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Indigenous knowledge application in increasing food security: A measure to consider?

Authors:
Charles A. Masango[1]
Victor W. Mbarika[2]

Affiliations:
[1]Research Office, University of Cape Town, Cape Town, South Africa

[2]College of Business, East Carolina University, Greenville, NC, United States

Corresponding author:
Chareles Masango,
charles.masango@uct.ac.za

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This article examines the role of indigenous knowledge (IK) in increasing food security. It questions whether IK can be regarded as inferior to increasing food security given that food scientists and technologists use scientific methods in increasing food security. The rationales for the examination stem from the notion that while IK has been recognised as one avenue for increasing food security, such knowledge is treated as inferior to modern measures or techniques. People who use IK are associated with poverty, backwardness and superstitions. Indigenous knowledge is often marginalised and given little attention in the mainstream studies, research and development institutions. Many professional experts tend to scoff or criticise such knowledge system, viewing them as nonsensical, superstitions, irrational and mythical. The article explores a theoretical research based on an extensive literature review for using IK in increasing food security and advances reasons why IK may or may not be regarded as inferior to increase food security. The theoretical research may be seen as a limitation in this topic, as an empirical research based on interview may have produced a better result. The article reveals that both modern technologies and IK play an important role in increasing food security. Following that IK as Intellectual Property (IP) is taking new significance in the search for answers to many of the world's most vexing problems, the article proposes measures within Intellectual Property Rights (IPR) in the form of patent and other approaches through which IK could be applied with other scientific methods to increase food security.

Keywords: indigenous knowledge (IK); food security; scientific methods; Intellectual Property Rights (IPR); Patent.

Introduction

There are many definitions of indigenous knowledge (IK). Masinde and Bagula (2011:277) define IK to be 'a body of knowledge built up by a group of people through generations of living in close contact with nature'. The Interinstitutional Center for Indigenous Knowledge (2012) note that IK focuses on 1000 years of knowing, seeing, thinking, experimentation and innovation in areas such as agriculture, animal husbandry, child rearing practices, education systems, medicine and natural resource management that are orally passed down from generation to generation. According to Ajibade (2003:100), IK is used to 'distinguish between knowledge systems developed by a community and scientific knowledge system which are generally referred to a Western or modern knowledge'. Following Kamwendo and Kamwendo (2014), IK is knowledge about soil fertility, disease resistance and quickly growing crops, soil conservation, weather forecast, pests and disease control, food preservation, processing and storage as well as water management techniques. Awuor (2013) is of the view that IK is the basis for local-level decision making in areas of seed selection, food storage and processing. Indigenous knowledge is 'knowledge that is unique to a given culture or society and denotes deeper understanding of the world around a particular community' (Tweheyo 2018:3). The purpose of this article is to examine the role of IK in increasing food security. This is by questioning whether IK can be viewed as inferior to increase food security because food scientists and technologists use scientific methods to increase food security. The rationale for the examination stems from the notion that although IK has been recognised as one avenue for increasing food security, 'such knowledge is treated as inferior to modern measures or techniques' (Kamwendo & Kamwendo 2014:97). Tweheyo (2018:3) is of the view that people who employ 'indigenous knowledge are linked with poverty, backwardness and superstitions'. It is reported that notwithstanding its perceived usefulness, IK is often marginalised and given little attention in studies, research and development institutions (Ghale & Upreti 2000). Furthermore, many professional experts tend to scoff or criticise such knowledge systems, viewing them as inferior, nonsensical, superstitions, irrational, and mythical (Kamwendo & Kamwendo 2014:97; Thrupp 1989). This article explores a theoretical research based on an extensive literature review on the rationale for using IK in increasing food security and advances reasons why IK may or may not be regarded as inferior to increase food security.

The objectives of this article are to examine the rationale for engaging IK to increase food security; examine the use of modern technology in increasing food security; explore the use of IK to increase food security; and explore the possible reasons why IK may and may not be inferior to increase food security. Finally, considering that IK as intellectual property (IP) is taking new significance in the search for answers to many of the world's most vexing problems (Interinstitutional Center for Indigenous Knowledge 2012), the article proposes measures within Intellectual Property Rights (IPR) in the form of patent and other approaches through which IK could be applied with other scientific methods to increase food security.

Rationale for using indigenous knowledge to increase food security

Among the rationale for using IK to increase food security is because it encompasses a 'non-conventional body of knowledge that deals with … the beliefs, practices and technologies developed without direct inputs from the modern, formal, scientific establishment' (Adedipe, Okuneye & Ayinde 2004:2). Nnadi, Chikaire and Ezudike (2013:19) explain that IK 'pertain to various cultural norms, social roles, or physical conditions'. In the view of Nnadi et al. (2013:14,15), a lack of documentation is a characteristic of IK, as it is mainly preserved in the memories of those who know it. Thus, IK:

> [*R*]ely on locally available skills and materials and are thus often more cost effective than introducing exotic technologies from outside sources … [*and*] local people are familiar with them and … do not need any specialised training. (Nnadi et al. 2013:19)

The World Bank (1998) points out that IK is:

> [*K*]nowledge that indigenous people have brought down with them from earlier times via the oral tradition [*and it is knowledge*] … used by local people to make a living in a particular environment. (p. 4)

It is argued that IK has:

> [*E*]volved through unintended experimentation, fortuitous mistakes and natural selection by farmers, and arises from the practical judgement and skill needed to survive in a fragile soil system by a number of environmental challenges. (Adedipe et al. 2004:2)

Bruchac (2014:3) adds that 'indigenous peoples around the world have preserved distinctive understandings, rooted in cultural experience, [which] guide relations among human, non-human, and other-than human beings in specific ecosystems'. Grenier (1998) opines that IK is based on experience tested over centuries of use. Nnadi et al. (2013:19) clarify that IK systems often are elaborate and adapted to local cultural and environmental conditions; and their efficiency lies in the capacity to adapt to changing circumstances. Thus, people who are familiar with indigenous practices and technologies can understand, handle and maintain them better than introduced Western practices and technologies. This is important as people are less dependent on 'outside supplies which can be costly, scares and unavailable regularly' (Nnadi et al. 2013:20).

Furthermore, because farmers are knowledgeable about their resources and the environment, as these govern their farming practices, and cultural heritage as well as traditional governance and leadership structures, and these are verifiable by scientific enquiry methodologies (Adedipe et al. 2004:2) is a justification for using IK to increase food security. Tharaken (2017) is of the view that IK covers all aspects of agriculture and health. Mazzocchi (2006) opines that:

> [*C*]ultures from all over the world have developed different views of nature throughout human history. Many of them are rooted in traditional systems of beliefs, which indigenous people use to understand and interpret their biophysical environment. (p. 463)

According to Nnadi et al. (2013:14), IK is a significant asset with regard to the social capital of local people and constitutes their main resources for their livelihoods. For example, farmers mostly in developing countries have planned agricultural production by using their IK to ensure food security. Khin (2019) adds that local people depend on the lands and resources on which they live and are inseparable to their identities, cultures and livelihoods.

Following that IK has the potential to incorporate shifting cultivation is a motivation for using the knowledge to increase food security. According to Warner (1991:9), 'shifting cultivation is the most widespread type of tropical soil management technique [and] … shifting cultivation are currently practiced on 30% of the world's exploitable soils'. Corroborating this view, Junqueira et al. (2016) opine that shifting cultivation is one of the most important forms of agriculture in the tropics, forming the subsistence base for many communities. Thrupp, Hecht and Browder (1997) add that:

> [*S*]hifting cultivation is the most complex and multifaceted form of agriculture in the world. Its highly diverse land use systems have been evolving since as early as 10,000 BC in a wide range of distinct socioeconomic and ecological conditions, from montane to lowland ecosystems, and from tropical forests to grasslands. (p. 1)

Adedipe et al. (2004:4) point out that shifting cultivation is generally accepted as a reasonable and effective method of maintaining fertility and output under appropriate circumstances. This is because shifting cultivation is often characterised by a season-to-season progression of different crops, which differ in soil nutrient requirements and susceptibility to weeds and pests. The specific crops and choice of succession may differ from country to country, but the 'general principle of the indigenous knowledge remains the same, although the essential character is being modified by emerging farming systems such as zero tillage and alley cropping' (Adedipe et al. 2004:4).

Furthermore, considering that indigenous farmers have used IK to develop various techniques to improve or maintain soil fertility is a rationale for using IK to increase food security. International Atomic Energy Agency (1998–2022) opines that soil fertility is the ability of soil to sustain plant growth and optimise crop yield. Nnadi et al. (2013) report that:

> [*L*]ocal farmers in the tropics have been known to conserve C in soils through the use of zero tilling practices in cultivation, mulching and other soil management technique. Natural mulches moderate soil temperatures and extremes, suppress diseases and harmful pests, and consume soil moisture. Before the advent of chemical fertilizers, local farmers largely depended on organic farming, which also is capable of reducing GHG emissions. (p. 18)

According to the International Atomic Energy Agency (1998–2022), soil fertility can be enhanced through organic and inorganic fertilisers to the soil. INFONET [n.d.] adds that sources of plant nutrients include soil reserves, crop residues, as well as organic and inorganic fertilisers that are added to the soil. The benefits of soil fertility were illustrated in Sudan, Zaire and Senegal. Adedipe et al. (2004) report that:

> farmers in Southern Sudan and in Zaire noticed that the sites of termite mounds are particularly good for growing sorghum and cowpea. In Senegal, the indigenous agrosilvo-pastoral system takes advantage of the multiple benefits provided by Faidherbia (formerly Acacia) albida. The tree sheds its leaves at the onset of the wet season, permitting enough light to penetrate for the growth of sorghum and millet, yet still providing enough shade to reduce the effects of intense heat. The tree also fixes nitrogen for improving crop yield. This represents a good IK of the plant physiological principles of canopy structure, light penetration and nitrogen fixation in moderating photosynthesis and crop productivity. (p. 4)

Nnadi et al. (2013:19) opine that IK can provide a powerful basis from which alternative ways of managing resources can be developed as the knowledge is dynamic, 'changing through indigenous mechanisms of creativity and innovativeness'.

Another ground for using IK to increase food security is because it can be used for biological pest control. Adedipe et al. (2004) are of the view that:

> biological pest control has been of recent scientific interest, yet IK practices pertaining thereto have been in existence for over a century, particularly in China where citrus growers place nests of the predacious ant Oecophylla smaragdini in orange trees to reduce insect damage. In India, local farmers intentionally plant sunflower in wheat fields so as to aid the bio-control of rats by owls at the stage of grain development. (p. 4)

According to Nnadi et al. (2013:18), 'indigenous knowledge provides the basis for problem solving strategies for local communities especially the poor'. Mihale et al. (2009:252) add that although the use of synthetic pesticides has been promoted for the past three to four decades, farmers are yet to fully integrate them into their insect pest management systems because of their high poverty levels. 'This makes them to rely on indigenous knowledge (IK) systems to meet their daily needs which are most relevant to the rural poor and marginalised population' (Mihale et al. 2009:252). In addition, Grzywacz et al. (2014) opine that the existing crop protection paradigm that relies on synthetic agrochemical pesticides has a marginal impact on the productivity of many poor farmers who constitute a major segment of agriculture:

> This is primarily because many of them are not able to afford or access these imported chemicals. A solution to this crop protection problem may be to harness biological resources that are locally available, such as endemic insect natural enemies and indigenous pesticidal plant materials. (p. 71)

Modern technology used in increasing food security

According to Fries (2017), technology holds remarkable guarantee for solving today's food challenges. Corroborating this view, Popp, Pető and Nagy (2013:243) argue that 'technology will unquestionably hold many of the keys to long-term global food security'. Stewart and Roberts (2012:78) acknowledge that there is 'enormous potential to raise crop yields with existing technologies'. Among the modern technologies used in increasing food security is chemical fertiliser. It is reported that chemical fertilisers on farm land boost the levels of nutrients in the soil, increasing crop yields (Biology Notes for IGCSE 2014). Stewart and Roberts (2012) add that:

> [*B*]oosting crop yields and closing the gap between actual and attainable yield can be achieved by the implementation and advancement of numerous practices and technologies, including nutrient management practices and fertilizer technologies. (p. 76)

Stewart and Roberts (2012) further add that:

> [*O*]ne-third of the increase in cereal production worldwide and half of the increase in India's grain production during the 1970s and 1980s have been attributed to increased fertilizer consumption. Since the mid-1960s, 50 to 75% of the crop yield increases in Asian developing countries have been attributed to fertilizers. (p. 79)

Furthermore, it is reported that studies from temperate climates clearly show how essential fertiliser is in cereal productivity, accounting for at least half of the crop yield. In addition, Stewart and Roberts (2012:81) report that 'fertilization is imperative if production from cleared land is to be continued for more than just a few cropping cycles'.

Another modern technology used in increasing food security is pesticides. According to the International Atomic Energy Agency (1998–2019), pesticide is a broad term, covering a wide range of products that are used to control pests in agriculture, such as insecticides, fungicides or herbicides (weed control). Bonner and Alvanja (2017:89) are of the view that 'pesticides are substances used to prevent, destroy, repel or mitigate any pest ranging from insects, animals and weeds to microorganisms'. Oerke (2006:31) is of the view that 'productivity of crops grown for human … consumption is at risk due to the incidence of pests'. It is reported that globally, an average of 35% of potential crop yield is lost to pre-harvest pests (Poppet al. 2013). According to Biology Notes for IGCSE (2014), the use of pesticides such as insecticides and fungicides to kill pests that feed on and damage crops increase crop yields. Oerke (2006:31) points out that 'the intensity of crop protection has increased considerably as exemplified by a 15–20 fold increase in the amount of pesticides used worldwide'. Andrade (2016) adds that pests and diseases are frequent constraints and can significantly reduce crop productivity. According to Oerke and Dehne (2004:275), 'among crops the loss potential of pests worldwide varied from less than 50% on barley to more than 80% on sugar beet and cotton'. Stewart and Roberts (2012:82) opine that 'the employment and further advancement of many technologies [such as] pest control [is] needed to meet the challenge ahead … to close the gap between actual and attainable yields'. Oerke and Dehne (2004) assert that the reduction of yield losses caused by pests are major challenges to agricultural production. Oerke (2006) acknowledges that:

> [*P*]esticide use has enabled farmers to modify production systems and to increase crop productivity without sustaining the higher losses likely to occur from an increased susceptibility to the damaging effect of pests. (p. 31)

According to Carvalho (2006:685), because of the 'resistance developed by pests to chemicals, every year … new chemical compounds are used to protect crops, [*to increase*] … the costs of food production'.

The use of modern machinery is a technology that increases food security. Corroborating this view, Biology Notes for IGCSE (2014) opine that the use of modern machinery, such as tractors and combine harvesters enables land and crops to be managed more efficiently. According to Rapsomanikis (2015:19), 'mechanically-powered technologies, such as tractors ... can contribute significantly towards increased production'. Negrete (2019) points out that:

> [*I*]t is less strenuous to drive a tractor, than to cultivate the field all day with a hoe or other hand tool. A tractor pulling a plow can grow an area larger than a man with a hand tool, at the same time, with the consequent increase in productivity and reduction in operating times. (p. 13)

According to Yang et al. (2018:99), 'modernization in agrarian production system has a significant influence on the availability of adequate and vigorous food, and also responsible for sustainable food supplies'. According to Bafana (2019) and Piesse (2019), because mechanisation improves land management and productivity as well as the quality of the crops that are produced, a wider adoption of agricultural machinery is necessary to raise crop yields and improve food security. Emami et al. (2018) opine that one of the strategies to increase agricultural production is mechanisation. It is reported that:

> [*A*]ttractive attributes of agricultural mechanization are deliverance of seed quantity and quality, redemptive 15% to 20% fertilizer, economize 20% to 30% time and labour, elevate 5% to 20% crop intensity and 10% to 15% productivity. (Yang et al. 2018: 100)

Negrete (2019) adds that:

> [*M*]echanization facilitates and reduces heavy work, alleviates the lack of labour, improves productivity and opportunity of agricultural operations, improves the efficient use of resources, strengthens access to markets and contributes to the mitigation of climate-related threats. (p. 13)

Yang et al. (2018:98) are of the view that the 'application of contemporary technologies in agriculture is a key for food security [*as it has the potential to*] rise food production'.

According to the Biology Notes for IGCSE (2014), a modern technology in increasing food security is the use of satellites to monitor crop development. Watanabe (2019) adds that with more informed farmers, better use of resources and ultimately more crops, satellites may be an important part of ensuring global food security. Powell (2015) points out that the first successful weather satellite, TIROS-1, was launched in 1960. The images picked up a typhoon 1000 miles east of Australia and showed the benefits of space observations, ushering in an era of much more accurate weather information. Watanabe (2019) opines that satellite-based technology can map cropland area and crop type, estimate area planted, estimate product yield and even detect early signs of droughts and floods. Watanabe (2019) adds that 95% of sub-Saharan Africa's farmable land lacks irrigation systems, thus making the farmland more susceptible to drastic land conditions such as droughts and floods. According to Vota (2017), from satellites circling the earth to ground-based remote sensors in the oceans, rivers and farms, it is possible to forecast the drivers of food insecurity with increasingly higher degrees of accuracy. For example, with satellite technology and remote sensing, farmers can shift their focus from reacting to disasters after they occur to planning response before the disasters cause damage. Because low soil moisture content is an indicator of drought, satellites can measure the soil's moisture content using microwave radiation and send an early warning to farmers in the affected area (Watanabe 2019). Watanabe (2019) points out that with satellite-based technology, farmers are better equipped to make informed choices about their land to protect their products. In places such as sub-Saharan Africa, where agriculture accounts for 64% of all employment, satellite-based technology is vital to combat food security.

Crop improvement through accelerated breeding is a modern technology in increasing food security. Lenaerts, Collard and Demont (2019) are of the view that population growth, climate change and economic growth are posing serious challenges to food security. Lenaerts et al. (2019) opine that crop improvement through breeding has been the major tool to lift people out of poverty and increase food security. To boost modern breeding, accelerated breeding method has utilised rapid generation advance (RGA) resulting to, for example, semi-dwarfness being bred into modern rice and wheat varieties, leading to a high yield and lodging-resistant varieties; maize being biofortified with increased beta-carotene; non-ripening tomato being developed with extended shelf life (Nature Plants 2018). Lenaerts et al. (2019)

point out that the advantages of RGA methods are speed, technical simplicity, requirement of less resources and low costs. It is reported that molecular breeding that encompasses modern breeding strategies, where DNA markers are used as a substitute for phenotypic selection to accelerate the release of improved germplasm, can be conveniently incorporated into RGS systems (Lenaerts et al. 2019).

Indigenous knowledge used in increasing food security

It can be said that developing countries typically develop food security strategies following paths and processes (Andrade 2016) that encompass IK as 'indigenous knowledge is increasingly becoming part of the development agenda [with the multiplicity of] local initiatives … which deserves to be exploited more systematically' (Tweheyo 2018:2). According to Meadu (n.d.), research knowledge generated at the local level has the potential to increase food security. It is reported that people in rural areas have always relied on their personal networks for information to help them weather crises, improve productivity and limit crop losses. In return, these relationships have facilitated the exchange of information and goods, diversified diets, strengthened farming techniques and guarded against hunger (Samberg 2020). Samberg (2020) adds that in order to increase food security the underpinnings of rural resilience must be supported, expanded and diversified. Mkentane (2018) opines that in order to realise food security, full benefits including the use of precision farming that encompass IK need to be exploited.

Among the indigenous methods used to increase food security is the storage of food in the granary. According to Tweheyo (2018:31), 'seed storage structures and granaries used by small scale farmers continue to draw heavily on traditional technologies'. The major purposes for granary storage are to:

> [*P*]reserve food for a long period of time so that they can be consumed in future; to preserve seeds for next season planting; to protect food from pests and weevils; to protect seeds from destruction by rain water. (Tweheyo 2018:31)

It is reported that in Senegal traditional clay granaries have proved to be effective based on the knowledge that non-winnowed maize stored in a granary takes long to be infested with insects (Gueye et al. 2013). Admire and Tinashe (2014) point out that insect pests cause 30% of the post-harvest losses of grains in sub-Saharan Africa because of poor storage systems. According to Tweheyo (2018:31), 'storage can play a significant role in influencing small scale farmers' decisions about the diversity of crops and varieties they adopt and maintain'. Tweheyo (2018) add that some foods, especially cereals like millet, sorghum, maize; grains such as beans and peas are stored in granaries. The granaries are constructed at a raised level to allow air flow and smeared with cow dung to prevent grains from being attacked by weevils and pests. Smelser and Baltes (2001) point out that rural people possess a wealth of knowledge that encompasses knowledge of the quality and relationship among crops, soil texture, climate change and pest control. Chambers (1989) opines that rural households' ability to classify, choose, improvise, adapt and test indigenous technology illustrated by examples of potato storage technology, seed variety selection, agro forestry, tool making, invention of complex cropping patterns, soil conservation, water harvesting and use of native species reflect their rich IK for enhancing food security.

Another indigenous method used to increase food security is smoking food. According to Tweheyo (2018:30), 'indigenous knowledge that enhances food and nutrition security is thus instantiated in meat preservation by smoking it'. Eyong (2007) says the practice of smoked meat originated in pre-history. The rationale behind smoking is to preserve meat for a:

> [*L*]ong period of time so that it might be consumed at a future date especially when it is scarce; traditionally, eating dry meat is deemed healthy because it is one way of reducing intake of cholesterol in the human body; socially, smoking meat preserves it for someone who is not currently at home, or abrupt and special visitors, a sign of togetherness and respect [*and*] it is also done as a preventive measure against famine. (Tweheyo 2018:30)

It is reported that when red meat or fish is smoked, it preserves the food that would otherwise spoil quickly, for long periods as the absorbed smoke acts as a preservative (Awuor 2013). Tweheyo (2018:30) points out that 'meat smoking was performed as a means of preserving it because smoking makes meat thoroughly dry so that it is kept for a long period of time'. Tweheyo (2018) adds that local people have precise knowledge of smoking food items such as meat, fish, maize and cassava. The practice is that racks are built in the kitchen on top of cooking fire, and meat or any other given food is placed on the rack and smoked until it is thoroughly dry. The rationale is to prolong its shelf life and preserve it from contamination. This procedure is important as it serves as a means of food preservation and as a health-promoting practice. Smoked meat is prepared whenever there is an emergency or in time of food shortage. Traditionally, smoking meat is performed as a means of preserving it because smoke itself acts like an acidic coating on the surface of meat hence preventing the growth of bacteria.

The selection of indigenous seed varieties is another indigenous method used to increase food security. According to Tweheyo (2018), local people in rural dwellings have knowledge of drought and disease-resistant seeds and hence have a drought-coping mechanism. They know which seeds do well in certain types of soils and those which do not in certain conditions based on their experiences. They have knowledge about seeds that mature fast and those that are good in responding to famine after long dry spells or other natural disasters. All this knowledge enables people to make a proper choice of seeds rather than buying from seed stores. This means that the use of agrochemicals and fertilisers is less important to them. Kamwendo and Kamwendo (2014) corroborate that with all this knowledge the use of agrochemicals and fertilisers may be irrelevant to rural dwellers. According to Tweheyo (2018), indigenous peoples' practices and techniques constitute the principles of permanence that permit continuous cropping all year around without the use of chemicals that do degrade the soil. Tweheyo (2018:29) adds that in Uganda, most cultures have 'early warning systems for weather prediction based on indigenous systems, for example, observing migratory patterns of certain bird species, water bodies of particular wells or streams, earthquakes, rainbow, and certain species of trees'. Gueye et al. (2013) point out that notwithstanding that the seed varieties developed by plant breeders are appreciated by market-oriented and large farmers, local farmers prefer varieties with good yields and which are reliable throughout the year despite adverse environmental conditions. Rural farmers believe that their indigenous seeds are less associated with health threats**.** Corroborating this view, Linnemann and De Bruyn (1987) say, farmers prefer their own seed for adaptation to their farming systems. It is reported that in Zambia, farmers' evaluation of high-yielding hybrid maize varieties and their description of the positive and negative characteristics of the locally adapted open-pollinated varieties have led to a more effective national maize-growing programme (Mwende 2011). According to Tweheyo (2018:33), indigenous seeds are selected based on:

> [*M*]aturity time, resilience to adverse climatic conditions, sweetness/taste, germination rate, sustainability, healthy ears/traits, cost of seed during planting season, and price after harvesting. They are also selected based on storability, open pollinated seeds, quality texture, marketability, disease and pest resistance, yield and the fact that they do not, need chemical fertilizers.

Is indigenous knowledge inferior in increasing food security?

It can be argued that new technologies are too complex for members of the public to understand as most small-scale farmers are not educated (Maynard 2016). This is a possible reason why IK may not be considered inferior in increasing food security. It is reported that, in Uganda, the education level of rural farmers is low and about 46% of rural farmers still 'prefer exclusively indigenous practices of farming and food security improvement' (Tweheyo 2018:49). In Ethiopia, the head of the average rural farmer:

> [*H*]as attained 2 years of education. In the United Republic of Tanzania, where just 9.7 percent of the population completes their primary school education, the [rural famer] head attains 4.6 years of school. ... In Nicaragua and Bangladesh the average years of schooling of the [*rural famer*] family head is about 3 years. (Rapsomanikis 2015:20)

Tweheyo (2018) explains that, in Uganda, IK is dominant in all key farming activities, especially in seed selection, food storage and processing. Maynard (2016) opines that for a new technology to be accepted and adopted within society, communities that are potentially impacted by it need to understand the benefits and risks to them. It is reported that many communities calling for food sovereignty are protesting the imposition of Western technologies on to their indigenous systems, which they believe might endanger their health (Kamwendo & Kamwendo 2014). Gueye et al. (2013) add that the use of agro-chemicals and fertilisers is adversely impacting on peoples' health and on the environment, while genetically modified foods are causing nutritional problems in the society. Khapayi and Celliers (2016) argue that chemicals such as pesticides and herbicides and integrated pest management methods need someone who will understand them and their instructions because they can be dangerous to humans. Tweheyo (2018) further adds that in Uganda farmers argued that unlike chemicals, red pepper, for example, is effective in preventing grains from weevil infestation and this does not have health hazards. According to Adams and Taylor (2012) people must have access to foods that are safe and acceptable.

Because soil degradation is caused by the misuse of industrial chemicals is another reason why IK may not be considered inferior in increasing food security. According to Lal (2015), there are four types of soil degradation that are physical, chemical, biological and ecological. Tweheyo (2018:35) is of the view that 'there is serious decline in soil organisms and soil nutrients as a result of misuse of industrial chemicals'. Lal (2015) adds that soil chemical degradation is characterised by acidification, salinisation, nutrient depletion, reduced cation exchange capacity, increased Al or Mn toxicities, Ca or Mg deficiencies, leaching of NO_3-N or other essential plant nutrients, or contamination by industrial wastes or by-products. Briggs (2005) argues that many insects and fungi commonly seen as enemies of food production that may be destroyed by chemicals are actually valuable for pollination. They contribute to biomass, natural nutrient production as well as natural enemies to insects and crop diseases. According to Rinkesh (2020), the excessive use and misuse of chemicals kill organisms that assist in binding the soil together as chemicals contribute to the killing of soil's beneficial bacteria and other micro-organisms that help in soil formation. Ting (2015) is of the view that beneficial insects and fungi suffer because of excessive use of chemicals making crops more susceptible to pests and diseases. Aktar, Sengupta and Chowdhury (2009) opine that chemicals must be lethal to the targeted pest, but not to non-target species. The rampant use of chemicals has played havoc with human and other life forms.

Indigenous knowledge may not be considered inferior in increasing food security because rural farmers 'cannot afford modern methods of farming' (Tweheyo 2018:57). Most of the world's poor live in rural areas. According to Rapsomanikis (2015:21), in Bolivia, up to 83% of rural farmers are poor compared with a national poverty average of about 61%. In Ethiopia, the poverty headcount ratio of rural farmers is 48%, and in Viet Nam, more than half of the rural farmers are poor. Furthermore, an average rural farmer in Kenya generates a gross income of about US$2527 per year, with a family size of five persons – women, men and children – this amounts to about US$1.4 per day per person. With this little money the family should meet a range of expenses – from buying food, inputs and clothes to paying for housing, education and health services. In Ethiopia, rural farmers with a farm of about 0.9 hectares generate income amounting to about US$0.8 per person per day (Rapsomanikis 2015:21). Rapsomanikis (2015) adds that:

> [*R*]ural farmers have multiple economic activities, often in the informal economy, to contribute towards their small incomes. Furthermore, rural famers cannot afford modern farming methods as they face considerable difficulties in accessing credit, as banks are often reluctant to lend to them due to poor collateral. (p. 13)

Hence, because rural farmers lack funds, they cannot own expensive farming tools such as a plough or tractor and renting it is even rarer (Rapsomanikis 2015). According to Rapsomanikis (2015:19), in Nicaragua, about 44% of rural farmers either own or rent tractors, trucks and other machinery. Even when they can, it is reported that mechanisation gives room for deep ploughing, reduction of plant cover and the formation of the hardpan (Rinkesh 2020).

However, it can be argued that IK may be considered inferior in increasing food security as opposed to modern technology when chemicals are used. It is reported that in India, for example, modern technology use has been powerful justifications for chemical use. According to Aktar et al. (2009), in the environment, most pesticides undergo photochemical transformation to produce metabolites that are relatively non-toxic to both human beings and the environment. As a result of the use of high-yield varieties of seeds, advanced irrigation technologies and agricultural chemicals, for example, food grain production, which stood at a mere 50 million tons in 1948–1949, increased almost fourfold to 198 million tons by the end of 1996–1997 from an estimated 169 million hectares of permanently cropped land (Aktar et al. 2009).

Furthermore, with the advent of climate change, modern technology as opposed to IK is a better option to increasing food security. Samberg (2020) opines that with people on the move, and climate change a growing concern, traditional information is no longer sufficient in increasing food security. According to the United States Environmental Protection Agency (2017), climate change can disrupt food availability, reduce access to food and affect food quality. For example, projected increases in temperatures, changes in precipitation patterns, changes in extreme weather events and reductions in water availability may all result in reduced agricultural productivity. Increases in the frequency and severity of extreme weather events can also interrupt food delivery, and resulting spikes in food prices after extreme events are expected to be more frequent in the future. Increasing temperatures can contribute to spoilage and contamination. Hence, in order to avert spoilage and contamination, modern technology such as satellite-based technology can be used as it has the potential to detect early signs of drought and floods (Watanabe 2019).

Because most of the personal networks on which farmers have traditionally depended to cope with issues of food security have been degraded is a rationale for the use of modern technologies as opposed to IK for food security. According to Samberg (2020), rural farmers have always relied on their personal networks for information to assist them during weather crises, improve productivity and limit crop losses. In return, these relationships have facilitated the exchange of information and goods, diversified diets, strengthened farming techniques and guarded against hunger. It can be argued that this is not the case today as farmers are hit by severe weather and violent conflicts forcing them to move and consequently discard their personal networks in the process. Edmond (2021) adds that around the world, someone is displaced every 3 s, forced from their homes by violence, war and persecution. Ironically, most of these displaced people are rural farmers. According to Samberg (2020), to improve food security today is by investing in new technologies that enable farmers to connect with information that can decrease uncertainty and mitigate risk. These new technologies are mobile networks and apps designed to collect and share agricultural information.

Intellectual Property Rights and other measures to enhance increase in food security

It can be said that IK can increase food security if, for example, small-scale farmers improve on the methods they use to increase food security and patent it as patents proffer rewards for the inventors (Ismail & Fakir 2004). According to Tweheyo (2018), indigenous peoples' protection of their IPR is extremely vital. The methods encompass granary, smoking and the selection of indigenous seed varieties. The patent would be a legal agreement that would state that all proceeds acquired from these methods would be shared among those farmers who patented the product. Ismail and Fakir (2004) opine that it is possible for proceeds to be shared within patentees by cartels being established to manage differing interests of multiple indigenous owners. Tweheyo (2018:34) is of the view that 'recognizing indigenous people and encouraging them to determine how their indigenous knowledge should be shared … is very important'. This could be that a legal agreement of the various governments of countries where, for example, the small-scale farmers come from would enact proper IPR in the form of patent laws to back the agreement. The incentive for patent protection is to enable the farmers to keep out all others from making, selling or using their product. According to Upadhya et al. (2014), firm and strong initiatives are required, both at the national and international levels, to protect the IPR of small-scale farmers. Wilder (2001) adds that countries are obliged to provide patent protection for any inventions, whether products or processes, in all fields of technology. It can be argued that through patent laws small-scale farmers would have a legal monopoly with the right to profit economically (Britz & Lipinski 2001).

Furthermore, to increase food security, it may be profitable and cost effective to apply both IK and modern technologies. According to Lemma and Hoffman (2007), the more local people experiment with external technologies, the more they strengthen their IK and practices. Asaba et al. (2006) add that external knowledge is a key component in improving small-scale agriculture. Adedipe et al. (2004:5) opine that 'IK should be supplemented with modern technologies'. Nnadi et al. (2013:14) explain that 'sustainable agricultural development may be better served by a system that unifies both indigenous and external knowledge systems'. Stewart and Roberts (2012:76) add that highest agricultural yields are the result of 'using both organic and inorganic nutrient sources'. According to Magni (2016), retaining IK and its use and only gradually adopting innovations would in turn preserve environmental damage potentially caused by high-tech alternatives to IK. Hence, for biological pest control on citrus, for example, both pesticides and the placement of nests on ant *Oecophylla smaragdini* to reduce insect damage as it is done in China may be cost effective. What *O. smaragdini* cannot eradicate, the pesticides will eradicate and vice versa. Also, by using both IK and modern technology, bio-control of rats by owls, for example, can be cost effective. It is reported that in India, local farmers intentionally plant sunflower in wheat fields to aid the bio-control of rats by owls. What, for example, the sunflower will not be able to eradicate, modern technology application of pesticides would do and vice versa. This is because it is important for scientists to respect and understand people's IK and build on them from within (Twikirize et al. 2013). Ogundiran (2019) further adds that IK empirical research can efficiently inform modern technologies on how to successfully achieve food security and food sovereignty. According to Hall and Midgley (2007), development approaches and interventions that do not consider people's IK and experiences have proved to be of limited effectiveness in addressing mass poverty and promoting human welfare. Thus, development should not mean a rejection of all past practices but rather building on them to ensure sustainability.

Furthermore, to effectively blend modern technologies and IK, small-scale farmers should be encouraged to upgrade their agricultural education level in either formal agricultural training institutions or colleges. Following that the educational levels of most small-scale farmers are low (Tweheyo 2018), they lack the knowledge to operate within the ambit of modern technologies. When small-scale farmers upgrade their educational level, they will be able to better use farming resources (Watanabe 2019). It can be argued that when small-scale farmers are better educated they will be able to identify and understand the benefits of modern technologies (Maynard 2016); and possibly refrain from protesting the imposition of modern technologies, which they say endangers their health (Kamwendo & Kamwendo 2014). With their upgraded agricultural education, they will be able to source information that will, for example, reveal to them that the use of agro-chemical and fertilisers does not adversely impact negatively on peoples' health and environment. Also, when the farmers upgrade their educational level, they would refrain from, for example, only applying their IK in seed selection, food storage and processing. It is reported that because of the low level of education among small-scale farmers IK is dominant in 'seed selection, food storage and processing' (Tweheyo 2018:43).

Conclusion

Although the research took a theoretical and not an empirical path based on interviews, it can be said that notwithstanding that modern technologies can be used in increasing food security, it is worth acknowledging that IK equally plays an important role in increasing food security. Because both modern technologies and IK play an important role in increasing food security, it may be reasonable and cost effective to apply both IK and modern technologies to increase food security. Furthermore, if modern technologies used to increase food security have IPR protection, it would be reasonable for small-scale farmers to protect their mode of increasing food security through IPR as it is equally a technology. Harris (2019) opines that IP protection is significant in an economy disrupted by technology. Patents, trademarks, copyright and designs are all gaining increasing significance alongside a dramatic rise in other types of IP protection, such as trade secrets and non-disclosure agreements. One can therefore argue that for a cost-effective mode of increasing food security, it would be germane to apply both modern technologies and IK.

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The authors have declared that no competing interest exists.

Authors' contributions

V.W.M. conceptualised the article together with C.A.M. who was involved in the conceptualisation, analyses and writing of the article.

Ethical considerations

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