Retooling Smallholder Farming Systems for Climate Change Resilience Across Botswana Arid Zones

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W. Leal Filho et al. (eds.), *African Handbook of Climate Change Adaptation*,
https://doi.org/10.1007/978-3-030-42091-8_168-1

Abstract

Background: Scientific progress and developments in technology have improved our understanding of climate change and its potential impacts on smallholder farming systems in sub-Saharan Africa (SSA). The persistence of such smallholder farming systems, despite multiple exposures to climate hazards, demonstrates a capacity to respond or adapt. However, the scale and intensity of climate change impacts on smallholder farming systems in SSA will overwhelm any indigenous coping mechanisms developed over centuries. Therefore, there is need to co-develop resilient farming systems with farmers and extension workers in anticipation of the looming food security challenges in the midst of climate change.

A survey comprising of participatory rural appraisal, focus group discussions, participatory resource mapping, and SWOT analysis was carried out for the purposes of farming systems diagnosis in reference to their resilience to climate change in three districts cutting across dry arid zones of Botswana agricultural landscape. The survey also sought to identify vulnerability of the farming systems to climate change and subsequently co-develop with farmers and extension workers new climate proofed farming systems.

Results: Detailed evaluation of current systems and their strengths and weaknesses were identified. Farmers highlighted constraints to their production being mainly drought related but also lack of production inputs. These constraints are location and context specific as extension areas within a district highlighted different challenges and even different CSA practices for similar production constraints. Through participatory approaches, farmers were able to identify and rank potential climate-smart agriculture practices that could ameliorate their production challenges and subsequently developed implementation plans for these practices.

Conclusions: The study demonstrates that climate change is already having significant adverse impacts on smallholder farming systems and therefore, climate proofing these systems is necessary if livelihoods of smallholder farmers are to be sustained. Therefore, retrofitting current farming systems to be climate resilient is the first step to climate proofing smallholder farmers' livelihoods.

Keywords

Botswana · Farming systems · Adaptation strategies · Climate change · Smallholder farmers

Introduction

Agriculture is a proven path to prosperity as no region of the world has developed a diverse, modern economy without first establishing a successful foundation in agriculture. This trend is going to be critically true for Africa where, today, close to 70% of the population is involved in agriculture as smallholder farmers working on parcels of land that are, on average, less than 2 hectares. As such, agriculture remains Africa's route for growing inclusive economies and creating decent jobs mainly for the youth. In Botswana, the agriculture economic sector is limited mainly to range resource-based livestock and pockets of arable farming based on rainfall and limited irrigated agriculture at several places (Alemaw et al. 2006). However, despite this aforementioned and the recent slowing in economic growth across much of the continent mainly due to the sharp drop in the global prices of oil and minerals, the prospects for African agriculture looks favorable. The African food market continues to grow with World Bank estimates showing that it will be worth US$1 trillion by 2030 up from the current US$300 billion (World Bank 2007, 2010). Demand for food is also projected to at least double by 2050. These trends, combined with the continent's food import bill, estimated at a staggering US$30–50 billion, indicate that an opportunity exists for smallholder farmers – Africa's largest entrepreneurs by numbers – who already produce 80% of the food to finally transition their enterprises into thriving businesses (AGRA 2017). Botswana is a net food-importing developing country (NFIDC); thus there is an opportunity to increase domestic production of basic foodstuffs, particularly cereals (grain sorghum and maize) and pulses. The national demand for cereal stands at 200,000 t per year, of which only 17% is supplied through local production (GoB 2019). Therefore, investments in arable agriculture will stimulate private sector development, create employment, value-addition opportunities, and enhance food security and ultimately exports.

Climate change poses a challenge to the attainment of agricultural potential. Climate change is threatening to undo decades of agricultural development efforts in developing countries with scientific projections pointing to a warmer climate characterized by increases in both intensity and frequency of extreme climate events, particularly in sub-Saharan Africa. Nkemelang et al. (2018) observed an increase in extreme weather events such as heat waves and late and high spatial and temporal rainfall variability across Botswana. Therefore, although climate adaptation is a global requirement, the need for adaptation is considered higher among developing countries where vulnerability is presumably higher (Adger 2003) and also in the interest of individual farmers who rely on the revenue generated from agricultural production (Holzkämper 2017). The need for adaptation is especially true in Africa as the population is highly dependent on rainfed agriculture (the most climate-sensitive sector) and particularly for smallholder farmers as they generally have limited adaptive capacity (Morton 2007), hence considered among those who will suffer most from the impacts of climate change (Easterling et al. 2007). Mogomotsi et al. (2020) highlight the vulnerability of smallholder rainfed famers to climate change and variability in Botswana. Smallholder agriculture has long been characterized by adaptive and flexible strategies to reduce vulnerability to climate natural variability and soil depletion (Adger et al. 2003; Tschakert 2007; Thomas et al. 2007; Eriksen et al. 2008). African farmers, particularly in dry land areas, have developed both on- and off-farm adaptation strategies in response to reoccurring droughts. Cooper et al. (2008) observed that coping better with current climatic variability in rainfed farming systems of sub-Saharan Africa is an essential first step in adapting to future climate change, while Muyambo et al. (2017) highlight the role of indigenous knowledge in drought risk reduction.

Nevertheless, climate change is going to negatively affect smallholder farmers beyond their coping capacity for naturally-occurring droughts, hence the need to hybridize traditional drought coping mechanisms with technology through co-development of climate resilience farming systems involving farmers, extension workers, and agricultural experts. Hence the need to retool farmers and extension officers for climate. Williams et al. (2019) observed that smallholder systems heterogeneity requires local specific climate adaptation for reducing the negative impacts of changing climate in regions heavily relying on small farms agriculture.

Due to the instability of agricultural production as a result of complex, dynamic, and interrelated factors such as climate, markets, and public policy that are beyond farmers' control, there is a need for farmers to develop new farming systems that incorporate innovations in their objectives, organization, and practices adapted to changing production contexts (Martin et al. 2013). While Thornton et al. (2018) highlighted that the scale of change required to meet the sustainable development goals, including those of no poverty, zero hunger, and the urgent action needed to address climate change, will necessitate the transformation of local and global food systems. Thus the main aim of this chapter is to develop resilient farming systems in Gantsi District and Bobirwa and Boteti sub-districts of Botswana. The chapter is premised on the following specific objectives: to evaluate current farming systems in the three districts and identify climate-smart practices within each district; identify alternative livelihood options (off-farm) in the catchment areas; identify indigenous knowledge of agricultural practices (ethno-veterinary and ethno-botanical) to cope with effects of climate change and co-identify (farmers and extension workers); and recommend potential climate-smart agricultural practices. The Republic of Botswana is a landlocked country with an area of 582,000 km^2 (Fig. 1). The climate is semi-arid to arid with high spatial rainfall variability. Rainfall decreases and temperature range increases westward and southward, varying from 650 mm per annum in the east to 230 mm in the south-west.

Agriculture plays a significant role in the lives of rural communities where it provides food and income and employs a majority of the rural inhabitants. However, the Intergovernmental Panel on Climate Change (IPCC 2007) has identified the country as vulnerable to climate change and variability, probably due to its low adaptive capacity and sensitivity to many of the projected changes. Therefore, it implies that with climate change, including high temperatures and frequent droughts conditions for agriculture, will worsen. For example, models have predicted that parts of Botswana will become much drier and hotter (IPCC 2001). Currently, there are projected statistically significant decreases in mean rainfall and increases in dry-spell length at each global temperature level (Nkemelang et al. 2018). IPCC special report on global warming of 1.5°C underlined that areas in the south-western region, especially in South Africa and parts of Namibia and Botswana, are expected to experience the largest increases in temperature (Engelbrecht et al. 2015; Maúre et al. 2018).

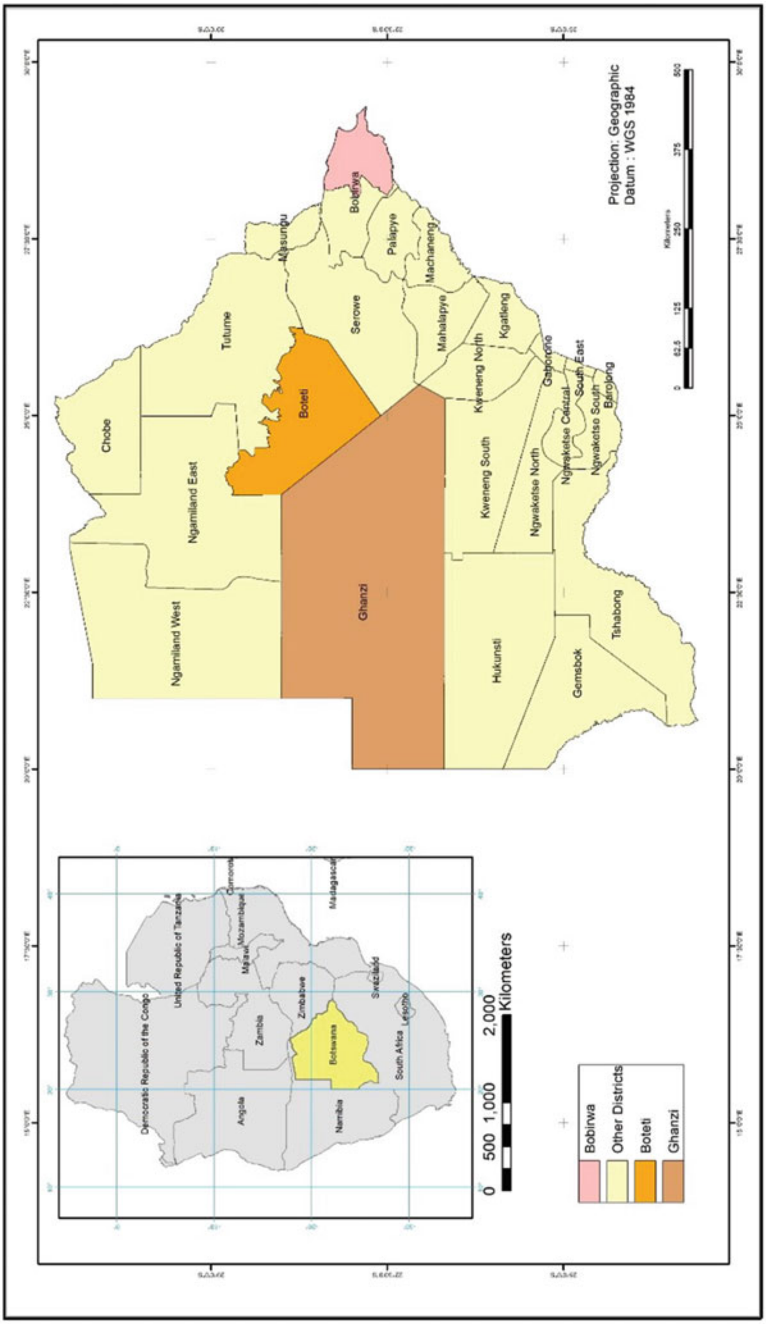

Fig. 1 Botswana location and the three study districts

Gantsi District and Bobirwa and Boteti Sub-Districts

Although the three areas of interest are very similar in their vulnerability to climate change impact, they vary in terms of land area, population, and physiography. Gantsi District has mostly sandy, infertile soils with low water holding capacity. Farming is the dominant economic activity in the district with pastoral being most dominant although of recent there has been an increase in irrigated agriculture. Bobirwa sub-district has relatively fertile soils although some. Integrated pastoral and arable rainfed farming are major activities in the district. Boteti sub-district practices both arable and pastoral farming.

A farming system model by Collinson (1987) was used to aid with farming systems diagnosis of the three districts (Fig. 2). In the model, there are visible and observable aspects, which are represented by solid boxes, and those that are deduced from the description of these aspects and verified by a discussion with farmers and extension officers, represented by perforated boxes.

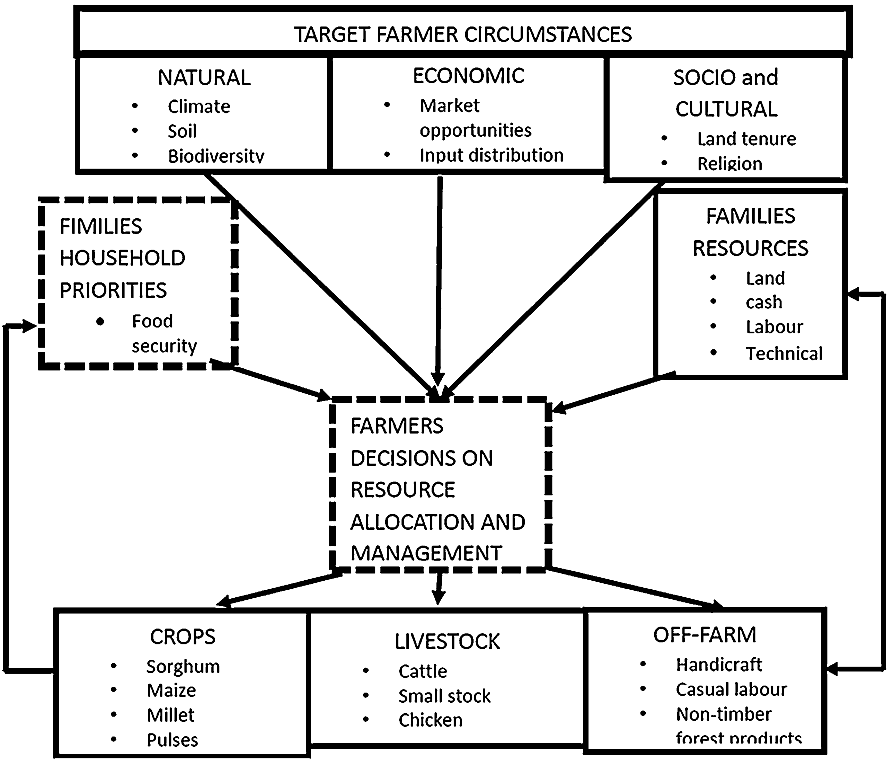

Fig. 2 Farming system diagnosis by Collinson (1987)

Information on current farming systems in each district was acquired through key informants, farmers, and extension workers. Two extension areas were randomly selected in each district.

(i) Gantsi District (Charles Hill, Ncojane)
(ii) Boteti sub-district (Mosu, Moremaoto)
(iii) Bobirwa sub-district (Bobonong, Gobojango)

Multistage sampling technique was used to determine the ideal sample size of participants in the focus group discussion (FGD) using Krecjie and Morgan (1970) formula. The multistage sampling process was conducted with the assistance of extension areas workers who provided facilitators with the number of active farmers in their catchment. Triangulation was applied where specific information was needed. A SWOT analysis was used to evaluate current farming systems, their strengths (resilient to climate change and droughts), and weakness (vulnerability to climate change and droughts).

The sharing of ideas (experience) among farmers and extension workers allowed them to evaluate the shared experience and seek more solutions to the prevailing livestock and crop production challenges and CSA practices in their respective extension areas. The list of proposed CSA options was discussed with participating farmers to ensure a common understanding was reached between them, facilitators and extension workers. During the discussion, farmers were encouraged to come up with additional practices especially those relating to indigenous knowledge practices (ethno-botanical and veterinary practices). At the end, ranking of the proposed CSA practices was done according to Khatri-Chhetri et al. (2017).

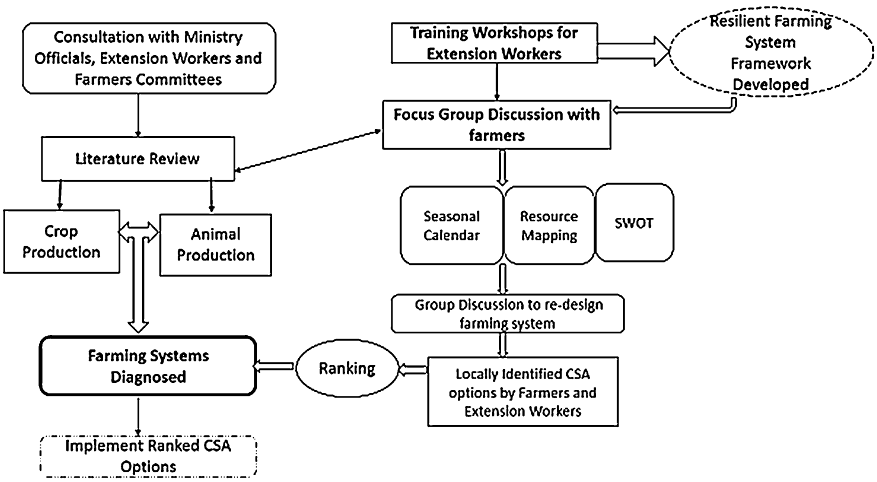

Fig. 3 Flow of methods used in developing the farming systems

The discussion of the predetermined options was designed into a participatory action plan that addressed the resources needed for implementation of the ranked CSA potential practices. The action plan and the developed activity plan was a step-by-step process that helped these groups of farmers together with their extension workers and facilitators to design and deliver solutions to address proposed climate-smart agricultural practices. Farmers ranked potential CSA practices for developing climate-resilient farming systems and together with extension workers developed their implementation guidelines. Figure 3 is a summary of the methods that were used to collect data needed to co-develop climate-smart resilient farming systems across the study areas.

Facilitators used a stated preference method to analyze the farmers' preference of CSA practices. In the stated preference method, participating farmers were asked about their preferences in a list of practices (Khatri-Chhetri et al. 2017).

Current Farming Systems in Gantsi District and Bobirwa and Boteti Sub-Districts of Botswana

Table 1 displays CSA practices currently found in the three districts. Such practices can be divided into crop and livestock related. Crop technologies that were common to all areas included fodder production and intercropping, whereas disease control and public health as well as ethno-veterinary practices were the only two livestock practices that cut across the three districts. Fodder production included planting of cowpea, lablab, maize, melons, forage sorghum, napier grass, and soybean. Cowpea and maize were not specifically planted as fodder, but their stover is normally fed to livestock after harvesting. Intercropping involves planting of rows of cereals such as maize, sorghum, and millet alternating with legumes such as cowpeas, lablab, and soybean and is part of integrated pest management as it provides conducive environment for natural enemies (Obopile et al. 2018) and also in maintaining soil fertility through biological nitrogen fixation (Pule-Meulenberg et al. 2018).

Current farming systems in Gantsi District is predominantly livestock farming as observed from the large number of cattle posts (livestock holdings) (Fig. 4). The rearing system is free ranging based on rainfed natural pastures. This resource (natural pastures) is prone to droughts and overgrazing leading to a large number of livestock mortalities.

As an adaptation move, farmers are moving toward some integrated crop-livestock systems with production of fodder crops, while some large commercial cattle ranchers use parts of their farms for diversifying into vegetable production. Smallholder farmers are also practicing small-scale irrigated gardens. Maize and cowpeas are the main rainfed arable crops in the area, and because of low drought tolerant of maize, yields are low in most years (Fig. 5). Minimum tillage is practiced and pioneered as a conservation agriculture (CA) in the district. However, due to the sandy nature of the soil, farmers complained of the disappearance of planting pits/basins, making their construction a laborious task that has to be repeated every year.

Table 1 CSA practices currently found in the Gantsi District and Bobirwa and Boteti sub-districts

Current CSA practices	CSA details	Gantsi District	Bobirwa Sub District	Boteti Sub District
Planting in tires	Vegetables	x		
Irrigation	Combination of different types of vegetables	x		
Holistic livestock management	Planned grazing in fenced farm	x		
Fodder production	Cowpea, lablab, Maize, Melons, Forage sorghum, sugar cane, soya	x	x	x
Intercropping	Intercropping legumes and cereals	x	x	x
Crop rotation	Cereals rotated with legumes	x		x
Backyard gardening	Different types of vegetables	x		
Integrated farming	Combination of different crop enterprises	x		
Integrated farming	Combination of different types of livestock, fodder, vegetables, field crops, and poultry	x		
Supplemental feeding	Using commercial and fodder	x	x	
Disease control and public health	Construction pit latrines to curb the spread of beef measles	x	x	x
Poultry production	Constructed poultry houses which control temperatures using natural ventilation. Collection of chicken manure to sell for vegetation production		x	
Small stock production	Apply recommended management practices that follow small stock calendar		x	x
Production of marula oil cake	Marula by products used for animal feeds		x	
Utilization of indigenous tree species for livestock feeding	Cutting *Vachellia* spp. (*Vachellia tortilis* and *V. erioloba*) species and mixing with stover to make livestock feeds		x	
Pigs production	About 300 individual pigs housed in large paddocks		x	
Minimum tillage (ripping using tractor)	Mainly cowpeas, watermelons, maize, sorghum			x
Minimum tillage (ripping using donkeys)	Cowpeas, watermelons, maize, sorghum			x
Planting pits/basins	Cowpeas, watermelons, maize melons, maize	x		x
Cover cropping	Mainly cowpeas, pumpkins, lablab, watermelons, melons		x	x
Fertilizer application as per soil analysis	Use of fertilizers on sorghum, maize			x

(continued)

Table 1 (continued)

Current CSA practices	CSA details	Gantsi District	Bobirwa Sub District	Boteti Sub District
Kraal manure application	Application of kraal manure on maize			x
Provision of housing	Housing for goats' kids			x
Vaccinations	Vaccinate against livestock and poultry diseases	x	x	x
Use of solar energy	Solar panels to generate electricity			x
Ethno veterinary practices	Examples: wood ash for retained placenta; powdered dead/sun bleached millipede skeleton to treat eye infection	x	x	x
Use of tolerant breeds	Use of Tswana goats, Boer goats			x

Boteti sub-district just like Gantsi District is a predominantly cattle-rearing area although has more rainfed arable farming. Figure 6 shows the spatial distribution of land uses in the sub-district. The main crops grown are maize, cowpeas, sorghum, and millet; the latter two being drought-tolerant crops, whose limitation is susceptibility to bird damage. Of recent, crop damage by wildlife especially elephants have increased in the sub-district.

Figure 7 displays current farming systems for crops and livestock in Letlhakane extension area of Boteti sub-district. In order to minimize drought impacts on both livestock and crops, it is imperative to increase the number of people that practice climate-smart agriculture technologies such as conservation agriculture, fodder production, and the use of drought-tolerant germplasm.

Of the three districts, in terms of both physiography and farming systems, Boteti lies at the transitional zone between Gantsi and Bobirwa in having some aspects of sandy predominant in Gantsi but also having the more fine-textured fertile soils found in Bobirwa. Similar to Gantsi District, livestock production is dominant in the Boteti sub-district. In Boteti sub-district, rainfed arable agriculture comprising sorghum, millet, maize, and cowpeas are among the major crops grown similar to Bobirwa.

Alternative Livelihoods in Gantsi District and Bobirwa and Boteti Sub-Districts

Table 2 shows alternative livelihoods outside the agricultural sector. It is evident that Gantsi District had many more alternative livelihood activities compared to the two sub-districts of Bobirwa and Boteti. This is probably due to the fact that Gantsi township is more urban compared to the villages of Bobonong and Letlhakane, which are the sub-district headquarters for Bobirwa and Boteti sub-district,

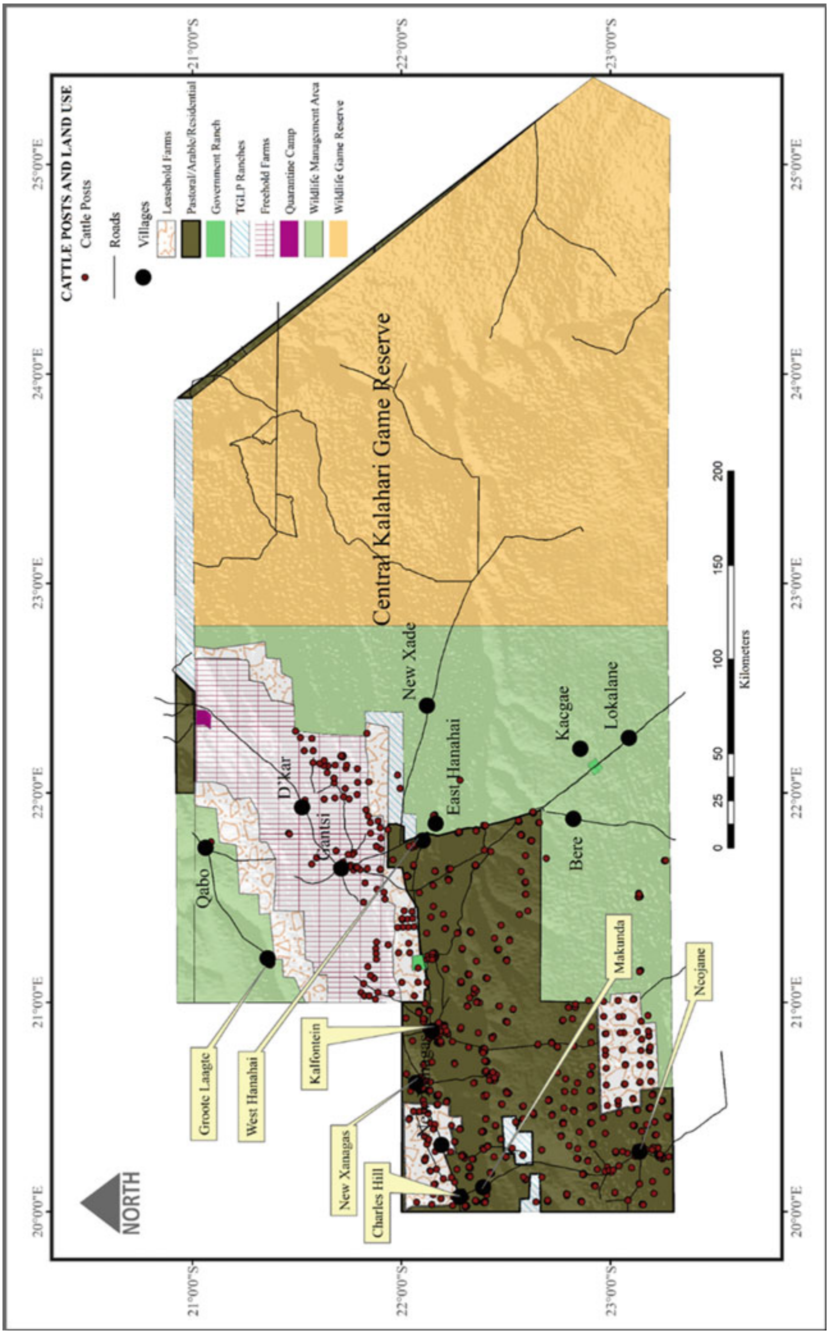

Fig. 4 Spatial distribution of current farming systems in Gantsi District

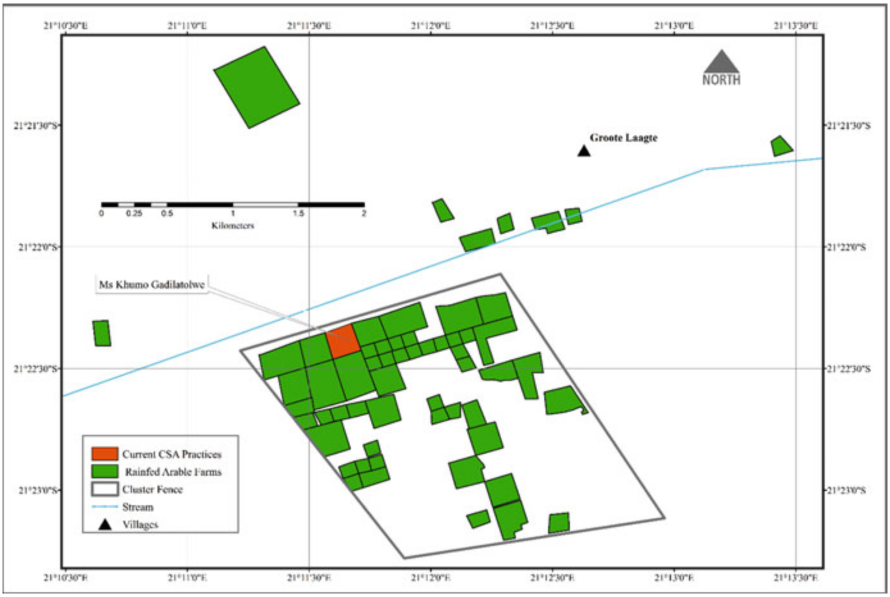

Fig. 5 Current farming systems for crops and livestock in Groote Laagte extension area (Gantsi)

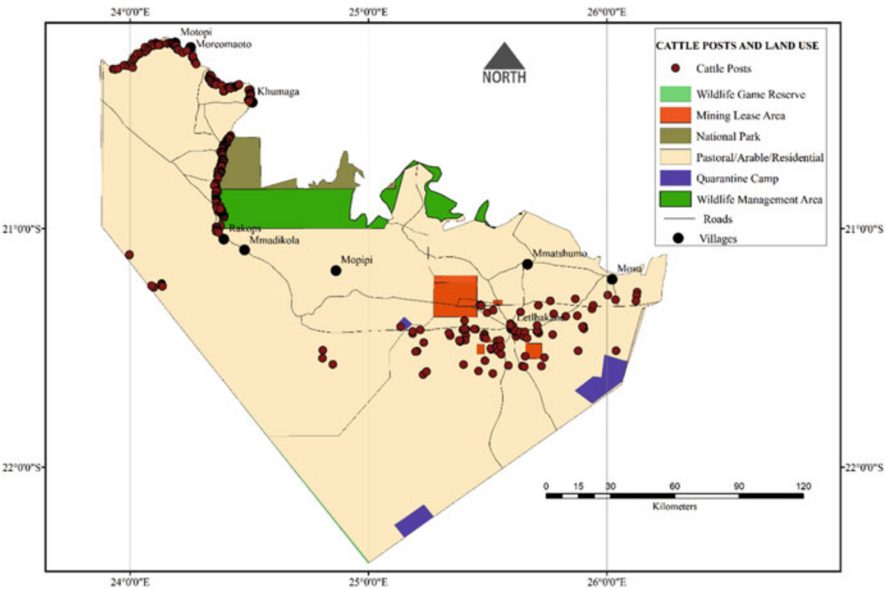

Fig. 6 Spatial distribution of current farming systems in Boteti district

Fig. 7 Current farming systems for crops and livestock in Letlhakane extension area (Boteti)

Table 2 Alternative livelihoods for Gantsi District and Bobirwa and Boteti Sub-Districts

Alternative livelihoods	Gantsi District	Bobirwa sub-district	Boteti sub-district
Employed in Ipelegeng projects	x	x	x
Traditional herbalists selling traditional medicines	x	x	
Selling of veld products	x	x	x
Provision of mechanical services mainly in Gantsi township	x		
Renting out houses	x		
Performing arts	x		x
Sale of traditional brews in shebeens	x		
Micro-enterprises (tuckshop)	x	x	x
Sales agents	x		
Farm work (livestock herding)	x		
Horse racing (jockeys)	x		
Dog racing	x		
Domestic work	x	x	x
Mobile safari	x		
Sale of game meat from community trusts	x		
Taxi services	x	x	x
Hired donkey carts for transport	x		
Game farming	x		
Handicrafts	x	x	x
Traditional brews	x	x	x
Labor for destumping arable fields	x		
Illicit substances (marijuana)	x		
Provision of transport for goods	x		
Cattle sales agent	x		
Brick molding	x		x
Poaching and hunting	x		

Bakery	x		
Dependency on male/female partners	x		
Garbage collection	x		
Fishing		x	x
Harvesting wood, grass and poles		x	x
Catering services	x	x	x
Sewing (tailoring)		x	x
Pottery			x
Thatching		x	x
Food processing			x
Sale of secondhand clothes		x	x
Sale of ornamental and fruit trees		x	
Sale of semi-precious stones		x	
Using recycled paper to make flower pots		x	
Sale of empty cans		x	
Recycling old tires to make livestock troughs		x	
Leatherworks		x	
Hair salons			
Wood carving		x	x
Destumping to increase hectarage in fields		x	
Panel beating and motor mechanic		x	
Pottery			x
Welding			x
Upholstering			x

respectively. In each of the three study areas, livelihood activities were varied as shown in Table 2. The common activities that cut across the three districts included employment through the Ipelegeng program (a Government of Botswana poverty alleviation scheme), sale of veld product, running of tuckshops, domestic work (being a maid), taxi services, sale of traditional brews, and catering services.

The types of veld products sold are area specific although there are some common ones. For example, they include the morama bean (*Tylosema esculentum*), mongoose seed (*Bauhinia petersiana*), and wild berries such as *Grewia flava*. In Bobirwa, some of the veld products being sold are the mopane worm (*Imbrasia belina*), fruit of baobab (*Adansonia digitata*) tree, marula (*Sclerocarya birrea*) fruits, monkey orange, *Grewia flava* berries, *Vangueria infausta* fruits, *Mimusops zeyheri*, and wild vegetables such as *Cleome gynandra*, *Amaranthus* spp., and wild okra. For the Boteti sub-district, veld products include the harvesting of the water lily which is as a condiment for meat and sale of indigenous vegetables as described for Bobirwa and wild fruits as baobab (*Adansonia digitata*) and marula (*Sclerocarya birrea*). The sale of firewood and handicrafts was also common among the study areas, the difference being the type of species that is being sold.

It is noteworthy that veld products are dependent on climate because during prolonged droughts when crops fail and livestock die, wild plants are equally affected; hence such products go off the markets. This situation is also true for traditional brews that are either made from mainly sorghum or wild fruits. During drought years, they would also not be available. This scenario shows the extent to which smallholder farmers are exposed to the effects of climate change, hence the need to adopt climate-smart technologies, on and off farm.

The recurring droughts leading to asset losses have driven communities in these three districts to develop some alternative livelihoods strategies for coping with drought challenges. Nevertheless, these alternative livelihoods strategies developed to cope with natural droughts are unlikely to match the severity and frequency of climate change-induced droughts because of their short-term nature (Table 2), hence the need for coming up with CSA technologies by Government and other stakeholders. However, the adoption of these CSA technologies has not been promising due to among other obstacles, weaknesses as highlighted in Table 3. These weaknesses or malalignment of the current CSA technologies used in the districts or their implementation may be due to that they were never meant for farming systems and cultures found in the three districts, therefore could have been adapted for these systems before implementation. Mwongera et al. (2017) noted that approaches that aim to identify and prioritize locally appropriate climate-smart agriculture technologies will need to address the context-specific multidimensional complexity in agricultural systems.

Therefore, to improve the adoption of CSA technologies, there is need for co-development of technologies with farmers and extension workers at the local level. Through participatory approaches, farmers ranked various CSA interventions. The examples in Table 4 below shows that preferences vary at local extension levels within a district and also between districts, highlighting the importance of considering local context and dynamics of farming systems when designing CSA practices

Table 3 SWOT analysis of current CSA farming practices in Gantsi District and Bobirwa and Boteti sub-districts

Strengths	**Weaknesses**
Improved soil fertility Technologies are adaptable to climate change High carbon sequestration Improved food and nutrition security Both males and females participate in farming activities Availability of underground water Availability of arable land Supportive Government policies Mild winters Availability of veldt products (natural resources) Fertile soils Moisture conservation Pest and weeds control (break life cycle) Reduction of soil erosion	Use of hybrid seed destroyed traditional crop varieties Destruction of CSA crop structures by wind erosion and livestock Unavailability of equipment for CSA crop practices The decision to sell livestock is predominantly done by males The decision to sell crops is predominantly done by females Shortage of livestock grazing land and grazing resources Poor vegetation Shortage of farming equipment Lack of farm input suppliers Poor roads and infrastructure Lack of research and development (e.g., abattoirs) Long-time taken by Land Board to allocate land Shortage of labor Very interested to do fish farming No financial assistance for fisheries Few trained officers in Aquaculture Unreliable rainfall Reliability on Government hand out Conflict on Government policies Unwillingness to change by farmers to new technologies High farmers to extension worker ratio Lack of documentation on fish farming in Botswana Blanket application of fertilizers
Opportunities	**Threats**
Adaptation with co-benefits Resilience to drought due to irrigation Diversified crop production Employment creation High demand for fish Commodity clusters of farmers can be helping in farming systems (e.g., poultry and dairy) Agro-tourism Diversification in farming Fish has a potential to grow since it is a new in Bobirwa sub-district and has a high nutritional value Enhanced import substitution Availability of sunlight for usage of solar power No Market for cattle to BMC because Bobirwa Sub District is not a green zone Irrigation (crops, fodder production) almost the whole year Multiplication of Musi breed Improved soil fertility (legumes)	Occurrence of extreme weather conditions (e.g., change of start of rainy season) Emergence of new pests and diseases Introduction of alien grass species in the rangelands (e.g., *Cenchrus biflorus*) Competition of labor with Government programs Other farmers may not cooperate in rotational grazing and correct stocking rate in communal areas Human-wildlife conflict (elephants) To develop small stock slaughtering facility Human-wildlife conflicts The rain pattern has changed Heat waves Lack of raw materials for feeds Use of hybrids seeds Use of exotic livestock and poultry breeds Lack of buy in by the Government on the programs for fisheries (just like LIMID) High budget to start fish projects Invasive species Stock theft from the neighboring countries Aging farmers Conversion of arable land to other land uses (e.g., tourism and settlements) Contamination of environment

and interventions (Tables 4–9). Khatri-Chhetri et al. (2017) noted that farmers' priorities for CSA technologies are linked with prevailing climatic condition of particular location, socio-economic characteristics of farmers, and their willingness to pay for available technologies.

Indigenous Knowledge of Agricultural Practices in Gantsi District and Bobirwa and Boteti Sub-Districts

Farmers across the three districts indicated that they had indigenous agricultural practices pertaining to production of livestock and crops (Tables 4 and 5). Table 4 shows ethno-veterinary practices across the three districts. A number of practices such as the use of *Senna italica* to treat calf paratyphoid, treatment of eye infection in livestock using sugar and/or branding around the infected eye, treatment of poultry diseases such as Newcastle and coccidiosis using *Aloe* spp., and the use of dried up and bleached millipede carcass for eye infections in livestock were found in all the study areas. It is noteworthy that about a third of the practices are plant based. Consequently, prolonged droughts caused by climate change will affect them, hence the need to intentionally conserve wild plants. Other practices are based on plant products such as charcoal, wood ash, and smoke.

Table 5 displays the ethno-botanical practices found in the three districts. The use of a mixture of tobacco, chillis, garlic, onions, and soap or a combination of any two with liquid soap is common among the three districts for the control of aphids (*Aphis craccivora*), red spider mites (*Tetranychus urticae*), and fungi. The digging of trenches around arable fields for control against corn cricket (*Acanthoplus discoidalis*) and the traditional magical powers to protect fields against pest were common in the Gantsi District and Bobirwa sub-districts. The use of chilli blocks to scare away elephants where crushed chillis and mixed with cow dung, dried, and burnt was practiced in the Bobirwa and Boteti sub-districts. Much like with indigenous practices for livestock, about a third of the practices are plant based. Other practices such as digging of trenches to control corn cricket, animal snares, scare crows, use of reflectors to scare away elephants, and other can be referred to as physical.

It is interesting that out of the list of indigenous practices for both crops and livestock, none deal directly with increasing production but are all for the protection of pests and diseases. Furthermore, many of the practices are plant based and therefore are equally affected by the harsh effects of climate change.

Potential Climate-Smart Agricultural Practices Identified by Farmers and Extension Workers

When designing CSA implementation strategies at farm level, one must consider adaptation options that are well evaluated and prioritized by local farmers in relation to prominent climatic risks in that location (Khatri-Chhetri et al. (2017);

Table 4 Indigenous (ethno-veterinary) practices in the Gantsi, Bobirwa, and Boteti

Practices	Gantsi District	Bobirwa Sub District	Boteti Sub District
Use of charcoal for diarrhea in calves			x
Use of charcoal for dressing livestock wounds		x	
Use of charcoal to treat poisoning in dogs		x	
Use mix of dry donkey dung, salt, and wood ash and administered orally for retained placenta in small stock			x
Use of *Senna italica* (sebete) for the treatment of calf paratyphoid	x	x	x
Ximenia spp. for the treatment of foot rot in livestock			x
Use of sugar to treat visually impaired eyes and eye branding	x	x	x
Bandaging a fracture with wood and soft cloth		x	x
Use of *Aloe* spp. (mokgwapha) for foot rot			x
Use of wood ashes mix for snake bites			x
Use of cow dung after branding or dehorning			x
Thamnosma rhodesica (moralala) for prevention of miscarriage and still birth		x	x
Diospyros lycioides (letlhajwa) for control of *Pasteurella*			x
Use of *Aloe* spp. (mokgwapha) in birds against Newcastle disease and coccidiosis	x	x	x
Use of "thobega" against fractures in livestock		x	x
Dry old bleached millipede is crushed and applied to treat visually impaired eyes	x	x	x
Use of sugar to treat visually impaired eyes	x	x	x
Use of *Ziziphus mucronata* leaves to treat eye infections			x
Ziziphus mucronata pounded leaves and paste applied to dress wounds	x		
Use of wood ash mainly *Combretum imberbe* (Motswere tree) to control external parasites in chicken and puppies		x	x
Use of burnt cow dung against mosquitoes			x
Use of wild cucumber (mokapane) for the treatment of wounds			x
Use of dried cow dung smoke for the treatment of mastitis; burning cow dung is placed under the udder of the animal for the smoke to cover the udder			x
A string is tied on the warts and left until it falls off			x
Ash of *Vachellia mellifera* is mixed with water and administered orally when an animal has retained placenta; can also be used to control weevils in grain	x		x
Use of hot ring iron to treat eye infection			x
Cutting of tail and ears for treatment of animals against *Pasteurella*		x	x
Liquid paraffin external parasites on chicken, cats, dogs, and rabbits		x	

(continued)

Table 4 (continued)

Practices	Gantsi District	Bobirwa Sub District	Boteti Sub District
Potassium per manganite to control chicken diseases (e.g., coccidiosis)		x	
Use of brake fluid to control mites	x	x	
Use of bitter apple fruits (thontholwana/morolana) to treat eye infection		x	
Use of charcoal to treat poisoning in dogs		x	
Use of sugar for control of uterine prolapse	x		
Use of purslane to control uterine prolapse	x		

FAO 2012). Table 6 is a compilation of how farmers in the three districts ranked CSA practices according to their preferences. At each district, at extension area level, through focus group discussions, farmers came up with a list of CSA practices that existed or was perceived to be of importance for their area. The list was presented to extension workers for validation and in many instances, extension workers added more practices to the list. Only two interventions were highly ranked across the three districts, namely, fodder production and vaccination calendar adjustment. The production of fodder is important because without good-quality animal feed, it would be difficult to have adaptation with mitigation co-benefits of reduced greenhouse gases (Herrero et al. 2013). It has been documented that one of the consequences of climate change is increased incidences of disease (Moonga and Chitambo 2010). Adjusting livestock vaccination calendar is therefore relevant and important to control disease and as seasons seem to have shifted, hence the need to vaccinate timeously. Out of the three districts, Gantsi has the most uniform physiography, for example, its soils are predominantly sandy (arenosols). Furthermore, livestock production is very important, with one of the highest livestock populations in Botswana. This scenario can explain the uniform agreement in ranking of the CSA interventions (Table 7).

Due to centuries of drought exposure, smallholder farming systems in the three districts have developed some level of resilience to natural droughts. Nevertheless, the frequent and severe climate change-induced droughts are beyond the coping capacity of these systems, hence the need to climate proof them through appropriate climate-smart agriculture practices. Effective adoption of climate-smart agriculture requires active participation by farmers not only in identifying constraints to their production but also in developing CSA practices for addressing the identified challenges. This approach requires hybridization of indigenous knowledge with technology. Resilient farming systems lead to sustainable livelihoods, thus, the need for an appreciation of smallholder livelihoods as the anchor on which to build them on. Successful CSA adoption requires co-development of implementation plans by farmers and extension workers.

Table 5 Indigenous (ethno-botanical) practices for crops in Gantsi District and Bobirwa and Boteti sub-districts

Practices	Gantsi District	Bobirwa Sub District	Boteti Sub District
Use of wood ash for pest control			x
Mixture of tobacco garlic and onion and sunlight for aphid control	x	x	x
Trenches for control of *Acanthoplus discoidalis* (setotojane)			x
Use of scare crows			x
Foot crushing of grasshoppers			
Animal traps (snares)			
Use of sugar to attract natural enemies			x
Application of *Combretum imberbe* and *Vachellia mellifera* (motswere and mongana wood ash, respectively, around plant stems and also application in seeds/grains to protect against storage pests			x
Use of chilli block, where chillis are mixed with cow dung, then dried, and then burnt to deter elephants		x	x
Python fat is mixed with seed before planting to protect the arable fields from predators		x	
Burn mohetola (*Indigofera* sp.) to accelerate sorghum maturity		x	
Use of empty containers to scare the birds and elephants		x	
Use of metal reflectors along the fence to scare the elephants		x	
Collect human urine and pour small bits of it on strategic places around the perimeter fence to scare kudus and jackals (mark territory)		x	
Filling a clear bottle with water and placing at strategic places to scare away jackals		x	
Digging a trench around the field to control pests, e.g., corn cricket	x	x	
Magically protect (Go upa masimo) through seeds	x	x	
Use of whey to control aphids	x		
Eucalyptus for the control of weevils in grains	x		

Table 6 Ranking of CSA practices in the Gantsi District and Bobirwa and Boteti sub-districts

		Ghanzi		Bobirwa		Boteti	
No.	CSA Intervention	Charleshill	Nojane	Bobonong	Gobojango	Mosu	Moreomaoto
1	Provision of animal shade	High	High	not rated	not rated	not rated	not rated
2	Fodder Production	High	High	High	Medium	High	High
3	Vaccination and breeding calendar adjustment	High	High	High	High	High	High
4	Correct Stocking rate	High	High	not rated	not rated	not rated	not rated
5	Feed processing	High	High	not rated	not rated	High	High
6	Use of hardy indigenous breeds	High	High	not rated	not rated	Medium	Medium
7	Harvesting and processing of enchroacher plant feed	High	Medium	Medium	not rated	not rated	not rated
8	Ethno veterinary practices	Medium	High	not rated	not rated	not rated	not rated
9	Water harvesting	Medium	Medium	not rated	not rated	Low	High
10	Pasture re-seeding	Medium	Medium	Medium	not rated	not rated	not rated
11	Manure application	Medium	Medium	not rated	not rated	not rated	not rated
12	Rotational grazing	not rated	Medium	not rated	not rated	not rated	not rated
13	Biogas production	not rated	Medium	not rated	not rated	not rated	not rated
14	Conservation and utilization of indigenous breeds	not rated	not rated	Medium	Low	not rated	not rated
15	On-farm AI of Cattle	not rated	not rated	Medium	Low	not rated	not rated
16	Harvesting indigenous plant species for feeds	not rated	not rated	Medium	not rated	Medium	not rated
17	Use of indigenous poultry breeds	not rated	not rated	Medium	Medium	not rated	not rated
18	Dip tanks	not rated	not rated	Low	High	not rated	not rated
19	Mobile laboratory	not rated	not rated	Low	High	not rated	not rated
20	Holistic pasture management	not rated	not rated	not rated	Medium	not rated	not rated
21	Solar energy use	not rated	not rated	not rated	not rated	High	Medium
22	Integrated farming	not rated	not rated	not rated	not rated	Medium	High
23	Feedlot weaner production	not rated	not rated	not rated	not rated	Medium	Medium
24	Small stock AI	not rated	not rated	not rated	not rated	Low	High
25	Termites chicken feed production	not rated	not rated	not rated	not rated	Low	Low
26	Leather processing	not rated	not rated	not rated	not rated	Low	Low
27	Kraal rotation	not rated	not rated	not rated	not rated	Low	Low
		Key	Rating	not rated	High	Medium	Low
			Code				

Table 7 Implementation plan for fodder production

CSA Technology	Activities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fodder production	Land preparation									■	■	■	■
	Buying fertilizers									■	■	■	■
	Buying seeds									■	■	■	■
	Planting											■	■
	Fertilizer application											■	■
	Weeding	■	■	■									
	Harvesting				■	■	■						
	Drying				■	■	■	■	■				
	Milling and Packaging							■	■	■			

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