INITIATIVE ON Mixed Farming Systems

CGIAR

Cereal-Legume Mixed farming system of Ghana: transformations, structure, and intensification options

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The Sustainable Intensification of Mixed Farming Systems Initiative aims to provide equitable, transformative pathways for improved livelihoods of actors in mixed farming systems through sustainable intensification within target agroecologies and socio-economic settings.

Through action research and development partnerships, the Initiative will improve smallholder farmers' resilience to weather-induced shocks, provide a more stable income and significant benefits in welfare, and enhance social justice and inclusion for 13 million people by 2030.

Activities will be implemented in six focus countries globally representing diverse mixed farming systems as follows: Ghana (cereal–root crop mixed), Ethiopia (highland mixed), Malawi: (maize mixed), Bangladesh (rice mixed), Nepal (highland mixed), and Lao People's Democratic Republic (upland intensive mixed/ highland extensive mixed).

Contents

1 Mixed-farming systems of Ghana

Agriculture in Ghana is characterized by several farming systems, unique in their characteristics and adaptation to agroecological zones. These farming systems largely depend on crops and livestock production dominated by smallholder farmers (Ellis-Jones et al., 2012). Farming systems are defined as a population of individual farm systems with varying degrees of interdependency on a complex of resources that are arranged and managed according to the totality of production and farm household-level decision making (Giller, 2013; Kuivanen et al., 2016; Timler et al., 2014). Farming systems are also characterized by their resource use and conservation practices.

It is challenging to fully capture the diversity of the farming systems in Ghana and characterize them into typologies. Several authors have however attempted to characterize farming systems in Ghana based on the biophysical, sociocultural, economic, and institutional factors. Alemayehu et al (2022) characterized farming systems in Ghana and Côte d'Ivoire using household demographic, agricultural, biophysical, economic, and institutional indicators. Ellis Jones et al (2012) also employed the use of the sociocultural and economic environment to characterize farming systems in Northern Ghana. Several other characterizations focus on crop and/or livestock production, soil and water management, pest and disease management, farm machinery and equipment as well as business management and marketing.

While high resolution spatial representation of farming system is not currently available, based on farm household resources, Kuivanen et al (2016) characterized farming systems in Ghana as either well-resourced, medium-resourced, resource-constrained, and severely resource constrained.

1.1 High-resource farm types

The well-resourced farming systems in Ghana comprise the commercial crop and livestock/poultry systems. The resource base for this system includes land, improved agronomic technology, mechanization (including transportation), post-harvest storage and well-structured marketing. These commercial crop-based farming systems also include irrigated cropping systems for rice, maize, vegetables, and fruit crops. The cereal-based focuses on the mono-cropping of cereals such as rice, sorghum, maize and millet while the legume-based also focuses on mono-cropped legumes such as soybean, groundnut and cowpea. The tree crop farming system in Ghana is also classified as well-resourced where the major resource base comprises land, improved agronomic technology (seeds/seedlings, good agronomic practices, pest and disease control) and well-structured markets. This farming system comprises plantations where sole tree crops are grown for commercial and industrial purposes (e.g. cocoa, oil palm, rubber, coconut, cashew); agroforestry where tree crops are integrated with crop production;

and the production of perennial fruit tree crops such as mango, avocado and citrus.

The well-resourced commercial systems also include livestock, poultry and the emerging aquaculture farming systems. These systems are also characterized by good land resources, technology and well-structured marking systems.

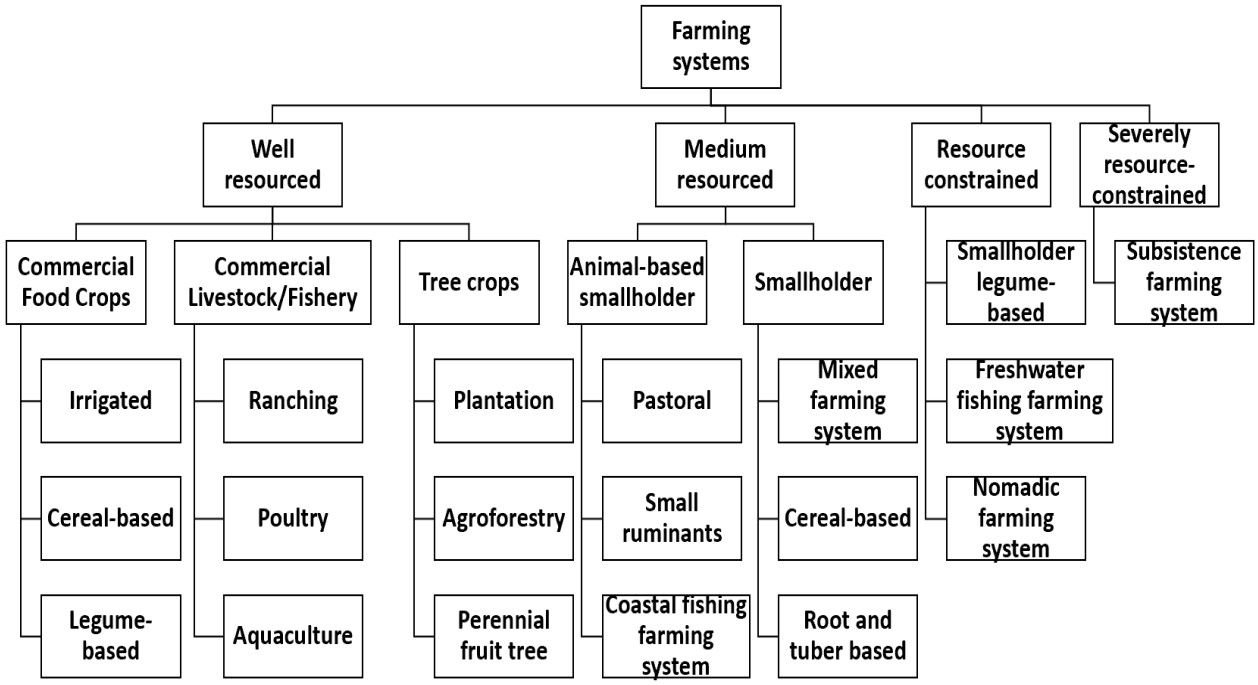

Figure 1. Classification of farming systems in Ghana based on resource use and availability (source)

Sheep and sometimes pigs are integrated into tree crop production systems. This is mainly found on oil palm, citrus and coconut plantations. Livestock farmers who practice this system show higher standards of stock husbandry than the agro-pastoralists. The biomass of the plantations comprises various shrubs, grasses and forage legumes. In a few cases, effort is made to introduce leguminous forages such as *Centrosema* sp. and *Stylosanthes* sp. into the biomass by oversowing during the dry season.

1.2 Medium-resource farm types

The medium-resourced farming systems include several smallholder systems such as the mixed farming system, root and tuber and cereal-based farming systems, the small ruminants and pastoral farming systems as well as the coastal fishing farming systems. Mixed farming systems involve the production of different crops and livestock(s) on available land space (Mekuria & Mekonnen, 2018). This system usually has a reduced resource requirement as resources are typically recycled within the system. The integration also ensures on-farm income diversification as well as

household food and nutrition security. The smallholder root and tuber-based cropping system here may be produced as a sole crop or intercropped with either legumes or cereals. Similarly, the cereals-based cropping system may also be produced as a sole or intercrop.

Under freshwater fish farming deals with raising and breeding aquatic animals (fish, shrimp, crab, shellfish, etc.) and plants for economic importance in rivers, lakes, ponds, reservoirs and other inland waterways (including brackish water), (Aheto, 2019). There is medium use of technology and can be capital-intensive.

1.3 Low-resource farm types

The resource-constrained farming systems in Ghana comprise the smallholder legume-based farming systems, the nomadic farming system and the freshwater fish farming system. Principally, pastoral and small ruminant farming systems have reduced resource availability and use. Production is mostly smallholder-based, with minimal technological inputs and low marketing structures. Pastoral production revolves around herdsmen, mobile livestock and rangelands where livestock herds are mostly stationary and allowed to grow on forage and high protein concentrations (de Leeuw et al., 2019). Dry season forage and water shortages force herders to move herds, seeking water, fodder and herd survival elsewhere (Ayantunde et al., 2011). In the nomadic system, farmers raise farm animals (cattle, goats, sheep, donkeys etc) and migrate with them in search of grazing land and water resources. It is characterised by hardiness, mobility and ability to subsist on sparse forage. The animals provide milk, cheese, meat, hair, wool, skins and dung for fuel.

The coastal fishing farming system is characterized by less resource availability and usage. Application of technology under this system is less. The system involves the use of boats, nets and other fish-catching equipment for sea fishing. This system is threatened by the over-exploitation of the common resource, both locally and by larger well-equipped fishing boats. It is also recurrently affected by increased climate change effects like cyclones, tidal bores and extreme tides. Coastal land resources are under pressure from the high population density along the coastline, and from the expansion of modern and capital-intensive aquaculture enterprises (Aheto, 2019).

Plant-based smallholder farming system is characterised under this system by its limited access to land, financial capital and inputs, high levels of vulnerability and low market participation (Chamberlin, 2008). There are macro- and micro-level structures, and these systems' drivers and constraints are shaped by constant interaction with the local social and biophysical context. Production is either crop or animal base or the integration of crops and animals in a mixed farming system. It's often sole cereal, root and tubers and legumes or a combination with animals (livestock or poultry). Mixed farming combines different agricultural activities, such as crop production and livestock rearing, on the same farm.

This type of farming system emphasizes using integrated farming practices that improve soil fertility, reduce soil erosion, and increase productivity. Major cereals include; maize, rice and sorghum; Mixed farming is a type of farming system that involves combining different types of agricultural activities, such as crop production and livestock rearing, on the same farm. Legumes include cowpea, groundnut and soybean while livestock such as cattle, sheep, goats and pig and poultry form the animal component.

Grain legumes such as cowpeas, soybeans, groundnuts and Bambara groundnuts are grown as mono-crop, intercrop or in rotation with other crops. The grain legumes have contributed in diverse ways to the restoration and maintenance of soil fertility as there is little use of inputs under this low-resource system.

Severely resource-constrained farming system focuses on subsistence objectives mostly practised by small-scale farmers who grow crops and raise livestock primarily for their own consumption. Subsistence farming usually involves low levels of technology and minimal use of external inputs such as fertilizers, pesticides, and machinery and the turnover is very low (Asare-Nuamah, 2021). It is usually practised on sole or mixed cropping.

2 Evolution of mixed farming systems

In this section, we explore factors responsible for diversification of cropping mix and nature of farming system in general. The structure and functions of farming systems undergo transformation in response to developmental trajectories pursued by governments that can be reflected in the key government development trajectories/strategies and government policy/budgetary support.

1.4 Government development strategies

In line with national development plans and strategies, the agricultural system tends to shift from food to cash crops, and from upland to lowland or from meeting food security to meeting nutritional security. Other development programs such as mechanization, processing industries, or market restrictions and facilitation drive spatio-temporal changes in farming systems (Amanor & Iddrisu, 2022). In this review, we take stock of eight decades of agricultural transformation in Ghana. During the period, we identify 4 changes in agricultural development that have been key in the evolution of Ghana's farming systems.

Pre-colonial, the focus was on cocoa production and farmers were supported through cooperative societies. Since its independence, the government of Ghana has supported agricultural development through state-led industrialization supplemented with large-scale state-owned farming and a series of heavily subsidized programs to produce prioritized food staples by smallholders. The objectives of the State Farms were to diversify export production away from cocoa, increase food production for the domestic market, and produce raw materials for agro-industries. The

State Farms focused on rubber and oil palms in the south, cotton in the Volta Region, and rice and maize in the northern sector (Amanor & Iddrisu, 2022). Rice farming was intensified, pre-dominated by medium and large-scale farmers.

Around 1984, there was a structural adjustment program where state-led industries were commercialized. The country saw an uninterrupted growth of Gross Domestic Product, mostly through services. The contribution of industries and agriculture has dwindled. The growth in agriculture is attributed to cocoa which has been promoted and heavily supported as the major export crop. With the formation and decades-long support to COCOBOD, there has been a shift from food crops. Cocoa accounted for the largest share of cropped area. In the past two decades (1994-2013), cocoa accounted for 12% of total value with growth of 5.6%. Cereals saw production growth of 2.9%, roots and tubers 4.9%, while livestock had a lower growth of 3.2% (Hailu, 1990).

Government public expenditure on agriculture has been below 10% since the 1960s and averaged 2-3% in recent years. The government has recently attempted to promote non-cocoa agricultural growth through several new subsidies and investment programs. The most prominent program in the 1990s was the Sasakawa Global 2000, through which the government distributed large amounts of seed and fertilizers to farmers under a state-led soft loan arrangement. The state-led soft loan failed due to failed recovery (Breth & Dowswell, 2003).

Mechanization, as a major production factor, has been found to play a significant role in agricultural transformation (Amanor & Iddrisu, 2022). Post-independence, the state-led mechanization supported largely wealthy farmers or tractor centers for medium-scale state cooperative societies that led to the dominance of large-scale state-controlled farms (Lipton, 1977). The system collapsed because the tractors were imported from John Deere and Massey Ferguson, whose operational costs were higher relative to farmers' income (Hailu, 1990). Since the 1960s and 1970s, there have been continuities and discontinuities in the state's support towards mechanization which has shifted farming systems. In recent times, since 2007, the government has been supporting mechanization for land preparation from 33% to 60% through the Agricultural Mechanization Services Centers (AMSECs) (Diao et al., 2014). The AMSEC also promoted the emergence of medium-scale commercial farmers who benefited from market liberalization. These shifts in farming systems follow the neoclassical theories of agricultural transformation which postulates that innovations induce change and lead to social differentiation (Amanor & Iddrisu, 2022). The medium-scale farmers tend to be urban traders and civil servant classes who connect rural spaces with the expanded agricultural markets. In case of Ghana, mechanization has focused mostly on the tractor services that has enabled farmers, even smallholders, to plough large tracks of land. Instead of intensification that is associated with mechanized farming, the mechanization in Ghana invertedly promotes extensification, thereby affecting agricultural

sustainability. The AMSECs enabled farmers to expand land under agriculture for cereal, root and tubers, and legume crops at the expense of other land uses, potentially into forest and grazing areas.

In most recent times, the 2017 planting for food and jobs shifted the focus from cash crops to food crops but failed to deliver value for money due to distribution inefficiencies along the value chain. Ghana's Planting for Food and Jobs phase two (PFJ 2.0) seeks to transform agriculture value chains for economic development with active private-sector participation in ten food crop value chains as well as poultry. Although the program runs in parallel to cocoa and tree crops programs, it received greater support from the government with the potential to influence farmers towards food crops.

1.5 Policy and budgetary allocation

This review aims to identify strategic policy directions and areas of reform that are essential for accelerated and sustainable growth of farming systems. Sustainable farming systems will contribute to the overall resilience of the Ghanaian economy and help Ghana achieve transformation and modernization of its farming systems. There are both challenges and opportunities to achieve this transformation and modernization. The current farming system is characterized by low yields in staple, cash crops and animals. Ghana is a net importer of staple foods (raw and processed), including rice, poultry, tomato, sugar, and vegetable oil. Ghana, however, has significant agricultural potential, particularly in the semi-arid agroecological zone of the Northern Savannah and the Afram Plains (World Bank, 2017).

Existing policies appear to emphasise high-input, resource-intensive farming systems, with much ongoing research focusing on intensive systems with high external inputs. Policy for farming systems should aim to move from resource-intensive systems to ecology-friendly farming. Such policies would ensure that sustainable agricultural approaches are considered and would fundamentally change the criteria for evaluating success in agriculture. Broader range of measures need to be considered when evaluating system success, including environmental protection, areas for tree planting, conserved land and the involvement of smallholders. (MoFA, 2009).

One of the best indicators of commitment to improving farming systems is the budget and expenditure. The priority is to improve sector budget allocation expenditure and management as well as budget coordination in agriculture. The second priority is for the Ministry of Food and Agriculture (MoFA) to improve the collection and analysis of agricultural statistics to regularly produce high quality and credible data for sector planning. Third, MoFA should improve the efficiency and effectiveness of input subsidy programs and close gaps in input supply legislation. Fourth, prioritizing public investments in infrastructure, particularly in areas with high agricultural potential, such as the Northern Savannah agroecological zone and the Afram Plains, is critical to maintaining the resilience and growth of the farming system. The government should promote

coordination in the implementation of its national action plan for climate-smart agriculture and food systems. The Government should also strengthen research on climate-smart agricultural technologies, promote sustainable agricultural mechanization and strengthen links between research and extension to promote technology adoption by farmers, especially in fragile locations with high potential (World Bank, 2017).

Farming systems would thrive better under community-supported agriculture programmes, e-commerce and participatory guarantee schemes that reconnect producers and consumers in rural and urban areas. Investment and inclusive finance-specific credit lines and investment schemes to promote system resilience. Flexible finance and insurance programmes that allow food producers to purchase local produce and make decisions based on their own needs will support autonomy and adaptability (MoFA, 2017). To complete this policy review, government spending on agriculture should be analysed and benchmarks and indicators created to track spending. These indicators are a better measure of policy transition and can serve as a basis for stakeholders' engagement.

2 Conditions and drivers of farming system evolution

In addition to the government strategies and investments that are shaping the farming system in Ghana, the actual transformation and status of the farming system are intricately linked to the specific biophysical settings of the area, coupled with the socio-economic drivers of farming. The interplay of these factors contributes significantly to the dynamic nature of the farming system. Under this section, we present the agroecological and other socio-economic drivers determining the transformation and nature of the farming system in Ghana.

2.1 Agro-ecological zonation

Ghana is considered one of the countries most affected by climatic variabilities. The country's vulnerability is highly correlated with its climatic and geographical peculiarities. The temperature and precipitation regimes influence soil temperature and soil moisture conditions, as well as the soil type, and are also responsible for the presence of distinctive vegetation types in each biome. From the southern part (i.e., shores of the Atlantic Ocean northwards), climatic variations determine the diversity of biogeographical (agro-ecological) zones from south to north. The zones are the Rain Forest (RF), Coastal Savannah (CS), Semi-Deciduous Forest (SDF), Forest/Savannah Transition (FST), Guinea Savannah (GS), and the Sudan Savannah (SS) zones. For more emphasis, these geographical areas are delineated based on climate homogeneity and impact on agriculture. Concerning agriculture, the six agro-ecological zones are defined not only

based on climate but also reflected by the natural vegetation and influenced by the predominant soil types (Kemausuor et al., 2013). The differences in the climatic conditions, soil types and natural vegetation cover. The various zones have varying effects on the productivity and type of crops grown in these zones. The characteristics of the agro-ecological zones are summarized in *Table 1*

In the RF zone near the southern Atlantic coast, the landscape is mostly flat with remnants of dense humid forests. It is characterized by warm temperatures and high rainfall with annual precipitation averaging around 2,200 mm distributed in a bimodal pattern in the wet southwest corner of the country (Qamar, 2005). The average daily temperatures range from 30°C during the day to 24°C at night with relative humidity ranging between 77 percent and 85 percent. There is a bi-modal rainy season from April through June and September through November.

The primary *soil*s found in the *rainforests* are Oxisols and Ultisols, which are *s*oils rich in iron and aluminum oxides (red color) but with low inherent fertility due to the high amounts of rainfall and fast uptake of nutrients from decomposing organic matter by plants. Agriculture in this zone focuses on tree crops, e.g., cocoa (*Theobroma cacao*), palm (*Elais guineense*) plantain (*Musa paradisiaca*), coconut (*Cocus nucifera*), roots and tubers; livestock plays a minor role. Due to the nature of the zone, trees on farms are very common and a dominant farming system in this *zone*.

Separated from the RF is a belt of forest intermediate in character between the moist semi-deciduous type. The deciduous forest is characterized by trees that lose their leaves at the end of each growing season in other words, plants lose their foliage for a very short period, when old leaves fall off and new foliage growth starts.

The FST zone has a total land area of 8400 km^2 and a mean rainfall of 1300 mm. The major and minor raining seasons occur between March-July and September-October of each year, respectively. The GS zone however has a total land area of 147,900 km^2 and a mean rainfall of 1000 mm. The unimodal rainfall regime of the GS zone occurs between May and September each year. The forest savannah transition (FST) is characterized by a bimodal rainfall regime (Codjoe & Bilsborrow, 2011). Additionally, the soils of the FST zone are loamy, well-drained and rich in organic matter.

Table 1 Characteristics of Agro-ecological zones of Ghana

Zone	Area (1000 ha)	Rainfall (mm/yr)	Length of growing season (days)	Dominant land use systems	Main food crops
Rain forest	750	2200	Major season: 150 - 160 Minor season: 100	Forest, plantations	Cassava, plantain, maize, oil palm
Deciduous forest	740	1500	Major season: 150 - 160 Minor season: 90	Forest, plantations	Cocoa, cassava, plantain, maize, oil palm
Transition Zone	6630	1300	180 - 200	Annual food and cash crops	Maize, cassava, yam, taro (cocoyam), plantain, groundnut, cowpea, maize
Guinea savannah	14,790	1100	180 - 200	Annual food and cash crops, livestock	Sorghum, maize, groundnut, millet, yam, cowpea, maize
Sudan Savannah	190	1000	150 - 160	Annual food crops, livestock	Millet, sorghum, cowpea, groundnut, yam, maize
Coastal savannah	580	800	Major season: 100 - 110 Minor season: 50	Annual food crops	Cassava, maize

Source: FAO, 2005

2.2 Social-economic drivers

2.2.1 Gender and social inclusion

Women account for 50% of the agricultural labour force in Ghana, directly engaging in the production of nearly 70% of food crops. Although women's contribution to the sector is quite significant, there exist notable gender and social inequalities in the sector. To this, there have been commitments through policies and investments towards gender equality and women's empowerment, however, there is a significant gap in converting these efforts into concrete developmental outcomes for rural women and their communities (FAO, 2023).

The inequalities in the agriculture sector are mainly because females in most rural Ghana have limited access to resources, namely land, livestock, and necessary agricultural services, they tend to operate smaller farms (CCAFS, 2021). Additionally, they have less access to finance, technology, and training, affecting their productivity and profitability (ACDI/VOCA, 2023). These inequities result in the susceptibility of female-headed households to food poverty in Ghana. Gender inequalities therefore influence food security (Addai et al., 2022). Women's agricultural production is mostly for household consumption. In most scenarios, they meet households' food needs but do not generate income. Their production of livestock is limited, with most of the majority raising poultry and livestock, while men are engaged in large-scale production of goats and sheep. In the agricultural value chain, women predominantly act as aggregators, purchasing food from producers and re-selling it in larger quantities, often to male wholesalers (CCAFS, 2023).

2.2.2 Access to information, especially CIS

Women are more vulnerable to climate events mainly due to the numerous obstacles they face in accessing productive inputs, assets, and services. Access to climate information services (CIS) is crucial for adapting to climate change and managing climate-related risks, particularly for smallholder farmers. However, there is a need to consider gender-specific needs in the design and dissemination of CISs to ensure equity and effectiveness for both men and women. Research has shown that men and women are likely to have different needs for CIS, and various gender groups have distinct preferences, understandings, and uses of CIS, which affect adaptation decisions differently (Acheampong et al., 2023; Assan et al., 2020; Partey et al., 2020). In Ghana for example, it is reported that access to weather and climate information services (WCIS) through mobile-based technologies improved the adoption of climate-smart agriculture (CSA) technologies such as multiple cropping practices, water management, and pest-resistant crops (Assan et al., 2020). Also, the

gender perspective of climate information use is not well studied, despite its necessity for developing gender-responsive CIS (Partey et al., 2020).

2.2.3 Access to inputs and technology

Access to inputs (e.g. land) and farming technologies are the most valuable production prerequisites for farming (Buehren, 2023). The availability and quality of agricultural inputs are crucial determinants of productive investments. In Ghana, agricultural productivity is central to poverty reduction, food security and GPD growth. For instance, Ghana's growth in 2022 was hugely driven by agriculture, which grew by 4.2%; the second highest to the Services sector (5.5%) (Bank of Ghana, 2022). However, access to inputs and technologies in the sector has been progressively slow and lags other developing countries like Kenya, India and Ethiopia; which can boast of access to high-quality seed, fertilizer and soil amendments, pesticides and crop protection.

Progressively, Ghana has made strides in agricultural technologies such as mechanization, GPS-guided tractors and drones for minimizing waste, ICT-enabled initiatives, motorized thermal screen systems and specialized automated greenhouses (WACCI, 2018). Also, mobile phones and technologies have helped to improve the coordination of input and output supply chains and provide farmers access to financial services. Despite these technology-driven incentives, Ghana's agricultural sector is yet to fulfil its full potential to achieve high productivity and needed food security to supplement other regions in sub-Saharan Africa. This paper will emphasize the current progress made in the agricultural sector concerning inputs and technologies and address the challenges associated with measuring the impact of access to input and technologies for agricultural initiatives in Ghana.

2.2.4 Access to knowledge/information

Beyond access to credit and insurance provision, farmers' need for information is an essential component of the agricultural process, ranging from climate information services (CIS), cropping calendar, good agronomic practices, cultivation practices and price value. However, due to the dispersed farming and marketing communities in Ghana, the traditional economic theory does not hold for readily sufficient information (Aker et al., 2016; Tanko, 2020) and farmers suffer from a lack of acquiring information. In this regard, a lack of access to information and required knowledge of good agricultural practices like input prices, weather patterns, natural disasters and new technologies may affect farmers' decision-making (Takahashi et al., 2020). Thus, there is a need to investigate how access to knowledge and information can impact agricultural outcomes and importantly develop models that tend to impact the efficient

transmission of knowledge via technological means to influence farmers' decision-making and performance in Ghana.

2.2.5 Coordination and linkages for technology dissemination

The Research-Extension-Farmer linkage system plays a critical role in the generation, development, dissemination and utilization of research results. The interactions between researchers, extension service providers and farmers are very critical for improved agricultural productivity as there is a direct link between technology adoption and the relationship existing between the technology providers (Battistella et al., 2016). Weak linkage between research and extension is a major constraint to agricultural development in many developing countries including Ghana.

The adoption of technologies by farmers depends very much on good communication and cooperation between researchers, extension service providers and farmer groups. According to Deneke and Gulti (2016), interaction among the stakeholders in the agricultural sector for improved adoption and productivity would be more effective if research and extension linkages are strengthened.

To address this problem of weak linkage between research and extension services in Ghana, the Ministry of Food and Agriculture (MoFA) in collaboration with Council for Scientific and Industrial Research (CSIR) established the Research Extension Linkage Committees (RELCs) in 1994; to serve as an interface between the National Agricultural Research System (NARS) and the National Agricultural Extension System (NAES). The research-extension-farmer interaction concept purposely is to bridge the gap in dissemination of search results to farmers.

In Ghana, research-extension-farmer linkages are operationalized through technical review meetings which are attended by key stakeholders such as extension, research and technical departments of MoFA.

The objectives of the RELCs among others include ensuring that research activities, particularly adaptive research respond to farmers' constraints which are identified through the Regional or District planning sessions as well as review of progress made by RELCs in solving farmers' problems and efforts made to promote proven technologies and best practices.

Since its inception in 1994, the RELC has been at the forefront of generating and disseminating demand-driven technology by providing a platform for key stakeholders in the agriculture sector to address farmers' constraints from all over the country. It further seeks to ensure the regular and timely release of budgeted funds by MoFA for RELC activities to facilitate generation of appropriate technology and its dissemination for enhanced productivity.

3 Limitations to farming system evolution

Ghana's farming system faces substantial challenges/gaps in management, technology, marketing and extension services, while having to deal with difficulties imposed by rising climatic variability (Harrison et al., 2016; Thornton et al., 2009).

3.1.1 Education and knowledge of farm resources management

Farming systems management involves the control and governance of units within the farming enterprise. The scope of management decisions ranges from crops, soil, water, pest and disease, mechanization and equipment, marketing and farm business management. Most Ghanaian farmers are smallholders, most of whom lack formal education. The lack of managerial knowledge and formal education hinders progress as most farmers lack the knowledge for crop selection, planting, fertilization, irrigation, pest and disease management and post-harvest handling of harvested produce. As such the productivity of farming systems is low. There are also serious gaps in the management and mitigation of erratic rainfall and drought both between and within seasons.

Most farmers are still unable to adopt improved technologies to manage key aspects of their production system. Though several efforts have been made to educate farmers in the various aspects of system management, farmers have difficulty understanding the design and operation of the technological and physical systems used in the agriculture system resulting in:

i. Low/declining soil fertility leading to low productivity
ii. Difficult in controlling pests and diseases
iii. Lack of access to financial credit
iv. Susceptibility to drought, unreliable/erratic rainfall and flooding
v. Issues with traditional land tenure system
vi. Over-reliance on traditional agriculture farming systems
vii. Difficulty in post-harvest handling and processing

3.1.2 Adoption of improved technologies

Technology adoption is a broad concept, it is affected by the development, dissemination and application at the farm level of existing and new interventions, all of which are encompassed in farm capital and other inputs. Several technologies have been developed to enhance the productivity of farming systems. Unfortunately, in Ghana, most of these technologies are focused on crops and animals with little to no attention paid to mechanization. In Ghana, mechanization at the farmers' level is all about land preparation (tractor operation), however, for farm systems to be productive, simple

equipment like planters, irrigators, and soil testers must be made available and affordable to farmers. Even the few pieces of equipment available are sophisticated to local farmers in terms of operation and maintenance and are mostly not adaptable to local conditions.

According to a study by Peasant Farmers Association of Ghana in 2011 most of the irrigation facilities which could have served as alternative sources of water supply had been abandoned all over the country partly because they could not be maintained locally (Osei et al., 2020). There is a need to fabricate local machinery that can be easily handled by Ghanaian farmers and can be operated between different components e.g. different crops with different architecture on the same field. Another gap is the low rate of technology adoption and the productivity growth occurring. The adoption rate of improved varieties, fertilizers, and agrochemicals is a challenge.

System productivity gains could be increased if farmers adopt new technologies. Increase in production is mainly explained by more intensive use of labour rather than by technological change indicating a gap in technology adoption. Science must keep on working to address the gaps of declining soil fertility, lack of improved seeds, problems of pests, disease and weeds, and the high cost of agri-inputs associated with farming systems. Some of these technology gaps are:

i. Lack of access to improved seeds and seedlings
ii. Lack of advanced technical knowledge in farming
iii. Low-level access to information on modern technology
iv. Lack of access and low adoption of mechanization and on-farm automation
v. Low usage of improved nutrient technologies such as integrated soil fertility management with emphasis on the use of improved seeds and organic nutrient amendments
vi. Lack of technology to control weeds and other invasive pests

Farmers, advisors and policymakers are faced with complex choices. They are faced with a wide range of technologies that are either available or under development; they must deal with the uncertainties of both the effects these new technologies will have throughout the agri-food chain and the impact that a whole range of policies will have on the sustainability of farming systems. In addition, there is increasing pressure on agricultural research and advisory budgets that must be accommodated. There is a linkage gap between community-based organizations and research and development organizations. Significant inefficiencies still exist in all farming systems, and this implies that there is potential to increase production given available inputs and current technology advances in the various farming systems.

3.1.3 Extension Service and farmer capacitation

The farmer-to-extension ratio of 1200 farmers:1 extension officer is a major gap to technology adoption and farmers' capacity building. This makes it almost impossible for most farmers to benefit from the services of agriculture extension officers leading to severe gaps such as:

- Low extension reach and capacitation of farmers
- Low confidence and engagement of farmers in extension
- Low farmer knowledge on improved and advanced farming technologies

Currently, intervention delivered to farmers focuses mostly on capacity building in technical skills, but capacities must also be built in leadership, communication, financial, and marketing skills. These components work hand in hand with knowledge to run farming systems. Technology adoption is affected by education, training, advice and information which form the basis of farmers' knowledge.

Existing mechanisms such as radio, television, and mobile phones could be used more intensively to provide access to more and better technical and market information in a cost-effective way (Chhachhar & Md Salleh Hassan, 2012). Educational workshops for AEAs and farmers need to be improved.

3.1.4 Post-harvest handling and marketing

Post-harvest handling and marketing are key to avoiding or minimizing post-harvest losses to the farmer and other stakeholders along the value chain. Identified constraints along the post-harvest to marketing chain include:

i. Lack of crop storage facilities leading to postharvest pest infestation and crop produce losses
ii. Lack of knowledge and on processing and value addition
iii. Lack of processing equipment such as shellers, dryers and grinding mills
iv. Lack of organized local markets,
v. Uncoordinated and low market prices
vi. Inadequate access roads and poor transport facilities
vii. Lack of planning to meet demand and supply

Markets in general had been less developed (inputs and outputs). It is important to pay attention to the market because whenever marketed output increases due to greater market access, small-scale farmers are quick to take up new technologies (Steve Wiggins, 2009). At present most communities do not have organized local market days, these being largely restricted to district and regional capitals. At the same time, poor transport links between communities affect the intercommunity movement of farm produce resulting in weak market access. Consequently, there is little incentive to increase productivity due to low farm produce prices received. Farmers complain of exploitation by middlemen, more especially in the Upper West region. Equally,

there are few local agro-dealers, so farmers have to depend on district and regional markets for purchasing farm inputs, resulting in high input costs.

These constraints present serious problems for intensification and the development of profitable market-driven, value-added farming system. Improving links between farmers and input-output markets is a prerequisite but this requires substantial improvement in market infrastructure, processing, and marketing skills. Making this a reality requires community leaders and policymakers to promote the establishment of community markets and market infrastructure development, particularly improved road access. Better input and output market links can increase crop yields substantially and result in improved farming systems. Farm output diversification is lacking, producers must diversify their farm enterprises as a strategy to manage inherent production, marketing, and income risks resulting from climatic, biophysical, and market-related factors (Chavas and Di Falco, 2012).

3.1.5 Economic and systems' productivity

Persistent high labour cost despite the rapid population growth is a major hindrance to the success of farming systems in Ghana. Smallholding farming systems are still characterized by price fluctuation, pests and diseases infestation, low financial power, low productivity. This makes it difficult for farmers to afford technology and manage the farming system for economic gains. For instance, integrating cereals with legumes will require different agro-inputs which resource-poor farmers cannot afford.

Financial institutions consider farming a high-risk area due to the unpredictable nature of their production, limiting access of farmers to greatly needed credit. The entire smallholding production is rain-fed, aggravated by climate change which makes financing riskier to commercial banks and other financial institutions. Both middlemen and processors can provide a ready market for farm produce provided the volumes of production are attractive to buyers. Consequently, the ability of prevailing institutions to apply innovative approaches to make credit more readily available to farmers deserves consideration.

There is a lack of consistent investment by both the government and private stakeholders to the agriculture sector. There must be improved access to credit, inadequate credit access has been ranked as a high-priority constraint, especially by women and youth preventing them from paying for inputs and farm operations.

3.1.6 Policy and enabling environment

Policies that promote and ensure a convenient environment for operations and marketing lead to improved productivity and serve as incentives for engagement in farming and farming systems. Policies must be designed to

encourage the adoption of mixed farming systems as a way to enhance productivity, spread production and market risk, and promote more stable farm incomes. Even though most farmers operate small farms, the prevailing tenure arrangements across different farming systems are critical in decisions regarding investments in their land as well as the proportion of land allocated to various crops and livestock to improve overall farm productivity. Improvement in policy will address critical questions; whether there are opportunities for improving smallholder performance by reorienting production strategies, modifying prevailing farming systems and technology, and enhancing managerial performance. The lack of access to government subsidies is another gap that must be addressed. Over many decades, policies for agriculture, research and development, education, training and advice have had strong influences on the choice of technology, the level of agricultural production and farm practices.

4 Conclusion

Agriculture is a vital sector in the Ghanaian economy, contributing about 20.3% of the gross domestic product (GDP) and providing a major source of income and employment for most households. As in much of the developing world, agricultural production systems in Ghana are based mostly on small farms, which constitute about 80% of domestic food production. The majority of farm holdings are less than 2 ha, and most farmers still use traditional production technologies and plant local crop varieties. Despite these limitations, Ghana's smallholder farming systems are the backbone of their survival and also provide food security to the nation. The concept of farming system refers to the capacity of agriculture over time to contribute to overall welfare by providing sufficient food and other goods and services in ways that are economically efficient, profitable, and socially responsible, while also improving environmental quality. It is a concept that can have different implications in terms of appropriate technologies whether it is viewed at the farm level, at the agri-food sector level, or in the context of the overall domestic or global economy. Efforts to modernize and improve farming systems in Ghana date back to the 1980s through the collaborative effort of the Government of Ghana, NGOs and development partners. The cropping systems in Ghana have migrated from subsistence farming to mixed permanent farming systems involving crops, animals and tree crops.

Farming systems in Ghana have witnessed significant changes in more recent times, including a rise in population densities, growing land scarcity, improved access to modern inputs (especially among major cereals, root and tuber crops, and legumes), growing urban demand for major food staples, and generally, a more favourable policy environment. Numerous efforts have also

been made in the areas of improved crop varieties (high yield, drought tolerance, pest and disease tolerant etc), fertilizers, mechanisation, irrigation, agrochemicals, climate information, infrastructure etc., yet there is evidence of considerable productivity gaps across farming systems in Ghana.

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