World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

Check for updates

Strengthening smallholder farmers resiliency for improved sustainable productivity of Irish Potatoes in Kenya

Caroline Muthoni Thuo [1,*] and Stephen Wambugu Maina [2]

[1] *Crops department, Kenya Agricultural and Livestock Research Organization (KALRO), Horticultural Research Institute - Tigoni Research Centre, Limuru, Kenya.*
[2] *Department of Agricultural Education and Extension, Faculty of Education and Community Development Studies, Egerton University, Njoro, Kenya.*

World Journal of Advanced Research and Reviews, 2024, 22(03), 512–520

Publication history: Received on 27 April 2024; revised on 06 June 2024; accepted on 08 June 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.22.3.1725

Abstract

Potato industry supports millions of people worldwide and plays a significant role in the global food security. It is an important pillar to Kenyas' economy. Low yields in potato production is a key challenge in Kenya, with an average yield of 9.8 metric tonnes per hactare, far below other major potato world producers, and therefore need to boost sustainable productivity. Low productivity of potatoes as a key component in agricultural food value chain system is a major concern because of its' impact on food security. The objective of this review was therefore to establish factors contributing to the low yields and mitigation strategies to strenghten farmers' resiliency against these challenges for enhanced sustainable productivity. Factors established attributed to the low yields include quality seeds inadequacy, climate change adverse effects, poor agronomic practices, pests, diseases and inadequacy in supportive services. Principles guiding resiliency in socio-ecological systems were considered as a guide to a pathway through which irish potato farmers resiliency can be strengthened against these factors. Mitigation measures identified and recommended include enhancing accessibility of quality seed by farmers; promotion of digital agricultural solutions and advisory services; adaptation of climate smart agricultural innovations practices; capacity building of farmers on good agronomic practices; implementation of developed policies to cushion farmers from exploitation; formation and strengthening of farmer groups and associations; development of appropriate infrastructures; supporting of research and extension. Attention is required to these issues by relevant institutions in effort towards strengthening farmers resiliency for continuous food security and improved farmers livelihood.

Keywords: Resiliency; Sustainability; Irish Potatoes; Smallholder farmers; Productivity; Food Security

1. Introduction

Irish potato (*Solanum tuberlosum*) is a key contributor to the world food and nutrition security and ranks fourth after maize, wheat and rice (Food and Agriculture Organization [F.A.O], 2023). The global potato production is about 376 million tonnes, with Asia producing 198 million tonnes, while Europe, America, Africa, Oceania produces 103, 46, 28, 1.8 million tonnes respectively. China and India are the highest world potato producers at 94 and 54 million tonnes respectively, followed by Ukraine, Russia, U.S.A, Bangladesh, Germany, France, Poland and Netherlands. Kenya is the fourth biggest potato producer in Africa with an output of 2.1 million tonnes, after Egypt [6.9], Algeria [4.4], and South Africa [2.6] (F.A.O., 2023).

As a food crop in Kenya, potato ranks second after maize due to its' attached socio-economic benefits (Kwambai, Struik,Griffin, Stack, Rono, Nyongesa, Brophy & Gorman (2023). The potato industry generates about US$ 480 million

* Corresponding author: Caroline Thuo

(Ksh. 54.4 Billions) annually and supports over 3.3 million people (Kenya Agricultural Livestock Research Organization [KALRO], 2021). About 800,000 farmers are engaged in potato production and directly depend on it for food security and income (Agriculture Food Authority [AFA],2023 ; KALRO, 2021). Potato value chain system is one of the most lucrative business in Kenya and its' demand continue to increase due to urbanization (Safiorganics, 2023). Despite these great importance, the potato industry in Kenya is faced with several challenges. One of the key challenge is low productivity level at 9.8 metric tonnes per hactare (AFA,2023), in relation to the expected potential yield of 40 metric tonnes per hactare (Mutegi, Muthamia, Gitonga, Mukami, Mutuma,Esilaba,Gikonyo, 2021). Also, this is far below the global average yields of 21 metric tonnes per hactare (CABI news, 2022). Various factors are attributed to the low yields, which includes climate change adverse effects, lack of quality seeds, pests, diseases, poor agronomic practices and inadequate supportive services (Kimathi, Ayuya, Mutai, 2020).

Climate change is a global crisis, and has greatly impacted food security. The unpredictable extreme weather patterns have become a threat to the existing global agricultural systems (Sene, 2023). African agriculture is rainfed and therefore climate change is a great threat to the African economies, whose agriculture accounts for a quarter of Africa GDP (Global Center on Adaptation [GCA], 2022). Smallholder farmers are the most affected, as the backbone of agriculture in Africa (Global Center on Adaptation [GCA], 2024). Climate change has significantly affected potato production in Kenya (Kangogo, Dentoni , Bijman, 2020). Adaptation of agricultural food systems to climate resilient agriculture (CRA) therefore critically required at scale and speed (GCA, 2024). CRA ensures agricultural system is robust and can cope with changing weather thus ensuring steady food production despite the uncertainity imposed by the changing climatic conditions (GCA, 2024).

According to the Global Agriculture and Food Security Program [GAFSP], (2021), there is need to strengthen resiliency in the entire food systems for food security, during the prevailing global crisis and even beyond. This is critical to boost the potential to feed the global population, which is expected to reach 900 billion people by 2050. Food security is already a challenge with 9.2 percent global population facing hunger and 19.7 percent (highest) prevalence of undernourishment in Africa (FAO,2023). With a combination of increased population and decline in productivity, it's estimated that Africa import of food could reach upto 110 million by 2025 and therefore need for enhanced productivity (GCA, 2022). In Kenya, great effort is required to boost its' food security, with 27.8 percent prevalence of undernourishment (FAO, 2023) and expected increase of population to 95 million by 2050 (Waaswa, Nkurumwa, Kibe, Kipkemoi, 2021). Due to the great role potato production plays in boosting food security in Kenya, intervention strategies towards issues affecting its productivity are critically required. This calls for need to strenghten smallholder potato farmers' resiliency for enhanced sustainable potato productivity in Kenya.

Resiliency is viewed as an essential building block for sustainability in the face of complexity and uncertainty (Kangogo, Dentoni, Bijman, 2020). Agricultural value chain resilience is a crucial component for food security and sustainable livelihood (Vroegindewey & Hodbod (2018). Resilience is the systems' capacity to deal with change and continue to develop (GCA,2024). Building resiliency in food production systems enhances productivity thus ensuring sustainable food and nutrition security. Understanding resilience in Kenya's agricultural food systems is key due to its key role of food and nutrition security and the derived livelihood by a large population.

Potato production contributes significantly to food and nutrition security (CIP, 2022). Data reflects low production of potatoes in Kenya, and calls for need to boost sustainable productivity for continuous food security and improved livelihood among farmers. This paper identifies the current potato production trends in Kenya, various challenges contributing to the low productivity and mitigation strategies identified to strengthen farmers resiliency for increased potato productivity and sustainability in Kenya.

1.1. Conceptual framework

Resiliency in agriculture is key in dealing with risks and uncertainty and in achieving sustainable agri-food systems (Kangogo et.al., 2020). It was therefore necessary to give more attention to resiliency concept and its' application within the smallholder irish potato farmers context. Principles guiding resiliency in a socio-ecological systems (Biggs, Schluter, Schoon, 2015), were considered as a guide through which, farmers resiliency can be strengthened. Based on the conceptual understanding, the existing opportunities were identified and recommended.

Maintaining diversity is a key principle in building resiliency in a social-ecological system (Biggs et.al., 2015). Components like plant varieties, knowledge systems, actors, institutions provide different options for responding to change and dealing with uncertainity and surprise. Systems with many different components are more resilient than those with few component. Potato crop is rich in genetic diversity and the genetic resources that include wild varieties, native cultivars, local farmer-developed varieties and hybrids of cultivated and wild plants. These varieties contain a

wealth of valuable traits, such as resistance to insect pests and diseases, nutrition value, taste and adaptation to extreme climatic conditions (Caldiz, Lutaladio Ortiz, Haverkort, 2009). These genetic pool is required in the development of the improved varieties to increase yield and sustain production. Maintenance of and increase in the genetic variability of available potato varieties is needed for sufficient broad genetic base adaptation of the plant to local environmental conditions, such as weather extremes, insect pest and diseases among others disturbances. In the potato production, farmers resiliency can be enhanced through development and availability of high yielding potato varieties, with pest, disease and drought resistance to guard against crop failure incase of their exposure to environmental disturbances, which ensures improved sustainable productivity in potato farming. Diverse sources of knowledge in organizations provide a diversity of perspectives, which can improve problem solving and support both learning and innovations. A lot of support need to be given to potato in research, for wider technology generation, which can allow quick recovery after a disturbance.

Managing connectivity is a critical principle for enhancing farmers resilience. High levels of connectivity between social groups enhances information sharing. Connectivity of farmers to digital innovation platforms is an easy and speedy intervention strategy towards adressing farmers needs and services. Farmers are strongly linked with service providers and market thus enhancing their resiliency.

Encouraging learning is another important principle that can strengthen resiliency in farmers. Social ecological systems are always in development and there is need to constantly revise the existing knowledge to enable adaptation to change and approaches to management. Continuous learning and experimentation supports efforts to enhance resilience of social ecological systems. It ensures that different types of knowledge are valued and considered when developing solutions. Emphasy is on knowledge sharing among actors. There is need for potato farmers to constantly revise the existing knowledge in potato production and learn emerging technologies and innovations to enable adaptation to changes through capacity building for strengthened resiliency.

Broadening participation as a principle by involving a diversity of stakeholders in the management of social ecological system can help build resilience by improving legitimacy, expanding the depth and diversity of knowledge and helping detect and interpret perturbations. Diverse participation can be particularly useful in the startup phase. This is because early participation means knowledge of the participants can be incorporated in defining management priorities and needs. Potato farmers need to participate in research and in the promotion of innovations among farmers. Working with smallholder farmers to increase their productivity and income is critical in strengthening their resiliency and sustainability of their farming operations. Farmers involvement ensures that their critical issues of concern and needs are addressed and projects associated with them are successful, for example seed production project.

2. Materials and methods

Literature review is the method used to prepare this research article. Articles from related studies and relevant statistics were reviewed. Google search was used to access necessary materials online using the key terms from the study title. Key terms that guided the search included potato production in Kenya, building resiliency in agricultural value chain systems, sustainability of potato production, climate change adaptation, food security statistics. Articles published in various agricultural journals, year books of statistics of FAO, AFA were used to provide necessary information. Latest literature on these issues related to the study was considered. All referencing materials cited contained issues contributing to the study.

3. Results and Discussion

3.1. Agronomic aspects in potato production in Kenya

Irish potato is the most important root and tuber crop (Caldiz et.al., 2009). Its'production is mainly done by smallholder farmers, under rain fed conditions (National irrigation Authority, 2022; Kimathi, Ayuya, Mutai, 2020), and occupies about 3.3 percent of the total agricultural land in Kenya. The crop is mainly grown twice per year, during the rainy seasons in April to August and September to January. The short production period gives quick returns to farmer and provide food during hunger months, when other crops especially grains are still green in the field (CIP, 2022). The crop is grown in high altitude areas between 1,500 to 3,000 meters above sea level, although improved varieties can do well below 1,500 m a.s.l. Rainfall requirements are approximately 1,200mm to 1,800mm with temperature ranging between 15 to 24 degree Celcius. Well drained loam soils, with adequate organic content and a pH level of 5.5 to 7.0. is required. Potato tubers are mainly used for propagation. The crop takes 3 to 4 months to mature, and has a potential yield of 40 tonnes per hactare . Potatoes are used in many ways as food and cash crop. Demand for potato processed products

continue to increase due to their conviniency, driven by rise in urbanization, diet diversification and lifestyle that leave less time for preparing the fresh product for consumption (Caldiz et.al., 2009). Potatoes are eaten as fresh vegetable , as raw industrial material for processing food products like chips and crisps, alcoholic beverages, starch, food ingredients and as animal feeds on crop residues.

3.2. Areas of potato production in Kenya

Figure 1 is a map of Kenya indicating the potato producing Counties.

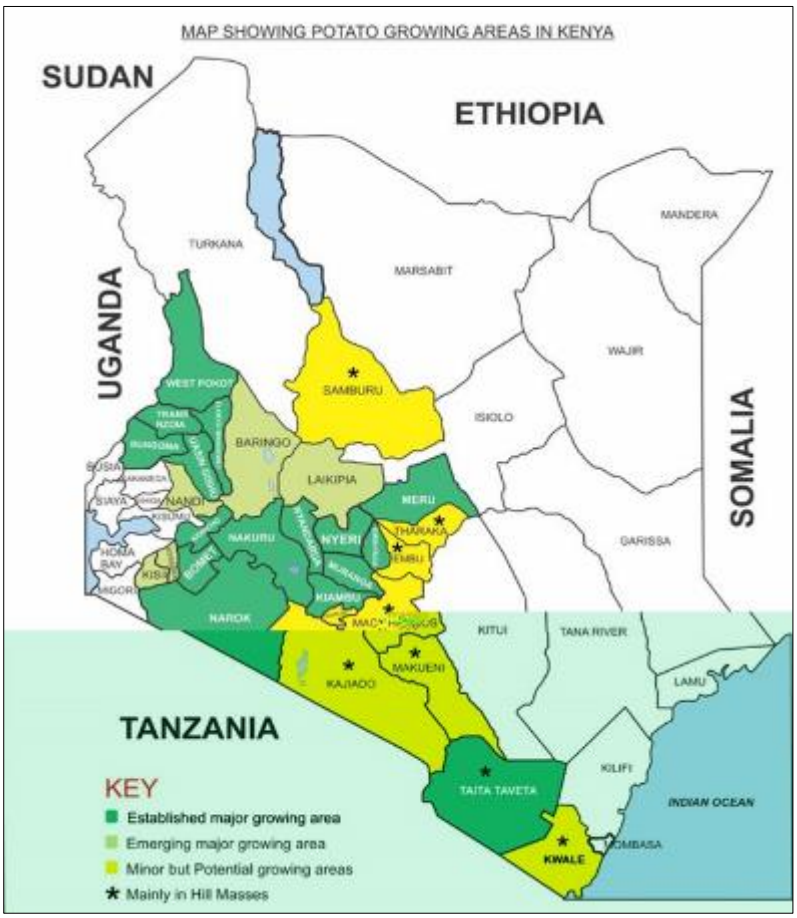

Figure 1 Potato growing counties in Kenya (MoALF, 2016)

3.3. Trends in potato production in Kenya

Table 1 shows irish potato production between 2018 to 2022. The yields are low, and characterized by fluctuations over the years. In comparison with other world leading potato producing Countries, potato yields are quite low as indicated in Table 2. Therefore, there is need for adoption of resilient yield enhancing production technologies that are sustainable in Kenya.

Table 1 Irish Potato Production Performance 2018-2022

Year	2018	2019	2020	2021	2022
Area (Ha)	217,315	212,976	176,252	214,600	209,770
Production (MT)	1,754,130	1,870,375	1,978,952	1,859,776	2,107,824
Yield (MT /Ha)	8.6	9.3	10.5	9.8	8.4

Source: AFA, 2023

Table 2 Average potato yields in leading world potato producing countries

Country	China	India	Egypt	Algeria	South Africa	Kenya
Yields(million tonnes)	94	54	6.9	4.4	2.6	2.1

Source: FAO,2023

3.4. Challenges contributing to the low productivity in potato farming in Kenya

Low productivity is a key challenge as indicated in Table 1 and Table 2. Factors attributed to these low productivity in Kenya are as outlined below.

3.4.1. Inadequacy in supply of quality seed

Availability of certified seed is the major challenge in potato farming in Kenya (KALRO, 2024), and the main constraints to the large scale adoption of research-bred improved varieties. Use of uncertified potato seeds has contributed greatly to yield decline (AFA, 2023 ; Kimathi et. al., 2020). Only 7,000 tonnes of clean seeds are produced annually against an annual demand of 30,000 tonnes (National irrigation authority, 2022). Approximately 96 percent of farmers use uncertified seed, either potato retained from previous harvest (farmer-saved seed), potato sourced from neighbors, or potato purchased from local markets (Fintrac Inc., 2015). Poor quality seeds from the informal sector, has significantly contributed towards low potato productivity (CABI, 2022; Caldiz et.al.,2009). Capacity limitation in terms of funding is one of the key reason certified seed producers are not able to meet the seed demand in Kenya.

3.4.2. Adverse effects due to climate change

This has contributed greatly to low potato production in Kenya (Waaswa et.al., 2022). The yields, which are below the potential are characterized with fluctuations due to climatic variations between 8 to 15 tonnes per hactare (Kimathi et. al., 2020). According to AFA (2023), poor rainfall distribution in some irish potato production regions caused area under potato to decrease from 214,600 hactare in 2021 to 209,770 hactares in 2022, resulting to decline in productivity from 9.8 mt/Ha to 8.4 Mt/ha as indicated in Table 1. In 2016-2017, rainfall reduced from 737mm to 126 mm and there was a tremendous yield reduction of 56 percent (Kimathi et.al). Inter-annual variations and extremities in weather conditions, particularly the eminent non-uniform rainfall patterns and temperature, have resulted in low yields or total destruction of field crops posing a negative impact on farmers' incomes and livelihoods (JKUAT, 2021). According to Caldiz et. al., (2009), there is need to develop resilience in the face of climate change and embrace adaptation strategies to increase productivity and sustainability of potato farming.

3.4.3. Lack of adequate technical knowledge on potato production

AFA (2023), has acknowledged that poor agronomic practices by most small scale farmers has been associated with low potato production in Kenya. According to Kwambai (2022), most farmers produce potatoes under sub-optimal management, resulting in low yields. According to GCA,(2022), lack of knowledge and resources in regard to response mechanism to climate change is believed to have affected smallholder farmers . Similarly, (JKUAT, 2021) identified that farming communities especially the small-scale holders rarely get access to up-to-date information on weather, climate information as well as access to quality farm inputs, which affects their capacity in potato production.

3.4.4. Pest and Diseases

Pest and diseases contribute greatly to low productivity in potato farming (Kimathi et. al., 2020). Late blight constitutes the most serious disease threat (Caldiz et.al., 2009). Bactarial wilt can cause yield losses between 30 to 70%. Black leg and soft rot diseases also contribute to the low yields and quality making potato unfit for the market. Low quality seeds supply by the farmer-based informal seed system promotes the spread of these diseases like bactarial wilt, nematodes and viruses (Caldiz, 2009). Major pests includes aphids, tuber moths, leaf miners and potato weevils.

3.4.5. Lack of inputs

Farmers access to quality farm inputs affects their capacity in potato production (JKUAT, 2021;Kimathi et. al., 2020). Good quality seed is usually the most costly input to potato cultivation, accounting for 30-50 percent of production costs (Caldiz et.al., 2009). High cost of certified seed has forced farmers to use self sourced seed.

3.4.6. Poor marketing services

Production of potatoes being largely rain-fed results to seasonal fluctuations in supply of potatoes. During the peak production periods, farmers sell directly from the field due to limited on-farm storage facilities, which results to glut periods, depressed prices and correspondingly low net returns to farmers (KALRO, 2021). Over 90% of farmers sell their potato produce through middle-men, who exploit them. The middlemen act as aggregators and force farmers to sell their produce using prices dictated by them. This ends up with farmers getting poor proceeds from potato production. This is worsened by poor road infrastructure in most potato growing areas. Potato transportation to the markets accounts for approximately 23% of the wholesale price. Poor packaging of potatoes in extended bags results to loss and exploitation of farmers by traders.

3.5. Mitigation strategies to strengthen farmers resiliency in potato production

Adoption of productivity enhancing technologies is critical to increase potato production and sustainability in Kenya (JKUAT, 2021;Kimathi et.al., 2020). This is one of the best options towards strengthening farmers resiliency in the potato farming. Outlined below are the mitigation strategies identified and recommended for enhancing and sustaining improved potato productivity in Kenya.

3.5.1. Enhancing accessibility of quality seed

Quality seed is the most important input, that hold key to increased agricultural productivity and income (Chandio & Yuansheng, 2018). It is a major requirement for improved farmers' yields and quality produce (KALRO, 2024 ; Okese, 2018). Even if all crop management practices are applied, without the right seed, production will still be low (KALRO, 2024). FAO (2023) emphasizes on use of high yielding variety seeds for increased crop production. According to Kidane, Lemma & Tesfay (2018), use of quality seeds alone can enhance crop productivity by 15 to 25 percent. Enhancing accessibility of quality seed, in sufficient quantities and affordable prices, is key to raise productivity of smallholder farmers, for enhanced food security and prosperity (Chandio & Yuansheng, 2018 ; Yagi, Shiratori, Alemu & Bekele, 2014). Continuous development of improved varieties along with efficient and adaptive mechanism of quality seed production and supply is of great importance (Yagi et al., 2014). A reliable supply of good quality seeds is therefore crucial to the development of the potato sub-sector in Kenya., and to boost the Country food security. Strong linkages between seed producers and farmers need to be established and existing ones strengthened and popularised, to enhance availability and accessibility of quality seeds by farmers. Seed nurseries and bulking sites need to be established closer to the farmers, for increased, accessible production of quality seeds. The existing rapid multiplication of certified seeds technologies that accelerates production of high-quality seeds by farmers like use of rooted cuttings, hydroponic, aeroponics need to be intensified through collaboration with stakeholders to boost production and distribution of certified planting materials. According to Kidane et al. (2018), promoting seed production and distribution by farmers, is an option to address existing seed supply needs. There is need therefore to build farmers' capacity to produce certified potato seed if potato production is to be improved. Such capacity includes training and financially empowering farmers through credit facilities. With the necessary support, farmers have potential to sustainably supply certified seeds through their participation (Thuo, Ombati, Nkurumwa, 2019). This would strengthen their resiliency in potato production. Efforts to increase availability of certified potato seed to farmers by some organizations like KALRO is in progress through involvement of farmers as seed multipliers within their own localities (KALRO, 2021;NTV Kenya, 2023). However more funding is required to support these initiative for wider scaling out.

3.5.2. Promotion of digital agricultural innovations platforms and advisory services.

In most countries public extension systems have broken down and it is therefore necessary to utilize digital platforms, to accelerate the speed at which useful information reaches the farmers (GCA, 2022). These platforms enhances efficiency in technology dissemination and marketing (Elbehri & Chestnov, 2021). They accelerates access to production inputs, market intelligence, climatic conditions and sharing information on good agricultural practices (JKUAT, 2021). Integration of digital advisory services and technologies into African agriculture has been recommended as a key approach towards enhancing resilliency in agriculture (CGA, 2022). Climate information systems, which includes weather forecast is required by farmers so that they can get timely weather information as a guide to adapt their farming systems to climate changè and helps to avoid input wastage (CGA,2022). Wider promotion of existing digital platforms with data sharing networks is necessary like Kenya Agricultural Observation Platform [KAOP], Kenya Agricultural Data Sharing Platform [KADP] and viazisoko application. KAOP, a mobile application uses geo-data from satellites to generate real-time and location specific agro-meteological advisories to farmers for more informed farming decisions (KALRO, 2020). KADP, a data sharing network offer digital agriculture solutions to farmers in Kenya (KALRO, 2023). The viazi soko digital platforms links farmers with service providers and offers efficiency in accessibility to quality inputs, potato marketing and advisory services (JKUAT, 2021). The digital platforms are therefore important tools to strengthen farmers resiliency in potato farming thus boosting their livelihood and income.

3.5.3. Capacity building of farmers on good agronomic practices

Continuous learning, experimentation, nowledge sharing and constant revision of the existing knowledge is key among farmers due to technological development and changes that oftenly take place within the agricultural systems and supports efforts to enhance resilience among farmers (Biggs et.al., 2015). Capacity building equips and refreshes farmers with skills and knowledge on best management practices thus strengthening farmers resiliency in potato production (Waaswa et.al.,2022). Technical training and regular extension services is also required for those farmers with inadequate skills and experience in potato farming to enhance potato productivity (Wamunyu, Bett, Kariuki & Cadot, 2022). Farmers participation in capacity building is important as it ensures their needs are addressed based on their training needs and expectations, thus strengthening their resiliency (CGA , 2022).

3.5.4. In corporation of climate smart agricultural innovations practices

Adoption of climate resilience enhancing strategies is critical to increase productivity of potatoes. The coping strategies includes provision of farmers with climate information, irrigation, crop rotation, agroforestry, inter-cropping, adoption of improved varieties that are high yielding, early maturing, disease resistant and drought tolerant varieties. According to FAO (2023), increased use of irrigation increases crop productivity. It counteracts the adverse effects of unreliable rainfall due to climate change (Waaswa et.al., 2022). Irrigation of potato farms, improves productivity in terms of quantity and quality (National Irrigation Authority, 2022; Caldiz, 2009). Through irrigation,farmers are able to produce potatoes continuously, even in the midst of drought, thus guarding food security for the Country. Farmers need to be equiped with innovative irrigation systems that increase water use efficiency, which includes improved water harvesting and soil water management systems to strengthen their resiliency (CDA,2022). Rapid expansion of Kenya irrigation development in hot and dry climates offers relief and great opportunity for the industry to take a potato trans-formative trajectory of potato and seed production that will in turn stimulate large scale processing for local and export markets" (N.I.A., 2022). Necessary support need to be availed to farmers in use of irrigation to ensure sustainable potato production and supply. Development and adoption of improved climate resilient potato varieties is necessary (Waaswa, 2022). Lack of awareness of their availability is a key constraint to their uptake and therefore need for promotion among farmers for increased production and food security in Kenya. These varieties improves farmers resilience to climate change in terms of increased crop yields, maturation period, resistance to pest and diseases and drought resistance. Massive scaling out of these climate stress tolerant varieties is critically required to enhance farmers resilliency and sustainability of potato production.

3.5.5. Implementation of developed policies to cushion farmers from exploitation

Attention has been given by policy markers to exploitation of farmers in potato marketing by cartels and necessary policies have been developed (NPCK, 2021). These policies need to be adopted and strictly adhered to ensure farmers get good profit from potato farming. The government need to enforce these regulatory measures such as weight standards strictly.

3.5.6. Formation and strengthening of farmers producer groups/ associations.

Platforms need to be created by farmers and existing ones strengthened for the articulation of pertinent issues that would interfer with production and marketing of irish potato, and facillitate provision of credit facillities among farmers. Caldiz et. al., (2009) recommended formation of producer groups that would help farmers share expertise and strengthen their bargaining power in marketing of their produce. Cooperatives can also serve as avenues for training farmers / extension delivery (Wamuyu et. al., 2022). Formation of farmer groups is necessary as they form local institutions, with members pooling resources together that may ease access to resources that are within and outside the community and collective action, which facilitates in the adoption of improved technologies. It facilitates risk pooling and enable people to build assets that help them in withstanding change shocks hence strengthening farmers resiliency.

3.5.7. Provision of credit facilities to farmers

Access to credit assist farmers acquire improved technologies like drought-tolerant varieties, irrigation equipments and other farm inputs necessary for enhancing farm productivity. Access to credit has been identified as one of the strong pillars that foster scaling out climate smart adaptation practices in Kenya (Waaswa et.al., 2022).

3.5.8. Development of appropriate infrastructure

Improvement of transport infrastructure and cold storage facillities has been recommended as one way of strenghtening the potato value chain (Caldiz et.al., 2009). There is need to build transport routes to enable rural connectivity and facilitate farmers to have better access to market (GCA, 2022). Improvement of the road network

would assist farmers in transport costs reduction. Development of sustainable storage facilities is key to prevent and reduce post harvest losses. Post harvest loss is a challenge to many farmers, losings almost 40% of their produce.

3.5.9. Supporting of research and extension

Research and extension facilities are critical for the development of production capacity to enhance resiliency in food systems. Research is key in the provision of yield improving technologies that boosts yields and reduce costs (Caldiz, et.al., 2009). Through research adaptation strategies for enhancing productivity are also developed. Potato farmers' resiliency can be enhanced through development of improved potato varieties through research that are high yielding, resistant to pests, diseases and drought to guard against crop failure incase of exposure to environmental disturbances. Potato farmers need to strongly participate in research for the realization of better results.There is need for substantial investment in research especially in breeding programmes and infrastructures to support and co-ordinate research activities. Breeding programmes need full support with continuous conservation of breeding stocks.

3.5.10. Promotion of value addition of irish potato products

Value addition is critical to realise the full potential of potatoes. Potatoes are very versatile and can be processed into various products ranging from fresh and frozen chips, fresh crisps, industrial starch and potato flour/powder among other uses. It can be dehydrated to lengthen shelf life and reduce post harvest losses and lengthen shelf life. Dehydrated products can be re-hydrated and cooked normally. With right market sourcing, farmers' income could be increased three-fold through diversified potato processed products, which strengthens farmers resiliency.

4. Conclusion

This review reveals that low potato productivity is a key challenge in Kenya. Factors attributed to the low productivity include inadequacy in supply of quality seed, adverse effects of climate change, lack of adequate technical knowledge on potato production, pest and diseases, lack of inputs and poor potato marketing services. Intervention measures to strengthen resiliency in irish potato farmers for sustainable potato production includes enhancing accessibility of quality seed; promotion of digital agricultural innovation platforms and advisory services; capacity building of farmers on good agronomic practices; in corporation of climate resilient agricultural innovations practices; implementation of developed policies to cushion farmers from exploitation; formation and strengthening of farmers producer groups; provision of credit facilities to farmers; development of appropriate infrastructure; supporting of research and extension and promotion of value addition of irish potato products. It is hoped that application of identified mitigation factors would enhance resiliency in potato farming for improved and sustainable productivity in the Kenys' potato industry.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Agriculture and Food Authority (2023). AFA year book of statistics 2023

[2] Biggs R., Schluter M., Schoon L.M. (2015). Applying resilience thinking. Seven principles for building resilience in social-ecological system. Brochure.

[3] CABI news (March 9, 2022). Low potato yields in Kenya, not down to magement practices only, CABI study suggest

[4] Caldiz D., Lutaladio N.B., Ortiz O., Haverkort A., (2009). Sustainable potato production: Guidelines for developing countries. Food and agriculture organization of the united nations, 2009. ISBN 978-92-5-106409-2

[5] Chandio A.A., & Yuansheng J. 2018). Determinants of Adoption of Improved Rice Varieties in Northern Sindh, Pakistan. *Rice Science*.Volume 25, Issue 2,103-110.

[6] Elbehri, A. and Chestnov, R. (eds), 2021. Digital Agriculture in Action- Artifical Intelligence in Agriculture, Bangkok, FAO and ITV.

[7] Food and Agriculture Organization [F.A.O], 2023. World Food and Agriculture – Statistical Yearbook 2023. Rome.

[8] Global Center on Adaptation [GCA], (2022, March 10). Webinar: Adapting agriculture in Africa to build resilience to climate change. Adaptation Dialogues for Africa [Video]. YouTube.*https://www.youtube.com/@GlobalCenteronAdaptation*

[9] Global Center on Adaptation. (2024, April 22). Webinar: Youth adaptation forum on climate-resilient Agriculture [Video]. YouTube.

[10] *https://www.youtube.com/@GlobalCenteronAdaptation*

[11] Jomo Kenyatta University of Agriculture and Technology, Corpolate Communication Office (2021). Promotion and adoption of climate smart ICT technologies in irish potato value chain. Project "Validating and scaling-up quality seed potatoproduction, post-harvest and distribution models and policies for improved access and income".

[12] Kangogo D., Dentoni D., Bijman J., (2020). Determinants of farm resilience to climate change:the role of farmer entrepreneurship and value chain collaborations. Sustainability. 12, 868; doi10.3390/su12030868.

[13] Kidane H., Lemma T., &Tesfay G. (2018). Determinants of smallholder farmers'participation in seed producing cooperatives in southern zone of Tigray, Ethiopia.Journal of Agricultural Extension and Rural Development, 10(4), 75-83. DOI:10.5897/JAERD2017.0868. ISSN 2141-2170.

[14] Kimathi S.M., Ayuya O.A., Mutai B. (2020). Adoption of climate-resilient potato varieties under partial population exposure and its, determinants: Case of smallholder farmers in Meru County, Kenya. Journal of Food & Science technology. *https:// doi. Org/10.1080/23311932.2020.1860185.*

[15] Kenya Agricultural and Livestock Research Organization (KALRO), (2021).Climate Smart Agricultural Technologies, Innovations and ManagementPractices for Potato Value Chain. Training of trainers' manual.

[16] KALRO (2024, January,25). Seed development: Seed shops to be opened countrywide. [Video]. YouTube. *https://www.youtube.com/@Kalromkulima*

[17] KALRO (2023, September,12).Launching of the Kenya Agricultural Data Sharing Platform (KADP) [Video]. YouTube.*https://www.youtube.com/@Kalromkulima*

[18] KALRO (2020, July,5). Kenya Agriculture Observation Platform (KAOP) [Video]. YouTube. *https://www.youtube.com/@Kalromkulima*

[19] Kwambai, T. K., Struik, P. C., Griffin, D., Stack, L., Rono, S., Nyongesa, M., Brophy, C., & Gorman, M. (2023). Understanding Potato Production Practices in North-Western Kenya through Surveys: an Important Key to Improving Production. Potato Research, 66(3), 751-791. *https://doi.org/10.1007/s11540-022-09599-0*

[20] Mutegi J., Muthamia J., Gitonga A.K., Mukami K., Mutuma E., Esilaba A., and Gikonyo E. (2021). Potato production in Kenya. A guide to good abronomic and plant nutrition practices. African plant nutrition institute. www.apni.net

[21] National irrigation authority (2022).Exploiting irrigation to improve potato farmingNational Potato Council of Kenya [NPCK], (2021). Potato variety catalogue 2021Safiorganics (January 17, 2023). Potato farming in Kenya,2023

[22] The global agriculture and food security program (GAFSP), (2021). Strengthening Farmers Resilience to Build Sustainable Food System. Annual report, 2021.

[23] Thuo C.M., Ombati J.M., Nkurumwa A.O., (2019.) Relationship between Farmers' Participation in Technology Development and Dissemination Processes; and Acceptability of Improved Sugarcane Varieties in Kakamega County International Journal of Agricultural Education and Extension (IJAEE). Vol. 5(2), pp. 250-259, www.premierpublishers.org. ISSN: 2167-0432

[24] Vroegindewey R. and Hodbod J., (2018). Resilience of agricultural value chains in developing countries context: A framework and assessment approach. Sustainability 10(4), 916.

[25] Wamuyu S.N., Bett H.K., Kariuki M.I., and Cadot J. (2022). Socio-economic factors influencing technical efficiency among smallholder potato farmers in Kenya. East Africa Agriculture Journal, Volume 86, 1-2, Pg 146-157.

[26] Waaswa A., Nkurumwa A.O., Kibe M.A., Kipkemoi N.J., (2021). Communicating climate change adaptation strategies: climate-smart agriculture information dissemination pathways among smallholder potato farmers in Gilgil Sub-County, Kenya. Sciencedirect. Volume 7, Issue 8. *https://doi.org/10.1016/j.heliyon.2021.e07873*

[27] Yagi, K., Shiratori K., Alemu D., & Bekele A. (2014). Seed Farmers School (SFS). Experience of Quality Seed Promotion Project. ISBN978-99944-5388-5.