Chapter 7
Precision Agriculture Under Arid Environments: Prospects for African Smallholder Farmers

H. A. Mupambwa, A. D. Nciizah, E. Dube, and M. Fanadzo

Abstract Precision farming is usually associated with high-tech equipment, requiring huge capital and infrastructure investments. In developed countries, precision farming has been linked to high-end computer technologies and remote data collection. In smallholder farming systems where such technologies do not exist, the discussion of precision agriculture has been limited. Our chapter presents precision farming in smallholder farming systems as an ideal approach for helping farmers to manage spatio-temporal crop and soil variability in order to increase site-specific productivity and sustainability. We present options that are critical in driving precision farming within the smallholder resource poor farming, context focusing on soil fertility management, water saving technologies, genetically modified crops, herbicides and hand-held fuel powered equipment. There is a need to demystify precision farming among African farmers and promote new knowledge sharing on the benefits of site-specific management options in increasing productivity and resilience under a changing climate. African governments will also need to expedite the changes in policies on genetically modified organisms, based on current research data, whilst also supporting farmers where technology requires capital and infrastructure investments.

Keywords Genetically modified crops · Hydroponics · Controlled environment · Herbicides · Parasitic weeds · Hand weeding · Soil fertility management

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7.1 Introduction

Agriculture throughout the world is faced with the dilemma of feeding an increasing population, and this calls for intensive production systems such as massive tillage, clearing of permanent forests, excessive use of industrially manufactured nutrients and use of chemicals in controlling pests. Though intensive farming systems have managed to increase land productivity in the nineteenth century, agriculture in the twenty-first century is now faced with a new challenge of climate change and soil resource degradation. Interestingly, technologies that increased land productivity in the previous century are now contributing to global change in the carbon cycle, which is making agriculture a contributor, yet also a victim of climate change. Climate change has become a major challenge to agriculture, and the world may soon not be able to produce enough food in the future due to a changing climate.

Climate change–related problems are already affecting the resource poor farmers in Africa and Asia. In Africa, smallholder farmers contribute up to 70% to the food basket, which means a decrease in these farmers' productivity will translate into food insecurity. Smallholder farms in southern Africa are mainly located on marginal lands where soils are poor in quality. With climate change resulting in increased frequency and intensity of droughts, flooding, higher temperatures, increased pest and disease incidences; the smallholder farmers will need to adopt new technologies. Subsistence farmers in southern Africa are sometimes located in semi-arid environments, where water limits productivity. Therefore, the adoption of precision farming can be critical in increasing the resilience and adaptation of the smallholder farmers in a sustainable way. Precision farming is being promoted in developed countries for mostly commercial farmers. However, research in Africa has been aimed at adjusting these technologies to be adoptable by local resource poor farmers. This chapter therefore presents information on precision farming technologies available for smallholder farmers with the intention of driving technology adoption, which is critical in securing household food security.

7.2 The Arid Environments of Africa and Agriculture

Africa is one of the driest continents of the world with 45% of its landmass falling under dry lands. Furthermore, 38% of this land is occupied by hyper-arid or desert land. About 50% of the African population lives in the arid, semi-arid, dry sub-humid and hyper-arid areas (Kigomo 2003). Africa which is dominated by the Sahara Desert in the north and the Namib and Kalahari Deserts in the south, contains a preponderance of hyper-arid and arid lands, which are mostly unsuitable for agricultural activities. The regional statistics of aridity zones for Africa are shown in Table 7.1.

With climate change, it is expected that heat waves will last longer, resulting in more persistent hot days approaching the year 2100 (Niang et al. 2014). The

Table 7.1 Percentage of area per aridity zone by sub-region for Africa

Sub-region	Hyper-arid	Arid	Semi-arid	Dry sub-humid
Northern Africa (%)	81	11	7	0
Western Africa (%)	33	20	18	7
Central Africa (%)	0	0	2	4
Eastern Africa (%)	14	27	28	12
Southern Africa (%)	2	13	42	15
Africa Total (%)	27	16	21	8

Source: Corbett (1996), UNDP/UNSO (1997)

warming trend experienced toward the end of the twentieth century is expected to continue into the future. For example, for the period 2071–2100 relative to 1971–2000, temperature increases of 4–6 °C are likely to occur in the African subtropics under low mitigation futures (Pereira 2017). These increases are projected to be associated with drastic increases in the frequency of extreme temperature events such as very hot days (>35 °C), heat waves, and high fire-danger days (Engelbrecht et al. 2015). Although rainfall projections for Africa are less certain than the corresponding temperatures, it is generally believed that the continent is becoming drier. Apart from changes in total or mean summer rainfall, certain intra-seasonal characteristics of seasonal rainfall such as onset, duration, dry spell frequencies, and rainfall intensity as well as delay of rainfall onset have changed (Niang et al. 2014). An increasing frequency of dry spells is accompanied by an increasing trend in daily rainfall intensity, which has implications for run-off characteristics (New et al. 2006). Over southern Africa, there is a greater likelihood of heat waves associated with reduced rainfall conditions. With the current trends, Africa is at a high risk of severe droughts and dry spells.

Much of African agriculture's vulnerability to climate change lies in the fact that agricultural systems remain largely rain-fed. It is estimated that about 95% of all cropping systems in Africa are rain-fed (McKinsey Global Institute 2020), and in the sub-Saharan regions, the figure is estimated to be 98% (FAO 2002). Climate change will impact temperature and rainfall, which are the most important variables for crop growth. This is expected to adversely affect yields of most crops. It is expected that the mean annual temperature across Africa will increase by more than 2 °C before the end of this century (Niang et al. 2014). In addition, changing rainfall patterns are a cause for concern. High temperatures and changes in rainfall patterns are likely to reduce cereal crop productivity across sub-Saharan Africa. A 2% decrease is expected for sorghum and a 35% decrease is expected for wheat (Nelson et al. 2009). Maize-based systems are particularly vulnerable to climate change, with yield losses predicted to be in excess of 30% (Schlenker & Lobell 2010). Under climate change, pressures from animal pests, weeds, and diseases are also expected to increase, with resultant detrimental effects on crops.

7.3 Climate Change in Agriculture Under Dryland Environments

Climate change has emerged as the foremost challenge curtailing agricultural production for African smallholder farmers. This has led to countless national and international organisations pushing several initiatives aimed at cushioning these farmers. The smallholder farmers are the most affected group of farmers due to their weak ability to adapt to changes in climate. The most anticipated changes are those of rainfall and temperature with wet areas likely to get wetter whilst dry areas will become drier (IPCC 2007). Consequently, smallholder farmers, whose farms are predominantly located in the drylands, which includes arid (with low rainfall between 200 and 500 mm/year) and semi-arid areas (500–1000 mm rainfall/year), will bear the brunt of climate change due to increased frequency of drought and water scarcity in these already water stressed environments (UNCCD 2009). Drylands include all regions (dry, dry-sub-humid, semi-arid and arid, exclusive of hyper-arid areas) in which the production of crops is limited by water (UNCCD 2009). These areas will experience frequent droughts, which will shorten the length of the crop growing season and will expose critical crop phenological stages to extreme weather events resulting in poor crop yields (El-Beltagy and Madkour 2012; AGRA 2014).

Unless farmers adopt new initiatives and technologies, climate change will certainly worsen the current challenges and further curtail the attainment of the Sustainable Development Goals (SDGs). Other challenges faced by dryland smallholder farmers in Africa include but are not limited to unsustainable farming practices, which cause land degradation, poor irrigation methods, lack of technical and financial support inequality, etc. In the worst-case scenario, climate change will render rain-fed agriculture unsustainable and therefore restrict the potential of smallholder farmers to meet their food requirements (Mupangwa et al. 2008).

7.4 Older Adopted Technologies in Farming

As food production shifted from the nomadic system to permanent settlement, smallholder farmers in Africa started using various technologies that are based on indigenous knowledge and other imported green revolution–based technologies. The major technology adopted was the use of industrially processed fertilizers to provide nutrients for crops. This saw a huge increase in crop yields of most farmers, though making production costs expensive, with some farmers being unable to afford the costs. With the introduction of synthetic fertilizers, smallholder farmers began applying fertilizer as close to the crop roots as possible to improve the fertilizer use efficiency. However, most of the farmers continue to use blanket application rates that are not informed by soil analyses. Though fertilizer application resulted in yield increase among smallholder farmers, the continuous use of the inorganic fertilizers also resulted soil degradation as organic matter was no longer applied to the soils when inorganic fertilizers were used.

Apart from inorganic fertilizers, the adoption of improved hybrid crop varieties caused the crops to yield more. The hybrid varieties have mainly been exploited in cross-pollinating grain crops like maize where yields increased from as low as 1 tonne per hectare to above 10 tonnes per hectare. Moreover, hybrid varieties were bred for specific areas which allowed farmers in different areas to have varieties that were almost tailor-made for their environmental conditions. However, similar to the synthetic fertilizers, the hybrid seeds came with a cost to resource poor subsistence farmers, who had a poor understanding of the hybrid seed technology. Such farmers preferred to retain seed from the hybrid crops as a cost-cutting measure, and this resulted in reduced crop yields due to a reduction in hybrid vigour over generations. Recently, open pollinated varieties are being promoted to allow for the harvesting of seed from the parent crops with limited reduction in vigour and productivity across harvests.

Conventional farming systems tend to favour weeds, and these have become a major challenge for smallholder farmers. As a smart solution to the traditional hand-hoe technique of managing the weeds, there has been an introduction of herbicides that selectively kill targeted plant species. Herbicides have been effective in the control of certain weed species in the commercial farmer sector, with very limited success among the smallholder farmers. This is due to the lack of proper extension services to promote this technology, coupled with the mixed cropping systems of legumes and cereals used by most smallholder farmers, which prevented the effective use of herbicides.

7.5 Precision Agriculture in African Agriculture

The idea of precision agriculture, also known as precision farming, is rarely discussed amongst resource poor smallholder farmers. It is associated or linked with high-end technology which most smallholder farmers would likely view as alien. In developed countries, advanced information systems that rely on sensors, data loggers while collecting data from satellites or drones are used in precision farming (Aune et al. 2017). However, such systems are quite expensive in developing countries where even the infrastructure is limited. Hence precision agriculture in developing countries should involve less remote data collection and less use of high-tech ICT equipment. For smallholder farmers, precision agriculture can be defined as a holistic approach that helps farmers to manage the spatio-temporal crop and soil variability within the field in order to increase site-specific productivity and sustainability and increase profits (Alemaw and Agegnehu 2019).

Precision agriculture in developing African countries allows for the timely farming operations (planting, weeding and harvesting); the use of precise amounts of fertilizers and irrigation water as well as using correct crop types and varieties specific to each site (Aune et al. 2017). Therefore, the precision farming system

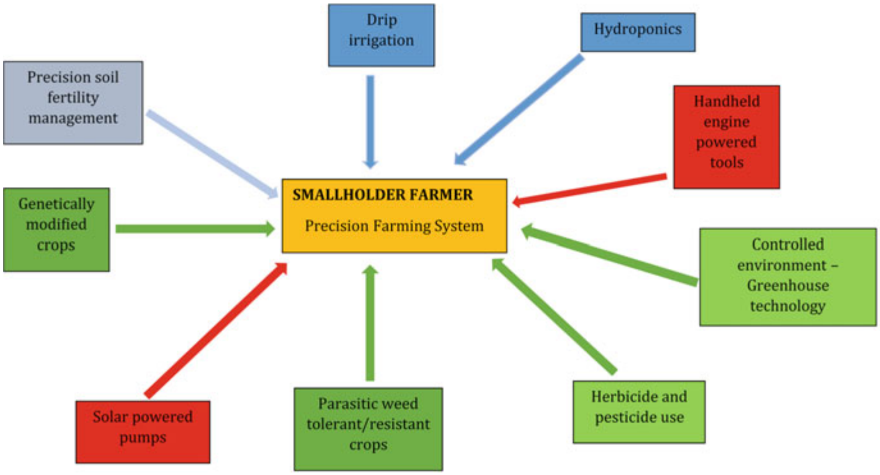

Fig. 7.1 A schematic representation of some aspects of crop farming that can be applicable to precision farming under smallholder farming systems in southern Africa

basically increases the chances of farmers making correct decisions during their production cycle. Under the traditional farming systems, smallholder farmers use blanket recommendations, for example, in fertilizer and seeding rates, with the aim of increasing productivity but with limited site-specific crop management (Alemaw and Agegnehu 2019). Precision agriculture is thus an important aspect of "sustainable intensification" which focuses on producing more food intensively with a limited environmental footprint (Aune et al. 2017). Due to site-specific management, precision agriculture is also considered as a climate smart agriculture practice as it results in increased productivity with limited greenhouse gas emissions (Aune et al. 2017). Of the various precision agriculture systems, those that have great potential for adoption by resource poor African farmers are indicated in Fig. 7.1.

7.6 Current Precision Farming Technologies Adoptable by Smallholder Farmers

7.6.1 Soil Fertility Management

With the shift from nomadic way of cultivating crops, where farmers would look for virgin land to plant crops with no fertilizer inputs, intensive tillage systems have resulted in high nutrient mining in most cropped lands. This mining resulted in the depletion of the nutrient levels in soils which translated into reduced crop yields and therefore led to the drive towards the introduction of industrial fertilizers. Inorganic fertilizers now constitute the major cost of production for resource poor smallholder farmers. As a way of assisting farmers, most governments in southern Africa came up with blanket recommendations for fertilizer application rates, which are still being used to date by extension officers. However, as indicated earlier, precision agriculture seeks to promote site-specific recommendations, and this applies to fertilizer recommendations as well.

On smallholder African farmlands, soil spatial heterogeneity is inherent, and this is due to the interactions between geological diversity; land use and management over time (Tittonell et al. 2015). The smallholder farmer's lands can be divided into various unique and similar zones which should be managed differently based on their characteristics (Ahmad and Dar 2020). The main elements that are deficient in most soils are nitrogen, phosphorus and potassium, and these need to be applied in higher quantities relative to other micro-nutrients, for enhanced crop yields, especially for cereal grain crops. Important to also note is the level of soil organic matter, pH and electrical conductivity on smallholder farms, which are all critical in improving soil fertility and health. However, most smallholder farmers rarely analyse the chemical fertility of their soils. This is a critical step in effecting the site-specific soil fertility management system under these farming conditions as it allows the farmer to determine the amounts of fertilizer required to bring their soils in each zone, back to high productivity for different crops. The variation in nutrient levels within the same farming unit has been core to the development of the variable rate technology that aims at applying inputs such as fertilizers, manure and seeding rate based on the individual requirements of the soils and crops (Ahmad and Dar 2020). The variable rate technology can be based on data collected physically through mapping or remotely using sensors, and for smallholder farmers, the use of physical mapping is recommended as it is less costly and complicated.

Another aspect important to also consider under smallholder farming systems is the use of staggered fertilizer applications during the cropping cycle. As indicated earlier, most farmers simply use blanket nutrient requirements, and this is applied as a once-off application. However, as most of the soils under the smallholder farming setup are poor in water and nutrient retention capacity, once off applications result in extreme loses through leaching and runoff. As a way to guard against this, it is therefore advised to apply precise amounts of nutrients which the crop is able to absorb through split applications, thus increasing the fertilizer use efficiency in relation to productivity at the farm. The various factors and linkages in informing the implementation of a precision-driven soil fertility management system for smallholder farmers are shown in Fig. 7.2.

7.6.2 Hydroponics

In southern Africa, most smallholder farms are located in arid to semi-arid regions where fresh water is a major limitation to productivity. This water challenge is further exacerbated by climate change, which has increased the intensity of droughts in these regions. As most of the smallholder farmers in Africa rely on rain-fed agriculture, inadequate rainfall translates into poor crop productivity, and reduced

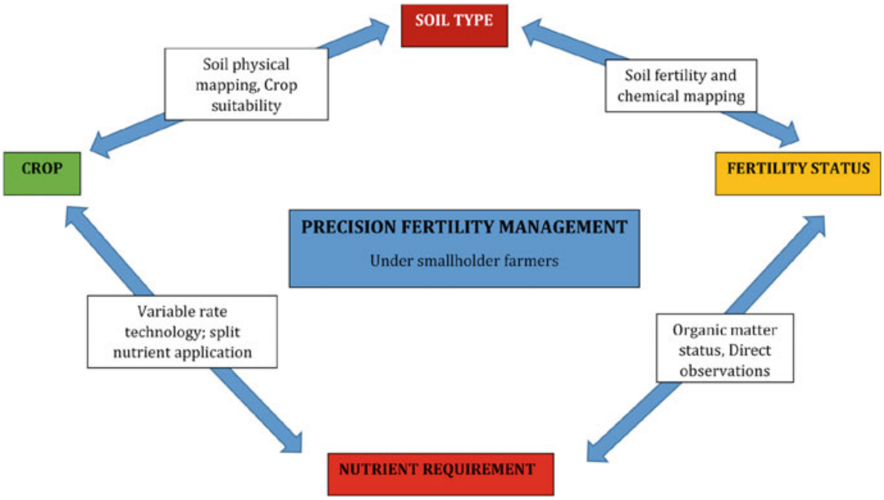

Fig. 7.2 A diagram showing the various factors to consider when implementing precision soil fertility management for smallholder farmers in southern Africa

food security. As part of precision farming, there is a need for the adoption of water saving methods of crop production, and hydroponics and drip irrigation are quite plausible for smallholder farmer adoption. The technology of hydroponics involves the growing of plants in the absence of soil, which ensures that most of the water applied contributes directly to crop growth, with very limited losses due to infiltration and evaporation. However, it is important to note that not all crops can be grown easily using the hydroponic technology, and this system has been reserved mainly for vegetable crop production with very little research having been done on grain crops. Interestingly, in a study Miller et al. (1989) observed that maize grown in a hydroponic system yielded much more compared to that planted in the soil. However, it is important to note that, though hydroponics can be used to produce cereal crops, the areas required to attain yields that can sustain smallholder farming household's annual food requirements, will require huge capital investments if hydroponics are to be used.

The technology of hydroponics, which is a precision farming technology, can be effectively used to produce horticultural crops among smallholder farmers. Crops like tomatoes, spinach, onions, peppers, cucumbers among others can be grown using various hydroponic systems, with yields that are quite high compared to soil planted crops. In some smallholder farming systems, farmers produce horticultural crops for household consumption and for income generation. Most of these farmers use non-water saving techniques like buckets, flood irrigation and overhead irrigation, which wastes water and nutrients. Of the various hydroponic technologies which include drip; deep water culture; ebb and flow (flood and drain system); nutrient film technique and aeroponics hydroponics systems; the drip system and the deep water culture system have potential for adoption by smallholder farmers. The deep water culture system has been shown to be effective in producing leafy vegetables, whilst the drip system using artificial planting media like coco-peat can be used for fruity vegetables like tomatoes and peppers. Most smallholder farmers rarely consider hydroponics as it is also linked to high-tech systems which require thorough understanding, though this technology is very simple to adopt. What is important to note is that for hydroponics, an inorganic water-soluble fertilizer source is often used, and this is often expensive for resource poor farmers. Research on the development of organic nutrient sources in the form of vermicompost leachate is currently underway at the University of Namibia, with the aim of producing a cheap source of nutrients that can be acceptable to smallholder farmers for vegetable production (Mupambwa et al. 2020).

7.6.3 Controlled Environment

As indicated in the previous section, smallholder farmers in southern Africa also produce horticultural crops for household food security and for generating income. Horticultural crops, unlike cereal grain crops, are more sensitive to changes in the environment which limits their productivity during dry or cold periods of the year. Controlling the above-ground environment in which the crop grows under is a very critical precision farming technique that can be used to reduce water uptake by plants, reduce pest and disease incidences and also increase the accumulation of heat units for low-temperature-sensitive crops. However, most smallholder farmers have a notion of the controlled environment agriculture as high-tech systems that require huge capital investments, though the low-cost systems are available and are preferred for smallholder farmers, whilst allowing the control of the most important biotic factors (Nordey et al. 2017). The low-cost controlled environment systems use simple covers on the soil or over the crops to reduce water, gas, heat and pest transfers between the crops and the outside environment (Nordey et al. 2017). Depending on the environment, the material used to control the environment is usually translucent plastic (to increase temperature) or shade netting (to reduce temperature) as illustrated in Fig. 7.3. Unlike the high-tech systems that make use of galvanised steel, the structure of a smallholder farmer can be constructed using ordinary wooden poles for the frame, with the use of UV protected plastic or shade netting. Having the ability to control the environment coupled with hydroponics technology presents great potential for smallholder farmers to increase their productivity and profits in horticulture, thus improving their livelihoods.

7.6.4 Genetically Modified Crops

In most countries in the SADC region, genetically modified crops are prohibited as these countries have taken a precautionary approach towards regulating this

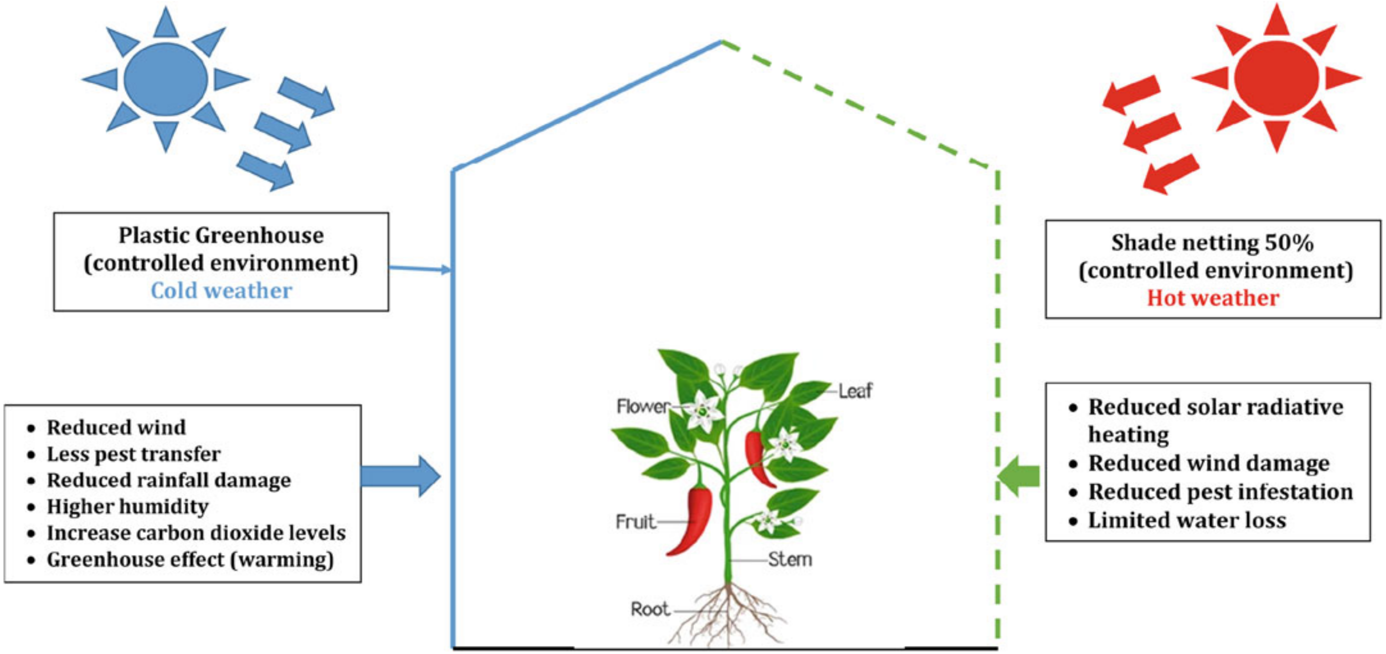

Fig. 7.3 An illustration of the potential benefits of the controlled environment on the farmer under both cold and hot environments. Plant image source: https://www.shutterstock.com/image-vector/illustration-showing-parts-plant-red-pepper-1018043545 accessed 01 June 2021

biotechnology (Muzhinji and Ntuli 2020). This approach has seen limited growth of genetically modified cropping systems in southern Africa due to fear of the unknown effects of these crops on the environment, genetic biodiversity and human health. In the entire southern African region, only South Africa and Eswatini have allowed the commercial growth of genetically modified maize, cotton, soya bean, among other crops (Muzhinji and Ntuli 2020). Interestingly, most of the cultivated crops available to all farmers these days are modified genetically through the use of conventional breeding methods, though these are not labelled as genetically modified organisms (GMO). In most terms, genetically modified crops are those that have had their genetic make-up artificially and precisely modified using laboratory-based methods employing genetic engineering to give the plant characteristics that does not naturally possess (Muzhinji and Ntuli 2020). The United Nations' Food and Agriculture Organization recognizes the improvement of crop genetics through innovative technologies such as genetic engineering and conventional breeding as critical in achieving sustainable increase in food productivity and ultimately food security.

Smallholder farmers in southern Africa are affected by several biotic and abiotic stress that include droughts, weeds, pests and diseases, which further increases their vulnerability to food insecurity. Yield losses due to these stresses have been reported to be up to 100% especially from the pests and diseases among smallholder farmers, which therefore presents a great challenge in attaining the sustainable development goals (SDGs) of zero hunger by 2030. However, genetically modified crops present an opportunity to introduce foreign genetic material into the crop's genetic make-up which can create instant benefits like pest, disease and herbicide resistance. Using genetically modified cotton, studies done in Argentina, China, India, Mexico and South Africa reported that insecticide use was reduced by up to 75% whilst yield was increased by up to 35% when compared to conventionally bred cotton (Qaim and Matuschke 2005). With weeds constituting the greatest labour requirement and production constraint for smallholder farmers, the wide adoption of genetically modified maize that is resistant to the non-selective systemic herbicide glyphosate could make a significant impact. Apart from pest and disease resistance, another important aspect of genetically modified crops is that of biofortified grain crops that are modified for enhance nutritional composition (Qaim 2009).

Though the production of GM crops in southern Africa remains controversial with very limited acceptance at national level, it is imperative to indicate that these GM crops present an important precision farming technique that can contribute to the attainment of the zero hunger SDG. As indicated by Qaim (2009), these GM crops have been shown to produce large aggregated welfare gains and these are more pronounced among the farmers from developing countries. Furthermore, the GM crops have been reported to reduce the environmental impact of agricultural activities linked to the use of chemical pesticides, which create huge health benefits through bio-fortification. As concluded by Muzhinji and Ntuli (2020), *Failure to adopt GM technology based on socio-economic issues or the precautionary principle is not hurting the scientist, the politician nor the policy maker but the poor peasant farmer, who expend a lot of energy toiling in infertile and unproductive land in anticipation of a bumper harvest each year. It therefore seems tragic to disregard* *a tool that has already been developed while the poor and the vulnerable communities suffer and depend on donor aid for survival.* It is important for the African governments to reengage the researchers to expedite the development of a GMO policy and allow the smallholder farmers to benefit from increased productivity attached to the use of GMO.

7.6.5 Herbicide Use

The use of herbicides in most smallholder farmers is also regarded as a new technology requiring sophisticated equipment that is mainly applicable to commercial farmers. This is further compounded by the high toxicity of some of these herbicides to humans and other animals if not carefully used, coupled with the misinformation that herbicides also kill the soil. For example, developing countries use only 25% of the global world pesticides though they experience 99% of the deaths linked to the improper use of these pesticides. However, with weed management being a critical element capable of reducing farmers' productivity by 55–90% (maize), 50% (common bean), 40–80% (sorghum), 40–60% (cowpea), 80% (groundnut) and 80% (cotton), the use of herbicides presents a precision farming technique that not only increases productivity but also reduces the drudgery of farming associated with weed control among smallholder farmers. Weeds compete with farmers' crops for space, sunlight and nutrients and cost time and money for the farmer to control manually. According to Gianessi (2009), smallholder farmers require 378 h per ha (groundnuts), 276 h per ha (maize) and 150 h per ha (sorghum), to undertake complete hand weeding, a task mainly done by women and children in southern Africa.

Herbicides that are applied post emergence of the crop have been effectively used to control some weeds that are propagated vegetatively such as couch grass (*Cynodon dactylon*), wandering jew (*Commelina benghalensis*), purslane (*Portulaca oleracea*), to mention a few, which are very difficult to control using hand hoes. Furthermore, pre-crop and weed emergence herbicides have also been shown to be effective against those weeds that produce huge quantities of seeds, making post-weed germination control difficult. Another group of weeds that have been effectively managed through herbicide use are the parasitic weeds that form parasitic interactions with the roots of the crop. The most yield-reducing parasitic weeds include *Striga asiatica* in maize and sorghum, whilst for cowpeas and groundnuts, there is *Alectra vogelii*. Parasitic weeds are unlike other weeds in that they require a host plant, which is usually the crop planted, to trigger germination, and usually remain attached to the host plant roots underground for most of the season, only to emerge during crop maturation, to produce seeds. The parasitic weeds produce huge quantities of seeds, with a *Striga asiatica* plant having been reported to produce up to 500,000 seeds (Mangosho and Mupambwa 2013). These parasitic weeds have been reported to cause yield losses of 50–100% if not controlled in crops like maize, sorghum.

With this information about the various weeds that present a challenge to improved productivity to most smallholder farmers in Africa, there is a need for proper extension of knowledge on the benefits of herbicides. Though herbicides present a precision farming technique for most resource poor farmers, its widespread adoption should be accompanied by proper education as herbicides are dangerous both to the user and to the crop, if incorrectly used. With most smallholder farmers practicing mixed crop farming systems, it is also imperative that the specificity of the various herbicides to certain crops be fully understood by these farmers before use.

7.6.6 Handheld Engine Powered Farming Tools

Draught power has been the main source of power for most smallholder farmers which mainly involves the use of donkeys, cows and horses for power at the farm. Though the use of animals at the farm is almost inseparable from any smallholder farmer in southern Africa, this technology has had its limitation in the new age. The changing climate, diseases, reduced grazing land due to population growth are now reducing the animal stocking of most smallholder farmers. Furthermore, though animals are effective in carrying out field operations, they tend to be slow and require more than one person to operate most times. The use of animal power has thus been associated with a similar drudgery as that of weeding at the farm. However, in the twenty-first century, new technologies are now emerging that are powered by fossil fuels and electricity, which can be used to drive most of the farm implements. These machines present a new precision farming opportunity that can be easily be taken up by most smallholder farmers, with a small capital investment. Of most importance are the powered rotary tillers, ploughs and planters, which can be operated by even younger persons at the farm. This technology will require support and buy-in at the government level as it requires some capital investment. The handheld fuel-powered machines are much cheaper than tractors and their heavy implements, and its possible for a farmer to sell a few livestock to fund the purchase of such equipment like handheld fuel-powered ploughs. However, there is definitely a need for government assistance in the form of subsidies to reduce the prices of this equipment, which are now mass manufactured in countries like China.

7.7 Conclusion

Most of southern African countries are located in semi-arid to arid regions, which greatly limits the water availability for crop production. Furthermore, smallholder farms, which are the food producers of most of these countries, are located in areas characterized by poor quality soils, which limit productivity in the face of climate change. Our chapter presents the option of precision agriculture from a smallholder farmer perspective. Though most precision farming techniques in developed countries are now powered by computer technologies, in the African context, precision agriculture focuses more on improved production systems that are holistic and site specific, sustainable and increase profits. In this chapter, technologies that focus on improving the crop productivity both in the soil and above soil whilst reducing competition have been presented. It is clear that smallholder farmers will need to adopt precision farming techniques to increase their productivity under a changing climate or these farmers will become food insecure. There is a need for demystifying some of the technologies presented here so that smallholder farmers feel comfortable to adopt some of these. Proper extension and knowledge sharing with the farmers is critical in driving the site-specific management farming systems. Overly, there is a need for government support on the adoption of other capital intensive technologies as well as development of new policy informed by research data, for the use of genetically modified crops in southern Africa.

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