Research Article ISSN 2770-2928

International Journal of Agriculture and Technology

Contract Farming Technologies, Opportunities and Challenges in Arid and Semi-Arid Lands-A Review Scenario in Kenya

Raphael M Wambua[1]*, Thomas Akuja[2] and Rachael M Sevu[3]

[1]*South Eastern Kenya University (SEKU), Department of Agricultural and Biosystems Engineering, Main Campus, Kitui, Kenya.*

[2]*South Eastern Kenya University (SEKU), Department of Agricultural Sciences, Main Campus, Kitui, Kenya.*

[3]*International Centre for Evaluation and Development (ICED), Kenya.*

***Correspondence:**
Raphael M Wambua, South Eastern Kenya University (SEKU), Department of Agricultural and Biosystems Engineering, Main Campus, Kitui, Kenya.

Received: 05 Mar 2025; **Accepted:** 17 Apr 2025; **Published:** 26 Apr 2025

Citation: Wambua RM, Akuja T, Sevu RM. Contract Farming Technologies, Opportunities and Challenges in Arid and Semi-Arid Lands-A Review Scenario in Kenya. Int J Agriculture Technology. 2025; 5(2): 1-7.

ABSTRACT

Contract Farming is considered to play a crucial role in sustainable and improved food security and community livelihoods. There are multiple challenges in Arid and Semi-Arid Lands (ASALs) of Kenya such as land degradation, water scarcity, and these are exacerbated by adverse effects of climate change. Despite the positive effects of Contract Farming (CF) on socio-economic growth, participation remains low in in rural ASALs of Kenya. Numerous studies have investigated the role and benefits of CF in improving livelihoods in these areas, but there is still scanty information specifically on opportunities, contract farming technologies, and challenges in Kenya's ASALs. To address this gap, this study explored CF technologies, opportunities, and challenges prospects with a view to helping in policy formulation for improved livelihoods in ASALs of Kenya was conducted. The key drivers of CF adoption in ASALs include improved technology, low production cost, market access, access to credits, and reduced faming risk. The review identifies System for Mobile (GSM) technology, smart-phone application, automation of irrigation systems, Artificial Intelligence (AI), Agricultural Robotics, Unmanned Aerial Vehicles (UAVs), Smart sensors and Internet of Things (IoT) as the prioritized Contract Farming Technologies (CFT) for enhanced success These improved technologies address critical barriers to CF adoption and related activities should be promoted and integrated by all stakeholders including the Policy makers for sustainability in enhanced livelihoods in ASALs.

Keywords

Contract Farming, Arid and Semi-Arid Lands (ASALs), Agricultural Technologies, Farming Opportunities, Farming Challenges, Food security.

Introduction

Agriculture contributes immensely to African economy in different ways including provision of food for the increasing population, supply of adequate raw materials to a growing industrial sector, a major source of employment, generation of foreign exchange earnings and provision of a market for the products of the industrial sector among others. Despite all these, agricultural sector continues to face challenges in maximizing yields, profits, and have positive impact on livelihoods. To advance the sector a greater adoption of improved technologies and modalities which aim at improving the production process are omnipotent.

Agricultural production in Arid and Semi-arid Lands (ASALs) has continued to face significant problems. For instance, there has been a challenge in sustainability of subsistence agricultural productivity in such areas, due to adverse effect of climate change and adaptation, its resilience and limitations [1,2], lack of appropriate and structured markets, credits and technology [3]. This problem is exacerbated by negative impacts of climate change,

unstable food prices and high cost of and global financial crises [4]. Agricultural production is a crucial catalyst in improving the economy within ASALs. However, in spite of its great potential to enhance food security, reduce poverty, people living in ASALs have persistently low agricultural productivity.

Arid and Semi-arid Land (ASAL) areas have been noted to have some restrictions to markets at local, regional and global levels due to sustainability issues [5] that are considered to emanate from climate change conditions. Contract Farming (CF) has an opportunity of connecting farmers to modern technologies, markets, credits, inputs and essential services. This has a positive impact of increasing agricultural productivity, income and livelihoods Sivramkrishna S.and Yotishi A [6]. CF is an approach to revolutionize ASALS improving opportunities for farmers in markets [7]. For the success of CF in ASALs the design that links SSFs with buyers, appropriate technology, credits and services should positively influence the interests of different sectors involved for sustainability of these arrangements [3].

Producing and selling on a contractual basis is a common arrangement in agriculture all around the world. Contract farming (CF) existed for a long time, particularly for perishable agricultural products delivered to the processing industry, such milk for the dairy industry or fruits and vegetables for making preserves. At the end of the 20th century, CF has become more important in the agricultural and food industries of the developed and developing countries. Spurred by changes in (international) competition, consumer demands, technology, and governmental policies, agricultural systems are increasingly organized into tightly aligned chains and networks, where the coordination among production, processing and distribution activities is closely managed. Contracting between producers on the one hand and processing or marketing agribusinesses on the other hand is one of the methods to strengthen vertical coordination in the agrifood chain [8].

In ASALs CF can be used to promote out-of-season agricultural production by increasing opportunities for marketing, commercialization and exporting products from these regions [7]. However, Small-Scale Farmers (SFs) in ASALs do not benefit from such due to some specific challenges. For instance, the flow of the right information at the right time has been limited in ASALs. There are lots of irregularities in information between the SFs and the prospective buyers. This also includes the deficit of the right information about the slow efficient agricultural production technologies and market opportunities can make prosperities of CF [9,10]. Secondly, access to credit and loans has been inadequate for SFs in drylands, in some areas there are no access, restricted credit, or available loans access. Most SFs in ASALs lack opportunities where to access credit and in some instances, when available the loans attract very high interest rate. Thirdly the farmer willingness to take risks is not readily accepted by the SFs in such regions. The SFs in ASALs are usually not willing to take risks, and for increased production, new technologies and inputs that may require risk arrangements are needed. However, farmers in these regions avoid the risks. SFs in ASALs prefer being involved in subsistence farming for food security [7].

CF is becoming prominent in ASALs areas. The ever-changing dynamics in industrialization, technology and human demography in the agricultural sector and market reforms can enhance CF activities, production and marketing solutions [11]. CF is a potential driver for uplifting SFs livelihoods in rural areas of the ASALs [12]. In terms of production and marketing there is Monopsonic (single buyer) and monopolistic (single seller) relationship. When the farmer enjoys monopoly of production in a certain area and period of time, this means single supplier or seller, the advantage and possibility of benefiting from high unit prices, and low risk of production if there are many buyers available in the market. However, if under monopsonic situation where there is a single buyer, there is high risk of production and the farmer(s) are likely going to receive low unit prices for the produce. There are more benefits of CF such as improving the productivity of SFs, reduce their risk of production, lowering transaction costs, promoting farmer income and thus enhance livelihoods in ASAL areas. SFs plays a crucial role in agricultural production in dry lands in Africa [3]. Approximately 90% of the agricultural production in Africa is contributed by the SFs and therefore they support socio-economic development, improved food security, environmental sustainability under climate change scenarios [13,14]. Perhaps one challenge of CF is to understand its context in farming communities, and the following section help in nexus description of the term.

Description of Contract Farming

Different authors have described the CF and in the context of this article only a few are reviewed and presented in the following list (*i-vii*).

Contract Farming is an agreement, oral or written, between farmer or farmer groups and processing and/or marketing firms, commercial or otherwise, for the production and supply of agricultural products under pre-determined conditions, prices [15,16].

(i) ***Contract Farming*** is a practice where farmers and buyers make advanced agreements on volume, quality, and time of delivery, use of inputs, and price or pricing formula. The contractor under Production Farming (PC) offers high-quality inputs. The buyer provides a fixed price of the produce in advance, to reduce the price risk for the farmers [17].

(ii) **Contract Farming** is a procedure for the production and supply of agricultural produce under forward contracts, the crux of such contracts/arrangements being a commitment to deliver an agricultural commodity of a type, at a time and a price, and in the quantity required by a known buyer. Such agreements can be either written or verbal, detailing the production or marketing conditions. CF permits agribusiness an undeniable degree of jurisdiction over production and marketing without possessing a farm which gives them the opportunity to ensure the availability of supply at required quantity, quality and time [18].

(iii) **Contract** Farming is a prearranged arrangement between farmers and buyers or companies, whether oral or written,

indicating one or more settings of production and/or marketing of an agricultural products [19].

(iv) **Contract Farming** is an agreement between a farmer and a purchaser founded in advance of the growing season for a specific quantity, quality and date of delivery of agricultural output at a given price or price formula fixed in advance [20].

(v) **Contract Farming** refers to agricultural production contract carried out according to a, prior agreement in which the farmer commits to producing a given product in a given manner and the buyer commits to purchasing it at an agreed price [21].

(vi) ***Contract Farming*** is defined as agricultural production carried out according to an agreement between farmers and a buyer which establishes conditions for the production and marketing of a farm product. To be binding and enforceable, such agreements depend not only on good contractual design, but also on the existence of an adequate legal framework. This aims to illustrate some of the legal issues involved in the design, negotiation and enforcement of farming contracts [22].

Drivers of Contract Farming

A number of factors affect CF and peoples' perception in a given area. These include age of the household head, total land size available for farming, farmer income, produce farm-gate price, off-farm income and crop productivity [12]. Figure 1 displays the main factors that can drive the success of CF in ASALs such as cost of production, marketing dynamics, improved technology, access to markets, price of the contract, contract risks, access to credits, financial resources and transaction costs.

The descriptions of how the factors of cost of production and marketing, improved technology access to markets, price and contract risks, access to credits and financial resources, and transaction costs are shown in Table 1.

Technologies that Enhance Contract Farming (CF) in ASALs

Different technologies can be used to enhance CF in ASALs include automation of irrigation systems, Smart phone and (Global Mobile for Systems communication) GSM technologies, Artificial Intelligence (AI), Robotics, Smart sensors, Internet of Things, Unmanned aerial vehicles and yield monitoring. The application of these technologies in ASALs are as illustrated in Table 2.

Technology transfer in Contract Farming

Different technologies may be required at different levels of contract farming. Thus the relevant technologies are required for adoption and there should exist possible pathways for the technology transfer. After exploratory research in this area, findings show that technology transfer may be applied in a number of approaches. Figure 2 shows the technology transfer block where technological innovations, farmer education programs, extensions services and farmer organizations are key in CF technology transfer.

Benefits of Contract Farming (CF) in ASALs

There are a number of advantages of CF in the Arid and Semi-arid Lands (ASALs), the major ones are summarized below

(i) ***Access to Markets:*** Access to High Value Markets: CF can link SSFs to high value markets where they can sell crops under

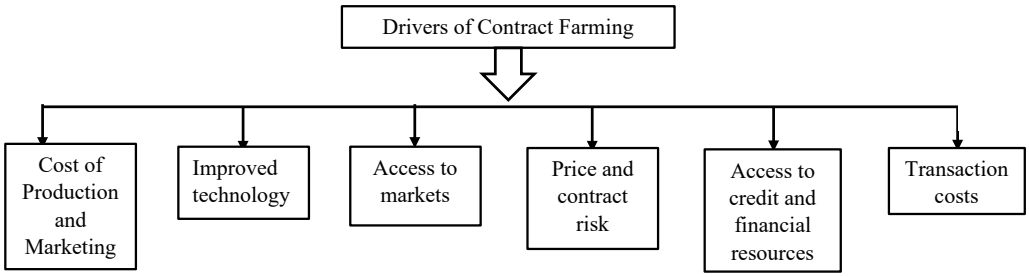

Figure 1: Flow chart showing the main drivers of contract farming.

Table 1: Description of the drivers of CF.

S.No	Factor	Description
1	Cost of production and marketing	Farming inputs and extension services can be obtained at reduced costs. In addition, low transportation costs can help in reducing marketing costs.
2	Improved technology	Access to Agricultural Technology has a positive influence on success of CF. Firms engaged in CF often provides necessary inputs which care mostly improved varieties seeds and fertilizers, technical assistance and timely training to their smallholder partners. Learning by doing may have spillover effects that increases productivity of non-contract crops
3	Access to markets	Access to consistent markets with attractive prices is key to ensuring that farmer are motivated to continue with farm production. CF offers a predetermined prices to farmers under market contracts, where the price of the commodity is not affected by the prevailing market conditions rather it is fixed at the beginning.
4	Price and contract risks	Arrangements in CF should focus at reducing price and fluctuation risk to farmers: In most cases, Contract Farming lowers the risk of price fluctuations of contract prices are pre-set. Furthermore, CF spreads production risk among the parties involved
5	Access to credits and financial resources	Contract Farming offers Small-scale Farmers (SFs) an opportunity to access capital from either contract firms or other financial institutions. Additionally, CF help the farmers to acquire inputs on credit for them to pay after harvesting period when the contracting firms purchases their agricultural produce.
6	Transaction costs	Some contactors or buyers may want to arrange for CF with large Agricultural farms. They prefer this in order to minimize on transaction costs. The problem with suh preference is that CF could marginalize extremely deprived small-scale farmers (SFs)

Table 2: Prioritized technologies for enhanced contract farming in ASALs.

S.No	Technological Advancement	Description
1	Automation of Irrigation systems	These are Systems that trigger and control irrigation devices remotely, and automatically. Such systems also predict how much water to be applied, and how often the irrigation water is applied. The two elements of amount of water to be applied and the time constitute the irrigation scheduling for proper water management, and crop water stress control. Automation is used to save on labor costs and save irrigation water expenses, increase crop productivity, and opportunity to grow diverse crops. Automation of irrigation may involve integration of soil moisture detection, irrigation water requirements, rainfall data, and internet of things (IoT) technology to optimize crop water application [23,24]. In ASALS water scarcity is a crucial problem and thus getting sufficient water for the crops can be challenging. Automation of irrigation is a key technique in irrigated agriculture in such areas. With new irrigation Techniques that have recently been developed the efficacy of water application has been increased in drylands and diversified cropping systems [25]. Some of the notable new techniques include (i) Variable rate irrigation (VRI) (ii) Plant water stress sensing (PWS) and (iii) Irrigation management zones (IMZ) Automation of irrigation has major advantage of saving resources such as water, time and labour. In addition, automation of irrigation water application can help farmers to mitigate on climate change impacts in ASALS.
2.	Smart-phone applications/ GSM technology	Smart-phone applications are being increasingly integrated to farming operations. Simply these are Smartphone-enabled agricultural applications used for instance in agricultural vehicle tracking, farm data management, market updates, weather updates, smartphone artificial intelligence (AI), and weed/pest/disease identification and control. GSM is an acronym for Global System for Mobile communications. It is a digital mobile network technology that has become the most important tool of communication for farmers to access agricultural-related information. It helps farmers in precision agriculture where smart sensors are important in modern farming as well as connect and close the information gap among themselves and other stakeholders (Soussi *et al*., 2024). There are various benefits to the use of smart-phones to the famers. For instance use of this technology provides easy access to market information, weather information, provide easy-to-use applications for operating hardware, Internet of Things (IoT) solutions, easy access to sensor data, cloud services access, and farm management applications. All these are available in the GSM technology interface at affordable prices to small-scale farmers in the ASALs.
3.	Artificial Intelligence (AI) Integration with Robotics	The system consist of unmanned ground platforms equipped with sensors and actuators with artificial intelligence (AI) capabilities. They process data, crop harvest, plant tissue sampling, soil sampling Planting, fertilizer and chemical application, weed management and control. AI systems may be integrated with robotics for farm operations. Robotics have an advantage of making agriculture more efficient and increased income. They offer key solutions to specific challenges in agricultural production via automation of data acquisition and processing, and control of complex labor-intensive operations. Some of these include like weed control, pest an disease control, fruit picking, and automation of crop harvesting [26,27]. Their main role is to increase food production and to support the increased food demand resulting from human population growth. However, the use of robotics have certain challenges. First the cost of robotic systems that is integrated with AI solutions is high for small-scale farmers especially in ASALs to afford. For success of this technology adoption, robotics should be cost-effective. In addition robotics should have an in-build, easy-to-use user interface that operates in different types of farm terrains and soil conditions. Another challenge in robotics use is that current robotic and AI-based precision agriculture solutions have also been divided into different sub-systems including robots, drones, tractors, and various other mechanical equipment. Little effort has been made to integrate these sub-systems to make one affordable and coherently integrated system. These sub-systems need to be integrated in a way that ensures affordability and convenience to the end-user.
4	Robotics in Agriculture	Robotic systems are machine-like systems that perform multiple operations on farms. One robot may do a lot of work and thus aid in labor cost-cutting. These are unmanned ground platforms equipped with sensors and actuators with AI capabilities to process data for numerous farm operations such as crop harvesting, plant tissue sampling, soil sampling, soil preparation, planting, fertilizer and chemical application, and weed control.
5	Unmanned Aerial Vehicles (UAVs)	These are vehicles equipped with sensors and data collection and input delivery mechanisms. They are able to sense crops and their characteristics, monitor yield, detect weeds, pests and control via chemical application. They maybe in form of small-scale drone pilot managed by one person to serve a group of small-scale farmers
6.	Smart sensors and the Internet of Things (IoT))	The system may comprise of Wi-Fi (a wireless networking technology that uses radio waves to provide wireless high-speed Internet access). The Wi-Fi has sensors for crop, soil, or weather and is equipped with data transfer, and cloud computing. There are cheap sensors Integrated with Internet of Things (IoT) technology for conveyance of alerts for managing farming operations. In a nutshell, *Internet of things (IoT*) refers to devices with sensors, processing ability, software and other technologies that connect and exchange data with other devices and systems over the internet and any other communication networks.
7	Yield monitoring and food traceability	These are new systems in agriculture that have been invented for monitoring and measurement of yield and for tracking Post-harvest activities. They additionally aid in yield mapping of farm fields, food traceability and is a key application in both organic and livestock farming [28].

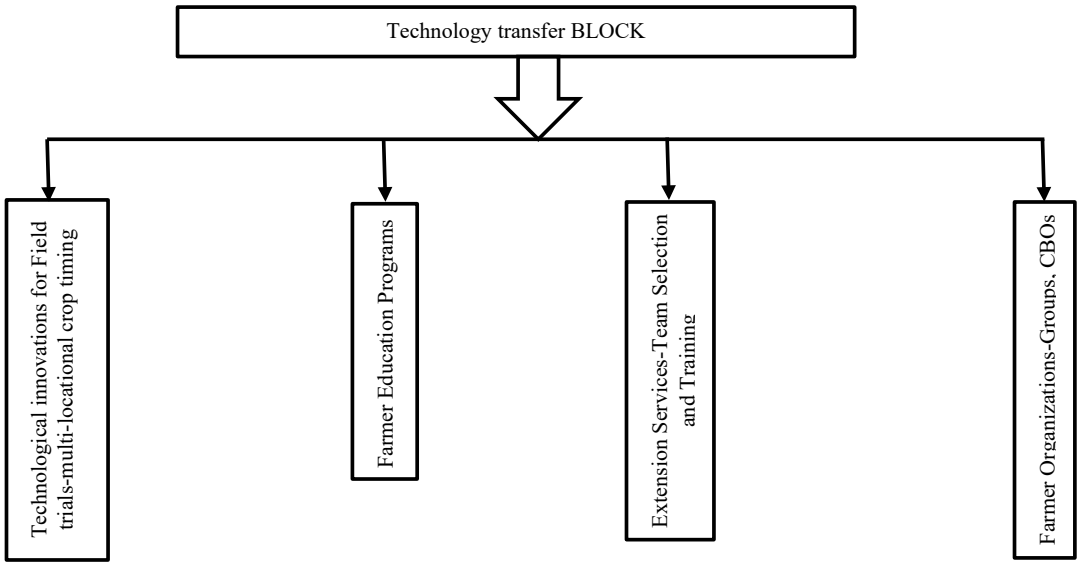

Figure 2: The technology transfer BLOCK key components.

favourable terms. However, the market access may have some shortcomings, for instance in Monopsonistic Markets Firms may exploit SSFs who are tied to a single purchaser (that is, extract increasing rents from farmers, charge high interest rates for input loans). Firms can also specify characteristics of contractors and exploit marginal producers

(ii) ***Production and Marketing Costs*:** Farmers can receive inputs at lower costs and extension services. It may ease transportation costs. Depending on contracted price, input and marketing costs may reduce farmer profit; farmers may have low bargaining power with contractors

(iii) ***Improved Technology*:** Access to Agricultural Technology: Firms engaged in CF often provide necessary inputs, technical assistance and training to their smallholder partners in a timely fashion. Learning by doing may have spillover effects that increase productivity of non-contract crops.

(iv) ***Price and Contract Risk*:** CF is used to reduce the price fluctuation risk. The CF lowers the risk of price fluctuations if contract prices are pre-set or predetermined. Additionally, CF spreads the production risk among the parties that are involved in the arrangement.

(v) ***Access to Credit***: Contract Farming offers SFs an opportunity to access capital an d financial support from financial organizations

(vi) ***Extension Services:*** In CF extension services is usually factored as part of the arrangement. Extension services supports the farmer to increase agricultural production by providing technical advice to farmers.

Problems with Contract Farming

Contract Farming may have some problems if not well organized, these include;

i. ***Monopsony***: Often crops that are grown in CF arrangement may have very little or no local demand. Thus the buyer may use this to some advantages including offering low prices and delayed payments to farmers since there is limited competition on the produce.

ii. ***Contract Rigidity***: the contract may be a bit rigid in terms of specific quality, timing sanitary, and regulations requirements for the export markets. This is more firm in developing countries which is a limitation to most local farmers.

iii. ***Side Selling/Marketing***: In some cases, where there is a local market for the crop being produced by local farmers, it may not be possible for the contracted price to be lowered below the local market price at the time of the harvest. For this scenario, farmers may be tempted to sell locally as it is perceived as a loss to sell under the CF arrangement.

Types of Contract Farming

There are three major contract farming types; Market specification Contracts resources-providing contracts and Production-management Contracts [29,30] briefly described below;

a) ***Market-specification Contracts*:** This is an agreement between farmers and the buyers about the marketing of the quantity produced at a predetermined price which is set to control the market risk. Such types of contracts put emphasis on product/ produce quality, their prices and timing. In most cases there is no provision for agricultural inputs. The producers endure most of the risks since they are the ones making most of the production decisions.

b) ***Resource-providing Agreement***: In this contract the buyers provide inputs and extension services at different stages of production. The inputs in most cases are in form of loans that may be settled during produce selling and delivery. Each party (the producer and buyer) may have some level of decision making at different levels and thus there is shared risk.

c) ***Production-management Contracts:*** In production contracts, the farmer provides land, labor and the necessary tools while on the other hand, the contractor provides farm inputs and extension services. The arrangement is such that cost of inputs and the services offered by the buyer, is deducted from the quantity produced after meeting the required standards of

the buyer. The buyer makes key decisions on production and harvest processes and timing. In addition, the buyer is required to provide technical advice or input during the production process.

Contract Farming (CF) models

CF is a system of transformation in Agriculture that integrates farmers, investors, buyers, traders and financial institutions. Such integration enhances optimization in agricultural performance along different value chains [31]. The working relationship of these different actors forms CF models, the major ones such as informal, centralized, multipartite, nucleus estate, and intermediary are described in Table 3 [32,33].

Table 3: Contract Farming models.

S.No	Name of the CF model	Description
1	***Informal***	Production contracts are designed, mostly, on an informal basis, often seasonally to enable the production of selected commodities suitability: The lack of coordination of farmers' activities requires government input through provision of essential farming services like agricultural research and extension
2	***Centralized***	Has a centralised buyer (agribusiness firm), which buys products from several farmers both large scale and small-scale farmers. It involves vertical coordination of the operations, with quota allocation and strict quality control Suitability: Annual crops, poultry, dairy and for tree crops requiring extensive processing, e.g tea or vegetables for freezing or canning purposes
3	***Multipartite***	Farmers are organized into cooperatives, which may receive funding from a selected financial institution Suitability: Organization of farmers into groups and cooperatives helps to ease administration of any financial support rendered
4	***Nucleus estate***	The sponsoring firm is expected to manage a central canning or estate. guarantees throughput for the processing plant though some sponsors may decide to confine it for research
5	***Intermediary***	Sponsoring firm's subcontracts bondages with farmers, for example, to go-betweens for ease of coordination and administration. A go-between has overseen that farmers abide by the dictates of the contractual agreement, however, with ultimate accountability to the sponsoring organization. suitability: The buying company lacks control of production and quality along with prices paid to the farmers

Making of a CF success in ASALS through Policy Steps

The following are the steps that can be adopted to make CF successful in ASALs

a) ***Offer Equal Opportunities***: The government at all levels (Local and National) National and development partners, and agribusiness companies can work together to ensure that CF offer equal opportunities to producers, and buyers and other key stakeholders.

b) ***Land reforms***: new programs that address challenges in land ownership, subdivision of land should be addressed for CF to thrive well.

c) ***Land Re-allocation***: Some land ownership has not been of any economic value for a long period, such land should be re-allocated to farmers or group of farmers that can pursue CF arrangements.

d) ***Promotion of gender balance and equality***: it is important to have an increase in female participation so that they benefit from CF since previous arraignments has favored male gender due to land ownerships issues. Historical land ownership and gender balance issues need to addressed fast to empower women farmers that can prosper in CF arrangements.

e) ***Improving Contract Framer bargaining power***: Contract farmers' bargaining power should be improved for increased their benefits. Thus the monopoly power of companies buying and promoting purchase from farmers should be discouraged where possible. There should be a situation where many alternative companies contract farmers with different contract arrangements for farmers to choose accordingly.

f) ***Improved information flow***: most farmers in ASALs are experience multiple challenges such as lack of information or limited flow of information, poor market networks, lack of inputs, lack of credits. There is need for ease of information access by farmers in the ASALs especially pertaining the CF and the available opportunities to allow them make appropriate decisions that are more beneficial than when they lack information.

g) ***Promotion of new research methodologies in CF***: like any other research, CF require data-driven information that can be used for making decisions and to direct policy. This calls the investment by the government and development agencies on Contract Farming and associated research undertakings.

Conclusion

CF Promote sustainable agricultural production and improved livelihoods in ASALs. It's a catalyst that can drive socio-economic development in Climate Risk areas such as ASALs. Numerous contract farming technologies (CFTs) that can be integrated into policies that define agricultural practices in drylands should be adopted. Some of the key ones include Artificial intelligence, automation of irrigation, Internet, unmanned aerial vehicles and robotics in agriculture. Farmers in drylands should be well sensitized on the opportunities of CF including access and flow of the right information, Access to credit and loans and low risk in farming. These factors should boost the SFs in ASALs to adopt the CF in ASALs and therefore bring about sustainable improved livelihoods.

Acknowledgments

The authors express their gratitude and thanks to Farai Mutondoro, and Charles Nyazungu who motivated the writing of this article. It was during the CF seminar in 2024 in South Easter Kenya University where CF as an opportunity for farmers from different backgrounds was highlighted. The authors thank the University and the staff who organized for the CF seminar, as well as giving academic staff an opportunity to participate in the seminar.

References

1. Vema KK, Song X, Kumari A, et al. Climate change adaptation challenges for agricultural sustainability, Plant Cell Environ. 2024: 1-12.
2. Baraj B, Mishra M, Sudarsan D, et al. Climate change and resilience, adaptation, and sustainability of agriculture in India: A bibliometric review. 2024; 10: 1-17.
3. Dhillon R, Moncur Q. Small-scale farming: Review of challenges and potential opportunities offered by technological advancement, Sustainability. 2023; 15: 1-15, 15478.
4. Touch V, Tan DKY, Cook BR, et al. Small holder farmers challenges and opportunities; implications for agricultural production, environment and food security, J Environ Manage. 2024; 370:1-17.
5. Golla B. Agricultural production systems in arid and semi-arid regions, J Agric Sc Food Technol. 2021; 7: 234-244.
6. Sivramkrishna S, Yotishi A. Monopsonitic exploitation in contract farming; articulating a strategy for grower cooperation, Int. J. Dev. 2008; 20: 280-296.
7. Neme AA, Tefera TL, Abdi BB, et al. The impact of contract farming on income of smallholder vegetables farmers in the central rift valley of Ethiopia, J. Discover agriculture. 2024; 11: 1-15.
8. Bellemare MF, Bloem J R. Does contract farming improve welfare? A review. World Development. 2018; 112: 259-271.
9. Tuyen MC, Sirisuplusxana P, Isriya B, et al. Perceptions, problems and prospects contract farming; insights from rice production in Vietnam, Sustainability. 2022; 14:1-22.
10. Ponguane S Impact of contract farming on smallholder farmers income and food security in Mozambique, A review, Nativa Snop. 2024; 12: 457-466.
11. Ma W Rahut D B, Soobe T, et al. Linking farmers to markets; barriers, solutions and policy options, Journal of Economic Analysis and Policy. 2024; 82: 1102-1112.
12. Murigi M, Muchai DN, Oganda MJ. Drivers of participation in Smallholders banana Contract Farming in Kenya, AJER. 2024; 12: 101-119.
13. Spencer D. The future of agriculture in sub-saharan Africa and south asia, sustainable food security for all by 2020, proceedings of the international conference. 2020.
14. Touch V, Tan DKY, Cook BR, et al. Smallholder farmers' challenges and opportunities: Implications for agricultural production, environment and food security, J Environ Manage. 2024; 370: 1-17.
15. Simmons, P. Overview of smallholder contract farming in developing countries. ESA Working Paper No. 2005: 02-04,
16. Narayanana S. Contract farming in Developing Countries, perspective, the promise and its perils, In Barret C. B (Eds)-Palgrave studies in agricultural economics and food policy, USA. 2025.
17. Otsuka K, Nakano Y, Takahashi K. Contract farming in developed and developing countries. Annual Review of Resource Economics. 2016; 8: 353-376.
18. Singh S. Role of the State in Contract Farming in Thailand: Experiences and Lessons. ASEAN Econ Bull. 2002; 22: 217-28.
19. Minot N. Contract Farming in Developing Countries: Patterns, Impact and Policy Implications Case Study 6-3 of the Program, Food Policy for Developing Countries: The Role of Government in the Global Food System. 2007.
20. Rehber E. Contract Farming: Theory and Practice CFA. 2007.
21. Silva C. The Growing Role of Contract Farming in Agri-food Systems Development: Drivers, Theory and Practice. 2005.
22. FAO Contract farming: Legal considerations on contractual design and enforcement Report. 2017.
23. Deepika R, Devadharshini V. Detection of soil moisture and automatic irrigation system by IoT. Compliance Engineering Journal. 2024; 13: 198-209.
24. Morchid A, Et-taibi B, Oughannou Z, et al. IoT-enabled smart agriculture for improving water management: A smart irrigation control using embedded systems and Server-Sent Events, Journal Scientific African. 2024; 27: 1-17.
25. Mogalhaes TOP, Pinto MF, Oliveira M VM. et al. Variable rate irrigation in diversified vegetable crops, AgriEngineering. 2024; 6: 3227-3241.
26. Moshayedi AJ, Sohail Khan A, Yang Y, et al. Robots in Agriculture: Revolutionizing Farming Practices. EAI Endorsed Transactions on AI and Robotics. 2024; 3:1-23.
27. Lytnidis C, Pachidis T. Recent advances in Agricultural Robotics for automated weeding, AgriEngineering. 2024; 6: 3279-3296.
28. Wassie A M, Aseged T, Shitaw T. Influence of artificial intelligence technology on the management of livestock farms, International Journal of Distributed Sensor Networks. 2024: 1-12.
29. MacDonald JM, Korb P. Agricultural contracting update: contracts in 2008. Econ. Inf. Bull. 72, Econ. Res. Serv., Dep. Agric., Washington, DC 2011.
30. Mukucha P, Tsekea S, Jaravaza DC, et al. Contract farming: a comparison of production and marketing contracts as sourcing strategies in the fast food restaurant industry. JFBR. 2024: 1–18.
31. Barik P, Bedamatta R. Vicraman S. Smallholdres in contract farming value chain; Challenges and opportunities, empirical evidence from West Bengal, India, Journal of International Food and Agribusiness Marketing. 2024; 1: 1-33.
32. Melese A T. Contract farming business models that maximize the inclusion of and benefits for smallholder farmers in the Value Chain, Uniform law review. 2012; 17: 291-306.
33. Narayananan S. Contract farming in perspective, Springer Nature Link, chapter: 2025: 13-25.