Chapter 2
From Soil to Fork: Can Sustainable Intensification Guarantee Food Security for Smallholder Farmers?

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Abstract Agricultural production on smallholder farms in sub-Saharan Africa (SSA) is hampered by countless challenges, chief among which is soil degradation due to unsustainable farming practices, inadequate technical and financial support, and climate change. Moreover, the ever-increasing African population, which is directly proportional to an increase in the demand for food, makes the situation grimmer. This has consequently resulted in the active search for alternative approaches to agricultural production that do not only ensure that there is enough food at the table but do so sustainably. One such approach that has attracted the interest of researchers, funders and policymakers is sustainable intensification. However, there have been numerous discussions and debates on the usefulness of this concept in increasing crops yields for African farmers, with some opponents going as far as labelling the approach an oxymoron. Therefore, it is important to assess the potential of the concept to not only sustainably feed the rural population but deliver food from the soil to their forks from an African perspective. Therefore, this chapter highlights key sustainable intensification approaches across sub-Saharan Africa that have resulted in significant yield gains across sub-Saharan Africa (SSA) and discusses policy issues required to promote this concept.

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2.1 Introduction

It is estimated that the demand for food will increase by 50% between 2012 and 2050 due to population growth especially in SSA and urbanization, while putting pressure on natural resource base required for agricultural production (FAO 2017a, b). The predicted huge population increase coupled with threats posed by a changing climate will certainly put more pressure on the already strained agricultural land (IPCC 2007). Moreover, there is also a need to overcome several other challenges including soil degradation (soil organic matter depletion, crusting, compaction, erosion and salinization) and persistent droughts if the SSA region is to end hunger and accomplish food security. Water scarcity worsens soil degradation, which further reduces the capacity of the soil to perform one of its most important ecological functions, i.e. feeding an ever-increasing population. Overcoming these challenges and hence achieving the Sustainable Development Goals (SDG), which aim to find solutions to, among others, hunger and poverty and taking action against climate change calls for the adoption of resilient food production methods. This is especially important since meeting the increased food demands with the current agricultural practices is likely to increase land degradation and greenhouse gas emission (FAO 2017a, b).

Over the years, numerous researchers and international research organizations have recommended several interventions and approaches as a sure means of ensuring food sufficiency. However, most of these interventions have many overlaps and only differ in names (Giller et al. 2021). Whilst this may end up confusing farmers, it does highlight the lack of a clear-cut solution to the challenges affecting agricultural production. Consequently, there is sustained interest in finding ways of addressing the mammoth task of increasing food production at minimum damage to the environment.

One of the most recent interventions put forward as a possible solution to the current challenges in agricultural production is sustainable intensification. Sustainable intensification of agricultural production entails feeding a growing population amidst an increasingly degraded environment compounded by climate change without opening up new farmlands (Pretty 2008). Accordingly, sustainable intensification permits farmers to produce more food from the same size of agricultural land. In other words, farmers utilize sustainable technologies to produce more food, while using fewer external inputs, which improves resource efficiency in farming (Pretty 2008). Consequently, sustainable intensification increases crop production per unit area, while minimizing possible environmental impacts (FAO 2017a, b).

Whilst there is a plethora of information on the concept of sustainable intensification, there is little documentation of the tangible success of the concept in Africa. Consequently, there is intense debate on the usefulness of the approach in addressing production challenges in (SSA). Intensification, through increased use of external inputs to increase output without increasing land area, could potentially increase GHG emissions leading to climate change. For instance, Tirado et al. (2010) argued that whilst intensification may increase food production under climate change, it might inadvertently increase the susceptibility of dry lands as the climate changes. To make the concept more appealing, sustainability was identified as one of the key features of intensification, hence sustainable intensification. However, some opponents still argue that the drivers behind the need for this intensification are the key issues that should be addressed. It therefore becomes imperative to review the usefulness of the concept from an African perspective concerning its ability to not only feed the rural population but also achieve this sustainably. It is thus necessary to highlight yield gains on smallholder farms achieved through sustainable intensification as well as highlighting the key practices that drove the yield increase. Consequently, the objectives of this chapter are to

1. Reveal the extent to which sustainable intensification has increased the yield in SSA smallholder agriculture and hence provided food on the table.
2. Determine whether there are any policies that support the sustainable intensification concept for smallholder farmers in (SSA).

2.2 Overview of Current Challenges to Agricultural Food Production in African Smallholder Agriculture

2.2.1 Population Pressure

The continued increase in population and growth in consumption will lead to a rise in the demand for food for at least another 40 years especially in SSA (Godfray et al. 2010). It has been projected that from 2008 and beyond, the world population growth will remain in the 4% range while in SSA and other still developing regions, growth is anticipated to average 6% (Mussa 2007). In SSA alone, the population is projected to increase to two billion by the year 2050 (Bremner 2012). The ever-increasing African population is directly proportional to an increase in the demand for food. However, the same cannot be said about food production. Despite the reports of increases in food production in Africa (Blein et al. 2017), the growth falls far short of the expectations and needs of the African population. As a result, food demand will surpass the domestic food supply. The rise in food demand leads to an increase in the prices of food products at market. In order to increase food production, African farmers tend to expand agricultural lands. Nevertheless, this strategy has its limits and can cause significant environmental degradation (via deforestation).

Increased population has increased urbanization and loss of agricultural lands. As a result, people end up opening up new agricultural lands in peri-urban areas. According to d'Amour et al. (2017), urban expansion takes up agricultural lands that are three times as productive as the average soil in SSA. In addition, the rise in food costs has forced many people in Africa to focus on using any available open spaces in the urban areas for food production. Studies have shown that peri-urban agriculture has resulted in a slight increase in food production in Africa. The growth in food production on the continent is attributed to the intensification and expansion of croplands into previously uncultivated areas. Cropland expansion has adverse effects on biodiversity, mainly through the loss of natural habitat (Chaplin-Kramer et al. 2015). The land plays a dual role as both a source and a sink of greenhouse gases. The land is also pivotal in energy, water and aerosol exchange at the soil surface/atmosphere interface (Arneth et al. 2019). The expansion of cropland disrupts the resilience of social-ecological systems like the carbon cycle, hence increasing global warming. The unsustainable agricultural practices used by most farmers in Africa further disrupt the ecological systems (Nciizah et al. 2021).

2.2.2 Unsustainable Farming Practices

Food production amongst smallholder farmers can potentially be increased by taking up agricultural intensification. Agricultural intensification is defined as the increase in agricultural production per unit of inputs (Kenmore et al. 2004). Productivity can potentially be increased by using high yielding crop varieties, increasing land under irrigation, increasing fertiliser use, improving access to market, governance, embracing information and communication technology, increasing the use of genetically modified crops and land reform (Jones 2015). However, agricultural intensification must be done sustainably. This presents a challenge for most African smallholder farmers who lack resources, knowledge and the will to follow sustainable farming systems. Instead, agricultural practices commonly used cause low fertility and high erodibility problems that have resulted in a decline in the productivity of field crops (AGIS 2013).

Soil degradation is a result of unsustainable agricultural production practices that cause rapid mineralization of organic matter and nutrient content of the soil, and have contributed intensively to low soil productivity, which creates high crop production risks in SSA (FAO 2016). Mills and Fey (2004) reported that soil degradation was due to unsustainable land use and management practices that deplete the soil organic matter (SOM), which erodes soils' natural fertility and capacity to fulfil its ecological functions. Soil tillage, which represents, arguably, the most influential manipulation of soil physical properties is one of the foremost factors that affect soil properties and crop yield (Nyambo et al. 2020a). Tillage practices, e.g., ploughing, enhances degradation by altering soil structure, which in turn increases runoff and soil erosion (Nciizah et al. 2021; Nyambo et al. 2021). Conventional tillage through ploughing also causes soil compaction (plough pans) and rapid mineralization of SOM (Laker 2004). Consequently, these practices result in the loss of SOM, the destruction of soil structure, and poor soil health and crop productivity (Thierfelder and Wall 2009). Moreover, crop residue mismanagement can lead to direct input of carbon dioxide (CO_2) into the atmosphere, hence aiding greenhouse gas (GHG) emissions (Lal 2010).

Most smallholder farmers in Africa remove crop residues from the fields. At a smallholder farm, crop residues are an important source of fuel, building material and animal feed (Turmel et al. 2015). Other farmers burn the crop residues before tilling their soils while some are left to be grazed in the fields (Nyambo et al. 2020b). Crop residues are vital for the supply of SOM and soil stability. The practice of removing all the crop residues and leaving the soil surface bare reduces soil quality, leading to a decline in crop yield. Furthermore, these practices leave the soil susceptible to erosion, environmental pollution.

2.2.3 Climate Change

Climate change has become a significant challenge to agricultural development in SSA. The escalation in unpredictable and erratic weather systems threatens food security and the livelihoods of most people in rural areas in SSA. Climate change is linked to increases in global temperature and extreme weather conditions such as dry spells, torrential rains, high winds, flooding and cyclones, ultimately affecting the standard ways of life and sustainable food production (IPCC 2001). Prolonged drought periods and flooding demonstrate the extent of a changing climate that destroys homes and farms, thereby leading to food-insecure rural communities (Nciizah et al. 2021). While the climate is changing, the primary concern for agriculturists is the magnitude of crop yield decline, especially amongst SSA farmers. Whilst a steady rise in temperature and carbon dioxide provides conditions that favour an increase in the yield of some crops (Porter et al. 2014), these potential yield gains in some regions are likely to be superseded by extreme events, mostly extreme temperature and water stress during crop flowering. Climate change negatively affects agro-ecological conditions, which directly affects food production and indirectly reduces income and demand for agricultural produce (Schmidhuber and Tubiello 2007).

Climate change has a potential to significantly contribute to food insecurity due to food price increase due to reduced agricultural food production (Mbow et al. 2019). Competition for land may increase because some parts of the land may be climatically unsuitable for food production. In the long run, global warming reduces food availability which causes a rise in commodity prices, thus increasing the vulnerability of the rural population (von Braun 2007).

2.3 Sustainability in Agriculture

In Africa, more than 70% of the farmers are small-scale or smallholders, who practise mainly subsistence farming. Though these farmers mostly produce to feed their families, they are critical in driving food security in SSA. The threat of climate change, intensification pressures to sustain the growing population and resource degradation that the smallholder farmers now face are significant threats to Africa's food security (Mungai et al. 2016). The growing world population has driven the food demand in the past century, and this has seen the need for intensive production systems with a limited ecological approach being used in crop and animal production. This food requirement challenge has also been experienced by African smallholder farmers, who have shifted from their nature-based farming techniques to Green Revolution technologies that make use of industrially produced chemicals in production. However, these technologies have actually seen most smallholder farmers realizing declining productivity and soil degradation. This has seen a recent drive towards sustainable agriculture even under intensive production. In general, there are four main constrains to intensified agricultural production and sustainability, which are soil, water, biodiversity and land (Pretty and Bharucha 2014). These constraints have been identified as the main focal points around which decisions of sustainability in agriculture and changes in production systems will need to be made (Pretty and Bharucha 2014). Figure 2.1 shows the effects of the various constraints under both sustainable and non-sustainable agricultural systems.

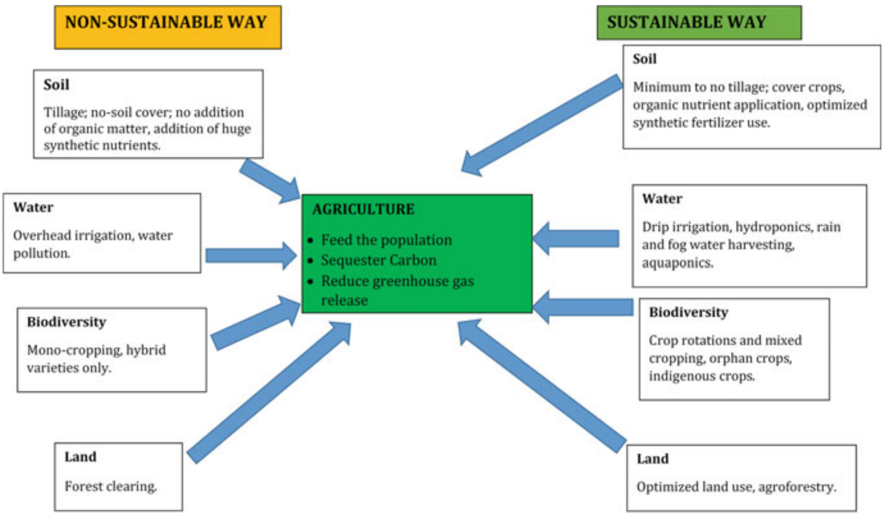

Fig. 2.1 Effects of various constraints to achieving sustainable agriculture under smallholder farming systems

Although sustainability is recommended in agriculture, it important to note that simply adopting the principles indicated in Fig. 2.1 may not be suitable to sustain the projected food requirements of the growing population. There is a need to undertake research on how to optimize the various sustainable technologies that are recommended. For example, in organic soil fertility management, as opposed to the traditional use of composts, improved composts such as vermicomposts need to be promoted and have their application and production optimized. Furthermore, technologies like hydroponics currently require expensive inorganic fertilizers, which most smallholder farmers cannot afford. Research on organic nutrient sources will be important in driving the sustainable utilization of water under hydroponic systems that conserve fresh water utilization in crop production.

2.4 What Is Sustainable Intensification of Agriculture?

As alluded to before, sustainable intensification is not an entirely new concept (Pretty 2008; Pretty et al. 2011), but has seen a lot of renewed interest over the past few years (Cassman and Grassini 2013). Sustainable intensification stems from the need to feed the burgeoning SSA population by increasing food production from the existing agricultural land, which is often over-exploited and used unsustainably. The concept recognizes the need to prevent further environmental damage or opening up new farmlands, hence intensification of agriculture, albeit sustainably (Pretty et al. 2011). Consequently, sustainable intensification addresses whole landscapes and ecosystems in a bid to augment the utilization and management of resources (FAO 2008). This is particularly important since, on one hand, agriculture is the biggest driver of environmental change and, on the other hand, it is the sector most affected by climate change (IPCC 2014). This then underscores the need for sustainability in farming systems, a major characteristic of which is high efficiency of internal resource use through such processes as conservation of soil organic matter and water as well as efficient nutrient cycling.

In simple terms, sustainable intensification enables farmers to grow more food without expanding land area through improved resource efficiency in farming. Sustainable intensification is particularly important in Africa since it provides prospects for boosting crop production per unit area, whilst addressing sustainability features such as social, political, economic and environmental impacts (FAO 2006). According to Pretty et al. (2011), continued population growth erodes improvements made in African agriculture because it stagnates or diminishes the per capita availability of domestically produced food. Given that expanding agricultural land is not feasible, production needs to become both more sustainable and resource use efficient if the natural resource on which agriculture relies is to be conserved. Therefore, sustainable intensification alleviates the potential conflict for land by producing food with a lower land footprint (Mbow et al. 2019).

The ability of sustainable intensification to achieve its goals is often debatable; on the one hand, proponents of the concept argue that it offers a new paradigm to meet food demand and resource scarcity. On the other hand, opponents view it as an oxymoron that sugarcoats intensive farming with sustainability (Cook et al. 2015). Nevertheless, before addressing the usefulness of sustainable intensification, it is perhaps pertinent to have an in-depth look at the practices used in sustainable intensification and how they relate to other models. This is especially important since some authors often contend that there is a lack clarification of the agricultural techniques to use to attain sustainable intensification (Mbow et al. 2019).

2.5 Sustainable Intensification Concepts and Practices

Cook et al. (2015) highlighted three fundamental assumptions about food security and agricultural production that drive the need for sustainable intensifications, i.e. the need to grow more food for the rapidly increasing world population, the need for agriculture to be more sustainable and resource efficient and the undesirability of expanding the arable land base. Consequently, sustainable intensification practices should aim to address all the three assumptions. This is especially true in SSA where there is a rapid population growth (Bello-Schünemann et al. 2017) and high rates of soil degradation (Tully et al. 2015), which are worsened by a changing climate (IPCC 2007).

Sustainable intensification comprises combinations of improved agricultural practices such as conservation agriculture (CA), agroforestry, organic agriculture, integrated pest management and ecosystem services as well as carbon benefits (Mbow et al. 2019). The various practices employed under sustainable intensification can be grouped into up to ten categories or approaches depending on how the technologies are applied (Table 2.1) (Pretty et al. 2018; Mbow et al. 2019; Xie et al. 2019). Several authors have reported significant yield gains following the use of several sustainable intensification approaches across Africa. For instance, smallholder farmers have achieved significant yield gains in several parts of SSA following the adoption of CA (Rusinamhodzi et al. 2011). Thierfelder and Wall (2012) reported between 35 and 56% increase in crop yield under CA compared to conventional tillage, whilst yield increases were up to 27% in Mozambique. These yield increases were attributed to increased soil organic carbon in the soil, which improved soil physical and biological processes. One of the reasons for poor yield under smallholder agriculture is poor pest control because chemicals are usually beyond the reach of many farmers. However, sustainable intensification practices such as integrated pest management often sustainably reduce pest and disease occurrence, hence preventing severe yield losses (Pretty and Bharucha 2015). Moreover, practices such as intercropping and crop rotation with legumes, which increase agricultural system diversity, not only break disease and pest cycles but also have an additional benefit of adding nitrogen to the soil. Intercropping, like any other multiple agroecosystem, has several advantages, which include increased productivity through better use or resources, that is, increased ability to capture light, reduction of weed competition and water loss. In addition, the system ensures a

Table 2.1 Sustainable intensification approaches, adapted from Pretty et al. (2018); Mbow et al. (2019); Xie et al. (2019)

Approach	Intervention
1. Integrated pest management	• Integrated plant and pest management. • Push–pull systems, natural enemies. • Increased pollination.
2. Increased agricultural system diversity and soil management	• Conservation agriculture practices such as zero and minimum tillage. • Soil conservation and soil erosion control. • Improved soil health – increased soil organic matter input. • Cover crops, intercropping, diversified crop rotations. • Compost/green manuring.
3. Integrated crop and biodiversity redesign	• Organic agriculture. • Systems of crop intensification. • Zero-budget natural farming. • Science and technology backyard platforms, farmer wisdom networks. • Landcare and watershed management groups. • Polycultures.
4. Pasture and forage redesign	• Mixed forage–crop systems. • Management intensive rotational grazing systems.
5. Trees in agricultural systems	• Agroforestry. • Joint and collective forest management. • Leguminous fertilizer trees and shrubs.
6. Irrigation water management	• Small-scale intensification. • Integrated aquaculture. • Water user associations. • Participatory irrigation management. • Watershed management. • Micro-irrigation technologies. • Precision agriculture. • Water recycling.
7. Organizational scale-up	• Community farms, allotments, backyard gardens, • Raised beds, vertical farms. • Group purchasing associations and artisanal small producers. • Micro-credit groups for small-scale intensification. • Integrated aquaculture.
8. Genetic improvements	• Genetically modified crops, breeding for drought tolerance. • Livestock breeding.
9. Technological approaches	• Crop and soil monitoring. • Increased fertilizer efficiency. • Greenhouse gas monitoring. • Precision agriculture.
10. Knowledge transfer	• Agro pastoral field schools. • Farmer field schools.

deeper and denser rooting system, which ensures high soil biological activity and nutrient cycling. Some studies have also shown that due to increased plant diversity, intercropping may result in large insect diversity and lower insect damage through decreased plant apparency, increased competition among pest and non-pest insects and improved natural enemy communities (Akbulut et al. 2003). Most importantly, the system has the potential to diversify farm income through the production of more than one type of crop, which leaves the farmer better placed to survive market downturns or crop failure.

Technological interventions such as crop and soil monitoring have increasingly become important since they are enablers of precision agriculture. Frequent soil monitoring allows the detection of soil variability on farms and the subsequent smart irrigation and fertilization, which not only reduces input costs but also protects soil and water bodies from degradation. Other important interventions include the development of improved genotypes that are both drought and disease tolerant. One example of genetic improvement is CIMMYT's Drought Tolerant Maize for Africa (DTMA) project, which was carried out between 2006 and 2015 in several African countries availing 60 drought tolerant hybrids and 57 open-pollinated varieties to smallholder farmers. The project availed seed to over 43 million smallholder farmers and their families. Genetic improvement of seed is thus a very important practice in sustainable intensification, especially if the seed is compatible with other sustainable intensification practices such as intercropping and conservation tillage. Similarly, CIMMYT's Water Efficient Maize for Africa (WEMA) project availed maize varieties that yielded between 24 and 35% more grain under moderate water stress conditions than currently available varieties in Kenya, Mozambique, Tanzania, South Africa, Uganda, Zimbabwe and Zambia. Table 2.1 shows several sustainable intensification approaches and the various interventions in each approach.

2.6 Benefits of Sustainable Intensification of Crop Production in African Smallholder Agriculture

Several field studies, reviews and meta-analyses have highlighted significant yield gains with sustainable intensification practices across Africa (Table 2.2). Whilst sustainable intensification practices can be applied separately or in combination, studies have shown that the adoption of multiple sustainable intensification practices outperforms the use of one practice. For instance, Kotu et al. (2017) analysed both the adoption and impacts of sustainable intensification practices using a dataset from Ghana. The authors used a multivalued semi-parametric treatment effect model to estimate the effects of adopting multiple sustainable intensification practices on the productivity of maize on smallholder farms. The model results showed that a higher number of sustainable intensification practices were significantly related to higher productivity. This was more evident when commercial inputs were combined with cultural practices. Similarly, Lungu (2015) reported maize yield increases of

Table 2.2 Examples of yield increase from the adoption of sustainable intensification practices in Africa

Location	Finding	References
Zambia	Maize yields increased by 45% & 22% for male and female landholders, respectively, between the 2006–2008 and the 2015–2017 (2000 k/ha) growing seasons. Increases in yield were attributed to the uptake of fertiliser and improved seeds and mechanization.	Djurfeldt et al. (2019)
Ethiopia	Direct seeding with a two-wheel tractor resulted in 25% and 13% higher wheat grain and straw yields, respectively, compared with the conventional practice used in the Ethiopian highlands. In the wheat systems, the two-wheel tractor direct seeded system had a 47% higher gross margin than the conventional practice.	ILRI (2020)
Ethiopia	Findings from experiments conducted in southern Ethiopia showed that the adoption of conservation agriculture–based sustainable intensification practices and technologies increased household return on investment in maize (32.6%) and common bean (49%) production, by growing common beans twice a year intercropping and relay cropping with the same maize crop.	Beshir et al. (2021)
Tanzania	Scaling out SIMLESA technologies through innovation platforms increased the number of farmers using improved seeds of maize and legumes from 30–40% to 85% whilst the adoption of a conservation agriculture–based sustainable intensification (CASI) technology package increased yields for maize from 1.5 t ha^{-1} to 4.5 t ha^{-1} and legumes from 0.38 t ha^{-1} to 1.5 t ha^{-1} in Tanzania.	Sariah et al. (2019)
Uganda	Compatible maize–bean intercropping patterns increased labour and land use efficiency and reduced soil degradation due to reduced soil nutrient mining and soil erosion.	Mubiru et al. (2019)
Ghana	A study in Ghana using multivalued semi-parametric treatment effect (MVTE) model to estimate the effects of adopting multiple sustainable intensification practices on maize productivity showed that moving from one of the following sustainable intensification practices—cereal–legume intercropping (IC), cereal–legume rotation (CR), CF, and SWC practices to all of them—increased maize yields by 296 kg/ha.	Kotu et al. (2017)
Zimbabwe	A study on maize production intensification using cattle manure on degraded lands showed that combining 25 t ha^{-1} manure with 100 kg N resulted in the highest yield of 9.3 t ha^{-1} on homefield clay soils, 6.1 t ha^{-1} on clay outfields,	Rusinamhodzi et al. (2013)

(continued)

Table 2.2 (continued)

Location	Finding	References
	7.6 t ha^{-1} in the homefield and 3.4 t ha^{-1} in the eighth season.	
Kenya	Rusinamhodzi et al. (2020) tested the performance of elite maize genotypes under selected sustainable intensification options in Kenya and observed reduced yields after intercropping maize and legumes due to increased competition. They concluded that there is a need to optimize intercropping through improved planting designs and custom mixed fertilizers suitable for intercrops.	Rusinamhodzi et al. (2020)
Tanzania	Mtengeti et al. (2015) Carried out a study to compare farmers' practices (control) and improved practices (the proper use of fertilizer, crop protection inputs and recommended crop seed variety) for maize and rice. The findings showed that maize and rice grain yield ranged between 2.5 and 5.4 t ha^{-1} in farmers' practices and between 6.6 and 8.5 t ha^{-1} under improved practices; moreover, maize and rice stover/straw biomass ranged between 5.33 and 15.4 t ha^{-1} for improved practices and 2.11 and 9.13 t ha^{-1} for farmers' practices.	Mtengeti et al. (2015)
Ethiopia, Kenya, Malawi, Mozambique and Tanzania	Mupangwa et al. (2021) carried out on-farm trials in five countries over a 7-year period to assess the effects conventional practice (Conv_sole) compared with variants of conservation agriculture (CA) such as sole maize (CA_sole), intercropping (CA_intercropping) and rotation (CA_rotation) on maize productivity. The results showed that the CA cropping systems outperformed conventional practices with groundnut and pigeon pea, resulting in the highest relative maize yield advantages, whilst common bean stabilized maize yields under CA than other legumes.	Mupangwa et al. (2021)

30–70% following the use of conservation tillage (deep ripping 15–30 cm), leaving crop residues on the soil surface, and using an appropriate maturity cultivar compared to conventional tillage. However, it is often important to use compatible practices since some practices may cause yield losses. For instance, Rusinamhodzi et al. (2020) carried out a study to determine the contribution of combining different cropping and tillage systems with different genotypes across several cropping seasons towards sustainable intensification. The study assessed the agronomic performance of six maize genotypes under intercropping with conservation tillage (no-till) over six seasons. The results showed that genotypes that yielded highest under sole cropping had lower yields under intercropping with up to 1.1 t ha^{-1} yield penalty. The lower yield under intercropping was attributed to competition. It was concluded that there was a need to use genotypes that reduce risk and maximize yield.

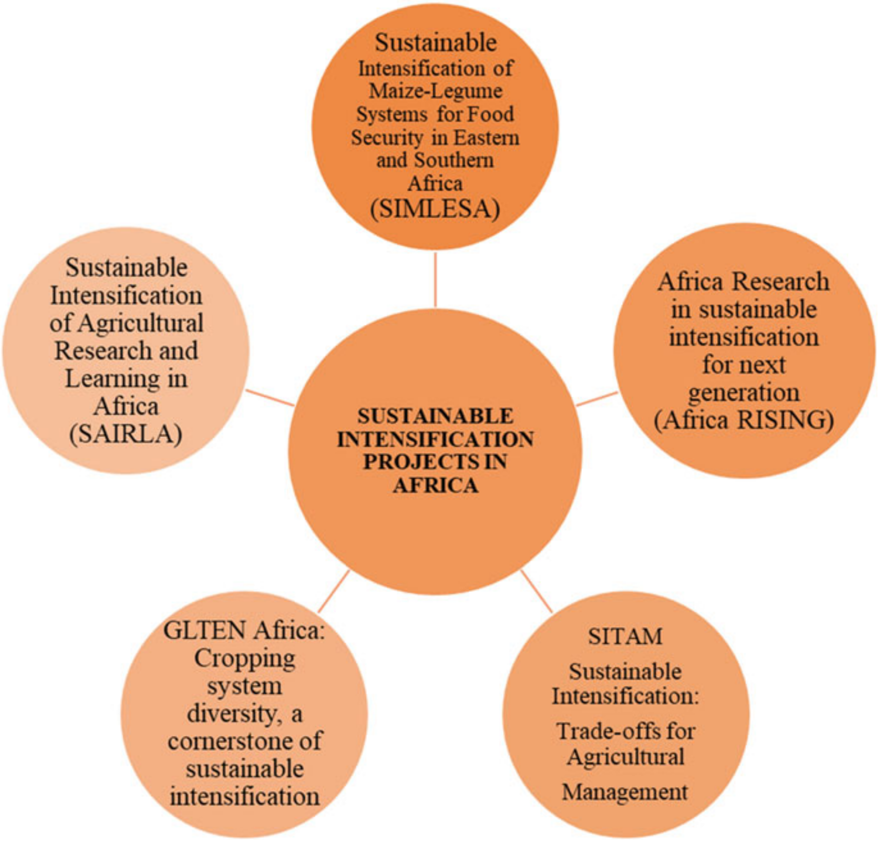

Fig. 2.2 Key projects on sustainable intensification in Africa

One of the recent practices that have been advocated for as part of integrated pest management (IPM) is the push–pull system to control pests. The Montpellier Panel Report (2013) showed that about 25,000 East African smallholder farmers were using the push–pull method to control pests with added benefits such as reduction of pesticide use, which subsequently increased income and increased soil fertility since the method produces a poly-agriculture system. The success of IPM systems hinged on the success of Farmer Field Schools for training and information dissemination. Knowledge transfer through farmer field schools is one of the approaches for sustainable intensification, which plays a crucial role towards the success of the concept. More examples of success stories of sustainable intensification in Africa are shown in Table 2.2.

The examples shown in Table 2.2 are from various funded projects (Fig. 2.2) on sustainable intensification carried out across Africa over the last few years. The high number of sustainable intensification projects in Africa is an indication of the interest the concepts has garnered among global stakeholders. These projects have so far produced insightful findings on the prospects of sustainable intensification as well as entry points of some of the practices in Africa. For instance, the Sustainable Intensification of Maize-Legume Cropping Systems for Food Security in Eastern and Southern Africa (SIMLESA) project was implemented from 2010 to 2018 in Ethiopia, Kenya, Malawi, Mozambique and Tanzania as well as Rwanda and Uganda. The goal of SIMLESA was to improve the food security of African smallholder farmers and increase productivity and income through the integration of sustainable intensification practices, particularly intercropping with legumes and conservation agriculture. The project established experimental trials to test the most promising conservation agriculture–based sustainable intensification (CASI) technologies, such as minimized soil disturbance, soil cover and the use of crop rotations and/or associations. The project also employed other agronomic practices like the use of inorganic and organic fertilizers, herbicides and improved varieties, timely planting, weed control and proper crop management (Wilkus et al. 2021). Findings from the study showed increased maize yield due to the implementation of CASI technologies. In Malawi, maize yield increased by 17 and 38% in the mid-altitude and lowland agro-ecologies, respectively, whilst Ethiopia saw increases between 5 and 18%. Another key project, the Sustainable Intensification of Agricultural Research and Learning in Africa (SAIRLA), was a 5-year project which ended in 2020, which sought to create new evidence and generate tools to enable key stakeholders to establish effective policies and investments in sustainable agricultural intensification (Gebreyes 2017). Some of the findings of the projects included the identification of land use practices that are both socially and environmentally sustainable.

2.7 Policies Supporting Sustainable Intensification of Crop Production in African Smallholder Agriculture

Sustainable agricultural intensification and production by farmers is vital to ensure global food security. The need for intensification is even more critical in SSA, where food production and supply are inherently insufficient. The agricultural support policies in these countries are either weak or poorly coordinated to ensure maximum output at the food production stage of the value chain. Sustainable intensification can be achieved by targeted policy interventions that seek to enhance productivity per unit of land, input supply, mechanization, technology adoption, irrigation, farm management as well as pest and disease control. However, the absence and weak national and regional policies that offer agricultural support often make the agricultural intensification concept unachievable.

As part of ensuring that African governments and policy makers give adequate support to the agricultural sector, a number of policy documents have been produced to guide the agricultural development agenda, including the intensification of the sector. In 2003, African leaders adopted the Comprehensive Africa Agriculture

Development Programme (CAADP), which aimed to promote agricultural growth, reduce poverty and improve food security on the continent (African Union 2003). The CAADP programme was vital because it stipulated how Africa's agricultural policy should be driven at national and continental levels. For instance, the programme made a recommendation that African governments should allocate at least 10% of the total government expenditure to the agriculture sector. It was projected that this level of investment was essential to achieve an average 6% annual agricultural growth rate and attain the Millennium Development Goal (MDG) of eradicating extreme hunger and poverty by 2015 (Matchaya and Chilonda 2012). The CAADP was then followed by the 2014 Malabo Declaration on Accelerated Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods adopted at the African Union summit at Malabo, Equatorial Guinea. The end goal of all these programmes was to end hunger and halve poverty in the continent through inclusive agricultural growth by 2025 (African Union 2014). It is important to note that these programmes were coined as an affirmation that:

- African agriculture was not performing according to expectation.
- There is potential for Africa to increase its agricultural output.
- There was increasing hunger and poverty among the population.
- If agricultural budgetary allocations are strengthened at a national level, there is room for turning around the economic fortunes of the continent.

The focus on resource mobilization through budget allocation is a crucial policy imperative that can enhance sustainable intensification of agriculture in Africa. This policy is measureable and monitoring of its implementation is fairly easy and manageable, although misallocation or misuse of the finance meant for the agricultural sector may be a challenge. As governments drive the budget allocation and implementation, it might be important to have a bird's eye view of priority areas that can make sustainable intensification of agriculture possible. These priority areas include the following areas:

- Building sustainable institutions—Weak institutions are Africa's major challenge, hence the need to strengthen them wherever possible. Ideal institutions must be capable of delivering technical and financial services that suit the diversity of the agricultural sector as a whole. Strong institutions are responsible for producing strong policies that can provide subsidies for equipment, fertilizers and seed, which make sustainable intensification a more practical and achievable objective. However, if agricultural institutions are weak or absent, sustainable intensification may remain a pipedream for Africa. All actors within the state are required in order to ensure sustainable intensification, including non-governmental organizations, which play a role in the development of communication networks for sharing access to knowledge and information regarding sustainable land use practices (FAO 2017a, b). Furthermore, informal co-operative arrangements and other types of social capital could provide local frameworks and institutions for risk-sharing that favour private investment in the area of sustainable agricultural intensification.

- Clearly defined incentive structure within the agriculture sector: Sers and Mughal (2018) argued that sustainable intensification can only alleviate poverty when returns to land and labour simultaneously increase. This means that agricultural policies must provide incentives that ensure both farmers' welfare and resource sustainability (Sers and Mughal 2018).
- Agricultural training, education and extension services: Despite enormous evidence that points to the importance of farmer training and extension services, African governments often fail to deliver enough of these services to the farmers. Training improves access to knowledge and information on appropriate technologies and feasible marketing strategies, which are key drivers of sustainable agricultural intensification (SAI). Although participatory technology development (PTD) has become increasingly popular and preferred over the years, formal training on sustainable agricultural practices using experimental research is still critical.
- Increased public infrastructure investment: Farmers face huge transaction costs due to poor road accessibility and distance to both input and output markets (FAO 2015). Although the production levels are low in Africa, the yield potentials are further worsened by poor infrastructure. Besides road network, smallholder farmers must be given access to modern communication and production technologies that keep them connected to the globe. Such technologies also enhance growth aspirations as well as market access.

For a sustained agricultural growth as well as positive spinoffs in the sustainable intensification of the sector, regional and continental institutions must devise joint strategies for promoting collaboration in information sharing, improvements in physical infrastructure, research and agricultural project implementation frameworks. As population increases in Africa, against static natural resources like land and dwindling agricultural water supplies, it means agricultural intensification must adopt a culture and not an optional approach.

2.8 Conclusions

Sustainable intensification of agriculture is not a new concept; however, the last decade has seen a rapid increase in funded projects, discussions and debates on the concept. There is sufficient evidence from key projects carried out by both regional and international research organizations on the effectiveness of sustainable intensification in increasing crop yields in SSA. Studies showed varying levels of yield benefits especially for maize production across Africa, showing that proper application of sustainable intensification practices can improve agricultural production and hence guarantee food security for smallholder farmers. However, some studies have shown yield losses for some maize genotypes when used in intercropping and conservation tillage. There is therefore a need for extensive research on the interaction of the various sustainable intensification practices of yield of various crops.

Some of the practices are knowledge intensive, which calls for the capacitation of smallholder farmers to ensure success of the concept. This may also encourage the uptake of multiple sustainable intensification practices. This is particularly important since some studies have shown farmers will get more benefit by combining up to four practices compared to just one. There is also a need for policy that supports smallholder farmers since agricultural support policies in most SSA countries are either weak or poorly coordinated to ensure maximum output at the food production stage of the value chain. Consequently, targeted policy interventions that seek to enhance productivity per unit of land, input supply, mechanization, technology adoption, irrigation, farm management as well as pest and disease control can assist in achieving sustainable intensification of agriculture and ensure.

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