutrition outcomes, intentional inclusion of nutrition as a strategy within both irrigated and non-irrigated agriculture needs to be enhanced. This can be achieved through well spelt out nutrition objectives within national and county (irrigation) agriculture and plans and policies to promote intentional focus on nutrition as an outcome of (irrigated) agriculture in addition to wealth creation, food productivity and food security. Women engagement in irrigation interventions through gender mainstreaming in irrigated agriculture is important in improving children nutritional status. Other interventions include disseminating agriculture-related knowledge such as through agriculture extension services, women groups, farmer field days, and other community communication channels.

1 Introduction

Food and nutrition security has over the years continued to be a global concern. The United Nations Food and Agriculture Organization (FAO) defines food security as *"a state that exists when all people at all times have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preference for an active and healthy life"* (UNICEF et al., 2022). FAO global estimates indicate that in 2020, there were 768 million hungry people with 278 million of these being in Africa.

In Kenya, the State of Food Insecurity in the World Report estimates that between 2019 and 2021, food consumption for 26.9 per cent of Kenyans was inadequate to meet the energy levels required for a normal, active and healthy life (UNICEF et al., 2022). In other words, 26.9 per cent of Kenya's population is hungry.

In addition, a food insecurity survey undertaken in 2020 during the COVID-19 pandemic revealed that 58 per cent of Kenyans were eating inadequate diets that compromised on quality due to the effects of the pandemic (KNBS-NIPFN, 2021b). In a hungry population, malnutrition of children under five is also prevalent. A review of the nutrition situation among children aged below five revealed that between 1993 and 2014, stunting had reduced at a rate of 1.6 per cent per year, from 39.8 per cent in 1993 to 26 per cent in 2014 (KNBS-NIPFN, 2021a). Despite this reduction, the stunting rate is classified as high (De Onis et al., 2019).

At the same time, Kenya faces a dual challenge of a growing population vis-à-vis a stressed agriculture sector. Over the past 57 years, Kenya's population has increased more than five-fold from 8.6 million in 1962 to 47.6 million in 2019 (KNBS, 2020). In addition, the population is also rapidly urbanizing as noted in the 2019 Population Census where 31.2 per cent were residing in urban areas. This represents a population that requires to be fed, but does not directly contribute to food production through agriculture, thus placing higher production demands on existing agricultural land.

To sustainably feed a growing population, there is need to increase agricultural productivity. Domenech (2013) estimates that if the Sub-Saharan region fails to increase agricultural productivity to match its growing population demands, net food imports will rise, potentially affecting food prices. Agriculture is the dominant sector of the national economy accounting for approximately 25 per cent to the nation's Gross Domestic Product (GDP) (Radeny et al., 2020). Further, agriculture contributes about 65 per cent of Kenya's export earnings, creating livelihood opportunities for over 80 per cent of its rural population with over 75 per cent of its labour being provided by women (Radeny et al., 2020). Specifically, irrigated agriculture contributes to 18 per cent of total agricultural production and 3 per cent to GDP (Food Agriculture Organization - FAO, 2015).

Despite this, the agriculture sector still faces several challenges, including the effects of climate change manifested through extreme weather episodes of droughts and floods; low crop diversification; and market fluctuations. With a land mass of over 582,000km^2, Kenyan agriculture is largely rain-fed with only 17 per cent considered medium-to-high agricultural potential and 83 per cent being semi-arid or arid, and representing a need for climate-smart agriculture to enhance agricultural productivity (Radeny et al., 2020; Sijali et al., 2011)

Table 1: Proportion of irrigated land by category in Kenya

Type of Irrigation Practiced	Acres	Hectares	Proportion of total irrigated land
Public/national irrigated farming	60,600	24,240	10.91%
Individual/private irrigated farming	220,000	88000	39.60%
Community/smallholder irrigated farming	275,000	110,000	49.50%
Total irrigated land in Kenya	555,600	222,240	

Source: Authors' computation derived from Ministry of Water, Sanitation and Irrigation, (2019) Guidelines for Promotion, Development and Management of Irrigation in Kenya

Irrigation development is broadly classified as private/individual, community/smallholder or public/national (Ministry of Water, Sanitation and Irrigation, 2019). The country's potential irrigable land is 3.355 million acres (1.342 million Ha) with merely 16.6 per cent of this being exploited 555,600 acres (222,240 Ha) (Table 1). Of the 555,600 acres of irrigated land, public/national irrigation schemes are on 60,600 acres, individual/private irrigated land is on 220,000 acres, while community/smallholder schemes are on 275,000 acres. However, in terms of households, about 5.8 per cent of farming households and 3.0 per cent of all households in Kenya practice irrigation based on the 2019 household census (KNBS, 2020). Data presented in Table 1 indicates that the largest proportion of irrigated land is owned by smallholders/community in comparison to the proportion owned by the national government or by private holders. This means the support accorded to smallholder irrigation bares potential to significantly contribute to both household-level food availability and the nation's economy.

The role of irrigation in improving nutrition outcomes is pegged on the potential role of agriculture to increase availability and accessibility of diverse diets to meet nutrition needs at household level. In Africa, the benefits of agriculture are projected to have potential impact on nutrition, with estimates of two million fewer cases of child malnutrition by 2050 if the region could triple its irrigated agricultural areas (Vivien and Briceño-Garmendia, 2010). This requires approaches informed by evidence on how improved food security, through irrigated agriculture, influences household nutrition outcomes.

Previous research indicates that the association between irrigated agriculture and nutrition outcomes is generally varied with inconsistent findings. Results from a study conducted in 2015 on rice farmers in Benin showed positive impact of irrigation on dietary diversity, food consumption score and body mass index. In this study, irrigated farming increased the chances of dietary diversity score by 3.8 per cent, food consumption score by 39.1 per cent and the probability of being in the normal body mass index (BMI) range by 3.9 per cent (Nonvide, 2020).

Similarly, another study conducted in Northern Ghana (Mekonnen et al., 2019) revealed a modest difference in the overall household dietary diversity score between households involved in irrigation and non-irrigating households. Another study conducted in Malawi demonstrated that the association between the use of irrigation by farm households and the growth performance of their children aged six months to five years was positive but weak, with a stronger and positive association between irrigated farming and household diet diversity (Benson, 2015). This study demonstrated irrigation as an important component in reducing seasonality in household dietary diversity.

However, some studies were not able to establish clear evidence on the impact of irrigated agriculture on household diet diversity and/or linear growth. For instance, in Tanzania, the production of diverse crops and increased income from small-scale irrigation did not have any significant relationship with household dietary diversity (Passarelli et al., 2018). Likewise, another evaluation in Ethiopia demonstrated that adaptation of irrigation among households did have higher incomes from the sale of high value horticultural crops but, in comparison to non-irrigating households, the diet diversity scores did not differ significantly (Usman and Gerber, 2020). Within a certain cross-sectional survey in Ethiopia, the impact of irrigated agriculture on stunting was adverse and this was attributed to maternal workload brought by irrigation activities (Belete and Melak, 2018).

The diverse findings imply that the influence of irrigation on diets and nutrition outcomes are largely context-specific, implying the need to generate local findings. In Kenya, an evaluation conducted by Veronicah et al. (2007) to determine the effects of irrigation on nutrition and food availability in the Nyeri Dry Area Smallholder Community Services Development established an improved nutrition status, higher height-for-age and weight-for-age scores amongst irrigating households compared to non-irrigating households. However, the study had a small sample size as it assessed households that were participating in a commercial farming project, within one division of the district. This study undertakes analysis with data collected from a national survey.

The overall objective of this study is to analyze diet diversity and stunting in households practicing smallholder irrigation in Kenya. More specifically, the study aims to establish whether and to what extent smallholder irrigation agriculture is associated with household diet diversity and establish whether and to what extent smallholder irrigation agriculture is associated with stunting.

2 Irrigation Policy Progress

2.1 Scope of Smallholder Agriculture in Kenya

This work covers households practicing smallholder irrigation agriculture and its influence on stunting and household dietary diversity. While there is no universal definition of smallholder agriculture, land size is the most common parameter applied to distinguish large versus smallholder farmers, with smallholder farmers owning and/or operating a low asset base of less than two hectares of cropland (FAO, 2021). However, it is acknowledged that this definition does not include other features that characterize smallholder farming, such as: *type of management*, with small-scale usually characterized as family farms; *market orientation*, with small-scale farms largely being associated with own-consumption/subsistence agriculture and *low economic output* (Khalil et al., 2017). In addition, smallholders also operate under structural constraints such as *sub-optimal access to resources*, *limited application of agriculture technology* and *limited access to market* compared to middle and large scale commercial farms (Cervantes-Godoy, 2015).

With regard to small-scale irrigated farming in Kenya, the working definition is applicable to irrigation schemes; i.e. orderly irrigation system covering a defined area of land (Ministry of Water, Sanitation and Irrigation, 2019). "A small-scale irrigation scheme - means a scheme which in size covers less than 100 acres (40 Ha)".

According to the Irrigation Act No. 14 of 2019 (Government of Kenya, 2019), irrigation schemes can be implemented by county or national government, strategic schemes or private entities. In addition, both (*The Irrigation Act No. 14 of 2019*, n.d.) and the Irrigation Guidelines (Ministry of Water, Sanitation and Irrigation, 2019) acknowledge smallholder irrigation and drainage schemes which are managed and owned by individual farmers and communities such as irrigation water user association groups (IWUA). This means that the total land area in small scale irrigation schemes (100 acres or less) is further divided into smaller parcels of land that are owned by individual farmers who together form IWUA for governance. For the remaining section of the document the terms small-holder irrigation and small-scale irrigation are used interchangeably.

2.2 Overview of Policy and Programmes in Irrigation

Irrigated agriculture is implemented, coordinated and regulated through the provision of several legislative acts, policies, guidelines and strategies (see annex 2) with varying levels of priority. Small-holder irrigation had historically received less emphasis but is increasingly gaining attention as a viable agri-enterprise option. Most of the stated policies, strategies and acts in Box 1 are broad, aimed at providing employment and settlement of the landless and regulating irrigation within large public schemes with less focus on small holder irrigation. However, 49.5 per cent of Kenya's irrigated land is covered by smallholder irrigation schemes compared to 10.9 per cent that cover large scale public-owned schemes (Food Agriculture

Organization (FAO), 2015). This necessitates increased policy and planning attention for small holder irrigation.

Kenya has a long history in practicing irrigated agriculture spanning over 400 years, in regions such as the lower reaches of River Tana, Elgeyo Marakwet, West Pokot and Baringo counties, which applied traditional technologies centuries ago. In 1946, The African Land Development Unit (ALDEV) focused on irrigation as part of a broad agricultural rehabilitation program. The unit initiated several irrigation schemes such as Perkera, Mwea, Hola, Ishiara and Yatta. In 1966, the National Irrigation Board (NIB) was established through Irrigation Act cap 347, to take over the activities of ALDEV and was mandated to: promote irrigation; settle the landless in public irrigation schemes in Kenya and develop and manage public schemes. The Irrigation Regulations (1972) included provisions to regulate tenancy arrangements, ensure proper use of the schemes, and enforce related penalties in case of violation.

Of importance to note is that these were broad strategies aimed at enhancing agriculture production and the national economy in large scale schemes, with less focus on small-holder irrigation. Large-scale public managed schemes are comprised of hundreds of smaller farming units with settled farmers under tenancy arrangements. These farmers form Individual Water Users Associations (IWUA) to voice their concerns regarding water allocation and scheme management. This means that initiatives aimed at small-scale farmers could apply to these farmers when approached through the IWUA. Gradually the focus on smallholder irrigation has evolved.

The Agricultural Sector Transformation and Growth Strategy (ASTGS) (2019-2029) (Ministry of Agriculture, Livestock, Fisheries and Irrigation, 2019), for instance, highlights support to small-scale irrigation schemes in addition to targeting the development of 50 large scale farms for irrigation. With the shift to devolved governance, irrigation functions were devolved regarding implementation and capacity development. Irrigation priorities are therefore provided in county documents.

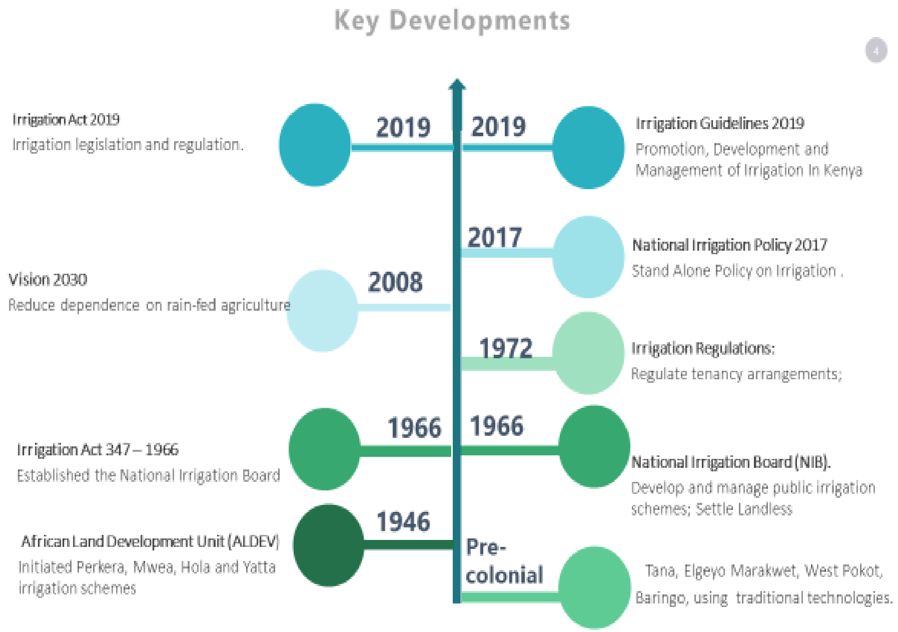
County Integrated Development Plans (2013-17; 2018-22) are a five-year strategy that spell out county priorities. CIDPS are the equivalent of the national government's Medium-Term Plans (MTPs) at devolved level, developed by each county. The objectives of both CIDPs and MTPs are towards attaining Kenya's Vision 2030. Irrigation is a shared function between national and county government, with large scale schemes being led by national government while county governments provide implementation leadership to small-scale schemes and smallholder irrigated agriculture. Irrigation is mentioned as a county initiative within each CIDP, but with varied levels of proposed initiatives and budgets. Small holder/small-scale irrigation specifically is accorded attention in 27 CIDPs of 2013-2017 and in 23 CIDPs of 2018-2022. Twelve counties accord attention to smallholder/small-scale irrigation in both first and second generation CIDPs. Irrigation is provided as an objective for increased food security, increased food production and as a strategy for wealth creation with four counties aiming to develop a county-specific irrigation policy. It is important to note that irrigation was a directorate under the Ministry of Agriculture during the 2013-2017 CIDP period, but under the Ministry of Water, Sanitation and Irrigation during the 2018-2022 plan period. This shift reflects in the CIDPs, with the first generation drafts focusing on extension services, while the second generation CIDPs have focused on infrastructure and technology. Moving forward, it is imperative that both agriculture capacity and water infrastructure development are blended to provide comprehensive support to small-holder farmers.

There had been no standalone policy on irrigation development and management until September 2017 when Cabinet approved the National Irrigation policy 2017 (Ministry of Water, Sanitation and Irrigation, 2017). Prior to this, the policies and strategies (Annex 1) did not comprehensively explore how the potential of irrigation could be optimally harnessed to ensure food security in the country. The National Irrigation Policy 2017 has detailed the provisions and mechanisms to address key aspects of irrigation sub sector including: the development, management, regulation, capacity building, financing, provision of support services, institutional arrangement and monitoring and evaluation of both small-user and large-scale irrigation schemes.

To implement and enforce the irrigation policy, The Irrigation Act No. 14 of 2019, was enacted in August 2019, to repeal Irrigation Act 347 of 1966. The scope of the Act covers irrigation development; management of irrigation schemes; financing; provision of irrigation services and regulation of the entire irrigation sector in Kenya (article 3 (1)).

The Guidelines for Promotion, Development and Management of Irrigation In Kenya 2019 (Ministry of Water, Sanitation and Irrigation, 2019) were developed to define the steps and requirements of initiating and developing irrigation schemes. It describes the policy and legal basis; defines stakeholders and their roles; advice on financing of schemes and describes the coordination and governance aspects. It also includes timeframes and the monitoring and evaluation process. Figure 1 depicts evolution of irrigation development in Kenya.

Figure 1: Timeline of irrigation development



2.3 What is the Unmet Policy and Legislative Agenda in Smallholder Irrigation?

a) Insufficient focus on small scale irrigation development

A World Bank review of the policy and legal barriers constraining smallholder farmers revealed insufficient policy and governance focus on small-holder irrigation, especially for farmer-led initiatives (Bancy M. Mati, 2021). Specifically, the nature of public funding for smallholder irrigation is not well coordinated, resulting in duplication of finance resource pools, which farmer-led smallholder irrigating households tend to exclude. In addition, water user fees to smallholder irrigators is the same as those charged to large-scale commercial enterprises and industry, leading to an uneven playing field. Another challenge is lack of a clear mechanism of channeling some of the remittances issued to Ministries Departments and Agencies (MDAs) back to Water User Associations, leading to weak associations. The stated challenges frustrate the efforts of small-holder irrigated farming from a commercial perspective, rendering them vulnerable to adverse economic shocks.

b) Insufficient linkage with nutrition outcomes and agri-nutrition strategy

The Constitution of Kenya (Government of Kenya, 2013) under Article 43 (1) (c) provides the right to be free from hunger and to have adequate food of acceptable quality, while article 53 (1) (c) provides that every child a right to basic nutrition. The irrigation policy broadly captures attainment of food security, employment creation and socio-economic development but nutrition outcomes are not captured within the policy's specific objectives, limiting the likely nutrition outcomes that smallholder irrigated agriculture could contribute to.

c) Weak management of irrigation schemes

While existing irrigation policies focus on infrastructure development, the management of schemes is equally critical for realization of the aims of irrigation development. A key challenge is inadequate emphasis on scheme management compared to infrastructure development as the measurement indicator for the same is still unclear.

2.4 An Overview of Irrigation Programmes

Irrigation is considered a key enabler to food and nutrition security and therefore a bulk of irrigation projects are part of the Big Four Agenda[1]. In 2021, the Ministry developed 48,000 acres under public schemes and community-based smallholder irrigation schemes contributing an average 66,000 tonnes of rice and 17,000 tonnes of maize annually, directly benefiting over 108,077 farmers. Further, the Ministry constructed 25,091 household water pans by end of June 2021 across 47 counties. This translates to 28.09 million m^3 of storage to irrigate about 14,980 acres of land. Table 2 highlights notable smallholder irrigation projects initiated under the Big Four Agenda[2].

1 The Big Four Agenda is a five-year plan from 2017 - 2022 aimed at fast tracking the realization of national goals towards Kenya's Vision 2030. One of the four agendas is 100 per cent food and nutrition security.

Table 2: Key Small-Holder Irrigation Projects to Support Food and Nutrition Security in the Big Four Agenda

No	Project Name	Service Area	Cost (KShs. Million)	Objective/Description	Status
	Small-holder Irrigation Programme Mt. Kenya Region	Embu, Kirinyaga and Tharaka Nithi	670	The project aims to construct six schemes namely: Gatene (in Embu); Miuka and Kandeki (in Kirinyaga); Mutino, Magati and Karuma Marimanti (in Tharaka Nithi); On completion 1,500 acres will be under irrigation.	The project commenced in February 2016 and is expected to end in December 2024. Nineteen irrigation schemes covering 5,460 acres and benefiting 6,088 farmers have been completed for phases one to three at a cost of Ksh1.427 billion. In the current Phase 4, detail designs for six proposed schemes have been completed, awaiting to advertise for construction works. The project is 33 per cent complete.
	Community-based Irrigation Projects	Countrywide	9,280	To construct/rehabilitate community-based smallholder irrigation projects which will put 30,000 acres of land under irrigation and benefit 32,000 farmers. The project involves construction of intake structures, main canals and infield structures in the various schemes that are yet to be completed.	The project started in July 2011 and is expected to end in June 2030. Construction of 1,900 acres at Kaigunji Irrigation Project Phase II Section II- is complete, Murang'a cluster is 80-90 per cent complete on 100 acres Kanini irrigation project is completed. A total of 15 projects covering 7,050 acres have been completed under the programme.
	National Expanded Irrigation Programme	Countrywide	123,930	Provision of irrigation infrastructure for abstraction, conveyance, distribution and application of irrigation water for 610 identified irrigation projects across the country.	The project started in June 2012 and will end in June 2030.To date, construction of over 240 irrigation projects across 47 counties with cumulative total area of 230,866 acres, directly benefiting 267,426 farmers has been done. Rehabilitation and expansion of public schemes by an additional 21,000 acres has also been done.

No	Project Name	Service Area	Cost (KShs. Million)	Objective/Description	Status
	Turkana Irrigation Development Project	Turkana County	9,197	The project aims to construct intake, conveyance canals for 5,000 acres of land in Naipa, expansion of Katilu clusters by 4,000 acres and groundwater for irrigation targeting 3,000 acres. These and others are expected to increase the area under irrigation in Turkana from the current 22,000 acres to 53,000 acres within five years.	The project start date is June 2016 and is expected to end in June 2026. Rehabilitation of 20 projects covering 19,000 acres of land has been completed to benefit 9,080 households and provide a stable supply of maize at an average of 38,000 tonnes of maize and millet.
	Micro Irrigation Programme for Schools	Countrywide	2,030	The project involves constructing micro-irrigation facilities in 2,000 schools. This will enable about 2,000 acres of land in schools put under production. It involves drilling boreholes to benefit 2,000 schools with water across the country.	The Programme was initiated in June 2016 and its end date is June 2024. In 2021/22 financial year, 11 schools were equipped with micro-irrigation facilities. Since 2016, a total of 81 boreholes have been drilled and equipped and 63 pilot greenhouses constructed in 120 public schools for vegetable growing and tree/fruit seedlings production.

2.5 Governance of Irrigation Initiatives

The Irrigation Policy Ministry of Water, Sanitation and Irrigation (2017), The Irrigation Act No. 14 (2019) and the 2020 Irrigation Guidelines (Ministry of Water, Sanitation and Irrigation, 2019) provide elaborate irrigation coordination mechanisms. The Irrigation Act 2019 establishes National Irrigation Authority (NIA) and County Irrigation Development Unit (CIDU) as responsible institutions for implementation of irrigation strategies in the two respective levels of government. At county level, irrigation falls under the CIDU - a department mandated by the Irrigation Act 2019 for the development and management of irrigation services within county government. The host institution can be Ministry of Water and Irrigation (MoWI) or Ministry of Agriculture, Livestock, Fisheries and Co-operatives (MoALFC) based on county arrangements. The CIDU coordinates the development and execution of county irrigation strategy, which is developed together with relevant stakeholders such as the Ministry of Health (MoH), MoALFC, development partners and private sector.

The Ministry of Health (MoH) is one of the stakeholders whose role is described as provision of health services for diseases exacerbated by irrigated agriculture. MoALFC role is to provide technical support to county extension services. The division of nutrition role in irrigated agriculture is not directly spelt out in existing coordination structures. Similarly, the agri-nutrition department has an opportunity to influence a focus on nutrition in irrigated agriculture, but its role is currently not elaborately spelt out within the current coordination mechanism.

The agri-nutrition department has potential to influence crops grown under irrigated agriculture and further, the desired nutrition outcomes within diverse irrigation schemes. In addition, nutrition concerns especially for vulnerable population groups could be mapped out and nuanced when considering diseases exacerbated by irrigated agriculture. This would enhance the realization of nutrition outcomes as food security objectives are being achieved.

3 Literature Review

According to UNICEF conceptual framework, under-nutrition is linked to multiple causes, ranging from immediate causes at individual level such as disease and inadequate diets, underlying causes at household and community level and basic causes which relate to societal structures and processes (Bhutta et al., 2013). The immediate causes are nutrition-specific interventions under health and nutrition sector, while underlying causes are nutrition-sensitive interventions under sectors such as agriculture and food security; social protection and Safety nets; Water, sanitation and hygiene (WASH), Gender among others (Bhutta et al., 2013; Ruel et al., 2013). This therefore calls for a multi-sectoral/multi-stakeholder approach to tackling malnutrition. For this reason, establishment of linkages between irrigation and nutrition outcomes is vital. This literature review seeks to interrogate the available body of literature on irrigated agriculture as a determinant of child stunting and improved household diets.

3.1 Irrigated Agriculture and Household Diet Diversity

Irrigation interventions possess potential to influence nutrition outcomes through diverse ways, one of which is increased agricultural production. Smallholder irrigation technologies in particular influence the type of foods grown with increased tendency in growing horticultural crops such as fruits and vegetables as opposed to starchy staples (Burney et al., 2010; Mekonnen et al., 2019). Such crops are considered nutrient dense, potentially improving the quality of diets. In addition, irrigated agriculture extends production seasons into lean spells, influencing intake of diversified diets more consistently (Kinfe et al., 2011; Xie et al., 2014). For instance, a Malawian study used national data from Integrated Household Survey to assess the influence of irrigation agriculture on diet diversity using Ordinary Least Squares regression (Benson, 2015). Comparing irrigating and non-irrigating farming households over a 12-month period, the study established seasonality did not negatively impact on household diet diversity scores (HDDS) within irrigating households leading to higher HDDS in irrigating households all-year round.

Irrigated farming also increases the chances of crop diversification. An analysis of national data from the India Human Development Survey established empirical association between smallholder irrigation and household diet diversity. The study applied regression analysis using Ordinary Least Squares and established smallholder irrigation as a strong and positive predictor of crop diversity, which was further positively associated with increased dietary diversity (Bhagowalia et al., 2012). Further, the impact of irrigated farming on dietary diversity was distinctively observed in small farms but not on medium and large farms.

However, crop diversification does not always produce consistent results with regard to increasing household dietary diversity. Evidence from a meta-analysis of over 46 countries indicates that in Sub-Saharan Africa, a household needs to increase production diversity by up to nine crops before increasing consumption diversity by one food group (Sibhatu and Qaim, 2018) while a similar analysis in Tanzania used mean variance optimization model and established that a farmer needs to diversify their production by four more food groups in order to diversify their diet by one more food group (Keenan et al., 2021). This implies a need for country and region-specific evidence on the interplay between irrigated agriculture and household diet diversity.

Small-scale irrigation is generally linked to increased income due to production of high value crops/cash crops such as nuts, fruits and vegetables, which yield better financial returns (Kabunga et al., 2014). A study in Benin sought to determine the impact of participating in a rice irrigation programme on 150 participants' household diet diversity. The analysis applied endogenous switching regression models and established increased dietary diversity score by 3.8 per cent and increased food consumption score by 39.1 per cent among irrigating households (Nonvide, 2020).

Even in cases where the cultivated crops are not necessarily considered high value crops, irrigated agriculture leads to increased yields, leading to increased income through sale of surplus yields. In Afghanistan, a multivariate regression of over 11,000 agriculture practicing households established smallholder irrigation to be positively correlated with diet diversity from market purchase (Kawsary et al., 2018).

Similarly, in Ethiopia, an evaluation of the association between irrigation and nutrition applied three stage least squares regression analysis to assess the influence of irrigation on nutrition in 430 households. The study determined that increased income through irrigated agriculture translated to increased household dietary diversity (Passarelli et al., 2018). On the contrary, another cross-sectional study in Ethiopia by Usman and Gerber (2020) applied Ordinary Least Squares regression model to review the impact of irrigated agriculture on stunting in 454 households. In this study, irrigating households reported higher income from sale of high value agriculture crops, but the diet diversity score did not significantly differ from non-irrigating households. This means that while smallholder irrigation is generally linked with increased income, the corresponding impact on diet diversity at household level needs to be established empirically.

The discourse on irrigated agriculture does not merely pertain to outputs such as yield and income but also inputs such as labour and time. In this regard, women feature prominently as they comprise up to 70 per cent of agriculture labour force (Palacios-Lopez et al., 2017; Pinstrup-Andersen et al., 2012). Irrigation could therefore have positive or negative impact on women's time. In Nepal, a qualitative analysis (cost benefit analysis) reviewed the impact of adopting drip irrigation within 131 households on women's workload and decision-making (Upadhyay et al., 2005). The study revealed that time spent by women on vegetable farms reduced by 50 per cent and time saved was spent on child care, and livestock rearing among other activities. In addition, this study further revealed that women gained increased control of income from sale of produce, and this translated to improved household diet diversity from purchase of, for instance, animal-sourced foods. Similarly, in Benin, a solar drip irrigation intervention targeted women groups to determine its impact on food availability, consumption and access. The analysis was approached via matched pair comparison and applied a Tukey-post hoc test to two treatment villages adopting drip irrigation and two control villages, each of which contained two women groups with each group having 30 to 35 women and determined that women from irrigation adopting groups had increased income, which was translated to purchase of diverse and nutrient dense foods even during lean seasons (Alaofè et al., 2016). With women as the primary key decision makers on meal preparation, the impact of agriculture on time and their resources is a significant contributor of the quality and diversity of family meals.

3.2 Irrigated Agriculture and Stunting

The section above has reviewed empirical linkages of irrigated agriculture on household diets. It is anticipated that improved diets at household level would translate to improved diet intake of individuals at household level, translating further to optimum growth and nutrition status of household members, including children under the age of five. However, as described in the conceptual framework (Figure 3), nutrition outcomes are attributed to several underlying and immediate cause, making linear attribution of diet diversity on stunting problematic.

For instance, a study in Ethiopia applied propensity score matching (PSM) by binary logistic regression to 130 irrigation adoption households and used average treatment effects to compare the nutrition status of children under five amongst irrigation adopters and non-adopters (Belete and Melak, 2018). The results showed that the nutrition status of the assessed children was poorer for households adopting irrigation technology than for non-adopters, and this was attributed to increased maternal workload brought by irrigation activities, which negatively impacted the amount of child rearing time mothers could accord.

Another study in Ethiopia sought to assess the effect of water quality from irrigating households on stunting by applying Ordinary Least Squares regression model to assess 454 households. The analysis determined that children from irrigating households had 1.7 higher chances of being stunted than children from non-irrigating households due to contaminated irrigation water, with 58 per cent of the water tested in this survey having E.coli contamination (Usman and Gerber, 2020).

While the two studies in Ethiopia indicate a negative association between irrigated agriculture and child growth, in Malawi, the impact of irrigated agriculture on stunting was not significant. A study that used Ordinary Least Squares regression to assess the nutrition status of children from 763 irrigated farming households out of national survey sought to establish the association between use of irrigation agriculture and child growth (Benson, 2015). The analysis outcome was insignificant regarding child growth between children from irrigating and non-irrigating households, implying that irrigated agriculture was neither positively nor negatively associated with child linear growth.

However, in some cases, irrigated agriculture has been linked to positive child linear growth. For instance, a study carried out in Nyeri District in Kenya used a comparative, retrospective cross-sectional study to assess the nutrition status of children hailing from a commercial irrigation farming project versus children from households that were not in the project. The outcome from the study which assessed two equal samples of children (aged six to 59 months) in project and non-project households was that stunting rates amongst children from irrigation project households was lower than for children in the non-project households (Veronicah et al., 2007). In addition, irrigation contributed to increase per capita food availability within irrigating households, leading to higher energy intakes, and this was attributed to have acted as a safeguard to the young children against chronic malnutrition.

This literature review has demonstrated that irrigated agriculture can lead to increased household diet diversity and in some cases increased child growth, with more empirical links with higher household dietary diversity score (HDDS) than with stunting. In some cases, irrigated farming is associated with stunting. Except for a few studies, most of the analysis were cohort studies, suggesting the need to build robust evidence from diverse study samples. The next section provides the methodology and study design.

4 Data Analysis and Methods

4.1 Conceptual Framework

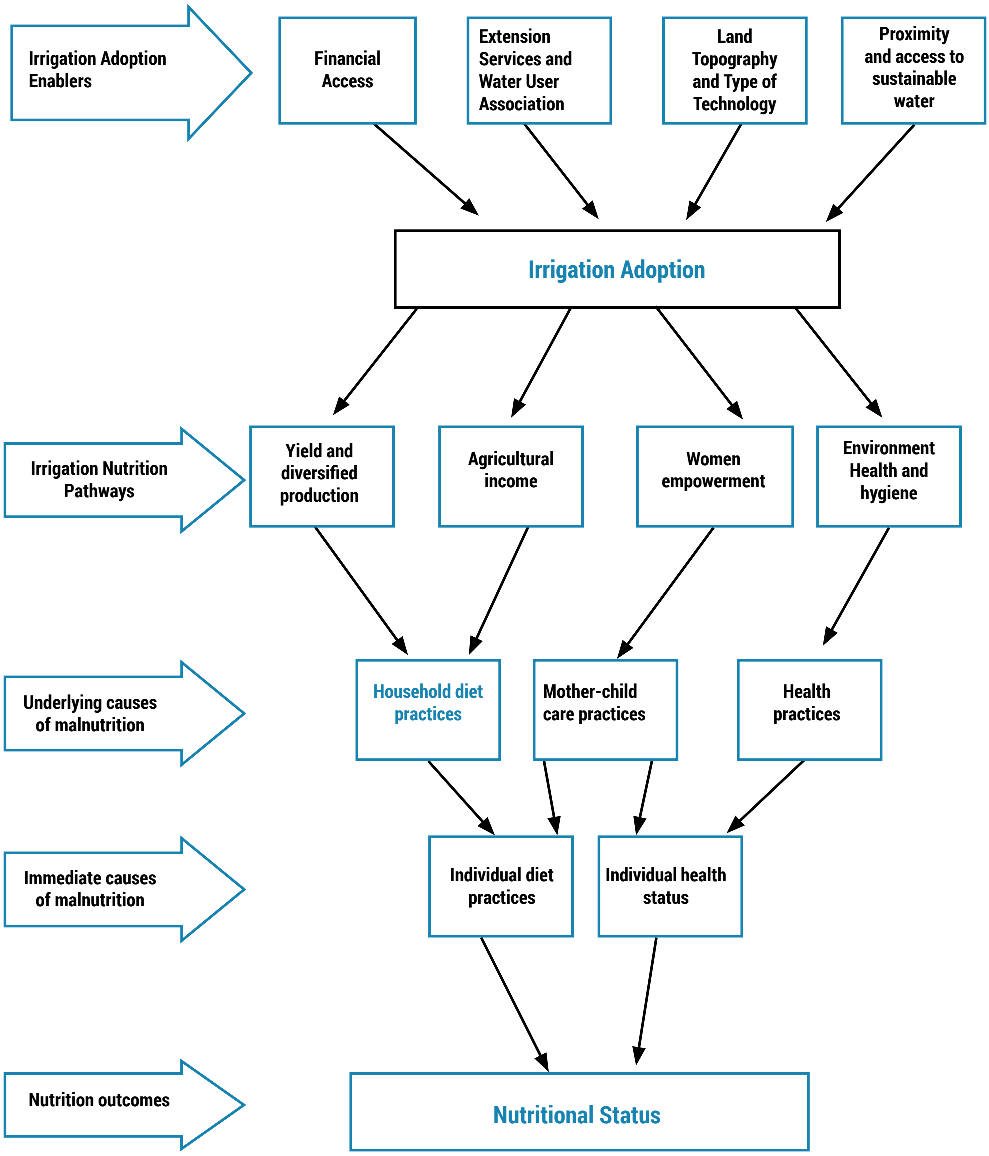
The conceptual framework in Figure 2 of irrigation nutrition is borrowed from Belete and Melak (2018) and adapted to provide a theoretical hypothesis of how irrigation potentially influences child nutrition outcomes. In this framework, irrigation adoption is influenced by several factors such as topography, access to agriculture extension service, proximity to water and financial access (Adeoti, 2008; Afrakhteh et al., 2015; Chuchird et al., 2017; Pronti et al., 2019; Saeed et al., 2014).

Following adoption, irrigated agriculture is anticipated to impact on nutrition through several pathways purported as irrigation-nutrition pathways in literature. They include: increased yield and diversified production, women empowerment, income and health (Belete and Melak, 2018; Benson, 2015; Domènech, 2015; Mekonnen et al., 2019; Okyere and Usman, 2021; Passarelli et al., 2018).

Irrigation provides an opportunity for mixed farming and diversified crop production, which is anticipated to improve diet diversity at household level. Irrigation technologies could either free up the time spent in agriculture, allowing women additional time for child care, or could adversely affect women's time by increasing their labour demands, thereby reducing time for child care. Increased yield through agriculture provides opportunity for sale of surplus, leading to increased household income which can then be allocated to quality diets and healthcare. Finally, increased access to water could lead to improved household hygiene and sanitation, thereby improving household health. Alternatively, poor water quality, if used for domestic purposes could lead to consumption of contaminated water such as from pesticides, leading to poor health outcomes.

The conceptual framework provided in Figure 2 serves to inform the theoretical model of how irrigated agriculture potentially translates to child nutrition outcomes as described in other scholarly articles (Belete and Melak, 2018; Benson, 2015; Domènech, 2015; Mekonnen et al., 2019; Okyere and Usman, 2021; Passarelli et al., 2018). It will, however, not be applied as an analytical framework of this write-up due to data limitations.

Figure 2: Irrigation-nutrition conceptual framework



Source: Borrowed from (Belete & Melak, 2018) and modified by the authors.

4.2 Analytical Framework

Due to the nature of the observational data used, which lacked sufficient data to connect the pathways described in the conceptual framework from irrigation to diet diversity, and finally to nutritional outcome (stunting), the study assessed the impact of irrigation on dietary diversity and stunting.

The treatment effects model was used to assess the experimental-type causal effects of irrigation practice on both household dietary diversity and stunting using the following model:

$$Y_{ijk} = \beta_0 + \beta_1 T_k + e_{ijk}$$

Where

Y_{ijk} is the outcome (dietary diversity/stunting) of child i in household j with irrigation practice k (k=1,0).

T_k is a binary variable indicating status of irrigation; 1 or 0.

e_{ijk} are the residuals

Causality and potential outcomes

In order to establish causation and determine potential outcomes, the following two conditional outcomes were set:

$$T_k = \begin{cases} Y_{ij1} \mid T_k = 1 \Rightarrow Y_{ij1} = \beta_0 + \beta_1 1 + e_{ijk} \\ Y_{ij0} \mid T_k = 0 \Rightarrow Y_{ij0} = \beta_0 + \beta_1 0 + e_{ijk} \end{cases}$$

Average Treatment Effect

The average treatment effect defined as the difference in potential outcomes, in this case dietary diversity, between children from irrigation households and children from non-irrigation households was calculated as follows:

$$\text{ATE} = E[Y_{ij1} - Y_{ij0}]$$

Average Treatment Effect on Treated

The average treatment effect on treated was defined as:

$$\text{ATET} = E\left[Y_{ij1} - Y_{ij0} \mid T_k = 1\right]$$

This is the difference in potential outcomes, in this case dietary diversity, between children from irrigation households and children from non-irrigation households given that both are from farming households. This difference is primarily to highlight the counter-factual nature of a causal effect.

Regression and matching

Because the study relied on observational secondary data from the Kenya Integrated Household Budget Survey, irrigation practice was not randomized. This meant that stunting, dietary diversification, and irrigation practice were not always mutually exclusive, and confounding factors in a regression setting could skew estimates of average treatment effects. Therefore, to account for demographic and background factors, regression approaches and matching techniques were applied. This was driven by the presumption that a vector of these observed covariates/characteristics, which related to irrigation practice status, was the only source of omitted variables or selection bias.

To satisfy the conditional independence assumption, which is required for regression or matching to identify a treatment effect, following Instrumental Variables (IV): region, total land area (in acres), total household size, mothers' education level, wealth quintiles, residence, household head education level, and gender of household head were selected.

Stata 14's treatment-effects feature with inverse probability weighting with regression adjustment (IPWRA) estimators were applied to account for non-random treatment assignment while modelling both the outcome and treatment probabilities. This approach is used to obtain unbiased treatment effect in presence of confounding (Hernan & Robins, 2020).

5 Results and Discussion

5.1 Descriptives, Means and Comparison

The objective of this study is to assess the impact of smallholder irrigation practice on household dietary diversity and stunting. The data was extracted from the 2015/16 Kenya Integrated Household Budget Survey (KIHBS), and the inclusion criteria were that the child must be between six and 59 months, have anthropometric data provided, come from a household that engages in farming or animal husbandry, and cultivate less than 25 acres of land. Other variables of relevance included household-level indicators of food access, demographic characteristics, measures of socioeconomic status, agricultural production, farm input, and irrigation practice. This cumulates to 338 children from irrigation-practicing households versus 5,233 children from non-irrigation practicing households.

A higher household dietary diversity score (HDDS) indicates a more varied diet. In lieu of this, the score was dichotomized by setting ideal targets based on the average diversity of the 33 per cent of households with the highest diversity scores (upper tercile of diversity). Cut-off points were obtained as 10 for the scores of the 12 food groups and 12 for the scores of the 16 food groups as a result. Further, children were defined as stunted if their height-for-age (haz) was more than two standard deviations below the WHO Child Growth Standards median. The size of the analytical framework is presented in Table 3.

Table 3: Size of analytical samples from KIHBS 2015/16 dataset

	Rural	Urban	Total
Households			
Full Survey	13,092	8,681	21,773
HHs practicing agriculture (percentage of agric HH of full survey)	8,886 (67.9%)	2,695 (31.0%)	11,581 (53.2%)
Agriculture HHs practicing irrigation (percentage of irrig HH of agric HH)	349 (3.9%)	160 (5.9%)	509 (4.4%)
Children 6 to 60 months			
Anthropometric information was collected	6,680	3,103	9,783
Anthropometric information from children in agricultural households (percentage of children with anthro collected based in HH that practice agriculture)	6,054	1,191	7,245 (74.1%)

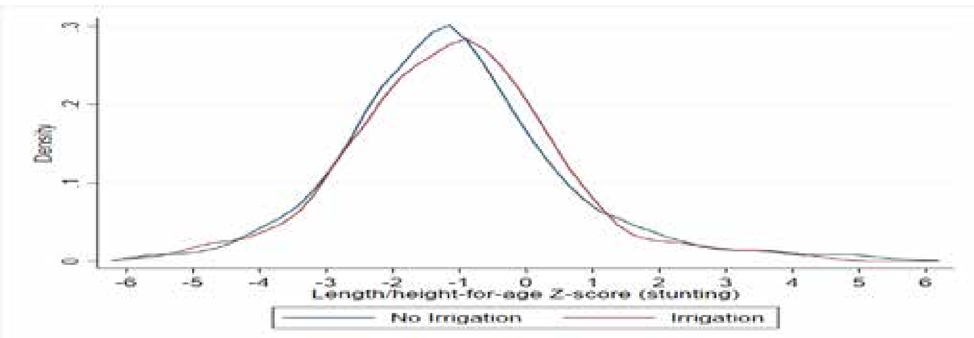
Anthropometric information from children in irrigation households (percentage of children with anthro collected based in HH that practice irrigated agriculture)	288	50	338 (3.5%)

Table 3 indicates that more than half (53.2%) of the sampled population practices agriculture, but only 4.4 per cent of the agriculture-practicing households apply irrigation technology. This is slightly lower than the national proportion of 5.8 per cent of farming households practicing irrigation (KNBS, 2020). Anthropometric measurements of 9,783 children were collected with 74 per cent of those children being in agricultural households, and 3.5 per cent in households practicing irrigated agriculture.

5.1.1. Graphical distribution of stunting and HDDS by irrigation practice

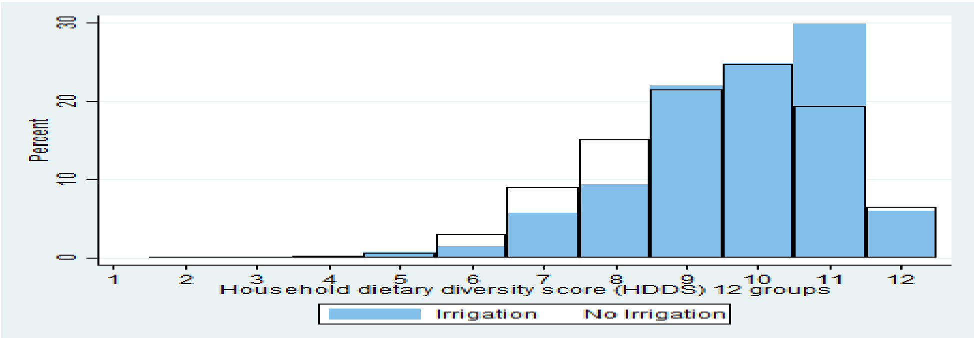
Figure 3 presents a graphical distribution of children's height for age z-scores based on irrigating or non-irrigating households. The Kernel distribution curve depicts negligible difference in growth distribution between children in irrigating and non-irrigating households. Overall, the growth distribution curve of children from all households is slightly skewed to the left, with the midpoint being clustered around -1SD.

Figure 3: Distribution of height-for-age z-scores



Analysis was done to determine the distribution of household dietary diversity scores based on irrigating practice and results are presented as histograms in Figure 4 and 5 for 12 and 16 food groups respectively. In both Figures 4 and 5, the left side of the histogram indicates decreasing diet diversity while the right depicts increased diversity. The diagrams indicate higher diet diversity scores from irrigating households. Likewise, the HDDS of non-irrigating households are generally clustered at the centre indicating lower diet diversity.

Figure 4: HDDS 12 Food groups by irrigating agriculture



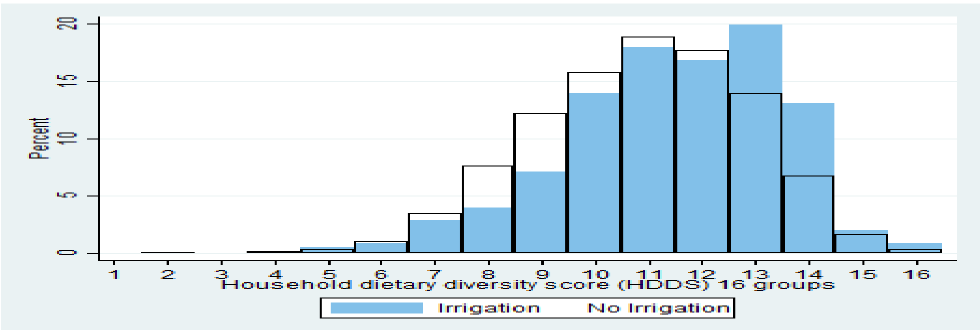


Figure 5: HDDS 16 Food Groups by Irrigating Agriculture

5.1.2 Means and proportions comparison of irrigating and non-irrigating agriculture households

Table 4 presents analysis on the comparison of the means and proportions of child anthropometry, household socio-economic characteristic and agriculture practice and outcomes of farming households by irrigation practice. Means and proportions comparison indicates several statistically significant differences between irrigating and non-irrigating households. The average household dietary diversity score (HDDS) for households in irrigating households is higher (9.8 and 11.7 for HDDS of 12 and 16 food groups, respectively) than that of non-irrigating households (9.4 and 11.0 for HDDS of 12 and 16 food groups, respectively). This implies that households that adopt irrigation eat a wider variety of foods. Diet diversity can be driven by higher income, physical availability of diverse foods as a result of production of the same, or both (Alaofè et al., 2016; Bhagowalia et al., 2012; Kawsary et al., 2018; Mekonnen et al., 2019; Passarelli et al., 2018).

Table 4: Means and proportions comparison of irrigating and non-irrigation households

	No Irrigation	Irrigation	t	p-value
Child's age in months	33.4	31.2	2.285	0.022
Height-for-age (HAZ)	-1.065	-1.143	0.633	0.527
Weight-for-age (WAZ)	-0.567	-0.624	0.578	0.563
Weight-for-height (WHZ)	0.028	-0.013	0.422	0.673

Body mass index (BMI)	0.160	0.132	0.280	0.780
Stunted proportion (-2SD)	27.94%	26.55%	0.435	0.664
Underweight proportion (-2SD)	10.74%	12.32%	-0.595	0.552
Wasting proportion (-2SD)	4.45%	4.83%	-0.270	0.787
Overweight proportion (+2SD)	4.81%	3.43%	1.223	0.222
Household dietary diversity score, 12 groups	9.4	9.8	-2.825	0.005
Household dietary diversity score, 16 groups	11.0	11.7	-3.360	0.001
Participation in nutrition programme	33.33%	24.94%	2.557	0.011
Mothers highest education is secondary or tertiary	29.24%	39.43%	-2.251	0.024
Female makes decision on input use and cropping	32.54%	24.16%	2.390	0.017
Female-headed household	26.36%	15.90%	3.678	0.000
Absolute poor	35.12%	24.18%	2.903	0.004
Food poor	29.00%	18.20%	3.41	0.001
Wealth index				
Quintile 1	27.17%	20.31%	2.048	0.041
Quintile 2	29.97%	18.02%	3.505	0.000
Quintile 3	24.88%	27.74%	-0.776	0.438
Quintile 4	12.86%	21.32%	-2.222	0.026
Quintile 5	5.13%	12.60%	-1.968	0.049
Annual per capita consumption (Ksh)	12,215	15,966	-2.974	0.003
Annual per capita food expenditure (Ksh)	7,735	9,142	-2.210	0.027
Total area of the land (acres)	1.71	2.19	-2.624	0.009
Simpson index[1]	0.47	0.74	-10.020	0.000
Production diversity[2]	4.22	5.74	-2.030	0.042
Pesticide use	27.9%	70.3%	-11.599	0.000
Grew cash crops	12.41%	17.93%	-2.171	0.030
Horticulture production	5.18%	38.14%	-8.399	0.000
Grew starchy staples[3]	95.56%	82.09%	4.030	0.000
Grew pulses	65.91%	52.88%	3.249	0.001
Total earning from sale of agricultural produce (Ksh)	12,690	71,939	-4.090	0.000
Total earning from sale of livestock (Ksh)	13,636	37,225	-5.122	0.000
Total gross income from crop and livestock sales (Ksh)	24,290	104,705	-3.367	0.001
Safe drinking water	52.6%	61.9%	-2.279	0.023

1 A measure of diversity that accounts for the number and abundance of species reflected between 0 as the lowest and 1 as the highest.
2 Count of number of animal and crop species with a higher number indicating increased diversity.
3 Grew grains, grain products, roots and tubers, plantains and other starchy crops.

Comparison of Household Dietary Diversity by Practice of Irrigation

Irrigating households in this sample have on average a higher Simpson diversity index and production diversity (at 0.74 and 5.74, respectively) compared to non-irrigating households (0.47 and 4.22, respectively). This suggests that the former cultivates a wider variety of crops and in addition possess animal species, therefore have increased physical access to diversified diets from own production compared to the latter. In India, increased production diversity within irrigated households was associated with increased household diet diversity, an observation that uniquely applied to smallholder irrigation farmers (Bhagowalia et al., 2012). The sample also indicates that irrigating households (38.14%) outnumber non-irrigating households (5.18%) when it comes to growing horticultural crops such as vegetables, cabbage, French beans, onions, garden peas, kales, tomatoes. In Benin, irrigated cultivation of horticultural crops was linked with increased dietary intake of the same (Alaofè et al., 2016; Burney et al., 2010). On the other hand, non-irrigating households grow more of starchy staples such as grains and root tubers from this analysis. In addition, irrigating farmers had a significantly higher pesticide use (70.3%) compared to non-irrigators (27.9%). This could be causally implied by high horticultural production which requires high pesticide use.

Furthermore, irrigating households have a higher average total agricultural production and livestock earnings (at Ksh71,938 and Ksh37,225, respectively) than non-irrigating households (at Ksh12,690 and Ksh13,636, respectively). Therefore, irrigating households seem to have not only more variety of food available to them, but also higher income, increasing access to diverse diets through purchase. In Afghanistan and Ethiopia, increased income through irrigated agriculture was linked to increased household diet diversity (Kawsary et al., 2018; Passarelli et al., 2018).

Despite the data indicating higher agricultural income amongst irrigating farmers, several indicators imply that irrigating households are of a higher socio-economic status. Mothers whose highest education is tertiary or secondary is higher amongst irrigating households (39.4%) compared to non-irrigating (29.2%) as is the proportion of male household heads that have completed tertiary education. A higher proportion of irrigating households are within the highest two wealth quintiles while a lower proportion of irrigating households are classified within the lowest two wealth quintiles or as absolute and food poor compared to non-irrigating households. In addition, the consumption per capita per year and annual food expenditure per capita is higher for irrigating households. This could mean that irrigation is leading to higher incomes for the households, or alternatively that higher income families are able to practice irrigated agriculture. For this reason, regression analysis controlled for household socio-economic characteristics to increase the ability to predict whether irrigated agriculture leads to improved dietary diversity and nutrition outcomes.

Comparison of Stunting by Irrigation Practice

The differences in household dietary diversity highlighted above are not observed in the prevalence of child stunting from the means test. While 26.5 per cent of irrigated children were stunted, 27.9 per cent of non-irrigated children were stunted, resulting in a small and statistically insignificant difference (p=0.664). Similarly, other child anthropometric indices did not indicate observed statistical differences (underweight, wasting or overweight) between irrigating and non-irrigating households. A similar finding was observed in Malawi where analysis of irrigating households derived from a nationally representative survey, resulted in an insignificant outcome with regard to child linear growth between irrigating and non-irrigating households despite a significant association of irrigation on household diet diversity (Benson, 2015).

Child nutrition outcomes including stunting are influenced by diverse determinants apart from financial and physical availability of food. For instance, a mother's level of knowledge, empowerment and education is a key determinant of child growth and nutrition (Heidkamp et al., 2021; Ruel et al., 2013). In this sample, a lower proportion of mothers from irrigating households participated in community nutrition programmes (24.94 per cent) compared to mothers in non-irrigating households (33.33 per cent). In addition, a smaller proportion of women make decisions of cropping and input use in irrigating households (24.16 per cent) compared to counterpart households (32.54 per cent). Therefore, even if irrigating households seem to be led by more educated heads, decision-making may not be in favour of females. In addition, irrigating households have fewer female-headed households than non-irrigating households.

In summary, results from means and proportions comparison indicate that there is increased household diet diversity within irrigating households and that the difference in diet diversity within irrigating and non-irrigating households is of statistical significance. However, the influence of irrigated agriculture on child stunting is not observed in this analysis. The next results indicate the outcome from assessment of the impact of irrigation practice on HDDS and/or stunting, in a weighted regression setting. Based on the observations on the socio-economic status in irrigating households, the next stage of analysis sought to account for demographic and background factors, through regression and matching techniques. The instrumental variables selected included: region, total land area (in acres), total household size, mother's education level, wealth quintiles, residence, household head education level, and gender of household head.

5.2 HDDS Regression Results by Irrigation Practice

The effects of irrigation practice on HDDS (based on 12 food groups) were estimated in a regression environment with other control variables such as wealth, gender of household head, education of household head and mother of child, location of residence, and household size. The results are presented in Annex table 1. Using the 12 food groups, practicing irrigation increases the likelihood of a household having a more diverse diet by 0.086 points (significant at the five per cent level), equating to an 8.6 per cent increase on average. Upon a second attempt of categorizing the HDDS using 16 food groups, an impact of same direction but lesser magnitude is observed. Similarly, in Benin, participation in irrigation scheme increased dietary diversity score by 3.8 per cent (Nonvide, 2020). This implies that irrigation leads to households having higher dietary diversity.

A limitation of this analysis is that it did not consider specific irrigation-nutrition pathways due to data limitations thus the specific pathways through which the diet diversity was achieved was not established. The analysis indicated irrigation led to increased crop diversity and cultivation of micronutrient-rich foods such as horticultural crops. In addition, it led to higher agricultural income. This implies production and income pathways are likely to influence HDDS. Future analysis could build increased nuance by analyzing the influence of irrigated agriculture on diet diversity based on the irrigation-nutrition pathways.

Another data limitation was lack of individual diet diversity indicators. A recommendation for future analysis is the inclusion of individual diet diversity indicators such as Minimum Dietary Diversity for Women (MDD-W) and Minimum Dietary Diversity for Children (MDD). Intra-household sharing and distribution is affected by cultural norms and analysis of individual diet diversity scores would build increased evidence of how increased HDDS resulting from irrigated agriculture translates to the individual diet practices of women and children as household members with unique socio-cultural and biological needs.

Stunting Regression Results by Irrigation Practice

The study found no clear evidence that irrigation had an effect on children's nutritional status (stunted), conditional on wealth, gender of the household head, mother's education, location, or household size. However, the sign of the coefficient indicated a reduction in likelihood of stunting. This finding is similar to that of Malawi where linear growth in children aged six to 59 months had a positive but weak association with irrigated agriculture and the association was not statistically significant (Benson, 2015).

A probable reason for this was a stronger focus within the policy and governance space as described in section 2, on irrigation for income generation and increased productivity and not nutrition. A meta review of irrigated agriculture across 19 countries indicated low/sub-optimal inclusion of nutrition objectives in irrigated agriculture interventions compared to socio-economic objectives (Domènech, 2015). While income variables are anticipated to influence nutrition intake and outcomes, non-income also impact on stunting. For instance, in India, education level of the caregiver, use of safe drinking water, access to improved sanitation and health interventions such as antenatal visits and adherence to children's immunization schedules had significant effects on child linear growth for irrigation adopters (Bhagowalia et al., 2012).

Another probable reason for unclear evidence between irrigation and child stunting is sub-optimal inclusion of women in smallholder irrigation agriculture. Results from means and proportions comparison indicate a lower proportion of mothers from irrigating households make decisions of cropping and input use in irrigating households (24.2%) compared to counterpart households (32.5%) (Table 4). This translates to one in four women in irrigating agriculture households and one in three women in non-irrigating agriculture households that participate in decision-making regarding cropping and input use. This implies decision-making may not be in favour of women in farming households in general, and more so in irrigating homes. Evidence indicates that a mother's level of knowledge, empowerment and education is a key determinant of child growth and nutrition outcomes (Heidkamp et al., 2021; KNBS-NIPFN, 2021a; Ruel et al., 2013). Moving forward, nuanced engagement of women within smallholder irrigation and agriculture in general is likely to translate to increased child growth as the social development goals of gender empowerment are realized.

Finally, sub-optimal participation within community nutrition programmes was a likely reason for unclear evidence between irrigation and child stunting. Results from means and proportions comparison indicate that participation in community nutrition programmes is lower for mothers in irrigating households (24.9%) compared to mothers in non-irrigating households (33.3%). However, the level of participation in both groups is low, representing one in four women from irrigating households and one in three from non-irrigating agriculture households. This means a significant proportion of women with children under five years are missing an opportunity of gaining a vital service that could impact their knowledge, behaviour and practice regarding infant feeding. Moving forward, nutrition messages such as diet choices, infant feeding, dietary diversification and knowledge on fortified and bio-fortified crops can be integrated within (irrigation) agriculture extension services, women groups, farmer field days, and other communication channels (radio, TV, WhatsApp, videos).

6 Conclusion and Recommendations

6.1 Conclusion

This analysis sought to establish the influence of smallholder irrigation agriculture on household dietary diversity and child stunting. The first objective was to establish whether and to what extent smallholder irrigation agriculture is associated with household diet diversity. Results indicate that practicing irrigation leads to increased household diet diversity. A household practicing irrigated agriculture has 8.6 per cent increased likelihood of having a more diversified diet than a non-irrigating agriculture household (p=0.019).

The second objective was to establish whether and to what extent smallholder irrigation agriculture is associated with stunting. The analysis found no clear evidence that irrigated agriculture had an effect on children's nutritional status as measured by stunting. Some of the likely reasons for this include unclear nutrition-integration in smallholder irrigation plans and policies. The review of smallholder irrigation policies and plans revealed nutrition outcomes are not captured as policy specific objectives limiting the likely nutrition outcomes that smallholder irrigated agriculture could contribute.

There is sub-optimal inclusion of women in smallholder irrigation agriculture. The results indicate low engagement of women in community nutrition programmes implying decision-making may not be in favour of women in irrigating homes. A mother's level of knowledge, empowerment and education is a key determinant of child growth and therefore low engagement and empowerment of women would limit child growth objectives.

There is low nutrition education and messaging in community programmes. The results indicate sub-optimal participation of women in community nutrition programme. This means a significant proportion of women with children under five years are missing an opportunity of gaining a vital service that could impact nutrition-related knowledge, behaviour and practice.

6.2 Recommendations

Interventions towards improving nutrition measurement and monitoring include:

(i) Undertaking nutrition analysis using the four irrigation-nutrition pathways established in the literature to build nuance of which pathways influence household diet practices and the extent of their influence.

(ii) Inclusion of individual diet diversity indicators in future irrigation related household surveys and assessments to strengthen evidence on the influence of irrigated agriculture on the diet practices of women and children as household members with unique socio-cultural and biological needs.

Interventions towards intentional inclusion of nutrition within irrigation policies and plans include:

(i) Ensuring nutrition objectives are spelt out within national and county (irrigation) agriculture ad plans and policies to promote intentional focus on nutrition as an outcome of (irrigated) agriculture in addition to wealth creation, food productivity and food security.

(ii) Engagement of women in irrigation interventions through gender mainstreaming in irrigated agriculture would enhance the opportunity for women to be beneficiaries of the economic empowerment resulting from irrigated agriculture which would translate to improved childcare practices.

(iii) Exploiting opportunities for disseminating agriculture-related knowledge such as agriculture extension services, women groups, farmer field days, and other communication channels (radio, TV, WhatsApp, videos) can be harnessed to integrate nutrition messaging such as diet choices, healthy eating, infant feeding, dietary diversification and knowledge on fortified and bio fortified crops.

(iv) Ensuring advancement of irrigated agriculture translates to improved nutrition outcomes, through intentional inclusion of nutrition as a strategy within both irrigated and non-irrigated agriculture is needed.

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Annex 1: Key policy documents

Legislative:

Irrigation Act Cap 347

The Agricultural Act Cap 318 Irrigation Regulations 1972

Irrigation Act 2019

National Planning:

Sessional paper No.4 of 1981 on National food policy;

Sessional paper No.1 on Economic Management for Renewed Growth;

Sessional paper No.2 of 1994 on National Food Policy;

The Economic Recovery Strategy (2003-2007)

Kenya Vision 2030.

County Plans:

County Integrated Development Plans (CIDP 2013 – 17; CIDP 2018 – 22)

Policies:

The Strategy for Revitalizing of Agriculture (2004-2014)

The Agriculture Sector Development Strategy (ASDS 2010-20)

The Agricultural Sector Transformation and Growth Strategy (2019-2029) (ASTGS)

National Irrigation Policy 2017

Guidelines:

Guidelines for Promotion, Development and Management of Irrigation in Kenya (2019

Annex 2: Irrigation and household dietary diversity inverse-probability-weighted regression with adjustment

	Stunted (haz<=-2)			HDDS 12 (hdds12 >= 10)			HDDS 16 (hdds16 >= 12)		
	coef	t statistic	p-value	coef	t statistic	p-value	coef	t statistic	p-value
Potential-Outcome Means									
Non-irrigating	0.279	36.12	0.000	0.530	62.14	0.000	0.428	49.61	0.000
Irrigating	0.260	8.24	0.000	0.616	17.13	0.000	0.514	13.22	0.000
ATE Irrigating vs Non-irrigating	-0.019	-0.57	0.565	0.086	2.34	0.019	0.087	2.19	0.029
ATET Irrigating vs Non-irrigating	-0.007	-0.20	0.838	-0.012	-0.40	0.692	0.025	0.83	0.404
Regression coefficients for the untreated potential-outcome equations									
Region									
Coast	Ref								
North Eastern	0.289	0.36	0.722	0.468	0.52	0.602	-5.558	-17.65	0.000
Upper Eastern	0.186	0.93	0.353	0.493	2.61	0.009	0.500	2.61	0.009
Lower Eastern	0.012	0.07	0.948	-0.615	-3.83	0.000	-0.699	-4.06	0.000
Central	-0.195	-0.96	0.335	-0.021	-0.11	0.909	0.159	0.86	0.388
North Rift	-0.020	-0.13	0.898	-0.324	-2.32	0.020	-0.133	-0.89	0.375
South Rift	0.051	0.31	0.753	-0.076	-0.52	0.605	-0.238	-1.48	0.139
Western	-0.475	-2.77	0.006	0.706	4.55	0.000	0.626	3.87	0.000
Nyanza	-0.314	-1.98	0.047	0.121	0.89	0.376	0.210	1.45	0.148
Nairobi	-0.984	-0.92	0.360	-0.531	-0.66	0.511	-0.133	-0.16	0.872
Total area of the land	-0.046	-2.21	0.027	0.091	4.33	0.000	0.066	3.20	0.001
Total household members	0.040	2.20	0.028	-0.037	-2.10	0.035	-0.043	-2.40	0.016

Mother education									
Below secondary	Ref								
Secondary and above	-0.207	-1.89	0.058	0.098	1.02	0.307	0.200	2.06	0.039
Wealth Quintiles									
1st	Ref								
2nd	-0.215	-2.17	0.030	0.519	5.46	0.000	0.587	5.69	0.000
3rd	-0.476	-4.38	0.000	1.117	10.84	0.000	1.071	10.01	0.000
4th	-0.661	-4.32	0.000	1.639	11.47	0.000	1.775	12.56	0.000
5th	-0.778	-2.99	0.003	2.375	9.19	0.000	2.522	10.02	0.000
Residence									
Rural	Ref								
Urban	-0.144	-1.15	0.249	0.122	1.20	0.229	0.176	1.69	0.091
Household head education									
Below secondary	Ref								
Secondary and above	-0.141	-1.27	0.204	0.284	3.06	0.002	0.163	1.71	0.086
Female headed household									
No	Ref								
Yes	-0.160	-1.75	0.080	-0.254	-2.97	0.003	-0.224	-2.47	0.014
Constant	-0.537	-2.95	0.003	-0.667	-3.90	0.000	-1.123	-6.24	0.000
Regression coefficients for the treated potential-outcome equations									
Region									
Coast	Ref								
North Eastern	-2.282	-2.18	0.029	-8.086	-9.02	0.000	-6.533	-11.59	0.000
Upper Eastern	0.714	1.06	0.288	0.275	0.42	0.678	0.230	0.39	0.698

Lower Eastern	-0.003	0.00	0.996	-1.366	-1.98	0.048	-1.411	-1.80	0.071
Central	0.970	1.45	0.147	-0.768	-1.18	0.237	-0.775	-1.23	0.219
North Rift	1.061	1.99	0.046	-0.603	-1.15	0.250	-0.305	-0.57	0.568
South Rift	-0.780	-1.11	0.267	0.741	1.09	0.277	0.792	1.21	0.227
Western	0.596	0.87	0.382	0.428	0.66	0.512	0.658	1.04	0.296
Nyanza	0.242	0.31	0.754	1.180	1.63	0.104	-0.340	-0.42	0.673
Nairobi	-3.909	-3.66	0.000	5.028	4.33	0.000	5.257	3.85	0.000
Total area of the land	0.090	0.93	0.351	0.004	0.05	0.957	-0.083	-1.11	0.268
Total household members	-0.059	-0.81	0.420	-0.107	-1.33	0.185	-0.123	-1.67	0.094
Mothers education									
Below secondary	Ref								
Secondary and above	-0.388	-1.01	0.313	-1.029	-2.22	0.027	0.175	0.39	0.697
Wealth Quintiles									
1st	Ref								
2nd	1.151	2.08	0.038	-0.435	-0.80	0.426	0.030	0.05	0.956
3rd	-0.506	-0.90	0.366	0.884	1.80	0.073	0.820	1.42	0.154
4th	0.398	0.64	0.525	1.474	2.50	0.012	0.573	0.92	0.360
5th	-0.221	-0.25	0.800	2.556	2.41	0.016	4.383	3.44	0.001
Residence									
Rural	Ref								
Urban	-1.077	-2.06	0.039	1.523	2.15	0.032	0.622	0.98	0.329
Household head education									
Below secondary	Ref								
Secondary and above	-1.287	-2.91	0.004	1.258	2.68	0.007	1.236	2.96	0.003

Female headed household									
No	Ref								
Yes	-0.464	-0.98	0.325	0.100	0.21	0.834	0.695	1.38	0.167
Constant	-0.945	-1.26	0.209	0.473	0.61	0.540	-0.017	-0.02	0.982
Probit treatment model									
Region									
Coast	Ref								
North Eastern	3.321	6.03	0.000	3.321	6.03	0.000	3.321	6.03	0.000
Upper Eastern	1.185	4.59	0.000	1.185	4.59	0.000	1.185	4.59	0.000
Lower Eastern	-0.686	-2.10	0.036	-0.686	-2.10	0.036	-0.686	-2.10	0.036
Central	0.100	0.34	0.737	0.100	0.34	0.737	0.100	0.34	0.737
North Rift	-0.059	-0.22	0.823	-0.059	-0.22	0.823	-0.059	-0.22	0.823
South Rift	-0.998	-2.70	0.007	-0.998	-2.70	0.007	-0.998	-2.70	0.007
Western	-0.377	-1.20	0.232	-0.377	-1.20	0.232	-0.377	-1.20	0.232
Nyanza	-1.543	-4.47	0.000	-1.543	-4.47	0.000	-1.543	-4.47	0.000
Nairobi	0.594	0.76	0.447	0.594	0.76	0.447	0.594	0.76	0.447
Total area of the land	0.076	2.92	0.003	0.076	2.92	0.003	0.076	2.92	0.003
Total household members	0.050	1.69	0.091	0.050	1.69	0.091	0.050	1.69	0.091
Mom education									
Below secondary	Ref								
Secondary and above	0.314	1.75	0.080	0.314	1.75	0.080	0.314	1.75	0.080
Wealth Quintiles									
1st	Ref								
2nd	-0.045	-0.20	0.840	-0.045	-0.20	0.840	-0.045	-0.20	0.840

3rd	0.404	1.87	0.061	0.404	1.87	0.061	0.404	1.87	0.061
4th	0.667	2.41	0.016	0.667	2.41	0.016	0.667	2.41	0.016
5th	1.077	2.78	0.005	1.077	2.78	0.005	1.077	2.78	0.005
Residence									
Rural	Ref								
Urban	-0.314	-1.61	0.108	-0.314	-1.61	0.108	-0.314	-1.61	0.108
Household head education									
Below secondary	Ref								
Secondary and above	-0.100	-0.55	0.583	-0.100	-0.55	0.583	-0.100	-0.55	0.583
Female headed household									
No	Ref								
Yes	-0.646	-3.31	0.001	-0.646	-3.31	0.001	-0.646	-3.31	0.001
Constant	-3.211	-10.11	0.000	-3.211	-10.11	0.000	-3.211	-10.11	0.000

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