



Improving Food and Nutrition Security in Kenya's Arid Lands-A Mini Review

Michael N. I. Lokuruka^{1*}

¹Department of Food Science and Nutrition, Karatina University, Box 1957-10101, Karatina, Kenya.

Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/ARJA/2021/v14i330129

Editor(s):

(1) Dr. Afroz Alam, Banasthali University, India.

Reviewers:

(1) Belete Yimer, Debre Markos University, Ethiopia.

(2) S. Vijayachandra Reddy, University of Agricultural Sciences, India.

Complete Peer review History: <https://www.sdiarticle4.com/review-history/73380>

Mini-review Article

Received 12 July 2021
Accepted 22 September 2021
Published 28 September 2021

ABSTRACT

This paper presents a review of the literature on food and nutrition security in Kenya's arid counties. It also provides strategies that can be adopted to improve food and nutrition security in the counties. Due to their aridity, they are associated with low economic, health, literacy and food and nutrition security indicators. They bear the brunt of food and nutrition insecurity and a proportionately higher percentage of their population faces starvation, whenever droughts occur. Stunting and wasting in the region's children averages 28 and 14%, respectively. The figures compare poorly with the national averages of 4% and 11%, respectively. As the indices are related to quantity, diversity and quality of food intake, there is need to reduce food and nutrition insecurity in these Counties. Past efforts to reduce food and nutrition insecurity have failed, due to lack of long-term commitment from the National-level of Government, the use of inefficient farming technologies and low level of mechanization. Poverty, low and unpredictable rainfall for rain-fed agriculture, inconsistent livestock marketing of poor quality livestock, high crop production costs, high food prices also contribute to food and nutrition insecurity of the region. To improve food and nutrition security, it is recommended that the National-level of Government cedes the implementation of food production programmes to County Governments, while it strengthens food production policies, diversification of livelihoods and supports resilience-building. Other recommendations include innovating solar and wind-power devices to run machinery for food production, processing and preservation. Improvements in water harvesting, storage and pumping with wind and solar-powered equipment can also be explored. These improvements should

*Corresponding author: E-mail: mlokuruka@karu.ac.ke;

eventually reduce dependence on food importation, which raises food prices, and de-incentivizes local farmers. Diversification of livelihoods, good governance and the application of appropriate technologies in food production, value addition and cooperation of the two levels of Government, are likely to gradually improve access and availability of quality and affordable food. The potential result is an improving food and nutrition security situation in Kenya's arid Counties.

Keywords: Food and nutrition insecurity; Kenya; arid counties; social transformation.

1. BACKGROUND

This is a review of the literature on the food and nutrition security situation of the arid lands of Kenya. Several strategies are provided that could generally be suitable for achieving food and nutrition security in the arid counties.

The ASALs occupy 89% of the country's land mass and are home to about 14 million people (38% of the population) and carry approximately 70% of the national livestock herd [1]. The defining feature of the arid and semi-arid lands (ASALs) is their aridity. Annual rainfall in arid areas ranges between 150 mm and 550 mm per year, and in semi-arid areas between 550 mm and 850 mm per year [2]. Kenya has 23 ASAL counties, with 9 of them being classified as arid and 14 as semi-arid. The focus of this article is the arid counties, where the pain of hunger, malnutrition, and poverty is endemic and underdevelopment is real. The arid Counties include: Garissa, Wajir, Tana River, Mandera, Marsabit, Isiolo, Baringo, Samburu and Turkana [1]. The extent of aridity within each County is variable and the lifestyle is predominantly pastoral, as defined by the high mobility of pastoralists and livestock, and limited crop farming. The semi-arid counties are mostly agro-pastoral, with integrated crop and livestock production systems being common, and, the availability of water influencing the level of integration. In terms of socio-economic development, the ASALs are generally marked by low human development indices-i.e., high poverty levels, low literacy, poor health indices and low population density, but a high population growth rate and poor infrastructure. Nevertheless, they are endowed with a variety of natural resources, key among them being wildlife biodiversity, wetlands, various minerals, diverse cultural characteristics and abundant sunlight, wind and in a few like Turkana and Baringo, geothermal energy.

Development challenges related to the changing dynamics in ASALs are of various forms. For instance, although mobility is the key coping

strategy for pastoralists in response to declines in the natural pastures and water resources after the short rainy season, and during the frequent droughts, the trend towards sedentarisation is increasing. This is due to the abandonment of nomadic pastoralism or loss of the livestock assets and with a few people in the agro-pastoral zones settling down to farm for greater household food security, with the hope of getting some gainful employment to secure some income and the adoption of children's education as an investment that they hope can help families escape poverty. The increasing population coupled with immigration from non-ASALs continues to exert pressure on natural resources such as land, water resources, fuelwood, building materials as well as on social services.

The ASALs contain more than 90% of the wildlife that supports the tourism industry. They contribute 12% of Kenya's Gross Domestic Product (GDP), and host 70% of the National livestock herd. Furthermore, they have enormous potential for renewable energy (both solar and wind) and other natural resources [1], which can be exploited for their development and socio-economic transformation. In spite of these advantages, the ASAL regions have the lowest development indicators in the country. Nevertheless, the Government of Kenya recognizes the potential contribution of ASALs towards the achievement of Vision 2030 development targets and the Big 4 Agenda [3] and therefore places a premium on strategies that can unlock the development potential of the ASALs in order to address the perennial problem of food and nutrition insecurity. This is an attempt in that regard in this article. Conceptually, "food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life" [4]. This definition reflects 4 key dimensions: availability, access, stability and utilization, through which food and nutrition security status can be assessed. However, the fifth dimension of "affordability is key to the

achievement of food and nutrition security as it affects availability and access by a consumer to food that meets their dietary needs. The concept of affordability is premised on the consumer having a reliable source of income as well as enough disposable income and therefore the economic ability to meet individual or family food needs at all times [5]. About a third of Kenya's estimated 57 million people are poor, and some 8 million people live in extreme poverty, while over 10 million people suffer from chronic food insecurity and poor nutrition. In recent years, it is estimated that at any one time about two million people require assistance to access food. During periods of drought, heavy rains and/or floods, the number of people in need can double [6], with the situation in the ASALs being worse as discussed in section 4.1 of this article. The Food and Nutrition Policy of 2011 [7] and Food Security Bill, 2017 [8] are the basis of most programmes on food and nutrition security for the country. Despite some improvements, especially after the formation of County Governments in 2013, much more still needs to be done to improve the food and nutrition security situation of the country's arid regions.

Currently, the National-level of Government is responsible for the implementation, monitoring and the evaluation of the extent to which the programmes that are being implemented under the 2011 Food and Nutrition Policy are achieved. However, this scenario presents potential conflict of interest. To avoid the conflict of interest, it is recommended that the National-level of Government cedes the implementation of the food production programmes in the irrigation schemes to County Governments, while it strengthens food production policies, infrastructure, research programmes, fair allocation of employment opportunities in the civil service, educational, and training opportunities to spur resilience-building for food sufficiency. Often, the National-level of Government extends grants to County Governments which can either be conditional or non-conditional and for specific deliverables. By extending conditional grants to counties to meet planned food production targets, the National-level of Government is able to work towards attaining food and nutrition security in the arid counties.

The arid Counties suffer from low skill sets, which are necessary to spur general development issues and food and nutrition security. The employment by the Counties of adequate numbers of food scientists,

agriculturists, water and energy engineers, and people trained in other relevant scientific and social disciplines, is required to provide the appropriate technical advice, build resilience in the farming communities through extension services to enable adequate food production, the application of appropriate food handling techniques and marketing. Improvements in farming technologies, water harvesting and natural energy harnessing are also needed. Currently, the use of inefficient methods such as manual labour to till the land, sow seed and weeding, curtails the attainment of higher levels of crop production and therefore food sufficiency. Some level of mechanization and improvements in efficiency in the various agricultural practices is needed to meet higher food production targets. Due to the high intensity of sunshine and wind in the arid Counties, the potential for harnessing wind and solar energy for application in food production and preservation theoretically exists. Concerted research efforts to increase the use of natural energy sources can lead to innovations in wind and solar-powered machinery for sowing seed, ploughing and weeding. These improvements are capable of placing more land under crop production. These improvements should eventually reduce dependence on food importation and incentivize the local farmers and enable Counties and the National-level of Government to achieve higher targets under the "food security item" in the Big 4 Agenda [3]. The attainment of the sustainable development goals number 1 and 2—ending poverty and hunger, improved nutrition and promoting sustainable agriculture-based livelihoods, is a likely result [9].

Generally, the youth of the arid counties have low educational achievement and their uptake of public service jobs is therefore not commensurate with their expected fair share at the recruitment of public servants by the Public Service Commission of Kenya [10,11]. Nevertheless, the Public Service Commission has the legal authority through the Constitution to intentionally raise the percentage of the youth from the region who could be employed in the public service [7]. This can be done through affirmative action [7]. But lobbying and some "push" from the region's political leadership and the citizens may be necessary to achieve it. Improvements in market access and higher prices of livestock, can also secure higher incomes for the herders from the arid regions, whose main source of livelihoods is livestock keeping [12]; as livestock herders are a major population group in the arid counties, progressive

reduction in food and nutrition insecurity can thus be attained through the potentially higher per capita incomes from better marketing of good quality livestock.

Also, better use of available farmland by County Governments, the application of appropriate technologies and science in food systems, as well as close cooperation between the two levels of government, are likely to improve food production, and the availability of affordable food of the appropriate quantity and quality.

2. GENERAL FOOD PRODUCTION IN COUNTIES

Due to the low amount of rainfall in the arid counties, current rain-fed agricultural production is generally low and unsustainable. It is mainly subsistence in nature and is practised on the banks of the seasonal rivers using some form of irrigation-either canal or basin. The rivers relied upon include Tana in Garissa and Tana River Counties [13,14], Daua River in Mandera [15] and the Turkwel and Keriyo Rivers in Turkana County [16]; Baringo County relies on the Perkerra and Molo Rivers to keep the Perkerra Irrigation Scheme running, while Samburu County and to a small extent Isiolo County, depend on the Ewaso Ngiro River. The low rainfall in the ASAL Counties calls for emphasis on crops with low water requirements. The intense sunshine aids in the fast growth of crops such that fast-maturing varieties should be the natural choice for cost-effective food production; the crops that do well in these Counties include-cassava, sorghum, millet, "Katamani" maize (3-month fast maturing), tropical fruits, a large selection of green leafy vegetables and legumes. Small ruminants-goats and sheep, are a regular feature of the farming systems in these Counties, although camels also feature prominently in the northeastern Counties of Mandera, Garissa, Wajir, Marsabit and in Turkana in the Rift Valley region. Due to the constant need to move with livestock in search of water and pasture, crop production suffers, thus precipitating food and nutrition insecurity in all the 9 Counties. This makes them rely on food support from governments, non-governmental organizations (NGOs) and international non-governmental organizations (INGOs). The hot climate and high ambient temperatures (day shade temperatures of 30-38°C) [17] result in high evapotranspiration rates from pasture, crop and surface evaporation from water courses. However, the commonly

grown crops can withstand dry spells for extended periods of time. Millet and sorghum contain higher protein content than maize [18] and yet the production of these high value, traditional crops for food has stagnated in the arid counties, similar to other parts of the country [19]. Millet and sorghum also require less water than maize to grow and are suited to dry climates. Re-emphasis on these crops is necessary for the attainment of food and nutrition security, especially because of their high protein biological value, low water requirements and the short period required to reach maturity. Irrigation guarantees some harvest for the small-holder farmers, especially of legume crops and vegetables, which are the commonly traded food commodities by female small-scale traders. Training and incentives such as the offer of free or subsidized seed, free marketing and extension services are likely to encourage those who have sedentarized to do some food production either in their backyards or on riverbank plots. This can contribute to self-reliance and reduce dependency on Governments and external food aid agencies. Currently, the National-level of Government runs and manages large food production schemes in a number of the ASAL counties including the Galana-Kulalu in Kilifi County, Hola Irrigation Scheme in Tana River County, Kalemunyang and Kaatilo in Turkana County, and Perkerra in Baringo County [20]. Most of these schemes have not attained sustainability despite the huge amount of resources expended on maintaining them over many years. A different approach is therefore required in the running of the irrigation schemes in the country and the pursuit of food and nutrition security for the ASALs. This author recommends that the County Governments take charge of these schemes, while the National-level of Government extends conditional grants to run and maintain them. The current scenario where the National-level of Government makes decisions on financing, running the irrigation schemes in the Counties, monitoring the work and eventually evaluating the achievements of "itself" is a breach of the need to avoid conflict of interest in the execution of public projects. A study by Mugeru [21] on the Hola Irrigation Scheme (HIS) established that the cost of inputs was high, with the costs of pesticides and fertilizer being the highest. The average gross margins per acre per year were calculated to be US\$ 1,099.80/year. For a family of 7-9 tilling an acre in HIS, this translates to about US\$ 13.00/month/head, an amount of money that will not encourage the full-time dedication of one's

labour to farming. More than 85% of the residents of the scheme and the environs practiced pastoralism prior to getting into farming, a clear indication that the community had minimal experience as far as farming was concerned [21]. Moreover, the farmers were unable to provide enough labour for their farms to operate the scheme successfully based on the labour requirements of the scheme, partly due to the engagement in pastoralism and the low margins from crop production in the scheme. The study also established that farmer trainings were inadequate, while the credit facilities though available, were severely limited, therefore contributing to the low gross margins in the HIS. Women took little part in decision-making, but participated more actively in the farming activities which could result in them being over-burdened. The low education level of the majority of the respondents was a major challenge that affected the decision-making in the farming processes. In conclusion, the high costs of production reduced the farmers' gross margins, the labour within the scheme was insufficient for all the irrigation activities and the project area lacked an agriculture training facility to support the project through training [21]. All these factors are likely to reduce the crop production potential of the scheme. Nevertheless, the attitude of the community living in HIS towards farming was positive and therefore may not have contributed to the low yields from their farms. The study recommended the support to agricultural production and establishment of market linkages through the value chain approach. Generally, the establishment of high value crops [22] and studies in meaningful ways to integrate pastoralism into the irrigation schemes and farming systems in the ASALs of Kenya are needed.

Another study by Randall [23] focusing on Mwea Tabere Rice Irrigation Scheme concluded that integrated management of irrigation schemes, where both the Government through the National Irrigation Board (NIB) and farmers were closely involved, caused conflict. The study recommended improvements in agricultural extension services along the rice value chain in production, processing and marketing, if profits were to increase, and more value was to accrue to the farmers. Although Mwea Tabere is not in an ASAL county, the storyline on the relationship between the NIB and the farmers is basically similar, to the situation pertaining in irrigation schemes in the arid parts of Kenya.

As livestock is the main source of livelihood for a majority of the populations of the arid counties (16, 15, 13, 14, 24), both levels of Government require to apply strategies that provide the most benefits to the nomadic livestock-keepers who are among the most vulnerable segment of the population of the arid lands, similar to the elderly, children, widowers and widows in the urban centres. Strategies with the potential for reducing the vulnerability of the nomadic pastoralists include: diversifying survival strategies that support pastoralism [25], subsidizing the growing and supply of fodder crops and hay, with stubble being available for animal grazing after harvest, and increasing and designating water points for livestock [26]; Value-added diversification of the products of the livestock and complimentary sectors, and ensuring that there are functioning mechanisms to keep more of the value within pastoralist areas should be encouraged [27]. Some animal by-products that are amenable to value-addition include hides, hooves, horns, bone, animal manure, fish scales, skins and gelatin, etc.

2.1 Specific-County Food Production Situation

An examination of the food and nutrition security situation in each of the arid counties reveals that: Wajir County has a total 1,024.06 km² of arable land out of which, 3,823 ha are under food crop production in the higher altitudes [28]. The county has a food poverty level of 72% and the majority of its inhabitants depend primarily on relief food, because the acreage under food and cash crops is negligible. In 2015, the county's level of absolute poverty was estimated to be 84% [28]. The main crops grown include fruits (pawpaw, watermelon, and lemon); cereals (maize, sorghum, and millet); pulses (beans, green grams and cowpeas); and vegetables (kales and spinach). There are efforts by the County Government to increase the crop acreage through irrigation, but economic viability of such enterprises should always be examined critically before project implementation. Any planned increase in the acreage under food production should be accompanied with investment in water harvesting and storage techniques, mechanization, better crop production technologies and planned extension services and training for the farmers.

The main food crops which include maize, sorghum, and watermelon, occupy approximately 700, 800, and 200 ha respectively [29]. The

seasonal Ewaso Ngiro River supplies water to Wajir town for drinking purposes, while the water in Lake Yahud outside Wajir town is saline, but supports livestock water needs [30]. In Isiolo County, over 70% of the inhabitants rely on livestock for their livelihood and about 26% practice agro-pastoralism [29]. The food poverty-level which stands at 77%, has led to a high dependence on relief food. The agro-pastoralists mainly practice small-scale crop farming (producing maize, beans, tomatoes, green grams, cowpeas, onions, and kale) across the County, relying on rain-fed agriculture and under some irrigation along the various rivers [31]. Malnutrition is highest among female-headed households and is mainly due to low access to production inputs, lack of access to adequate and potable water, and considerable workload (domestic, petty trade and farm predominantly being done by women), which eventually affects maternal and child health [31]. The prevalence of wasting in children was estimated at 3%, while child stunting rates were 19% [31]; the rates compare with the National level of 4 and 11% for wasting and stunting, respectively [32]. In 2014, the County had an absolute poverty-level of 72.6% [33]. High unemployment, low literacy levels, and exposure of the population and livestock to climate change hazards explain the high poverty incidence. Food insecurity in the County is largely driven by low agricultural productivity, frequent droughts and high ambient temperatures, low and erratic rainfall, periodic outbreaks of livestock and crop pests and diseases, poverty and inter-tribal conflicts [31]. The food and absolute poverty-levels in Garissa County are slightly lower than in the other arid Counties. The population living under absolute poverty in Garissa is estimated to be 50% [13]; this contrasts with the high 84, 72 and 72.6% for Wajir, Mandera and Isiolo Counties, respectively [28,31,24]. Nevertheless, similar to the other arid counties, a considerable percentage of the population is heavily dependent on relief food from Governments and NGOs. The high incidence of poverty can be attributed to frequent droughts, regular floods, and inter-clan and inter-tribal conflicts [31]. In all the arid counties, droughts, whenever they occur, reduce the number of livestock for the pastoralists, hence exposing them to poverty. Low access to credit which is compliant with Sharia Law for the Counties of Wajir, Garissa and Mandera, and poor marketing strategies for cash crops and livestock, hamper the higher potential growth of small business enterprises and may be contributing to poverty. In Turkana, Isiolo,

Baringo and Tana River Counties, access to credit is much lower due to the lack of the collateral required by financial institutions to access loans.

Garissa County is water-scarce with only 23.8 per cent of the population having access to safe water [28]. This compares with 20%, 23.5, 34.6, 23.5 and 23.6% in Turkana, Wajir, Mandera, Baringo and Tana River Counties, respectively [16,28,33,34,14]. In all these counties, access to piped water is limited to sub-county headquarters and this affects residents' health and nutrition security as good nutrition is intertwined with the availability of potable water, good sanitation and therefore health, especially for children in order to safeguard against water-borne diseases and the concomitant morbidity and mortality. The main crops grown in Garissa County are: watermelons, mangoes, vegetables, tomatoes, paw paws, bananas, cowpeas, simsim, maize, beans and green grams [13]. These are produced on a small scale under irrigation along the River Tana. The Daua River is the main source of water for food production in Mandera County. The major crops produced under irrigation in Mandera are maize, sorghum, simsim, kales, cowpeas, onions, tomatoes, spinach, mangoes, bananas, lemons and watermelon. The river traverses the county for over 150 Km and provides an irrigation belt of about 20,000 ha. However, only 4,000 ha, which represents 20% of the irrigation potential is exploited [31]. Maize and cowpeas are the main crops under irrigation and they take up approximately 51 and 30% of the irrigated area, respectively [33]. The considerable irrigation potential in the County therefore remains untapped with only 18% of the households using irrigation water as an input in farms [33]. Capitalizing on this considerable irrigation potential as long as it is cost-effective, is likely to lead to increased crop production, and can supplement livestock production and lead to potential improvement in the food and nutrition security in the county. Input use in crop production is generally low and this is attributable to various factors including-high poverty levels, high input prices and long distances to input markets. Livestock manure is used by less than 10% of the households in the county [33]. The low use of manure can be linked to the non-sedentary nature of most of the inhabitants of the county who frequently move with livestock in search of pasture and water. High poverty levels and the long distances to input markets negate any efforts by the farmers to increase the use of

agricultural inputs. The County has a poverty level of 72% [35], with over 67% of the households being food-insecure [36]. Turkana County stands out as the most food-insecure of the 9 arid Counties, with its poverty level standing at 79.4% [16]. The combination of low literacy, a very low share of public service jobs, cross-border conflicts, low and erratic rainfall, dependence on pastoralism as the main source of livelihood, poor sanitation and low availability of health services negatively influence the food and nutrition security situation in the County [16]. The County suffers from acute food and nutritional insecurity, with food-poverty standing at 81%, due to the wide gap between food requirements and supply that is reflected in high food prices [37]. These phenomena are attributed to: physical and economic water scarcity, the cyclic droughts, low pasture, fodder and crop production, inadequate technical planning capacity, uni-sectoral planning, poor projects' co-ordination, short-term project cycles and inadequate Institutional arrangements [37]. Although livestock rearing is the main economic activity in the County, the frequent droughts and famines have depleted the natural resources. The food produced locally is insufficient to cover local requirements and is exacerbated by the steady population growth and the very low use of the water of the Turkwell and Keriyo Rivers, which are left to flow into Lake Turkana untapped for over 100 km for either river. Due to the similarity in environmental and socio-economic conditions, the food and nutrition security situation in Marsabit, Tana River and Baringo Counties approximates to that in the other arid counties.

2.2 Mechanization and Technology Utilization in Food Production

Agriculture contributes 26% of Kenya's GDP, 65% to total exports, 18% to formal and 70% to informal employment [38]. Approximately 70% of the rural population depends on the sector for their livelihoods and the sector is a major source of raw materials for industry. It is a key driver to the realization of Vision 2030 targets and the Big 4 Agenda [38]; for the latter initiative, the attainment of the "Food Security" and "Manufacturing" sub-agenda is pegged on higher agricultural output. It is estimated that agricultural production systems in Kenya rely on human labour to the extent of 50%, animal draught power contributing 20% and motorized power supplying 30% of labour input [38,39]. To realize higher production, mechanization of agriculture is

necessary at a higher level than currently. Mutua *et al.* [40] estimated the country has 1 (one) tractor to 195 hectares. This is comparable to 1.3 tractors per square kilometre in Rwanda and 43 per square kilometre in South Africa, versus 128 tractors per square kilometre in India and 116 per square kilometre in Brazil [41]. FAO and UNIDO [41] estimate that Africa has less than 2 (two) tractors per 1,000 hectares of cropland, compared with 10 tractors per 1,000 hectares in South Asia and Latin America.

Some benefits of mechanization include: a) increased labour productivity, b) increased land productivity, c) potential decrease in the cost of production, d) enhancement in the quality of produce/products, e) removal of drudgery, f) greater involvement of the youth in agricultural production with the ultimate aim of them replacing the ageing farmers. It also strengthens entrepreneurship, conservation of soil and water, and industrialization through cottage industries, and, j) Value addition through agro-processing and the creation of employment and higher incomes [42], through potentially higher outputs.

For consumers in the arid counties, the high consumer price of food most of which is imported despite a little being produced by small scale agriculture impedes the attainment of food and nutrition security for a majority of the population. The high cost of consumer goods thus justifies the establishment of programmes that promote local food production in the marginal Counties, in order to avoid being "eternal" consumers of "imported" food even when conditions are favourable for local food production, as for those who live in the riverine environments.

In Kenya, most of the planting operations are done using human labour as the source of power. Mechanization for crop planting is practiced mainly for maize (56%), wheat and barley (95%) [42]. However, for rice, industrial crops and horticultural crops, mechanization is minimal, if not non-existent. However, the preparation and planting of crops in the large scale farms is done using machinery.

In view of the high level of poverty and low development indicators in the arid counties, the level of mechanization is low. Moreover, the land sizes are small and the use of tractors in pay-for-use schemes by farmers may not be cost-effective for machinery vendors. Nevertheless, County Governments have upped the use of tractors for land preparation in the irrigation

schemes to reduce the drudgery in the use of human labour in the hot climate of the arid counties. Farmers are being encouraged to work together through Cooperative Societies with County Ministries of Agriculture and Cooperatives taking the lead to organize them. This may make it easier for County Governments to reach out to as many people as possible and with short turn around project implementation times. In many counties, the preparation of land, provision or subsidy of seed, fertilizer and pesticides are critical contributions from County Governments. These steps ensure that delays are minimized for farmers to maximally use whatever little rain falls to grow food crops.

According to Mutua *et al.* [40], records from the Kenya Revenue Authority revealed that four wheel tractor (4WTs) sales in Kenya have risen slowly since 1961 when only 6,422 units were operational. This rose to 12,844 units in 2002 which translates to one tractor to 195 hectares. Most 4WTs operating in the country are in the large commercial farms, both in the public and private sectors, including those growing sugarcane, wheat/barley, tea and maize. Tractor ownership among small scale Kenyan farmers stands at 5% and the use of the machine is declining because of the continuous land fragmentation [43]. However, the quest for agricultural mechanization faces certain challenges such as: a) inadequate machinery, b) inadequate qualified management staff, plant operators and mechanics, c) inadequate mechanization extension services and inadequate access to mechanization technologies, d) lack of adequate credit and finance to farmers and private contractors, e) inadequate after-sales and service back-up, f) decreasing land sizes and enterprises that do not support the mechanization business model [44,45]. Other challenges include: vast area of coverage for the National-level Government machinery stations, inadequate resources/funding for stations, gender and youth imbalance in agriculture and the aging farmers [42].

Some current interventions to ameliorate some of the challenges include: the development of an agricultural mechanization policy to guide the sub-sector, b) strengthening the management of the agricultural machinery stations and the Agricultural Technology Development Centres, c) supporting farmer cooperatives in the large irrigation schemes, and d) capacity building for National-level Government and County Ministry teams, e) reform and transformation of agricultural mechanization extension services,

development of a framework for Public-Private-Partnership in service delivery and the promotion of local manufacturing and distribution, and capacity building for staff and other stakeholders [42]. There is need to invest in skills development and related policies to improve activities of agricultural organizations. There should be a wide range of courses in the training institutions and these should be made flexible. Moreover, promotion of information and communication technology (ICT) in agricultural mechanization would significantly attract the youth into agriculture. The low enrolment of women in colleges could be due to the low support for women in the operation of farm machinery. Machinery training and operation should be gender-sensitive to encourage more women to operate farm machinery. More training institutions should be strengthened, especially with regard to providing internships for graduates and more so for female engineering graduates. As agriculture may not be attractive to the youth, there is need to design clear policy frameworks that encourage youth involvement in agriculture [45]. The youth may also lack role models in agriculture. The potential of ICT and access to credit in increasing youth engagement in agriculture will require reform and strengthening. It is possible that higher mechanization will get more youth to get involved in agribusiness. ICT and mobile phone applications have tremendous opportunities for agricultural development if connectivity is improved and quality control measures are put in place. From an agronomic point of view, the impact of tractor use included deep ploughing which may improve fertility, timeliness of operations and improvement of soil aeration and water retention [46]. In addition, tractor use allows for planting of large areas and overall reduction in the cost of farm operations. However, there may also be negative impacts, such as potential reduction in soil fertility by deep ploughing, increased soil erosion and soil compaction [46].

The implementation of technical and policy interventions in mechanization can lead to the realization of measurable qualitative and quantitative outcomes through productivity improvement in value chains and ensuring improved farm production, incomes, and food and nutrition security [42].

2.3 Livestock Production and Marketing

With over 70% of the national livestock herd [1], the arid and expansive environment of the

ASALs is appropriate for migratory pastoralism which relies on local zebu breeds of cattle, camels, goats and sheep. The ASALs supply more than 50% of the meat needs of Kenya [47], with the sales providing cash for the food and other needs of herders and their families in the ASALs. Selling the animals in good condition can fetch good prices for sellers, but that requires good marketing strategies and clear communication channels in the value chain. For those who have settled in urban centres, chicken rearing is a fairly cheap venture that is capable of contributing to family protein needs from the consumption of eggs and occasional meat when the birds are slaughtered. Keeping pigs may also be a worthwhile venture. Aquaculture also seems to be an attractive alternative for these regions, but the lack of adequate water may be a deterrent unless water from boreholes of the appropriate quality and quantity is made available by Governments. Because aquaculture requires a good level of knowledge in fish feeding, disease control and pond management, the provision of extension support services from the Fisheries Departments in the Counties is necessary for farmers who would be inclined to try the venture.

Whatever the venture, the main objective of food production projects in the Counties should be to improve, diversify sustainable rural livelihoods and food and nutrition security through improved livestock productivity, diversification of sources of family incomes, good marketing strategies, better management of droughts and reduced livestock losses. Areas of support for the pastoralists should include animal health-regular vaccinations for endemics and surveillance for ticks, zoonoses, parasitic infections, early drought warning systems, etc. Often, pastoralists do not sell their animals before droughts strike and thus end up losing a large percentage of their stock. Good livestock marketing strategies are therefore necessary if the smooth transfer of animals to market has to be achieved. Also, good prices can only be paid for healthy animals that are sold before droughts take the toll on the animals. In order to encourage pastoralists to dispose of their healthy stock in good condition, payment of cash on delivery would be a good motivator. However, where farmers sell their stock through a cooperative or a marketing association, regular payments to farmers can also encourage the disposal of stock on a regular basis, otherwise they will be reluctant to get into the business. Good communication and structured channels between sellers and buyers are important for the

needs of the market and sellers to be functionally synchronized. More than 56% of the population of Turkana County are nomadic herders [16]. The number is higher in Wajir and Marsabit [31,28] but lower in Baringo (since it is mainly in East Baringo that pastoralism predominates as the mode of production and livelihood), Garissa and Tana River Counties [13,14]. The trade in live animals is likely to improve internal and cross-border trade and create wage employment for animal drivers and for some middle persons who set up butcheries in urban areas to sell meat, a commodity that is a staple in the country. Some of the County governments like the Turkana County Government have set up business centres to train and encourage small-scale local businesses to grow [16]. Broadly, diversifying incomes within the arid counties, through petty trade, bee keeping, small stock-keeping, artisanal fisheries and domestic processing and handicrafts, can contribute to increased incomes, which will ensure wider access to the available food. Improved health and knowledge strengthen the human resource base, and education in particular, will be essential to increasing employment opportunities outside agriculture. Other initiatives can include the provision of subsidized drought crops/hay or the delivery of other grasses to support the natural pastures for herders [48], the provision of adequate water points and early warning system to better manage livestock production and marketing [49,50]. Such initiatives can improve food and nutrition security through increased and regular incomes, increased employment of rural families, especially the youth, the encouragement of the growth of the business culture in the management of livestock assets by pastoralists, diversification of the business portfolio for farmers, the reduction of livestock mortality and improved water supply and building resilience and sustainable rural livestock-based livelihoods [51, 50]. The result will be a reduction of dependence on food aid from Governments, INGOs, NGOs, faith-based organizations and improved family health through better nutrition.

Fish farming enterprises have lately been developed in the high potential areas of Kenya starting in 2009 through the Government-supported economic stimulus programme [52]. The project entailed the production of fish under aquaculture systems for food and commercial purposes. The aim of the programme was to produce food, create employment and generate income, particularly for the unemployed youth and the associated households, through

sustainable aquaculture enterprises. The project components included; a) the construction and stocking of earth fish ponds, b) construction of hatcheries and productions of fingerlings by the National-level Fisheries Department, c) provision of subsidized fish feeds and seeds by donors, the Government and INGOs, d) marketing of table-size fish and the support of investment in ice plants for fish preservation, while in transit to market, e) capacity building on good aquaculture husbandry and aquaculture business practices, f) the formation of aquaculture production and marketing groups, and g) tree planting around pond areas to support afforestation initiatives and raise forest cover in the counties [53,54,52]. The benefits from the enterprise included the sale of fish and fish fingerlings, besides food production and improved nutrition and health at the individual and household level [53,52]. The fingerlings and hatchery management is best done by County Government due to the specialized knowledge and investment required, while the farmers raise fish in the ponds with extension services being provided by County Governments. However, none of the arid Counties have benefitted from the project and should therefore be considered should the project be extended beyond the Western, Central, Southern and Central Rift Regions of the country. Nile tilapia (*Oreochromis niloticus*) demonstrates a high feed conversion ratio, a lower mortality and grows better at 27-32°C compared growing it at 35-37°C [55]. Khallaf et al. [56] also showed a lower fecundity of *Oreochromis niloticus* at the warmer temperatures of summer in Egypt. Therefore some kind of shade may be necessary for aquaculture enterprises in the arid counties where day shade temperatures can be as high as 36-40°C. Nile tilapia is the most farmed fish in Kenya accounting for 75% of aquaculture production [57]. The success of aquaculture ventures will also be influenced by the cost and availability of appropriate feed and market. Where expertise exists and adequate and good quality water is available, there is no reason why aquaculture trials should not be conducted in arid counties to supplement efforts towards food and nutrition security realization.

3. DIVERSIFYING EMPLOYMENT AND INCOME SOURCES

The broadening or diversification of the household economic base is fundamental to reducing food insecurity and vulnerability in the arid counties. This can be achieved by

diversifying the farming systems, particularly by expanding the use of short-cycle livestock such as poultry, sheep, goats, pigs, and, where water resources allow, fish through aquaculture [58]. These systems can be integrated so that outputs from one form of farming can serve as inputs for another-such as crop production and animal dairying or fish farming and crop production. The integration tends to reduce the cost of production and increase efficiency and output [58]. In pastoral areas, the processing of milk and meat products, hides and skins may provide opportunities for supplementing incomes. Options for raising additional earnings from non-wood forest products such as gums and resins also exist in the arid Counties of Kenya.

In the long term, it is essential that conditions be created for people to have increasing access to employment opportunities outside crop production and livestock keeping. This can be secured through a combination of improved and expanded educational, business and vocational training opportunities, better transport and communications, easier access to markets and financial services, and, in some cases, a reduction in the legal and bureaucratic barriers to entry into business. The arid Counties require employing experts with emphasis on local expertise so that they develop the local economies, and act as role models for the younger generations to emulate. To obtain improvements in food and nutrition security through increased agricultural production, County Governments require prioritizing the employment of dryland agronomists, water and irrigation engineers, extension service experts in veterinary medicine, livestock health, etc. To harness the intense sunshine and wind power available in these areas, energy engineers will need to be innovative in the utilization of these resources for the benefit of the small scale farmer. Reduction of cost of production by the use of locally fabricated machinery and the use of renewable energy can raise-food production with the potential to improved food and nutrition security.

The public sector is the largest employer in Kenya with over 700,000 employees (including the members and employees of the Kenya Defence Forces) on the public payroll. All the 44 ethnic communities of Kenya are allocated quotas at public service recruitment as long as they are qualified [11,12] as required by Article 10 and 232 of the Constitution of Kenya [7]. Unfortunately, this has not always been easy to

implement as the populous and the politically-stronger communities take proportionately more slots than is due to them thereby denying the arid Counties of their rightful slots, as observed from the employment trend for 2018/2019 and 2019/2020 financial years [11,12]. All the arid Counties are thus marginalized in regard to public service employment. A plan for higher employment quotas to those who qualify for the various positions from the marginalized counties over a period of a few years can reduce the gap between what the numbers of the marginalized communities in the public service are and should be. The reluctance by the better-off communities to let the marginalized communities catch up means that the gap in the public service numbers for the marginalized communities will therefore take a long time, if ever, to get to what they should be. The result of this is that the economies of the arid counties will not change any time soon due to the tiny remittances from the few public servants to dependent relatives. Improvements in food and nutrition security of the indigenous communities in the marginal areas of the country will therefore take long to realize.

4. FOOD SECURITY AND HUMAN NUTRITION IN THE ASALS

The Arid counties of Kenya are identifiable by high rates of malnutrition, stunting and wasting in children. The rate of stunting stands at 36, 39, 26, 19, 27% and 20% in Mandera, Garissa, Wajir, Isiolo and Marsabit and Turkana County, respectively [59-63,38,64]. Wasting is also high and stands at 15, 9, 21, 3, 16% and 18% in Mandera, Garissa, Wajir, Isiolo, Marsabit and Turkana County, respectively [59-63, 64]. The country average for stunting and wasting in children is 4 and 11%, respectively [32]. The resource base on which to build better livelihoods is generally poor and, insufficient for populations of the arid counties, and this limits the range of options that are open to enable them respond to opportunities that could remove them from the constraints that are responsible for the deprivations that they suffer from. Where there are opportunities for improving agricultural and pastoral systems in ways that can contribute to better living standards, better nutrition and food security, these must be encouraged and seized. Throughout much of the arid Counties, improvements in agricultural and pastoral systems will not be sufficient in themselves to bring about significant or rapid improvements in living standards. Due to frequent droughts and

poverty, the dependence of households on food donations from INGOs, NGOs and governments is a perennial problem [31,33,16,13,24]. Diversification of incomes sources must be encouraged to improve food access, availability, and affordability in order to secure good family nutrition. Any level of improved nutrition, health and education for children will play fundamental and long-term roles in the transformation of rural society, through diversification of local economies and increasing the competitiveness of their members in the labour market, especially in the public service where the numbers of the ethnicities from the 9 arid counties are much smaller than they should be [12]. By providing scholarships and bursaries to school-going children and providing formal education facilities, the burden on parents to provide fees for their children gives parents the opportunity to concentrate on using any spare resources they may have on food production or investment in trade. The boarding schools in arid counties may often be the only facilities for feeding programmes for children of the nomads [65]. Government and donor investments in school feeding programmes are currently undertaken by the Government of Kenya and the World Food Programme [65]. This provides opportunities for families to look for other sources of income thus diversifying and improving family incomes and potentially providing better nutrition for healthier families. Improvements in family health and access to education by the children and knowledge through training and extension services for farmers will lead to a progressive reduction in reproduction rates for younger families, which together with emigration from the most fragile areas will contribute to a better equilibrium between population and the available natural resources [66]. Nonetheless, those who migrate to the urban areas also face challenges of poor and crowded accommodation, poor sanitation and inadequate or even complete lack of access to health services generally, especially if they do not find some source of income to support them pay for these services. The immigrants are often unable to access adequate food, and, are therefore unable to afford quality nutrition. Food and nutrition insecurity is therefore an ever present and dire situation in the slums, where a majority of the immigrants from the rural areas may find themselves. The provision of subsidized water for the practice of urban agriculture in the backyards for vegetable growing would be a worthy investment by donors and governments as part of the support to slum dwellers. Urban agriculture may contribute to

food and nutrition security for the poor slum dwellers in the urban centres, especially through vegetable crops which do not require much land to grow. Nevertheless, the contribution to food and nutrition security is minimal when considering the large size of Kenya's families and the lack of adequate land in urban areas for cost-effective farming. Families grow cereal crops, pulses and even keep livestock in the peri-urban areas of cities (Omondi *et al.*, 2017). However, as vegetable crops are fast-maturing and require little soil moisture to keep them producing leaf, and can therefore supplement family food requirements in cities, they would be a better commodity to emphasize for urban agriculture. The vegetables are an affordable source of minerals and vitamins for the poor and slum families. However, caution to make sure that where waste water or water from sewers is utilized for crop growing it does not introduce health concerns and food safety, should be brought to the attention of families practicing urban agriculture. The use of such water is attractive in view of the inability by urban families to afford adequate potable water for irrigation and domestic use. A study by Kiende *et al.* [67] revealed that most streams in Thika (Kenya) were contaminated with heavy metals, implying that crops irrigated with water from such rivers, as well as water from open and closed sewers, could pose serious health risks to consumers. Amoah *et al.* [68,69] and Gerster-Bentaya [70] note that some urban farmers utilize untreated waste water, making products cultivated using such water risky to human health, as some may be targeted for market. Irrigation with sewer water poses health risks to consumers of these vegetables, especially if they are eaten raw as salads or semi-cooked [70]. In Ghana, for instance, most of the vegetables produced in Accra, Tamale and Kumasi were found to have faecal contamination [71].

4.1 Women's Work and Contribution to Food Production

Women face particular barriers accessing productive resources, economic opportunities and participation in decision-making processes. Female farmers face a number of constraints in accessing agricultural inputs, services and markets that make it particularly difficult for them to rely on agricultural production as a pathway out of poverty [72,73]. Women are reported to supply 43 percent of all agricultural labour in low and middle-income countries [58]. This share reaches at least 50 percent in many countries in

sub-Saharan Africa and elsewhere, especially where poverty is particularly entrenched and women have few other employment opportunities. They also tend to have poorer access to productive assets. A recent study of 24 countries in Sub-Saharan Africa by Graham *et al.* [74] found that among households spending more than 30 minutes collecting water, adult females were the primary collectors of water across all countries, ranging from 46 percent in Liberia to 90 percent in Cote d'Ivoire. They may also face constraints in matters related to land and capital, inputs and technology, as well as services. Their decision-making capacity therefore remains limited, including in community decisions over natural resources. Women's limited access to productive resources may hamper productivity growth on smallholder farms and perpetuating income inequalities. In sub-Saharan Africa, the agricultural productivity levels of female farmers are between 20 and 30 percent lower than those of male farmers because of the gender gap in access to resources [72]. Along with another trend, the "feminization" of agriculture, due to the migration of males to cities to look for work, may overburden women. These burdens and constraints could have strong negative impacts on household food security and welfare in many countries including Kenya. Women also face constraints on their use of time, often because of local norms and beliefs that affect their land rights, work stability and the type of activities in which they can participate. Women, for example, are heavily involved in collecting water and fuelwood, both for household consumption and agricultural use [74]. In 2010, an estimated 66% of households in sub-Saharan Africa, 55% in South and Southeast Asia, and 31% in Latin America relied on collected fuelwood for cooking, with women being primarily responsible for fuelwood collection [74], thus leaving little time for other activities and potentially overburdening them. However in Mandera County of Kenya women contribute 50% of farm and pastoral animal-care labor requirements [63], while the pastoralist males mainly take part in the herding of livestock-mainly sheep and goats, and, in addition, camels in Garissa, Wajir, Mandera, Marsabit and Turkana Counties [13,63,59,16].

4.2 Research related to Food and Nutrition Security for Arid Counties

Innovations from the Kenya Agricultural and Livestock Research Organization (KALRO)-affiliated research institutes located in the arid

counties have not really been felt in the arid counties as far as the author is concerned. Of the 16 research Institutes under KALRO, three are in the ASALs [75]. The Sheep and Goats Research Institute is located in Marsabit, and most of its research activities are being implemented in Marsabit and Isiolo counties and virtually none in the other 7 counties that it is supposed to serve. The Institute was established to enhance the growth of the small ruminant industry.

The Arid and Rangelands Research Institute in Kiboko, Makueni County, is mandated to develop, adapt and upscale scientific research innovations and information that is geared towards sustainably managing the livelihoods of communities living in arid and semiarid areas [75]. The Apiculture Research Institute located in Marigat, Baringo County, has the mandate to support the apiculture subsector through the use of best practices in a bid to contribute to food and nutrition security. The other arid counties have not really benefitted from the apiary research innovations that have made Baringo/Marigat Honey a household name in Kenya, despite recent adulteration practices which are maligning the image of the apiary products from the County. The research outputs of the three Institutes located in the ASALs do not therefore seem to have contributed meaningfully to the food and nutrition security situation of the arid counties, outside their locations. In order for these Institutes to make a contribution to the development of the Counties they are supposed to serve, greater involvement in the development initiatives of the Counties in areas of their jurisdiction is advised. They should endeavour to pro-actively seek to work with County Governments to make their work count, otherwise the objectives for which they were established, will remain a mirage. This is made even more necessary as the National Treasury continues to cut down budgetary allocation to research activities in the Country, whenever it is faced with a cash crunch, a situation the country currently faces as COVID-19 continues ruin the country's economy. There is need for the Governments to focus on how to fund agricultural mechanization, and renewable energy research (in wind and solar resources) in order to develop innovations especially for small scale farmers who till small land sizes that are characteristic of the arid lands. The funds should also enable the setting up of facilities including modern laboratories, workshops, equipment and implements, and, the training of scientists and technicians from the arid counties among their

lot. The research institutes should continue to face up to the new challenges of climate change in their mandates and areas of jurisdiction.

4.3 Governance to Support Food and Nutrition Security Attainment

Governments should develop and implement a comprehensive food security and poverty alleviation policy framework that distinguishes between the roles of the public sector, the private sector and civil society. The framework should embrace not only agricultural production, but also education, health, population planning and good nutrition, the development of infrastructure (including water resources), the diversification of employment and income, marketing and processing, women's participation in socio-economic activities, environmental stewardship, and disaster preparedness [76]. Where governments have successfully redefined their core functions to include only those activities that cannot be supplied more efficiently by the private sector or civil society and have formulated viable policies and strategies, support may usefully be provided to reinforce the performance of essential public services. Other policy reforms that should be pursued include removal of trade restrictions, liberalization and promotion of competition in banking and rural financial services, combating corruption, streamlining budget planning and implementation of appropriate projects for the urban and rural-poor and pastoral communities [77,76]. Effective decentralization of legislative and administrative functions through devolution means that local people have greater say in the political process and strategy formulation so that services are better able to respond to local needs [7]. Conditional grants to county governments can be part of the effective devolution of projects that are able to improve food and nutrition security attainment. The institutional strategy should focus particularly on raising the fiscal and administrative capacities of decentralized public bodies and encouraging the emergence of strong community-based organizations that can contribute to improved livelihoods through the promotion of better and responsive governance [78]. Letting the County governments take over food production initiatives as provided for in the Constitution [7], while National-level of government concentrates on policy making for tailored policies that aim to solve the existing difficulties in building resilience to food and nutrition security initiatives especially for the pastoralists, who still make a good percentage of

the population of the ASALs, is necessary to remove the likely conflict. The specialization is likely to make it easier to achieve the desirable food and nutrition security targets. Clarity is needed to encourage investment and to minimize the risk of conflict, especially in pastoral areas in land and water access rights, in order to encourage investment in food production and related services. Governance and empowerment that supports dryland communities to control and manage their own lands and resources will potentially encourage the adoption of strategies that are geared to reducing food and nutrition insecurity in Kenya's arid Counties [77].

5. CONCLUSIONS

The potential for irrigation development in the dry lands is substantial, but the likely impact on crop output may not be economically considerable in comparison to that achievable by fully exploiting the available opportunities to further develop rain-fed agriculture. County and National-level Governments should map out the water resources, legal and regulatory issues, environmental and social issues, and the economic viability of potential agricultural land, including soil characteristics, crop/animal water requirements versus what is available, local climate data, and the availability of extension support for rain-fed agriculture in each of the arid Counties. The use of drought and salt-tolerant crops, improvements in soil and water conservation techniques, farmer and pastoralist training, extension services and enforcement of measures to protect riparian zones are required for sustainable agriculture. The diversification of the household economic base is fundamental to reducing food and nutrition insecurity and vulnerability, while protecting and providing for the needs of the poor and food-insecure. It is necessary to diversify and integrate farming systems, expand the use of short-cycle livestock assets such as poultry, sheep, goats, pigs, and, where water resources and expertise allow, fish. In pastoral areas, the processing and sale of milk and meat products, hides and skins, bones and other by-products may provide opportunities for supplementing incomes. The option of raising additional earnings from non-wood forest products such as gums and resins should be encouraged. Improving knowledge to strengthen the human resource base, training and education, will be essential to increasing employment opportunities outside agriculture, especially for the youth who may not be attracted to careers in agriculture. When residents of the

arid regions successfully and diversify their livelihoods, they will become more resilient to shocks, and the need for emergency interventions by donors and governments will reduce. The resilience can further be realized if investment in technical education for the youth is emphasized, training and extension services are provided to farmers and herders so that they can improve the productivity of the natural resources that are available for them to improve their lives, food, nutrition and health. Fair allocation of quotas in employment in the public service is necessary for the communities in the arid counties to transform their livelihoods through higher incomes, diversified diets of higher quality and therefore improved food and nutrition security for better family health. Each of the 45 communities that make up Kenya is a link in a chain. "The country wins when the weakest links in the chain get linked and are secured strongly to strengthen the chain." The weakest links in the chain are the poor folk, most of who live in the arid counties. The prosperity of Kenya will be measured by how much these weak links develop and can sustainably support themselves and not necessarily how fast the progressive Counties prosper to outpace the rest.

6. RECOMMENDATIONS TO IMPROVE FOOD & NUTRITION SECURITY IN ASALS

These recommendations though provided for resilience-building for improved food and nutrition security in Kenya's arid counties, can also apply in other situations:

1. Improving health, education, training and diversifying job opportunities for social transformation
2. Integrating and improving farming systems, water and renewable energy generation and application
3. Expanding access to adequate water for livestock and safe water supplies and sanitation for humans
4. Ensuring access to affordable and adequate food of the appropriate quality, access to markets and market information for agro-pastoralists and pastoralists alike
5. Improving drought and extreme events prediction, early warning systems and response capacities, while emphasizing climate-smart technologies in food production and environmental stewardship
6. Providing appropriate nutrition interventions to the most vulnerable (the

urban food-insecure, widowers/widows, children, orphans, the elderly, persons living with disability, etc.) promptly and cost-effectively. Food and nutrition security is a fundamental human right according to Kenya's Constitution [6].

7. Expanding and provide access to knowledge systems, research and use of the resultant innovations for public good
8. Ensuring good governance, protection of human rights through appropriate legislation for the protection of the weakest and most vulnerable in society.
9. Cultivating publicly-beneficial and honest working relationships between the national and county levels of government as provided for in the Kenya Constitution and enabling legislation

DISCLAIMER

The author declares that no competing interests exist with respect to the conceptualization, writing, publication and any product and innovation mentioned in this article. The work was not funded by any of the companies, counties and organizations mentioned in the review, but only by the author.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Ministry of Devolution and the ASALs. Content;2019. Available: www.asals.go.ke. Accessed on 20th April, 2021.
2. FAO, Rome. FAO. Kenya-Socioeconomic and ecological characteristics;2002. Available:<http://www.fao.org/3/AB396E/ab396e02.htm#TopOfPage>.
3. GoK. Food Security Bill. MoALF, Nairobi;2017.
4. FAO. The State of Food Insecurity in the World;2001.
5. Maxwell S. Food security: a post-modern perspective. Food Policy. 1996;21(2):155-170.
6. Republic of Kenya. The Constitution of Kenya. Kenya Law Reform Commission Nairobi; 2010.
7. RoK (Republic of Kenya). Food and Nutrition Policy, MoALF, Nairobi; 2011.
8. Government of Kenya (GoK). "The Big Four" – Immediate priorities and actions: Specific Priorities for the new term. Office of the President, Nairobi; 2017.
9. UNDP. Sustainable Development Goals; 2017. Available:www.SDGs_Booklet_Web_En.pdf.
10. Public Service Commission (PSC). Status of the Public Service Compliance with the Values and Principles in Articles 10 and 232 of the Constitution for the Year 2018/2019. PSC, Nairobi; 2019.
11. Public Service Commission. Status of the Public Service Compliance with the Values and Principles in Articles 10 and 232 of the Constitution for 2019/2020. PSC;2020. Nairobi.
12. Krätli S, Swift J. Counting pastoralists in Kenya-determining the magnitude of the pastoralist sector in Kenya. DLCI/REGLAP Report, Nairobi;2014.
13. Garissa County Government. County Integrated Development Plan (CIDP), Garissa, Kenya;2013.
14. Tana River County Government. CIDP 2018-2022. Garsen, Kenya;2018.
15. Mandera County Government. Ministry of Energy, water, environment and natural Resources, Wajir, Kenya;2020. Available: <https://mandera.go.ke/the-ministry-of-water-sanitation-and-natural-resources/>. Accessed on 4th June 2021
16. TCG Turkana County Integrated Development Plan II (2018-2022). TCG, Lodwarr. Kenya,2018.
17. Christy JR, Norris WB, McNider RT. Surface temperature variations in East Africa and possible causes. Journal of Climate.2009;22(12):3342–3356.
18. Hassan ZM, Sebola NA, Mabelebele M. The nutritional use of millet grain for food and feed: a review. Agric & Food Secur. 2021;10:16. Available at: <https://doi.org/10.1186/s40066-020-00282-6>. Accessed on 17th September, 2021.
19. Tegemeo Institute of Agricultural Policy and Development. Sorghum Production in Kenya: Farm-level Characteristics, Constraints and Opportunities. Technical Report. (Tim Njagi, Kevin Onyango, Lilian Kirimi & Joyce Makau), Egerton University, Kenya; 2019.

20. National Irrigation Authority. 2021. News and events. Available: www.nia.go.ke
21. Mugeru WN. Factors Influencing Crop Production in Irrigation Schemes in the Arid and Semi-arid Lands of Kenya: The Case of Hola Irrigation Scheme in Tana River County, Kenya. A Project for the award of the Master of Arts Degree (Project Planning and Management), University of Nairobi;2012.
22. Morton J, Kerven C. Livelihoods and basic service support in the dry lands of the Horn of Africa. Brief prepared by the Technical Consortium, a project of the Consultative Group on International Agricultural Research (CGIAR) hosted at the International Livestock Research Centre (ILRI). Brief #3, ILRI, Nairobi;2013. Available:<http://www.technicalconsortium.org/publications/>
23. Randall RLN. Socio-economic aspects of Irrigation Schemes In Kenya: The Case of Rice Production In Mwea Tabere Irrigation Scheme, Kirinyaga County, Kenya. Project For award of M. Sc. (Agricultural and Applied Economics), University of Nairobi;2012.
24. GoK/Isiolo County Government. County Integrated Development Plan-Isiolo County, Isiolo, Kenya;2013.
25. Achiba GA. Managing livelihood risks: Income diversification and the livelihood strategies of households in pastoral settlements in Isiolo County, Kenya. Pastoralism: Research, Policy and Practice. 2018;8:20. DOI.org/10.1186/s13570-018-0120-x
26. Aklilu Y, Little P, Mahmoud H, McPeak J. Market access and trade issues in the dry lands in the Horn of Africa. Brief prepared by the Technical Consortium, a project of the Consultative Group on International Agricultural Research (CGIAR), hosted at the International Livestock Research Centre (ILRI). Brief #2. Nairobi: ILRI;2013. Available:<http://www.technicalconsortium.org/publications/>.
27. Little PD. (Ed.). Resilience and risk in pastoralist areas: recent trends in diversified and alternative livelihoods. USAID/East Africa Resilience Learning Project;2016. Available: 21, <http://www.agri-learning-ethiopia.org/>content/uploads/2016/07/TUFTS_1610_Risk_Pastoralist_V3_online1-
28. Wajir County Government and World Food Programme. Wajir County Capacity Gaps and Needs Assessment. World Food Programme, Nairobi;2015.
29. CGIAR. Climate Risk profile-Isiolo County, CGIAR;2020. Available:///C:/Users/Professor%20Michael%20Lo/Downloads/isiolo_Climate_Risk_Profile_Final%20(1).pdf.
30. CGIAR. Climate Risk profile-Wajir County. Kenya; 2020. Available:https://cgspace.cgiar.org/bitstream/handle/10568/96286/Wajir_Climate_Risk_Profile_Final.pdf
31. Government of Kenya (GoK). Revised Mandera County Integrated Development Plan. Government of Kenya, Nairobi;2013.
32. UNICEF. Nutrition: Preventing and treating malnutrition in Kenya;2017a. Available:www.unicef.org/Kenya/nutrition.
33. GoK. Agricultural Sector Development Support Program. Ministry of Agriculture Livestock and Fisheries (MoALF), Nairobi;2014a.
34. Baringo County Government. County Integrated Development Plan (CIDP, 2018-2022). Kabarnet, Kenya;2018.
35. GoK. The basic report on well-being in Kenya, Kenya Bureau of Statistics, Nairobi;2007.
36. Waithaka MG. Analysis of household food insecurity and implication of measurement error, Mandera County, Kenya. Ph.D., Thesis, Kenyatta University, Kenya;2015.
37. Oduor AR, Cherogony K, Maimbo MM, Mutune J, Karuma A, Nyolei D, Onyango D, Ajele C, Wafula W, Njalale S, Lusweti A, Maina P. Food Security Master Plan for Turkana County. International Centre for Research in Agroforestry (ICRAF), Nairobi; 2012. Available:<https://www.worldagroforestry.org/publication/food-security-master-plan-turkana-county>
38. Ministry of Agriculture, Livestock Development and Fisheries (MoALF). Achievements under the Jubilee Government's One Year in, MOALF, Nairobi. 2015;1-18.
39. FAO. Farm power and mechanization in sub-Saharan Africa- Agricultural and Food Engineering Technical Report 3. 65 pp,

- Food and Agriculture Organization of the United Nations. Rome, 2006.
40. Mutua J, Kaumbutho P, Mung'oo J. Farm Mechanization and Conservation Agriculture for Sustainable Intensification (Facasi Project- Kenya), 2014;1–88.
 41. FAO and UNIDO. Agricultural mechanization in Africa.. Time for action: Planning Investment for enhanced agricultural productivity Report of an Expert Group Meeting;2008, Vienna, Austria.
Available:<http://www.fao.org/3/k2584e/k2584e.pdf>.
 42. Nkanya JAM. Agricultural mechanization in Kenya. Presented during Consultative Meeting on Mechanization Strategy, Dakar, Senegal. Agricultural Engineering Services, Ministry of Agriculture, Livestock and Fisheries, Nairobi;2016.
Available: <http://africamechanize.act-africa.org/wp-content/uploads/2016/12/Agricultural-Mechanization-in-Kenya-Eng.-Nkanya.pdf>. Accessed on 6th June, 2021.
 43. Bymolt R, Zaal F. Moving to Mechanization: Mechanization in Maize Farming Systems in Kenya, Tanzania and Ethiopia, Nairobi;2015.
 44. Mellis D, Matsuert H, Mwaniki B. Participatory technology development for Animal traction; Experiences from Semi-arid areas of Kenya. In Starkey and Kaumbutho (Eds.). Improving animal Traction Technology. Proceedings of the first workshop for East and Southern Africa held 18-23 January, 1992, Lusaka, Zambia. Technical Centre for Agriculture and rural cooperation (CTA), Wageningen, The Netherlands. 1999;490. ISBN 92-9081-127-1.
 45. Wawire NW, Bett C, Ruttoh RC, Wambua J, Omari FG, Kisilu R, Kavoi J, Omari J, Wanyonyi NW, Patrick K. The status of agricultural mechanization in Kenya. KALRO/RFA/KAFACI, Nairobi; 2019.
Available:https://www.kalro.org/sites/default/files/kafaci_report.pdf.
Accessed on 15th September, 2021
 46. Maina J. Tractors can change farming in good ways and bad: lessons from four African countries;2020.
Available:<https://theconversation.com/tractors-can-change-farming-in-good-ways-and-bad-lessons-from-four-african-countries-151698>.
Accessed on 15th September, 2021
 47. Kenya National Bureau of Statistics (KNBS), The 2009 Kenya Population and Housing Census: Population Distribution by Age, Sex and Administrative Units, KNBS, Nairobi;2010.
 48. Manyeki JK, Kubasu D, Kirwa EC, Mnene WN. Assessment of socio-economic factors influencing adoption of natural pastures improvement technologies in arid and semi-arid lands of Kenya. Livestock. Research for Rural Development 2013;25. Article #193.
Available:<http://www.lrrd.org/lrrd25/11/kiba25193.html>
 49. Mati BM, Muchiri JM, Njenga P, Vries F, Merrey DJ. Assessing water availability under Pastoral livestock systems in drought-prone Isiolo District, Kenya. Working Paper 106.
 50. GoK. Agricultural Sector Development Strategy, 2010–2020, Office of the President, Nairobi;2010.
Available: <http://npck.org/Books/ASDS.pdf>. Accessed 17th September, 2021.
 51. Alila PO, Atieno R. Agricultural Policy in Kenya: Issues and Processes A paper for the Future Agricultures Consortium workshop, Institute of Development Studies, University Of Nairobi;2006.
Available:http://www.fao.org/fileadmin/user_upload/fsn/docs/Ag_policy_Kenya.pdf. Accessed on 17th September, 2021.
 52. Standard Media. The economic stimulus package-did it really stimulate? Standard Media, Nairobi;2011.
Available:<https://www.standardmedia.co.ke/financial-standard/article/2000032568/the-economic-stimulus-package-did-it-really-stimulate>. Accessed on 15th September, 2021.
 53. Munyi NB, Kiruja E. Determinants of Sustainability for Fish Farming Project Initiative under the Economic Stimulus Programme in Kenya - A Case of the Central Constituency of Kirinyaga County. Global Journal of Commerce and Management Perspectives GJCMP) 2016;5(5):1-8.
 54. ACP. Final Technical Report: "Strengthening Fisheries Management in ACP Countries". Support to legislative development in Tanzania and Preparation

- of a draft Aquaculture policy in Kenya, ACP; 2011.
55. Pandit NP, Nakamura M. Effect of High Temperature on Survival, Growth and Feed Conversion Ratio of Nile Tilapia, *Oreochromis niloticus*. Our Nature. 2010;8(1):219-224. DOI:10.3126/on.v8i1.4331.
 56. Khallaf EA, Alne-na-ei AA, El-messady FA, Hanafy E. Effect of climate change on growth and reproduction of Nile tilapia (*Oreochromis niloticus*) from Bahr Shebeen Canal delta of Egypt. Egyptian Journal of Aquatic Biology & Fisheries. 2020;24(5):483-509. Available: www.ejabf.journals.ekb.eg.
 57. Opiyo MA, Marijani E, Muendo P, Odede R, Leschen W, Harrison Charo-Karisa H. A review of aquaculture production and health management practices of farmed fish in Kenya. International Journal of Veterinary Science and Medicine 2018; 6(2):141-148. DOI: 10.1016/j.ijvsm.2018.07.001.
 58. FAO. The Future of Food and Agriculture; Trends and Challenges. FAO, Rome; 2017.
 59. MoALF. Kenya County Climate Risk Profile Series (Mandera County), MoALF, Nairobi, 2017.
 60. MoALF. Kenya County Climate Risk Profile Series (Garissa County), MoALF, Nairobi, 2016.
 61. MoALF. Kenya County Climate Risk Profile Series (Wajir County), MoALF, Nairobi, 2017.
 62. MoALF. Kenya County Climate Risk Profile Series (Isiolo County), MoALF, Nairobi, 2017.
 63. MoALF. Kenya County Climate Risk Profile Series (Marsabit County), MoALF, Nairobi, 2017.
 64. UNICEF. Turkana County Nutrition Fact Sheet-why good nutrition matters! February 2018, Nairobi, 2018.
 65. World Food Programme. 2016. Supporting National School Meals Programme in Kenya. Available at: <https://www.wfp.org/publications/supporting-national-school-meals-programme-kenya>. Accessed on 17th September, 2021.
 66. Birch I. Economic Growth in the Arid and Semi-arid Lands of Kenya. K4D (Knowledge, Evidence and Learning for Development;2018.
 67. Kiende JI, Kawaka F, Orinda G, Okemo P. Assessment of heavy metal concentrations in urban grown vegetables in Thika town, Kenya. African Journal of Food Science. 2012;6(3):41– 46.
 68. Amoah P, Drechsel P, Abaidoo RC, Henseler M. Irrigated urban vegetable production in Ghana: microbiological contamination in farms and markets and associated consumer risk groups. Journal of Water and Health. 2007;5(3):455– 466.
 69. Amoah P, Drechsel P, Abaidoo RC, Ntow WJ. Pesticide and pathogen contamination of vegetables in Ghana's urban markets. Archives of Environmental Contamination and Toxicology 2006;50(1):1– 6.
 70. Gerster-Bentaya M. Nutrition-sensitive urban agriculture. Food Security. 2013;5(5):723– 737.
 71. Keraita B, Silverman A, Amoah P, Asem-Hiablie S. Quality of irrigation water used for urban vegetable production. In: P. Drechsel and B. Keraita, eds. Irrigated Urban Vegetable Production in Ghana: Characteristics, Benefits and Risk Mitigation. 2nd Edition. International Water Management Institute, Colombo. 2014;62– 73.
 72. FAO. The State of Food and Agriculture 2010–11. Women in agriculture: closing the gender gap for development. FAO, Rome;2011.
 73. Quisumbing AR, Meinzen-Dick R, Raney TL, Croppenstedt A, Behrman JA, Peterman A. Gender and Agriculture: Closing the Knowledge Gap. Springer Science & Business;2014.
 74. Graham JP, Hirai M, Kim SS. An analysis of water collection labor among women and children in 24 sub-Saharan African countries. PloS one. 2016;11(6):e0155981.
 75. KALRO. Institutes list;2020. Available:<https://www.kalro.org/institutes>. Accessed 15th Sep, 2021.
 76. IUCN. Kenya-Arid and semi-arid lands: Restoration of Kenya's arid and semi-arid lands through bio-enterprise development and other incentives under the restoration initiative (TRI).
 77. OXFAM. Delivering the agenda: Addressing chronic under-development in Kenya's Arid lands;2006.. Available:<https://reliefweb.int/report/kenya/delivering-agenda-addressing->

- chronic-under-development-kenyas-arid-lands.
78. Thomas Tödting, Conrad Bosire, Ursula Eysin. Devolution in Kenya: Driving Forces and Future Scenarios. Konrad Adenaur Stiftung (KAS), Strathmore Press, Nairobi;2018.

© 2021 Lokuruka; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
<https://www.sdiarticle4.com/review-history/73380>