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# The Role of Indigenous Vegetables to Improve Food and Nutrition Security: Experiences From the Project HORTINLEA in Kenya (2014–2018)

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Many warning signs indicate that the food security goals formulated in 2015 will not be achieved. This situation is particularly true for the African continent. After substantial progress up to 2015, the situation has hardly improved or has worsened in many respects. In addition to the rapid population growth, the increasingly frequent long dry periods or sometimes erratic rainfall have contributed to this. In addition, current production systems have dysfunctional side effects due to increasing yield optimization and specialization. Thus, besides the associated resource degradation, it also leads to a monotonous food supply and the emergence of vitamin and mineral deficiencies (hidden hunger). A meaningful way to diversify the food supply is to cultivate and market previously underutilized species. However, they are characterized by not being known and traded globally and usually having only local importance. Accordingly, they have been widely ignored in research. Increasingly, however, there is a growing realization worldwide that these plants can make an essential contribution to food and nutrition security, especially for poorer segments of the population. Moreover, they are adapted to local conditions and are often produced with less resource input. This article aims to show how these species can be better utilized to provide nutritious food through sustainable production, using the example of African indigenous vegetables. In doing so, the impact of emerging social and ecological changes in Kenya will be considered. This source is an interdisciplinary collaborative research project, Horticultural Innovation and Learning for Improved Nutrition and Livelihood in East Africa (HORTINLEA), which was carried out in Kenya from 2014 to 2018. Many different disciplines were involved in the German-African cooperation project. The results will be brought together in this article with the help of a food-sensitive value chain approach, and the experiences gained from this project will be reflected.

**Keywords: African indigenous vegetables, smallholder, nutrition-sensitive value chains, gender, climate change, urbanization, food security, post harvest management**

# INTRODUCTION

## Problem Background of the Project

In September 2015, 192 countries approved the 2030 Development Agenda at the UN General Assembly, entitled "Changing our world: the 2030 Agenda for Sustainable Development". SDG 2 and SDG 3 occupy an important place among the 17 goals: Zero Hunger, Good Health and Wellbeing (Griggs et al., 2017). From 2000 until 2014, the number of chronically undernourished people steadily decreased. Since 2014, however, this trend has reversed. The United Nations estimates that between 720 and 811 million of the world's 7.7 billion people were suffering from hunger in 2020. More than two billion people, about a quarter of the world's population, had no regular access to nutritious and sufficient food in 2019 (Food Agriculture Organization of the United Nations, 2021). Projections for 2030 highlight that the current effort is not even close to ending malnutrition in the next decade (FAO, IFAD, UNICEF, WFP, and WHO, 2021).

Globally, about 150 million children under five are suffering from stunting in 2020. Forty-five million of these children were wasted. At the same time, about 39 million children worldwide under 5 years are overweight (United Nations Children's Fund, 2021). Childhood obesity has almost tripled worldwide since 1975 and now reaches every country in the world (Global Panel on Agriculture Food Systems for Nutrition, 2020).

On the other hand, food systems are a significant cause of environmental degradation on which they depend (High-Level Panel of Experts on Food Security Nutrition, 2019; Global Panel on Agriculture Food Systems for Nutrition, 2020; International Panel of Experts on Sustainable Food Systems, 2020). They are the most critical cause of anthropogenic greenhouse gas emissions (28% between 2007 and 2016), and agriculture alone accounts for 70% of freshwater consumption.

Sub-Saharan Africa's population continues to increase significantly. In Kenya, the strong population growth with an average annual growth rate of 2.3% (United Nations Department of Economic Social Affairs Population Dynamics, 2021) has led to increasing demand for food and increased use of natural resources. As in many African countries, Kenya's population will double by 2050. However, 36.8% of the population or more than 18 million people in Kenya, live below the poverty line of 1.9 US dollars a day. The prevalence of malnutrition is around 25% of the population and has risen again under the problematic climate conditions of recent years. Estimates by UNICEF at the end of August 2019 have revealed that around 665,000 children under the age of five are acutely malnourished (FAOSTAT, 2021).

At the same time, the rural migration and unfavorable climatic conditions led to low agricultural productivity and a shift to non-agricultural income-generating activities. As a result, the rural population, which constitutes the most significant part of the agricultural labor force, declined by 3.2% between 2008 and 2014 (Food Agriculture Organization of the United Nations; Swedish International Development Cooperation Agency, 2019). Thus, unless significant efforts are made, compliance with the commonly formulated nutrition targets is not expected in the coming years. Because of the increasing number of significant weather events caused by climate change, such as persistent drought or erratic rainfall combined with widespread flooding and political upheavals, confidence in a reliable supply has been lost (Béné, 2020). This situation makes it necessary to discuss the resilience of food systems, especially regarding food and nutrition security.

## The Potential of Indigenous Crops

The precondition for good nutrition is that a variety of food is available and affordable for all people at all times. Most efforts tried to ensure food and nutrition security by intensifying production and introducing high-yielding, stress-tolerant crop varieties. However, the prevailing guiding principles of agricultural intensification do not ensure universal access to a diverse diet and, in some cases, jeopardize the long-term sustainability of the agricultural resource base (Food Agriculture Organization of the United Nations, 2017).

It also reduces ecosystem services. Biodiversity is necessary for many ecosystems functions critical for agricultural production, such as pollination, soil fertility, water quality, and genetic diversity (Hunter et al., 2020; Padulosi et al., 2021). Genetic diversity in agriculture protects the ability of species to evolve in response to changing environmental conditions and increases species resistance to diseases, pests and parasites (Padulosi et al., 2011; Capuno et al., 2015; Chivenge et al., 2015; Hunter et al., 2020; Laborde et al., 2020). Agricultural diversity also enhances the supply of foods that offer nutritional benefits (Fanzo et al., 2013). The challenge, therefore, is to protect biodiversity and preserve natural resources while producing enough food.

Kenya is endowed with agrobiodiversity, such as African Indigenous Vegetables (AIVs) (Yang and Keding, 2009; Weller et al., 2015; Akinola et al., 2020). Given the increasingly perceived importance of fresh fruits and vegetables for healthy diets and the prevention of micronutrient deficiencies and diet-related non-communicable diseases, a stronger focus on the horticulture sector is crucial (Keatinge et al., 2015; Food Agriculture Organization of the United Nations, 2017; Aiyelaagbe et al., 2018; Wopereis, 2018; Laibuni et al., 2020; N'Danikou et al., 2021). About 200 indigenous plant species are used as leafy vegetables in the country. Only a few (4) have been fully domesticated, a number (15) are semi-domesticated, while most are wild (Maundu, 2018). The challenge is to protect biodiversity and natural resources while producing enough food (Gotor and Irungu, 2010; Ebert, 2014). The literature is full of evidence of benefits associated with the production and marketing of indigenous African vegetables by smallholder farmers.

- **Contribution to healthy diets:** At the local level, excessive intensification (i.e., monoculture) risks narrowing diets, thus worsening regions' nutritional situation. Indigenous vegetables are essential sources of dietary components. They contain essential minerals and vitamins necessary for maintaining human health and strengthening resistance to disease and infection (Padulosi et al., 2013; Cogill, 2015; Keatinge et al., 2015; Neugart et al., 2017).

- **Contributing to sustainable food production and climate change adaptation:** With a view to small holdings, Ricciardi et al. (2021) illustrate that smaller farms, on average, have higher yields and greater crop and non-crop biodiversity at the farm and landscape level than larger farms. Diversifying agricultural production systems by promoting underutilized species offers opportunities to strengthen the adaptation, mitigation and resilience of both natural and socio-economic systems. Being native to the African continent, AIVs have been selected over many generations against various stressors in tropical environments, especially drought. Therefore, they have co-evolved adaptive mechanisms that ensure broad adaptation (Keatinge et al., 2018). Most of them are grown very fast after the first rainfall, and harvesting begins 3–4 weeks after germination. Unlike most exotic vegetables, AIV species do not require large amounts of fertilizer and chemicals (Shayanowako et al., 2021).
- **Contributing to improving smallholder income by production, processing and marketing:** African Indigenous Vegetables (AIV) are an integral part of the diet in many Sub-Saharan African (SSA) countries. Several publications indicate that the market for these crops will continue to grow (Ngugi et al., 2006; Pichop et al., 2016; Rampa and Knaepen, 2019). In Nairobi, for example, about 30% of all vegetables sold are AIVs grown around the city. AIVs find their way from the field to the market through various channels, and AIVs support a large number of small-scale farms along the entire value chain in urban and peri-urban areas (Weinberger and Pichop, 2009). Women are significantly involved in all chain segments, including wholesale and retail. In addition, low capital requirements for entry enable even the poorest households to participate (Weinberger et al., 2011).
- **Rural development through job creation:** Rural development has risen high on the agenda of development challenges (Altenburg, 2017; Food Agriculture Organization of the United Nations; Swedish International Development Cooperation Agency, 2019; Sumberg, 2021; Sumberg et al., 2021). Due to the lack of good prospects in rural areas, many young people migrate to growing cities. However, the development of the industrial and service sectors cannot absorb this large number, so many of these youth end up in urban slums. Therefore, creating attractive jobs in rural areas is of enormous political importance. The development of modern AIV value chains could contribute to this.
- **Acceptance through cultural embeddedness:** AIVs are an essential part of the diet of many people in Sub-Saharan Africa. Rural and urban communities traditionally accept and use them as vegetables (Weinberger, 2007). The use of many of these varieties and species abundance is based on traditional knowledge about cultivation methods and meal preparation. However, this knowledge is being lost at an alarming rate (Cernansky, 2015; Maundu, 2018).

Given these potential benefits from the production, marketing and consumption of indigenous vegetables, the question arises why it has not yet been possible to give these products a higher priority in the diets of poor rural and urban dwellers. The reasons often assumed for this are the predominantly small-scale farm structure in which production occurs. Despite some advantages of small-scale production, these farms are confronted with particular constraints and obstacles and therefore find themselves in a "poverty trap" (Ngugi et al., 2006; Gatzweiler and von Braun, 2016; Poole, 2017; International Finance Corporation, 2018). For example, access to high-quality inputs (e.g., seeds and fertilizers) is often limited due to a lack of financial resources, and investments (e.g., irrigation) cannot be made. In addition, institutional deficits result in unclear land use rights (especially near larger cities) and water use rights. Often there is a lack of knowledge to adapt to climate change and increased consumer and trade demands.

Last but not least, smallholder farmers also face many interrelated risks to their livelihoods. The occurrence of those shocks not only threatens already vulnerable food production systems, but the likelihood of those events causes some smallholder farmers to become more risk-averse and to pursue more subsistence-oriented activities, thereby perpetuating smallholder poverty (Fan and Rue, 2020; Gómez y Paloma et al., 2020).

Linked to the constraints mentioned above, the increasing division of labor in the rapidly changing value chains that take the products from the producer to the consumers in the growing cities cause part of the problems (Fan et al., 2013; Fan and Rue, 2020). For example, considerable logistical demands are associated with supplying more distant sales markets. In addition, the growing number of wholesalers and retailers is placing ever higher demands on the quality and preparation of the products, including sorting standards and, in the case of supermarket supply, certification of the processes. Finally, yet important, there are changes on the consumer side. Increasing imports and demographic changes in society, such as the migration of young, well-educated people to the cities and growing middle-class development, are associated with a change in diet (Tschirley et al., 2015; Bloem and de Pee, 2017). As a result, the knowledge of traditional vegetables' nutritional value and preparation is increasingly forgotten. Moreover, higher preparation effort is no longer well-matched with larger women's work engagement and/or childcare.

## THE HORTINLEA PROJECT

This article will present results and experiences from the collaborative research project Horticultural Innovation and Learning for Improved Nutrition and Livelihood in East Africa (HORTINLEA), which focuses on promoting the production and consumption of local vegetables in Kenya and the role of smallholder farmers in this respect.

### Background Information on the HORTINLEA Project

In 2013 The German Federal Ministry of Education and Research (BMBF) had launched the funding initiative "Global food security" (GlobE) to support the development

of sustainable and high-yield agriculture. Projects of the funding initiative "should follow a systemic and interdisciplinary approach: In collaboration with local partners, the situation on the ground should be analyzed before the start of the investigations and, based on this, research questions for the joint research projects should be formulated". Furthermore, projects should develop solutions tailored to local conditions and are considered both necessary and sustainable by regional partners in Africa.

In summer 2014, we organized a workshop in Nairobi to bring together the different partners and previous experiences and get to know the problems on the ground more precisely. In this workshop, existing issues and obstacles were discussed in more detail, and the expected outcomes of the overall project and the individual sub-projects were jointly articulated.

Against the background and the discussed problems, the joint project HORTINLEA aimed to investigate how small farmers and small enterprises can use the opportunities offered by producing and processing indigenous vegetables. The expected outcome of the joint research project was to generate knowledge that enables relevant decision-makers in the sector to develop better strategies and support decision-making processes that improve the nutritional situation of resource-poor households in rural and urban areas. To reach these expected results, HORTINLEA was directed toward answering the following questions:

- Promotes production and marketing to improve food and nutrition security? What future opportunities arise from the production and marketing of AIVs? (3.1)
- What are the mechanisms or pathways through which the production and marketing of AIVs contribute to food and nutrition security? (3.2)
- How can production, marketing, processing and distribution be improved so that the poorer population, in particular, can benefit? (3.3)
- How can processes of value chains for food and nutrition security be improved so that small and medium-sized enterprise can benefit from it? (3.4)

## The Need for a Common Understanding of the Project: The Conceptual Framework

To fulfill this complex task, it was, on the one hand, a question of finding relevant scientific disciplines (sub-projects) and practice partners both in Germany and in Kenya for the project. At the same time, however, the challenge was to develop a "common language" and organize the cooperation of the respective sub-projects so that the results could be processed coherently and comprehensively.

A jointly developed conceptual framework is necessary to support these requirements. As value chains play a crucial role in determining food availability, affordability, quality, and acceptability, they offer opportunities to promote nutrition (Hawkes and Ruel, 2011; Humphrey and Robinson, 2015). Therefore, a starting point for our considerations was the so-called value chain approach, which has already been used for many years in development cooperation and has frequently been improved and adapted. In the discussion on inclusive value chains, the main question was whether and how the interests of resource-poor households, in particular, can be taken into account. Further discussions revolved around how other goals, such as environmental sustainability and gender equity, can be considered in value chain strategies. The value chain food and nutrition security approach goes one step further by paying particular attention to providing sufficient and healthy food and exploring pathways to achieve this goal, especially for poorer populations (Fanzo et al., 2017). The constraints may be on the demand side of the chain (e.g., low consumer demand) or the supply side (e.g., production and nutrient losses during transport) (Gelli et al., 2016).

The framework was intended to help delineate the problems to be addressed in a meaningful way and clearly define the role and obligations of the research disciplines involved. Simultaneously, this approach should support the systematic discovery of obstacles and inefficiencies of the value chains. Therefore, we have tailored it as a conceptual framework for our collaborative project (see **Figure 1**). The approach is characterized by a strong focus on market transactions and emphasizes the role of the private sector. However, the role of the public sector in creating supportive framework conditions (e.g., financing of small enterprises, reliable legal framework, and infrastructures such as advisory services and transport) and in shaping the food environment is also intensively discussed.

In our view, the value chain approach for food and nutrition security (VCFNS) offers the following advantages:

- By looking at possible pathways to improve food and nutrition security, it aims to shed light on the mechanisms through which nutritional goals can be achieved.
- It supports identifying relevant stakeholders who had to be integrated into the project for necessary changes in the value chain.
- It is forward-looking in that it considers current and future local conditions. Changes in food systems are driven by external and internal factors and feedback mechanisms between these factors. External drivers are, for example, climate change, socio-demographic developments or urbanization. Internal drivers are, for example, innovations, changing actor constellations or changing consumer behavior.
- It explicitly includes governance and infrastructure issues in the analysis. It thus also creates the prerequisite for addressing the role of politics and actors from the mesolevel (associations, lead companies in the chain).
- Last but not least, it forms a good heuristic tool allowing to detect the complex interrelationships and interdependencies in the system. Heuristics often helps practitioners to plan their interventions.

## Information About the Procedure and Scope of the Examinations

Research on five AIVs [African nightshade (*Solanum scabrum*), Amaranth (*Amaranthus cruentus*), Cowpea (*Vigna unguiculata*), Ethiopian kale (*Brassica carinata*) and Spider plant (*Cleome*

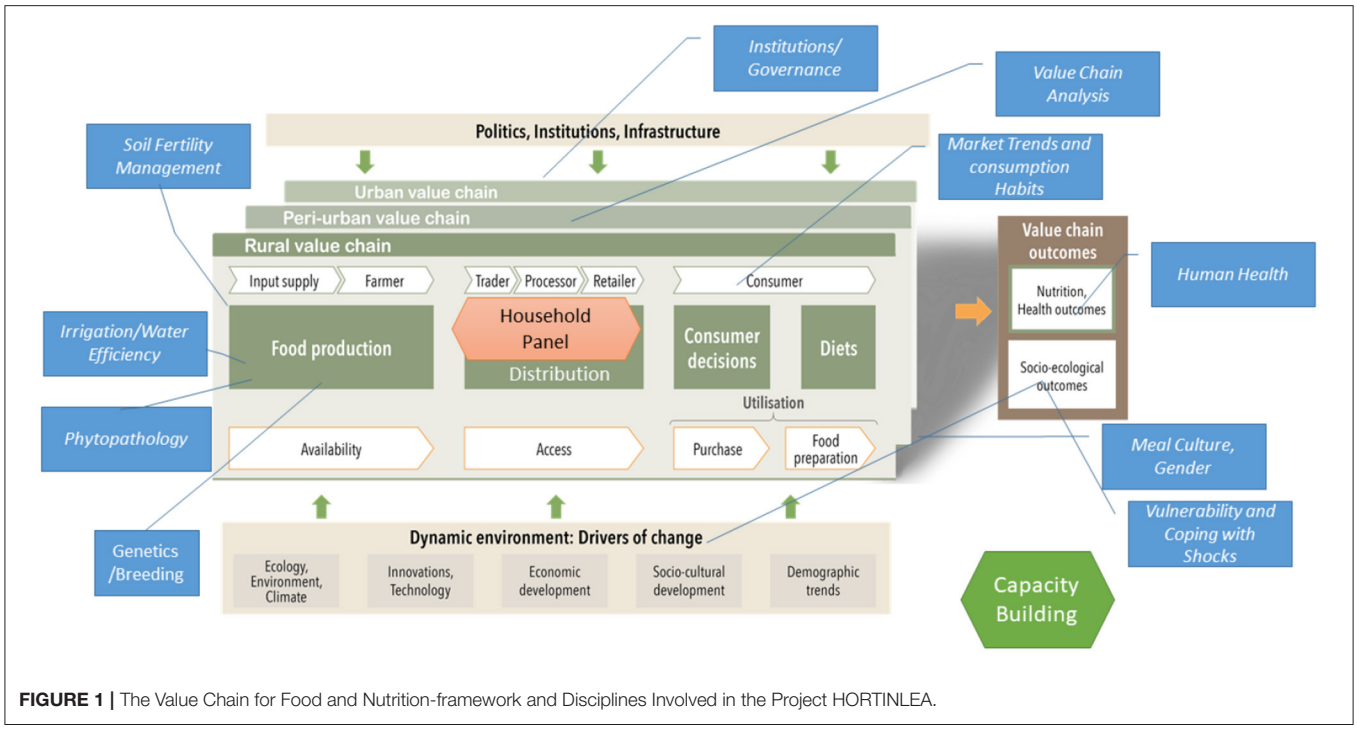


**FIGURE 1 |** The Value Chain for Food and Nutrition-framework and Disciplines Involved in the Project HORTINLEA.

*gynandra*)] was conducted to enhance relevant knowledge about these crops' production, marketing, and consumption. For the design of the HORTINLEA-project, it was essential to consider environmental and socio-economic changes and future demand. Twelve sub-projects have focused on different facets of the value chain: soil fertility, breeding opportunities and seed system, water management, pest management, post-harvest management, nutritional aspects, marketing, food preparation and processing, gender, climate change adaptation and capacity building. In the HORTINLEA project, some disciplines worked with experimental research methods, and socio-economic studies relied on qualitative and quantitative methods of empirical social research (Kebede, 2014). In many cases, actors from the sector were involved in the research process. However, there was a regular exchange of results and experiences within the research network and among the researchers involved, predominantly African PhD students. Results of individual sub-projects of the von HORTINLEA project have mainly been published disciplinary scientific journals.

## RESULTS AND DISCUSSION

This article attempts to summarize results and experiences against the background of the VCFNS framework. To this end, some selected project findings and recommendations for action derived from them are summarized and discussed in light of the current literature. Attention will be paid to the threats and opportunities arising from the changing market trends and framework conditions. Subsequently, our approach will be critically reflected upon to identify existing gaps in knowledge, formulate the need for further research, and provide thoughts for implementing the results.

### Benefits and Opportunities of Promoting the Production and Marketing of Indigenous Vegetables in Kenya

The debate on food security has historically focused on agricultural production and rural areas. In the last decade, however, it has become increasingly clear that supplying the urban population will be at least as necessary for Africa's food security in the future (Bloem and de Pee, 2017). Rapid urbanization focuses attention on the importance of urban agriculture for feeding the urban population. Ruel et al. show that poverty, food insecurity, and malnutrition in all its forms are widespread in cities, and the rapid rise in obesity is worrying. They call decision-makers to be better informed about this situation through research (Ruel et al., 2017). Currently, informal markets are the most important suppliers of AIVs in the cities. Predominantly, women are involved in both the production and marketing of local vegetables here. Most intermediaries buy the vegetables from the farmers to resell them in the urban markets at retail prices.

In the last decade, interest has focused on the rapid emergence of supermarkets and the resulting impact on food security and welfare (Neven and Reardon, 2008; Tschirley et al., 2010). The supermarket "revolution" presents both opportunities and challenges for small-scale farmers and consumers. On the positive side, supermarkets and modern supply chains

offer significantly improved food safety, the ability to fortify staple foods with essential vitamins and minerals, and the potential to stabilize food prices and thus contribute to food security.

The power relations between the supermarkets and the suppliers have a modular governance structure—the supermarkets do not provide technical or financial support to the farmers and therefore have limited ability to monitor the production process to ensure the quality of the vegetables (Otieno, 2019). Government policies can influence the positives and the negatives to a limited extent. However, most supermarket growth dynamics are stimulated by economic incentives, technological changes, and consumer demand. These factors are largely beyond the control of governments.

The results from HORTINLEA on the determinants of AIV farming also suggest that AIV has made the transition from a "poor man's food" to an exciting crop in Kenya (Gido et al., 2017). Generally, farmers who sell AIVs achieve a higher per capita income than farmers who do not sell AIVs. This effect increases with a higher level of commercialization. Food security of producer households significantly improved in the dimensions of access and stability, mainly through an increase in disposable income (Krause et al., 2016; Krause, 2020). However, our results show that market distance is still a barrier for most farmers producing these perishable products. As distances between production sites and urban markets were often within a day in our study, it became clear that post-harvest handling such as cold storage and reliable logistics that maintain quality would allow farmers from rural areas more sales opportunities.

While this direct income effect is already interesting for farmers and their production decisions, policymakers should also have a strong incentive to increase AIV production. Even under current production conditions, AIVs and other horticultural food crops have more substantial positive effects on rural economies than tea, coffee or maize (Krause et al., 2019a). Moreover, the growth and diversity of urban food markets allow farmers to expand their range of products, enter new consumer segments and thus increase their income. Against this background, investments by small and medium-sized enterprises in retailing, wholesaling, processing, packaging and logistics play an important role. Tschirley et al. (2014, 2015) refer to these small and medium-sized enterprises as the "hidden middle" because policymakers and researchers have often ignored them in the nutrition debate (Altenburg et al., 2016). In addition, investments in infrastructure are necessary to benefit from this growing market and enable a wider group of farmers, including women entrepreneurs, to access inputs, rural services, and extensive information. Accordingly, government and donors need to ensure that investments flow into energy, sanitation, transport and food marketing infrastructure and other urban infrastructure (Hawkes and Halliday, 2017). In addition, investments in the rural road network also consider the development of secondary towns and communities.

**Conclusions 3.1** Benefits and Opportunities

In Kenya, as everywhere else in the world, the proportion of urban population is increasing. This expansion poses particular challenges for their reliable supply of healthy food. However, there are also opportunities for many small producers and other value chain actors in distributing and processing indigenous vegetables.

In recent years, the perception of the population has changed so that indigenous vegetables are no longer seen as poor men's food, but their nutritional value is increasingly recognized.

To date and for the foreseeable future, informal markets still play a dominant role in urban and rural regions. Therefore, investments in infrastructure (hygiene, storage) and fair access to these markets by smallholders could substantially contribute to improving the supply of the population. Nevertheless, in the coming years, supermarkets and supermarket chains will gain importance for supplying the growing middle class in the cities.

On the one hand, this development poses a threat to small farmers due to unequal bargaining power and increasing demands by buyers. On the other hand, however, it also provides opportunities by opening up new market segments and developing new products. To use these opportunities, investments in infrastructure as well in logistics are necessary, and value chain actors need to improve distribution processes. However, these measures also open up opportunities for job creation in rural and peri-urban areas.

## Looking on Pathways to Food and Nutrition Security

The concept of value chains for food and nutrition security emphasizes that there should be a particular focus on pathways to achieve Food and Nutrition Security (Hawkes and Ruel, 2008; Herforth and Harris, 2014; Gelli et al., 2016; Maestre et al., 2017; Kennedy et al., 2018; Sharma et al., 2021).

### Production for Household Self-Consumption

Production for household consumption is the most direct way to increase food availability and food security at the household level. For example, households can meet their needs for staple foods through their production while relying on markets for other products, such as fruits, vegetables or meat. Others may depend mainly on their gardens for fruits and vegetables. In this system, production to generate income plays a subservient role. With a favorable distribution of food within the household, this pathway can improve food intake and nutrition for the weaker members of the family.

However, empirical findings evaluating this pathway are very diverse. Sibhatu and Qaim systematically reviewed studies that examined linkages between production diversity, dietary diversity and nutrition in smallholder households. While most of these studies come to positive conclusions, according to them, there is little evidence that increasing agricultural production diversity is an effective strategy for improving the nutrition of smallholder families (Sibhatu and Qaim, 2018). Regardless of the crops studied, the links between increased intensification, production diversity and food security need further investigation. Furthermore, analysis of our household data in the HORTINLEA project has shown that surpluses are sold at local markets or in the neighborhood whenever possible. A significant disadvantage of this practice is that excesses are often associated with an ample

market supply and accompanying low prices. However, in highly rural areas of Kenya with little market access, less diversity in production can harm household dietary diversity (Krause et al., 2019b).

### Selling the Vegetables on Markets to Generate Income

Increased market orientation brings a second path to better food security into play. In this way, income-based production becomes more critical than self-sufficiency. The results from the HORTINLEA project indicate a positive impact of focusing on commercial AIV production in terms of food security for smallholder households. The positive effects of increased commercialization of AIVs are attributed to positive income effects associated with specialization. Income becomes the critical determinant of food availability and access, while household production for subsistence plays a complementary role (Krause et al., 2019b). Farmers take their decisions about production based on the prospect of selling products on the market and the price obtained. Often, risks are perceived with the volatility of markets and opportunistic behavior. One way of limiting market risks could be maintaining and promoting kitchen gardens and small animal husbandry alongside commercial AIV production.

### Favorable Retail Prices for Food

Improving production systems combined with higher yields leading to lower food prices is another way to improve nutrition for poorer populations. Increasing production puts downward pressure on food prices, especially in areas where markets are less integrated and where poor people are the primary residents. Lower prices facilitate access to food and essential nutrients for net food consumers. The tremendous inclusive power of informal markets helps explain their resilience. Low-income consumers in informal settlements and on the urban fringe can find staple foods, fresh foods, animal products, processed or prepared foods that suit their financial, time or space constraints. Informal markets also create comparative advantages for smallholder farmers. Informal traders pay cash, come to the farm and buy all qualities (Otieno, 2019).

"Inclusive growth" has become a buzzword of development agencies and governments. Therefore, it is paradoxical that "inclusive growth" initiatives focus mainly on formal markets.

### Empowerment of Women

Resources and the income that women dispose of through their involvement in agriculture provide another significant pathway for household nutrition. Research on value chain development was gender-blind for a long time (Pyburn and Kruijssen, 2020).

The HORTINLEA sub-project on gender conducted qualitative studies in Kenya's Nairobi, Nakuru and Kakamega regions between 2015 and 2017 (Musotsi et al., 2018a,b). The results show that the consumption of AIVs in Kenyan households is highly gendered. Women are responsible for most of the tasks related to the preparation and cooking of AIVs. However, women also use their power to circumvent some of the stratifications they face. The interviews also illustrate that women play the leading role in the production and marketing of AIVs. Almost 60% of the interviewees in our HH-sample of 1,500 people) indicated that women are responsible for producing AIVs, and in about 57% of the sample, women are also responsible for marketing. When women are responsible for marketing AIVs, in 90% of cases, they also have control over the income generated from these sales. However, the share of income from AIVs of the total household income is relatively low, averaging 9.4%. If there are no other sources of income, women are left with a relatively small budget to spend according to their own needs. Previous studies also confirm that AIV in Kenya is still seen as a subsistence crop and traditionally a "women's crop". The situation is different in urban areas, where the share of men in AIV production is much higher, mainly attributed to the changing perception of AIV as a profitable crop (Weinberger and Pichop, 2009). The commercialization of AIV has encouraged men to cultivate and market it. As a result, they take on more lucrative functions of the AIV value chain, e.g., marketing. The research has shown that women in producer groups increase AIV production. In addition, the research has shown that women (unlike men) are proactive and more resilient in sharing their resources and less likely to compete for leadership roles.

Nevertheless, women often prefer to be in mixed producer groups. To have access to more credit, women need collateral in the form of land registered in their name. The right to and use of natural resources in society is gendered, and women in patriarchal societies often lack access to and control over natural resources and assets (Brückner, 2020). While men and women are affected differently by climate change and environmental degradation, men have more economic alternatives. To attain food security, sustainability is required not only in production but also in consumption. By sustainable consumption, we refer to the ability to meet individuals' food needs and preferences and thus to take actions that contribute to a more equitable availability of AIVs, more equitable access to knowledge about AIVs and, finally, a more equitable sharing of food-related labor.

### Changes on the Consumer Side

AIVs vary enormously in their concentrations and profiles of secondary plant metabolites. In general, a mixture of AIVs can be recommended for a healthy diet, with benefits such as antioxidant activity, higher uptake of provitamin A or uptake of anti-cancer compounds (Baldermann et al., 2016; Neugart et al., 2017). However, apart from their nutritional value, they must be acceptable to consumers because of their appearance, ease of preparation and social and cultural norms given the prevailing taste, consumption habits and preparation methods. The HORTINLEA project investigated the socio-cultural practices of AIV consumption in Kenyan households (Baldermann et al., 2016; Brückner and Caglar, 2016; Musotsi et al., 2018a; Brückner, 2020). Differences in practices can help distinguish nutrient-dense foods from less nutrient-dense alternatives, but they can also pose significant acceptability problems. For example, willingness to pay will decrease if consumers and/or shoppers associate higher nutritional value with less taste or more time-consuming preparation (Gido et al., 2017; Brückner, 2020). In the HORTINLEA project, extensive research was conducted on accepting and preferred shopping

places for indigenous native vegetables (Bauhardt et al., 2015; Gido et al., 2016; Gido, 2017). They were able to show that the acceptance of these vegetables is high among both the urban and the rural populations. However, the frequency of consumption is significantly higher in rural areas (four times a week) than in urban areas (twice). Education, income and a short distance from the market favor the consumption of vegetables. However, the choice of shopping venue when buying leafy vegetable AIVs showed differences between rural and urban areas. Local open-air markets were the most preferred by rural dwellers; in contrast, urban dwellers showed the highest preference for green food markets. Although the process of urbanization in Kenya continues, Tschirley et al. (2014) assume that the "modern" sector will continue to account for far <50% of the market in the future. Also, AIVs have the inherent potential to address malnutrition, and their consumption is still limited by poor perception and lack of awareness of their nutritional benefits. To date, there are few studies on the effectiveness of information campaigns to influence the perception and acceptance of AIVs. We have identified several barriers to AIV consumption and entry points on how to overcome them.

- Younger respondents often dislike AIV. Therefore, we suggest explicitly targeting the younger generations. Here, it is crucial to give the younger generation a voice and include them in the discussion to voice their concerns and attitudes toward AIVs actively. In addition, opportunities need to be created to contact AIVs, learn about their nutritional value, importance to the environment and wellbeing, and socio-cultural significance in Kenyan food cultures. It could also be essential to work with school gardens and kitchens to develop participatory tools (workshops, training).
- There is a knowledge gap regarding the nutritional properties and preparation of AIVs. Creating and sharing knowledge about AIVs among women, men, girls, and boys are critical. Hands-on experiences in the kitchen, opportunities to taste vegetables and practice cooking techniques can be a practical starting point. The role of women in all these activities is crucial, as they can actively provide knowledge and skills about AIVs and their preparation (Brückner and Aswani, 2017).
- The time-consuming preparation of AIVs is a gendered issue (Brückner, 2020). Although women are engaged in paid employment, they do most reproductive work. Nevertheless, women are creative in managing the job assigned to them, and our research has shown that they have developed ways to work around the problem of time constraints. Their methods and indigenous knowledge (e.g., drying and preserving AIV, using AIV that takes less time) need further exploration and should be the starting point for product-based interventions. Careful, context-specific implementation is required for all these interventions and suggestions, making these strategies beneficial to those addressed in our research project.

The results of HORTINLEA in the context of meal cultures show that despite challenges in preparation, cooking and consumption, AIVs remain a core part of Kenyan households. Daily consumption in rural areas shows that consumers still prefer AIVs over exotic vegetables.

**Conclusions 3.2** Looking for Pathways

The debate on food security has focused on agricultural production and rural areas. However, the concept of value chains for food and nutrition security draws attention to the fact that a better provision of healthy vegetables, especially for the poorer population, can be achieved in various ways. In analyzing the value chains, they focus on the mechanisms that can ultimately improve the food situation of more impoverished parts of the population. Subsistence farming still plays a significant role at present. In addition to farms, production takes place in home gardens and schools. It helps to increase resilience to shocks, e. g. from price fluctuations and weather events. However, sufficient and continuous supply, easy access to produce and lower prices are needed to ensure a reliable supply for the non-farming population. In this context, yield enhancements and efficiency improvements in value chains play a prominent role. This pathway should also lead to an improvement in incomes, especially for agricultural households. Women play a vital role in producing and marketing indigenous vegetables. Strengthening their role in the family and society is essential for feeding and caring for household members than for taking advantage of the opportunities available to them through the production and marketing of these vegetables. Better information and training through government campaigns and promotion can increase demand. In addition, smallholder farmers and other value chain actors need market information to adapt to changing consumer demand. All these pathways are not mutually exclusive but should be considered together. Understanding the different mechanisms that lead to the progress of the nutritional situation of poorer population groups helps avoid a too strong focus on particular problem areas within the value chain framework.

## Enhancing AIV-Value Chains: Upgrading Strategies

The concept of upgrading describes how companies in the value chain move to make processes more efficient and/or shift to value-adding activities (e.g., processing), achieving higher prices, entering new markets, and increasing their income (Giuliani et al., 2005; Mitchell, 2014). In our article, we follow the proposal of Kilelu et al. for a broad-based modernization strategy to develop value chains in the smallholder agri-food sector (Kilelu et al., 2017).

### Process Upgrading

Process upgrading increases production efficiency either through improvements to the production and post-harvest processes and/or improved means of production. This way is fundamental given the low productivity of AIV production in Kenya. Productivity describes how much yield a farm produces with the resources available. One reason for the low productivity is that farmers, researchers and seed companies have long neglected AIV (Cernansky, 2015; Moraza et al., 2018), resulting in significant knowledge gaps. In addition, the poor availability of inputs and poor access to capital are essential factors.

#### *Production*

The AIV producers studied in Kenya mainly use traditional production practices (Kebede and Bokelmann, 2016, 2017). They often use organic fertilizer and promote local biodiversity through their cultivation. This contributes to improving soil fertility and environmental sustainability. In addition, the use

of local seeds minimized operating costs and the cost of non-renewable inputs.

*Breeding and Seed System.* The growing interest in AIVs, especially among the urban population, has raised a problem. In most African countries, AIV production uses local landraces in low-input systems. Products harvested are intended for own consumption or sale in nearby towns and villages. Farm-saved seed and low availability of improved varieties predominate in production. As specific AIV-production shifts to urban areas with higher consumer demand, farmers' demand for high quality, healthy seeds and improved varieties that meet the quality requirements of urban markets is lacking.

Like other aspects of production, little attention has been paid to breeding enhanced varieties. As a result, poor seed quality remains a significant constraint to AIV (Kirigia et al., 2018) productivity. In the meantime, some improved AIV varieties are already produced by seed companies, including amaranth, African nightshade, jute mallow, kale/Ethiopian mustard, cowpea leaf spider plant (Abukutsa-Onyango, 2015; Jansen van Rensburg et al., 2015; Dinssa et al., 2016; Ayenan et al., 2021).

Seed production includes the selection of suitable plant material, harvesting and seed processing. An excellent understanding of the species' reproductive biology is also crucial to prevent contamination by other genotypes. Considerable efforts are still needed to improve the seed system and develop suitable varieties. Several projects within the framework of HORTINLEA have addressed this question (Omondi et al., 2016, 2017a,b; Menssen et al., 2017; Ronoh et al., 2018, 2019; Shilla et al., 2018). However, developing new varieties to market maturity requires considerable perseverance and institutional support, such as the World Vegetable Center.

To improve the seed system, the technical capacities of African seed and/or breeding companies would need to be strengthened, seed regulations revised, and, above all, access to seed and advice on its use improved. Investment in these measurements would help to encourage private sector investment in the vegetable seed sector (Schreinemachers et al., 2021). Depending on the regulatory framework and the level of development of the seed sector in a given intervention area, community-based and informal seed systems should be still promoted to provide access to higher quality AIV seed.

*Plant Health.* The production of AIVs faces several challenges, including yield losses due to viral, bacterial and fungal diseases and arthropod pests (Agbodzavu, 2019). A HORTINLEA survey in Kenya and Tanzania found several arthropods could infest AIV. Still, detailed information on the damage caused by the different pests and species identity is lacking in East Africa (Mureithi et al., 2017). Therefore, the first step toward developing sustainable integrated pest management strategies was a field study in Kenya and Tanzania to determine the specific pest species that attack AIVs. As the impact of pests and the identity of species can vary from region to region, the survey covered the main growing areas in both countries at different altitudes, i.e., from the highlands to the coastal regions. There were significant differences in the prevalence of arthropod species in the two countries, in the two growing seasons and at the different altitudes for Lepidoptera and Coleoptera species, but generally not for Homoptera pest species (Mureithi et al., 2017).

There are alternatives to chemical insecticides. Locally produced seed coatings, entomopathogenic fungi and biopesticides derived from botanicals such as neem need further development (Mweke et al., 2016, 2018; Juma et al., 2017; Agbodzavu, 2019). Together with tolerant varieties and traits and some production technologies such as soil solarisation, integrated pest management strategies are available. While not aiming at total pest eradication, alternative technologies can lead to more environmentally friendly production methods. Further work should be done on the potential of beneficial insects, breeding better lines and varieties, technologies for early detection of pest problems (e.g., pheromone traps) and training of farmers to use sustainable production techniques as essential pest control strategies.

*Soil, Plant Nutrition.* To take full advantage of AIVs-benefits, more knowledge about potential agronomic constraints is still needed. In this respect, one objective in HORTINLEA was to assess soil fertility status on AIV-producing farms in western Kenya and establish databases to quantify species-specific fertilizer requirements for AIV production and the input of organic C from plants into the soil (Onyuka et al., 2018). In addition, such chemical soil fertility indices were measured as the potential ability of soils to supply plants with nutrients (e.g., P, S, K, Mg, Zn) and harmful elements (Cd). To assess whether a given index value limits productivity, the data were compared with reference data for sufficiency and deficiency zones. For the study, we took soil samples from 413 fields on 150 farms in different counties in western Kenya (Kakamega and Kisii). All were characterized by intensive AIV production. Extreme acidity ($pH < 4.5$) was a problem in 27% of the fields. Low soil pH reduces the chemical availability of nutrients such as P and Mo. In addition, it can affect root growth through Al toxicity. Low root growth, in turn, can increase the vulnerability of plants to dry periods by hindering water uptake from deeper soil horizons. The application of lime is generally recommended to raise the pH of the soil. If this management approach is not practical due to supply constraints and high costs, replacing inorganic nitrogen fertilizer with animal manure and returning plant residues to the cropland can reduce acidification.

Soil organic carbon (SOC) content indicates various chemical, physical and biological processes that regulate soil fertility. The average SOC at the district level was significantly higher in Kisii (3.2% C in dry soil matter) than in Kakamega (1.7%), suggesting that natural factors, including mean annual temperature and rainfall, have a significant influence on SOC. Another reason for the higher SOC in Kisii compared to Kakamega may be

the shorter duration of agricultural use, i.e., the shorter time since forest conversion to cropland. In Kisii, SOC in all soils was higher than 1.5% C in dry soil matter, a threshold value representing sufficient SOC to maintain soil functions associated with soil fertility. In Kakamega, however, SOC was below this threshold in 47% of the soils, with the proportion of soils with critically low SOC in Mumias being exceptionally high (63% of all soils). This indicates that farmers in Kakamega should increase SOC, e.g., adding more organic C to the soil through plant residues or manure. Other management options to increase SOC include reduced tillage and reducing the frequency and duration of fallow in the crop rotation (Onyuka et al., 2018). In his thesis, Nambafu (2018) also measured value-giving and toxic element concentrations in leaves of different AIVs. He interprets it as an indicator for the nutritional value, the performance under different rates and forms of phosphorus (P) supply due to adaptation to suboptimal chemical soil conditions, and the harvest-related nutrient outflow from the soil as an index for fertilizer need.

*Climate Change Adaptation.* Kenya is a water-scarce country (World Bank, 2021), and only 17% of the land is productive cropland. Kenyan agriculture is mainly rain-fed; <3% of arable land is currently irrigated. The agriculture sector is the largest emitter, accounting for 33% of carbon dioxide equivalents in 2010. The Kenyan National Adaptation Plan (NCCAP) 2013–2017 envisaged initiating a low-carbon, climate-resilient development pathway through sustainable development and climate change mitigation activities (Global Center on Adaptation, 2021). In agriculture, the focus was on programs to promote irrigation, value addition through processing, weather-based crop insurance, autonomous adaptation measures based on decentralized community projects, climate information systems for farmers, improved financial support and drought-resistant seeds.

The share of greenhouse gas emissions from AIV crops is negligible concerning the agricultural sector, as greenhouse gases are primarily generated through livestock production. However, two interesting questions arise in the adaptation debate for the production of AIVs, which a HORTINLEA sub-project was able to answer (Chepkoech et al., 2018). First, the results show that climate change is present in farmers' perceptions: The household survey indicates that 67% of sample farmers (269 AIV-Farmers) are negatively affected by increasing variability of rainfall patterns and 85% by changes in temperatures (Stöber et al., 2017). The historical analysis of weather data for different agro-climatic zones shows statistically significant temperature increases in all three zones, the humid, the semi-humid and the semi-arid areas. In particular, night temperatures have increased significantly and disproportionately between 0.02 and 0.08°C per year. These are 0.7 and 2.7°C, respectively, over 1980–2014. Changes in precipitation are not significant, with a few exceptions, but variability in rainfall, unpredictability and heavy rain occurrence coupled with short dry spells are consistently mentioned.

Farmers need to adapt their farm-level management to climate change to cope with these challenges. In general, AIVs are known to be relatively unresponsive to weather influences. The HORTINLEA sub-project provides qualitative results from a hitherto completely unexplored field (Chepkoech et al., 2020). From their observations and wealth of experience, the smallholder farmers interviewed derive relatively straightforward statements. In focus group discussions, they prioritized the AIVs according to their insensitivity to extreme weather conditions. The parameters yield/growth, diseases, pests and weeds justified their decision. The spider plant and Ethiopian kale, which are very popular on the market, react relatively sensitively to heavy rain. However, cowpea, which is very resistant to drought, does not tolerate too much rain and moisture, as the fungus Protomycopsis phaeseoli infects the leaves (black spot). Therefore, it is classified by farmers in the medium tolerance group. The least sensitive AIVs include amaranth, crotalaria, vegetable jute and pumpkin leaves. These almost always succeed and generally contribute to a stable agro-ecosystem on farms. Even though consumers do not demand them as much, they play a significant role for plant hygienic reasons.

Therefore, farmers need to adapt in a context-specific manner, with agro-climatic zones, value chain character and the particular AIV species requiring different adaptation strategies. In general, the process of adaptation aims to reduce the negative impacts of climate change. Which adaptation strategies farmers ultimately choose depends primarily on the adaptive capacity of AIV farmers (Chepkoech et al., 2020). One Question relates to how common it is for smallholder farmers growing AIVs to adopt sustainable intensification practices and the socio-economic factors influencing their adoption. Agro-biodiversity strategies are widely adopted, i.e., growing multiple AIV crops per farm and manure for soil improvement. Improved irrigation methods and integrated soil fertility strategies, using organic and synthetic fertilizers as needed, are standard among only 9 to 12% of smallholders. Proximity to urban areas, access to formal markets such as restaurants, bulk buyers or supermarkets, information technologies and extension services, and membership in farmers' organizations or groups, among others, were significant factors in the adoption of sustainable farming practices (Kurgat et al., 2018a,b).

In questions about adaptation strategies with 269 smallholders, it was found that from a tested list of 26 strategies, the following five measures were the most widespread and equally distributed in all three agro-climatic zones: Manure application, more frequent weeding, the use of more pesticides, crop rotation and mixed cropping, and water with a watering can. The characteristic of widely-used adaptation strategies is that farmers can apply those with low risk and little financial input, but they are all associated with higher labor input. In contrast, the main characteristics of the five least common strategies are that they are not available on the market, not easy to implement and require financial resources, knowledge or broad networks. These include, for example, moving to the cities, taking out crop insurance or acquiring additional leased land, which is rare in Kenya. Furthermore, only a tiny proportion reported

seeking off-farm activities to adapt to climate change. This means that the adaptation portfolio as a whole is autonomous from support structures (which are still lacking) on the farm with little capital input but high labor input, and other transformative adaptation strategies are not widespread among farmers.

The results of HORTINLEA concerning agronomic topics of production and especially on the options for climate change adaptation have provided a wealth of exciting and essential results. However, it also became clear that there is still a considerable need to catch up in this context. Compared to the major crops, the need to catch up in technical production know-how is evident here.

### *Post-harvest and Processing*

Indigenous vegetables need to preserve their valuable ingredients until consumption. Especially African indigenous leafy vegetables are highly perishable products with a short shelf life. Advanced post-harvest handling and processing are essential to ensure freshness and good quality, reduce losses and benefit from reasonable prices. However, due to the high water content, the quality of AIV deteriorates quickly. In addition, the high metabolic activity leads to high post-harvest deterioration. Despite many indications of high post-harvest losses in AIV-Value Chains, few studies have focused on quantifying them (Gogo et al., 2017b, 2018). However, reliable data on the actual extent and nature of quantitative and qualitative post-harvest losses are essential for formulating measures to address the problem. Research in the HORTINLEA project (surveys and experimental setups) to identify causes of AIV losses along the supply chain in Kenya has shown that losses at harvest to marketing can be 50%. They vary by location, supply stage and distribution and marketing dynamics. Not only is the loss of quantity harmful to upward mobility, but the loss of nutritional quality is also highly problematic. Quantitative, nutritional and economic losses varied across districts. For example, higher losses of cumulative produce, nitrogen, calcium, protein, provitamin A (carotenoids) were observed in Kakamega, while Nakuru had higher losses of potassium, magnesium, iron, and zinc (Gogo et al., 2017b, 2018).

Along with value chains, nutrients can be lost during processing, storage, distribution and/or preparation due to spoilage, improper handling or preparation methods. By breaking down the economic losses at different stages of food value chains, it can be made clear to growers and sellers how important post-harvest handling can be. Furthermore, making the economic impact of volume and quality losses visible can help to encourage the adoption of new post-harvest handling technologies, such as UV-C treatment (Gogo et al., 2018).

Enhancing affordable and easy-to-use handling, processing, and post-harvest methods for smallholder farmers on the one hand, and innovative new post-harvest technologies for supermarkets on the other are essential for ensuring the quality of AIVs in terms of providing nutritious and health-promoting ingredients, as well as reducing food losses in post-harvest (Gogo E. B., et al., 2016). For example, other research has shown that determining an optimal maturity stage or index for harvesting each AIV plant species allows for higher levels of nutrients for human consumption and/or post-harvest processing. In combination with biodegradable film packaging (PLA) bags, Modified Atmosphere Packaging (MAP) bags can significantly reduce post-harvest quality losses, preserving the shelf life, visual quality (leaf color), and nutritional and health-promoting properties of AIVs. The effect of MAP is exceptionally high under retail conditions (20°C). AIVs have an optimal shelf life at temperatures of ∼0–5°C. The spoilage of these products increases two- to three-fold with each 10°C increase in temperature (Gogo et al., 2016). The HORTINLEA project also tested easy-to-use and low-cost cooling systems, such as the evaporative cooling system using zero-energy brick coolers or evaporative charcoal coolers (Ambuko et al., 2017). Treatment of perishable AIVs with UV-C is a new approach to extend the shelf life and improve the health value of fresh horticultural crops (Gogo et al., 2017a).

There is an urgent need for more quantitative evidence on the actual extent and nature of quantitative and qualitative post-harvest losses in these nutritionally and economically valuable African leafy vegetables for smallholder farmers. Nevertheless, the results provide a starting point for optimizing efforts and strategies to deal with AIV losses. Value chains are used to establish trade linkages between rural and urban areas and achieve a win-win outcome. Rural producers benefit from higher economic returns and urban consumers from a variety of nutritious food at affordable prices. Promoting investment in modern value chain logistics is necessary to ensure supply to urban markets without loss of crop and quality. Further studies are needed on affordable, safe and easy-to-use pre-and post-harvest treatments in conjunction with farmer training to promote and sustain commercial AIV cultivation (International Finance Corporation, 2018).

## Product Upgrading and Tapping Into New Markets and Discovering New Consumer Segments

Product upgrading—improving product quality and increasing consumer benefits—can be stimulated by end-market changes. Product improvement involves improving product quality (e.g., certification, safety standards, traceability) and switching to higher-value products (e.g., processing, packaging, and branding). Often it is linked to process upgrading.

In order to better assess the prospects for improved market access and the exploitation of new consumer groups, it is essential to have information on consumer behavior and emerging changes. In the project HORTINLEA, consumer surveys were also conducted to address these questions (Gido, 2017) better. Among a sample of 450 consumers in Kenya, African nightshade is the most commonly consumed, followed by amaranth and cowpea. About 2 out of 3 consumers report that the woman in the household buys the AIVs. Consumers prefer to buy from local vendors in open markets mainly because they are cheaper, closer and offer fresh vegetables. About 72% of consumers said they would buy more AIVs, having reduced prices. Most AIV markets open early in the morning and are open all day. However,

almost 80% of consumers disagree or strongly disagree that AIVs are available in sufficient quantities all year round. This is due to seasonality, dependence on rainfall, perishability and lack of suitable storage facilities. In addition, more than 85% of consumers believe that the sale of AIV in supermarkets leads to its scarcity in rural markets. Almost all consumers cook and consume AIVs at home. Most consumers get information on preparation and nutritional benefits from relatives and family members.

For various reasons, Value Chains for African indigenous vegetables offer opportunities to create sustainable and challenging jobs by opening up new markets (e.g., through convenience products), improving agricultural services, logistic services and related business models. The discussion on so-called nested markets addresses the importance of alternative market structures for rural development. Nested markets (Hebinck et al., 2015) are not organized globally. Instead, the exchange takes place at real meeting points. Van der Ploeg (2015) emphasizes the complexity of such exchange processes and that ethical and social values like product quality, human relations, territorial development, and environmental protection are linked to them (e.g., reliable relationships with schools, kindergartens, and hospitals). Here, too, the expansion and use of indigenous vegetables offer tremendous opportunities.

Value addition, such as processing (e.g., drying, blanching, and fermenting), can help address scarcity during lean seasons and mitigate the problem of high spoilage. Traditional food processing aims to maintain the supply of healthy, nutritious food throughout the year, especially in times of scarcity. Commercial food processing also seeks to generate income for the producer and seller. While most people in rural areas still rely on traditional foods for their basic needs, people in urban centers tend to buy processed and packaged foods for convenience. Today, the increasing number of women working outside the home adds to the pressure for such changes. Even people with healthy traditional diets demand external products, either as occasional delicacies, such as gas-laden drinks or as staples.

Better access to finance could help with storage and processing, as the AIV market is volatile, with prices dropping in the rainy season and skyrocketing in the dry season. In addition, more even availability throughout the year could prevent wastage and scarcity. On a less material level, knowledge about the value and preparation of AIVs is also slowly being lost, both orally and practically, especially in urban areas.

Supermarkets have the niche of those who want to consume AIVs who are willing to consume AIVs but lack the time or knowledge by selling ready to eat vegetables. This could also be an opportunity for women to exploit their expertise through cookbooks, seminars, etc. This includes functional upgrading, where producers or other actors in the chain take on new functions, such as providing inputs or services.

**Conclusions 3.3** Upgrading strategies

The analyses in the HORTINLEA project have made clear that the yield differences between the farms are pretty significant and that overall productivity could be increased significantly. Furthermore, HORTINLEA could show that a large part of the harvest gets lost during transport and distribution. The project also identified ways to increase the value of the products through processing. These results create some starting points discussed under the headline process and product upgrading.

Process upgrading is about increasing the efficiency of processes and thus also productivity. Those interventions should reduce losses in the value chain (disease infestation and post-harvest losses). In this context, farmers' particular difficulties due to the changing climate need to be considered. Even if farmers have already developed specific strategies, support is required to reduce the increasingly occurring risks (e.g., water-saving irrigation, insurances).

A significant source of reduced yields is the lack of good quality seed that also meets the changing needs of younger consumers in particular. Systematic breeding is still in its infancy, therefore incentives for private breeding companies are needed. Particular yield problems result from the fact that, despite relatively high resistance, the plants are increasingly attacked by plant diseases and often suffer from nutrient deficiencies. The shortfall in yields is due to knowledge gaps and the low availability of means of production. There is a particular need for support through extension services and long-term systematic research.

At least as serious problems occur after harvesting. In addition to yield losses, the loss of essential ingredients during transport and distribution is a particular concern. Adapted technologies in cooling, storage facilities at markets, packaging and improved infrastructures would be necessary to better serve urban markets.

So far, little use has been made of the opportunities to meet the changing needs of urban dwellers, and especially of women through processed products (e.g., convenience) and at the same time to bridge periods of low supply during dry periods.

## Improving the Coordination—The Role of Governance and Collective Action

The value created in the nutrient-rich food value chain needs to be distributed to the chain actors involved to provide incentives for sustained cooperation. The functioning of the overall system depends on the actions of each actor. Economic power is a crucial determinant of the distribution of benefits and can lead to disincentives without an appropriate legal and policy environment. Price-cost spreads are an indicator of benefit distribution. In our view, a fair distribution of benefits is, therefore, a prerequisite for the upgrading strategies described below.

In recent years, promotional campaigns by research institutions and public authorities have led to an increased demand for AIVs, especially among urban consumers. These efforts have led to a more extensive and diversified sales market in urban areas. It also provides smallholders with the opportunity to participate in value chains with higher margins. However, access to and participation in higher-margin value chains is a question of production and how smallholders can access such value chains.

As part of the HORTINLEA project, Otieno (2019) uses a mixed-methods approach to shed light on the role of value chain

actors involved, their activities, the coordination and governance structures that determine participation in AIV value chains in Kenya and influence outcomes. He compares the governance of traditional and modern "coordinated" value chains for rural and peri-urban smallholder farmers (Otieno, 2019). Traditional and coordinated value chains coexist in Kenya. However, small informal actors dominate them. This hinders vertical integration. Of the 269 farmers involved in the study, the majority (98%) participate in traditional value chains compared to only 2% who supply supermarkets in the context of 'coordinated' value chains. Although farmers' associations exist, they are too weak to organize collective production and marketing. Moreover, the use of productivity-enhancing technologies such as improved seeds, irrigation and fertilizers is too limited, so continuous supply to markets cannot be guaranteed.

Farmers often do not have direct transactional relationships with the more lucrative urban traders and supermarkets. Rural households consume about 40% of their total production and sell about 60%. On the other hand, 85% of production is marketed in peri-urban areas. Strong farmer marketing groups enable their members to sell wholesale and supply supermarkets in urban areas. About 41% of AIV producers in groups indicated that better prices are the essential benefit of a vegetable farmer group membership. Farmer groups play a vital role in providing production and market information, linking farmers to central input and output markets, and mobilizing savings and credit in rural areas where formal savings and credit institutions such as banks are lacking. Therefore, AIV producers organized in groups benefit related to commercial AIV producers who are not organized in groups (Otieno, 2019). About 70% of the group members are female, indicating that women are more likely to cooperate than men.

Food safety requirements and quality standards are generally flexible for AIVs (Homeister et al., 2016). However, participation in such value chains is associated with significant uncertainties for small farmers. The vertical linkages between value chain actors in both coordinated and traditional value chains are characterized mainly by "arms-length" market transactions (Otieno, 2019). While some studies point to the benefits of supply contracts with supermarket chains (Fischer and Qaim, 2012; Ogutu et al., 2020), our findings suggest that agreements in AIV value chains neither reduce uncertainty for small farmers nor incentivise farmers to invest in modernization.

Strategies to improve the emergent AIV-value chains should encourage collective action by smallholders and support investment in infrastructure development, including cold storage, and ensure better access to urban markets. Horizontal coordination is about cooperation at one level of the value chain; e.g., collaboration between producers, whose partnership enables farmers to reduce costs (use economies of scale), increase revenues (better prices, new markets) and reduce risks (Helmsing and Vellema, 2012; Vellema et al., 2013; McKaque, 2014; International Finance Corporation, 2018).

The participation of smallholders in profitable, market-oriented fresh vegetable production is—as the research has shown—associated with several difficulties. Nevertheless, research and practical examples show that collective action can support the integration of smallholders into profitable value chains. Bizikova et al. point out that access to markets through information, infrastructure and logistical support should be central to Farmer Organization (FO) design. However, natural resource management could also be more integrated into the services provided by FOs to mitigate the risks associated with environmental degradation and climate change (Bizikova et al., 2020). The potential role markets play in conserving agrobiodiversity through product diversification and increasing competitiveness in niche and novelty markets is receiving increasing attention. Several case studies explore market-based approaches for on-farm agrobiodiversity conservation and improved food security. These case studies highlight the need for improved trust, mutual understanding of stakeholder participation and an agreed process of collective action with a high level of community participation (Kruijssen et al., 2009). The support can be achieved in several ways (Fischer and Qaim, 2012):

- Collective action is key to the sustainable management of natural resources critical for agricultural production, especially in rural and remote communities.
- Collective action enables transaction costs to be reduced and economies of scale in procurement, production and marketing to be exploited.
- Collective action can increase the bargaining power of small producers vis-à-vis large traders.

In studying conventional and institutional markets for leafy vegetables, Mwema et al. found close networks of family members, friends, and neighbors as gatekeepers in accessing institutional markets. In addition to farmer groups, non-farmer and religious groups are also strategic networks that facilitate bulk purchases and link smallholder farmers to markets (Mwema et al., 2021).

To develop the potential of collective action for poverty reduction, certain conditions must be present inside and outside the group. The HORTINLEA project examined three existing forms of collective action in the form of case studies: (a) collective natural resource management by individual AIV producers (Kanyua, 2020); (b) AIV producer groups selling to supermarkets (Populus, 2015); (c) self-help groups of women AIV producers. The studies were conducted in Kiambu and Nakuru, two peri-urban counties in Kenya (Mwema and Crewett, 2019).

In the case of collective natural resource management, it has not been possible to increase AIV production during the dry season. The case shows how difficult it is to implement collective action from the top down. The problem was caused by a lack of common goals among the members, where not all of them saw sufficient benefit in participating, accompanied by a lack of enforcement of the measures (Kanyua, 2020).

In the supermarket study, collective action enabled information and connections to business partners in premium price value chains. In addition, pooling assets enabled them to cross a production threshold, making them potential business partners for supermarkets. However, our case study of AIV sales in supermarkets contradicts the assumption that collective action increases the bargaining power of small producers. Under

the supply arrangements, a large part of the transaction costs was shifted to farmers; they resulted in additional but uncertain income from sales to supermarkets (Populus, 2015).

Collective AIV production in the case of women's self-help groups increased income, food security and self-esteem of vulnerable women farmers. In these groups, collective action has crossed a threshold that has enabled the acquisition of agricultural inputs that would not be available to individual members. Respondents reported that they were empowered by financial independence. Collective action also provided a training ground for experimenting with new business models, leading to individual enterprises and further empowerment.

**Conclusions 3.4** Improving Coordination

The results from the HORTINLEA project confirm the findings of many other studies. Due to diseconomies of scale, small farmers have difficulties obtaining their production and financial resources and have little access to up-to-date information and the necessary knowledge. They do not have the resources to access more distant markets and, due to their relatively weak position in the value chain, are in a poor negotiating position vis-à-vis local traders and supermarket buyers and do not have the means to enforce their claims against these actors. These restrictions lead to low yields, high post-harvest losses, low prices for their products, and low incomes.

Forms of coordination in value chains are being sought that can strengthen the position of small farmers vis-à-vis other actors in the value chain, avoid food losses, and promote adaptation to the changing demands of consumers. Vertical linkages between value chain actors are primarily characterized by informal market transactions in coordinated and traditional value chains. Our findings suggest that contracts in AIV value chains neither reduce insecurity for smallholders nor create incentives for investment in modernization. Policymakers are needed to minimize the disadvantages for farmers. They should ensure that smallholders assert their rights and enable access to inputs, land and water. In addition, it could help reduce functional deficits of small enterprises (joint purchase of means of production, coordinated logistics and distribution, collective contract negotiations with market partners) by creating suitable legal framework conditions and financial support for producer organizations or other forms of collective action. However, the initiative for collective action should usually come from private actors in the VAC who want to follow jointly formulated goals.

## A CRITICAL REVIEW OF THE RESEARCH FRAMEWORK, THE RESULTS ACHIEVED, AND THE NEED FOR FURTHER RESEARCH

Local food systems around the world are diverse and, above all, site-specific. While they share some common characteristics, efforts to improve those systems need to consider their uniqueness. They result from the different areas' traditions, cultures, economic structures, and ecological conditions. This situation requires that different scientific disciplines are involved in the analyses and jointly contribute to the agreed objectives of such a project. Therefore, a regular exchange between the partners had to occur during the project. In this respect, the concept of value chains for Food and Nutrition security contributed significantly to a common understanding of the problems on the ground and the integration of the findings.

We propose that the connection between emerging social, demographic and ecological changes and the food system's resulting (local) adaption needs should be given greater attention in research (Kurgat et al., 2018a; Stöber et al., 2018; Chepkoech et al., 2020). Furthermore, given the increasing shocks from market development and climate change, the question arises of how to make local food systems and their actors more resilient (Ngenoh et al., 2018).

Even though the HORTINLEA project has produced a wealth of valued results, our studies have also made apparent that the existing knowledge and practical insights into production, quality maintenance, and processing are insufficient due to the low level of research interest. There are still considerable gaps in existing knowledge compared to the main crops that have been intensively researched worldwide. Due to the great importance of indigenous vegetable varieties for improving the food supply, there is a considerable need to catch up here. Irrespective of the significant gaps in knowledge on the subject, many publications provide partial results on specific aspects of production, quality management and processing of AIVs. Therefore, it is also an essential task of science to compile this knowledge by meta-analyses and reviews (see as examples: Nono-Womdim et al., 2009; Shackleton et al., 2009; Akinola et al., 2020).

Even if the state of knowledge on AIVs can be significantly improved in the foreseeable future, this does not yet ensure that this knowledge will be put into practice. Therefore, the multifaceted results HORTINLEA were compiled and made accessible to practitioners and extension workers (Henze et al., 2020) (https://edoc.hu-berlin.de/handle/18452/23783). PhD students and project partners from the study regions significantly contributed to this brochure. In addition, some farmers participated in the critical review and correction of the manuscript. In addition, policy briefs have been written aimed at practitioners and extension workers. Toward the end of the research, meetings were also held with farmers in different areas of Kenya, where the scientists involved presented their findings.

Nevertheless, the transfer of the results was not entirely satisfactory. This is partly due to the limited time frame in which such a project is funded. The question remains how the existing knowledge can be transferred into coherent practical actions given the complexity and the specific local situations in each case. On the one hand, this has to do with preparing this knowledge and making it available to the decision-makers in the value chain. More Collaboration with extension workers and other knowledge brokers is necessary, and professional training at various levels of the education system must be established. At the same time, however, the political framework conditions must be designed so that the actors involved in the value chain have sufficient incentives to participate in these systems. This framework conditions also include the necessary investments in infrastructure.

More knowledge is also needed to meet the specific challenges of social inclusion and environmental sustainability in food and nutrition security value chains. Therefore, case comparisons could even identify the causes of success and failure more precisely. In addition, the pooled experiences from the multitude of value chain projects could provide valuable suggestions in this

respect. Finally, to better use the experience gained from such projects, a systematic evaluation of such results would generally be needed.

The options for enhancing value chains identified in the HORTINLEA project require technological, social and/or organizational innovations (Barrett et al., 2020). Those innovations are emergent phenomenons (Kansiime et al., 2018). The process requires adaptive management while addressing local conditions and needs. In the agricultural innovation system concept, innovation emerges from complex interactions between researchers, input suppliers, extension workers, farmers, traders and processors who work together to identify problems, analyse them and research, design, test and implement strategies (Gevorgyan et al., 2015; Kuntosch and König, 2018; Sanya et al., 2018; Klerkx and Begemann, 2020).

Because of the necessary long-term development opportunities, the issue of capacity building is also of significant importance. The HORTINLEA project involved mainly African PhD students and produced many concrete results. In addition, linking problem-solving research and the training of young professionals at higher education institutions is of particular importance. Finally, we hope that the exchange among the participants in the international project and the hints on how research results can be actively and better prepared for practice could provide ideas for future activities in Kenya.

## DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary materials, further inquiries can be directed to the corresponding author.

## AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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