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Building Inclusive Seed Systems for Semi-Arid Areas: Insights from Zimbabwe Super Seeds

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Preface

This paper forms part of a set of five Climate Smart Agriculture (CSA) innovation model papers that are premised on the adoption and integration of various climate smart agricultural approaches to smallholder farming in East and Southern Africa (ESA). Funded by the United Kingdom's Department for International Development (DFID), the cases draw on pilot initiatives within the Agricultural Development portfolio of the Vuna programme. The pilot projects are country-specific with different project components that are based on CSA. The papers explore the experience of different models designed to strengthen the delivery and uptake of climate smart agricultural practices, inputs and partnerships among smallholder farmers. Notably, the implementation period of the Vuna innovation models was short, ranging between 9 and 12 months. Consequently, the findings contained herein are based on emerging insights and the potential of the innovation models supporting farmer resilience in a scalable and sustainable manner. The innovation model series of papers sought to assess and identify early lessons emerging from the innovation model's adoption, uptake and ownership by implementing partners.

The series of the *innovation model papers* include:

- Building Climate Resilience for Dairy Farmers, through Climate Smart Solutions: Insights from The Malawi Smallholder Dairy Sector;
- Integrating Climate Smart Agriculture in Pigeon Pea Production: Insights from Export Trading Group in Mozambique;
- Integrating Climate Smart Agriculture Capacity Development in Out-grower Schemes: Insights from Musoma Food Company Ltd and G2L Ltd in Tanzania;
- Integrating Climate Smart Agriculture into E-Voucher Farmer Input Subsidy Programme: Insights from Zambia; and,
- Building Inclusive Seed Systems for Semi-Arid Areas: Insights from Zimbabwe Super Seeds (this paper).

The research was conducted between October 2017 and February 2018, in three phases. First, available literature on CSA, climate change and agriculture in the focus country and within the region was reviewed. Second, desktop research of Vuna project documents (baseline reports, quarterly reports, grant application(s), and the Vuna project plan) was done. Third, field research was conducted to assess the extent to which the innovation model has been adopted and whether it's being adapted to enhance desirable outcomes for key value chain actors. Field research results were analysed to determine the potential for the sustainability of the interventions.

Acronyms

AGRITEX	Agricultural Technical and Extension Services
AR5	Intergovernmental Panel on Climate Change's Fifth Assessment Report
CA	Conservation Agriculture
CIMMYT	International Maize and Wheat Improvement Center Spanish: Centro Internacional de Mejoramiento de Maíz y Trigo
CSA	Climate Smart Agriculture
ESA	East and Southern Africa
DFID	The United Kingdom's Department for International Development
FAO	Food and Agriculture Organisation of the United Nations
IPCC	Intergovernmental Panel on Climate Change
MEWC	Ministry of Environment, Water and Climate
MoU	Memorandum of Understanding
NGO	Non-Governmental Organisation
NR	Natural Region
PRP	Protracted Relief Programme
SSI	Seed Services Institute
ToT	Training of Trainers
OPV	Open-Pollinated Variety
ZSS	Zimbabwe Super Seeds

Executive summary

Improving access to climate resilient seed for smallholder farmers is among the promising climate smart solutions intended to tackle the impacts of climate change. In Zimbabwe, availability of certified seed on the market has improved, but for a number of reasons, smallholders still struggle to get access to quality certified seed. Key among the constraints they face is the high cost of certified seed, the substantial cost and logistical difficulties of reaching retailers in urban locations, and the unavailability of certified seed for some crops especially small grains and legumes. This has resulted in most farmers using their retained crop as seed. In addition, the performance of hybrid seed varieties under the increasingly drier, hotter and more variable climatic conditions in Zimbabwe's semi-arid regions has been unsatisfactory.

Zimbabwe Super Seeds (ZSS) is pioneering an inclusive seed business model, partnering with smallholder farmers in the multiplication of climate resilient seed varieties, and marketing certified seed through a network of local agro-dealers and retailers. Improved availability of locally adapted high yielding, drought-tolerant seed varieties at affordable prices is expected to increase the use of such seed, leading to higher and more stable yields and incomes of farming households in semi-arid regions. The participation of smallholder farmers in seed multiplication is also expected open a new income opportunity through participation in high-value (seed) crop production, which guarantees them premium prices and market opportunities. Capacity building and on-going extension support for seed producers is also elevating farmers' technical, managerial and organisational competencies in various aspects of production and marketing as well as enabling them to self-finance future farming operations.

This paper draws on the ZSS experience to answer two related questions; (i) is the ZSS business model building the resilience of farmers and other market players given current and projected climate risks; (ii) is the business model sustainable. In addition, the paper distils lessons on what drives resilience building and sustainability of interventions.

Findings show that the impact of farmer training and on-going support has been significant. Yields for smallholder farmers participating in seed multiplication have doubled and many aspects of crop management have seen significant improvement due to farmer support services through ZSS and its partners. The quality of seed crops produced by the farmers has continued to improve each year. The farmers are enjoying premium prices of $1400 per tonne for beans, and $600 for a tonne of maize which are nearly double those for commercial crops. These financial benefits have also brought some secondary increase in productivity as farmers set high-performance targets each successive season and can afford the required inputs. Higher incomes are also enabling farmers to invest in capital assets and diversify their production systems.

> Yields for smallholder farmers participating in seed multiplication have doubled and many aspects of crop management have seen significant improvement

The increase in yields of target crops points to the success of the ZSS model in reducing sensitivity of key crops to climate risk in these regions. Although more time is needed to ascertain the tolerance of ZSS seed varieties to moisture stress, current indications are that yields are either increasing or stable across years. Seed sales and testimonies from farmers and agro-dealers also suggest that the ZSS seed varieties are popular and demand is on the rise. This positive trend has been key to the ZSS business as they have consistently surpassed their production and marketing targets. Improvements in availability of seed has been reported by farmers and agro-dealers, particularly for legumes such as sugar beans and cowpeas. This is resulting in more farmers including these in their rotations. Such diversified production systems are expected to improve soil fertility management as legumes fix the much-needed nitrogen in these fragile environments, and also reduce exposure to both climate and market-related risks. Based on these observations this paper concludes that the ZSS business model is performing to expectation and farmers are reaping the intended benefits.

Although the ZSS business model is still new, aspects of adaptation of the model are emerging to enhance its effectiveness. For example, the strong commercial incentives are encouraging more and more farmers to pay for foundation seed upfront instead of expecting ZSS to pre-finance as has been the case. This is enabling ZSS to expand its

operations without stretching their financial resources. In addition, some of the seed producer farmers are now able to use their contracts with ZSS as collateral to access production finance from financial institutions. This is improving their access to productivity-enhancing inputs and enabling expansion of production without putting pressure on ZSS's financial base.

Although it is too early to attribute any changes in the wider seed market system to the ZSS business model, it is evident that the inclusive business model in seed multiplication is gaining traction in the country. A number of new seed companies are now engaging smallholder farmers in seed multiplication and also marketing their certified seed through networks of agro-dealers. Although ZSS benefited from donor support during its early years, and recently from the VUNA program to expand into two new districts, its plans to independently expand into two further districts points to the success and viability of the business model.

A number of lessons emerge from the experience of the ZSS that are relevant for the design and implementation of CSA and resilience building interventions in smallholder systems. These are summarised below:

- CSA innovations must be based upon a strong commercially viable business case for key partners involved. The success of the ZSS model hinges on its ability to leverage and align the strong commercial incentives that have underpinned adoption by ZSS itself, participating farmers, and also agro-dealers.
- Climate smart, drought resistant quality seed varieties can be commercially produced by smallholders in order to maximise local climate and eco-system relevance and adaptability. The ZSS model increases access to locally adaptable seed by selling through local agro-dealers lowering logistical and transaction costs for farmers.
- Robust partnerships between private and public entities with clearly defined roles and responsibilities can add significant value to the sustainability and scalability of CSA delivery models.
- Viable smallholder-based multiplication models require relatively high investment and technical support in the short- to medium-term. The ZSS model has benefited from a partnership with the government extension service which enables sustained but cost-effective extension support to seed producing farmers.
- Where the length and risk profile of CSA investment warrants external support and/or seed financing, that investment should contribute to institutional capacity strengthening to support a long-term exit strategy and model sustainability.

1 Introduction

Climate change is altering rainfall patterns, and inducing more severe and frequent extreme weather events such as droughts and flooding in many parts of East and Southern Africa (ESA).[1] These changes threaten to deepen the challenges already being faced by millions of farming households. The situation is even more alarming in regions that are already semi-arid where climate risk is endemic. Unless decisive adaptation action is taken to build resilience of the agricultural sector, food insecurity and poverty are set to worsen. Effective response measures are urgently required to sustainably increase productivity, stabilise yields and diversify production systems while building the adaptive capacity and resilience of farming communities.

Climate Smart Agriculture (CSA) is a promising adaptation approach for the agricultural sector that has gained much traction among governments, non-governmental organisations (NGOs), private sector and donors. CSA has been formally defined by the Food and Agriculture Organisation of the United Nations (FAO) as consisting of three components: (i) sustainably increasing agricultural productivity and incomes; (ii) adapting and building resilience to climate change; (iii) reducing and/or removing greenhouse gases emissions.[2] The concept of CSA has now been widely adopted at various levels.[3] Significant levels of national and international funding are correspondingly being allocated to the development and promotion of CSA.

A key challenge is prioritising an extremely broad array of agricultural practices, technologies, institutional arrangements, and activities now being called "climate smart".[4] Equally lacking is an understanding of both the effectiveness and sustainability of different models for rolling out CSA. This paper assesses the effectiveness of one such approach to CSA that focuses on increasing the use of climate resilient seed among smallholder farmers through an inclusive business model for local seed multiplication. This business model is being implemented by the ZSS in the semi-arid Southern and Western provinces of Masvingo and Midlands in Zimbabwe. ZSS is a social enterprise that started off as a development project supporting the inclusion of smallholder farmers in seed value chains, particularly for drought-tolerant self-pollinating crops such as open-pollinated varieties (OPVs) of maize, small grains and legumes. The analysis draws on evidence from a recent investment to expand the ZSS business model to three additional districts through support from Vuna-Africa, a UK Department for International Development (DFID) funded regional CSA programme. The paper seeks to answer two key questions: (i) is the business model building resilience of smallholder farmers; (ii) is it sustainable and can it be scaled-up?

While the insights shared in this paper are intended to answer questions on the effectiveness of private sector-based approaches to achieving developmental outcomes, they will hopefully inform better design of climate smart investments in smallholder systems.

The paper sets the scene with a brief description of the local context, including the livelihood system in the areas of focus, the nature of climate risk facing farmers, key trends in climate change and the structure of the market system within which ZSS operates. This is followed by an overview of the ZSS's seed systems for semi-arid areas business model, emphasising its main features, its theory of change, key stakeholders and their roles (Section 2). The main analytical sections of the paper (Section 3 and 4) assesses the adoption of the ZSS business model and the extent to which it is been adapted to ensure sustainability. The paper concludes with a summary of key lessons and recommendations for model improvement (Section 5).

1 IPCC 2014
2 FAO, 2013; p.ix
3 For example, the Global Alliance for Climate Smart Agriculture (GACSA) is a multi-stakeholder coalition promoting the incorporation of CSA approaches within food and agricultural systems (United Nations, 2014). Its African affiliate, the Africa Climate Smart Alliance (AfricaCSA), has committed to up-scale the adoption of CSA approaches, targeting 25 million smallholder farmers in Sub-Saharan Africa by 2021 (AfricaCSA, 2014).
4 Rosenstock *et al*., 2016; Nzuma *et al*., 2014.

1.1 Local livelihoods system

Masvingo and Midlands provinces cover most of the central areas of Zimbabwe, spanning three different semi-arid agro-ecological zones locally known as Natural Regions (NR).[5] These are characterised by low rainfall, high temperatures, as well as fragile, low organic matter sandy soils that are prone to erosion and heavy leaching of nutrients, particularly nitrogen. Agriculture-based livelihoods in these provinces are dominated by mixed crop-livestock enterprises. Despite being more susceptible to drought, maize is the dominant cereal due to strong local dietary preferences. Other important crops include the more drought-tolerant cereals such as sorghum and millet, as well as legumes like beans and cowpeas. Crop production in these smallholder systems is primarily for subsistence use, although most farmers usually sell any surplus for cash income.

Livestock farming with cattle, sheep, and goats, is also a very important economic activity, particularly in the drier regions where cropping is highly risky. Livestock is largely seen as a store of wealth and savings, only sold to cover critical expenses. Other products include milk, manure and occasionally meat, as well as services such as transport and tillage for cropping. Although livestock-based systems tend to dominate in the driest districts, cropping is almost universally practised due to strong food security imperatives.

1.2 Climate risks and impacts

Farmers in Zimbabwe's Southern and Western provinces have identified increasing frequency and intensity of droughts and floods, rainfall variability and rising temperatures as the most significant climate hazards for agricultural production (Figure 1 and Annex 1). Droughts are however viewed as the single most devastating climate-related hazard in this region. Local empirical research and more than a dozen studies cited by the Intergovernmental Panel on Climate Change (IPCC's) fifth assessment report (AR5)[6] concur with these local observations. Historical rainfall records indicate a reduction in late summer precipitation during the second half of the 20th century over this region. The early 1990s had 20% lower rainfall than the 1970s, with significant droughts in the 1980s, early 1990s, 2002 and more recently in 2015.[7] In addition to declining rainfall, observers cite intra-seasonal changes to the onset of the rainy season, increasing intensity of dry spells, and increasing intensity of daily rainfall (with associated flood risk)[8]. Rainfall varies by year and by intensity within the season. Seasons start late and end early. Mid-season dry spells are common.[9]

An analysis of temperature data from Zimbabwe's Department of Meteorological Services reveals a progressive warming trend.[10] A consistent national pattern of temperature increases of up to 1.12 degrees Celcius has been recorded in the last three decades. Further analysis shows that the period of most rapid warming occurred since the early 1980s to date. Between 1975 and 2012 the Southern and Western regions experienced an increase in temperature of between 0.86 degrees Celcius and 0.9 degrees Celcius. Modelling results also anticipate increases in temperatures in this region by a further 1.5 to 3.5 degrees Celcius by the end of the century.[11]

In combination with higher temperatures, lower rainfall and erratic seasonal patterns result in significant yield losses due to moisture stress, especially when they occur at critical stages of crop growth such as flowering and grain filling. These risks have been identified as the most significant climate-related threats to food production in the near term.[12]

5 NR III - semi-arid intensive; NR IV - semi-extensive farming and NR V - arid extensive farming
6 IPCC, 2014
7 MEWC, 2012; Unganai 2009; Unganai *et al*, 2015
8 Sango and Nhamo, 2015; Unganai *et al*., 2015
9 Brown *et al*.., 2012; Unganai 2009; Unganai et al., 2015
10 Brown *et al*.., 2012; Sango and Nhamo, 2015; Unganai, 2009
11 Brown *et al*., 2012
12 FAO, 2016; IPCC, 2014

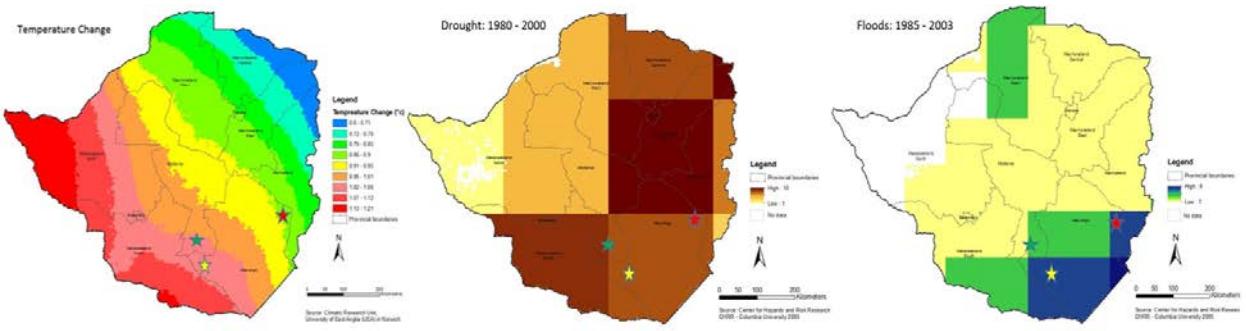

Figure 1: Climate trends in Zimbabwe. Temperature (Left) Drought (middle) and Flood Incidents (right) in Zimbabwe. The districts are marked with stars; Bikita – red, Mwenezi – yellow and Mberengwa – green.

Even with the current climate risks, agro-ecological conditions in these provinces are among the most challenging for most forms of agriculture. Without significant investment in adaptation measures to counter the impacts of a changing climate, crop production in many parts of this region will be nearly impossible with predicted climatic changes. Among the most promising CSA investments is a focus on breeding and multiplication of adaptable, drought-tolerant, moderately yielding and short-season crop varieties that can still perform under such harsh climate. Finding solutions to managing moisture stress is also a priority for these regions. Soil and water management practices such as those included in Conservation Agriculture (CA) are among the most promising solutions.

1.3 Structure of the seed market system

Traditionally, seed used in smallholder systems has mostly been retained from previous harvests and preserved using local methods. The last four decades have, however, seen a significant shift towards the use of certified seed by smallholder farmers due to a combination of sustained extension advice and aggressive marketing by seed companies. The benefits of using improved seed are now largely appreciated particularly for maize which has received much of the research and extension support.

With more than 42 large seed companies operating in the country, availability of certified seed on the market has significantly improved, but for a number of reasons, smallholders still struggle to get access to quality certified seed. First, access to seed by most smallholder farmers is limited by their remote locations that complicates access to urban locations where agricultural retailers are mostly located. The substantial cost and logistical difficulties of reaching retailers in urban locations places a significant burden on smallholder farmers and often results in them deciding against using certified seed. Second, the price of certified seed from most seed houses remains a significant production cost for a large segment of the smallholder farmers, forcing some of them to use retained crop as seed or limit the quantity of certified seed they purchase each season. Lastly, for some crops that are not popular within the large-scale farming sector such as small grains and most legumes (e.g. beans and cowpeas), certified seed is rarely available on the market as large seed companies have not been interested in investing in such crops.

Zimbabwe's seed sector is one of the most well developed on the continent, with a mix of both large, well-established corporates as well as medium-sized to small players, a number of which are still new entrants on the market. Nationally, there are 42 registered seed companies. ZSS is among the new generation of entrants who are less than 10 years old and mostly still in the establishment phase. A large concentration of the seed companies focuses on multiplication and marketing of hybrid seed varieties on exclusive licenses, largely in partnership with large-scale commercial farmers in high potential areas. In recent years, a number of the large seed companies has moved towards producing drought-tolerant as well as short season varieties, mostly for maize. However, their overarching strategy has overwhelmingly remained on maximising yields and to a limited extent, disease resistance.

ZSS focuses on multiplication of climate resilient seed for OPV maize, sorghum, millet, and the self-pollinating legumes such as groundnuts, sugar beans, and cowpeas. They are currently the only seed company with an overarching focus on climate resilient seed varieties. Four other seed companies - National Tested Seeds, Klein Karoo, Mukushi and Agriseeds-

are direct competitors of ZSS, targeting the same market and operating through similar models. ZSS, however, has a more deliberate focus on climate change resilience and also produces all its certified seed in semi-arid conditions which are typical of their target market.

In seed multiplication, ZSS partners with smallholder farmers in the drier regions of Masvingo and Midlands. These farmers plant foundation seed for multiplication which is then bought by ZSS for processing, packaging and marketing as certified seed. Seed multiplication has now expanded to cover six districts - Mberengwa, Mwenezi, Bikita, Gutu, Zaka and Masvingo. The bulk of certified seed is sold on the local market through a network of agro-dealers of varying sizes, from very small village-based dealerships to large retailers operating based at large service centres. The bigger retailers are supported by merchandisers who promote the products and provide information to farmers. ZSS has also started exporting some of their seed into the region, particularly to Zambia and Swaziland.

Other key players include the research institutes such as the Crop Breeding Research Institute and the Mexican headquartered International Maize and Wheat Improvement Center (CIMMYT) that provide foundation seed for multiplication. The government of Zimbabwe's Seed Services Institute (SSI) is the certifying authority which registers seed growers, monitors standards through inspections and certifies seed for purity and germination. Although ZSS and other seed companies have field staff to support seed farmers, they largely rely on partnerships with the Agricultural Technical and Extension Services (AGRITEX), the government's agricultural extension arm with a nation-wide network of field officers.

> "ZSS focuses on multiplying climate resilient seed in partnership with smallholder farmers and key public service providers. Our marketing partnerships are anchored on a network made up of the full spectrum of players from large national retailers to very small, village-based agro-dealers. This allows us to place climate-relevant certified seed right at the farmer's doorstep at a significantly reduced price since the seed is also produced in the same locations.
>
> *Mr Nelson Munyaka, ZSS Managing Director*

1.4 The nature of the problem facing Zimbabwe' smallholders in semi-arid regions

The threat of climate change is now well appreciated among key players in the seed sector, yet many smallholders are only now beginning to recognise the link between the changing agro-ecological conditions in their areas and climate change as well as some of the promising climate smart options.

The most pressing adaptation needs related to cropping in the two provinces are related to tackling moisture stress, largely due to a general decline in rainfall and more frequent and intensifying incidences of mid-season dry spells that often cause crop failure when they coincide with critical growth stages. Equally important is the need to find solutions for the shorter growing seasons that result from a delayed start and abrupt ending of the rains. Although flooding is a problem in some areas, moisture stress is regarded as the single most pressing climate risk facing farmers and agribusinesses in semi-arid agro-ecological conditions

The continual need to adapt prevailing seeds to climate change is both a challenge and an opportunity for the seed sector. Few seed sector players are investing significantly in the development of climate resilient seed varieties, regarding this still as a niche and difficult market. While producing seeds in semi-arid conditions allows more rigorous selection of appropriate varieties, it also comes with greater risk of climate-related uncertainty in supply and quality as well as reputation in the market as products are expected to perform under otherwise harsh conditions. Potential seed suppliers face the exact challenges as the farmers in these dry regions, particularly in with respect to the process of localised, large-scale seed multiplication.

Consequently, the supply of locally adapted, drought tolerant seeds for smallholders in dry regions of Zimbabwe remains limited and unable to meet demand. Smallholders continue to rely upon a combination of improved but not necessarily

well-adapted seeds varieties, and the use of their own production as a supply of more adapted but unimproved seed. Neither option is an ideal response to the increasing pressures of climate change.

2 Innovation model description

2.1 Innovation model rationale

Drought, heat stress and low soil fertility are major contributors to low maize and legume yield and breeding for these constraints enables farmers to have seed varieties that offer a suite of benefits. The challenge in this region is that it takes a long time for farmers to change to new hybrids. Many of the hybrids used were developed 20 years ago and, therefore, are no longer well adapted to current conditions.

The seed industry in Zimbabwe is specialised in that it is highly regulated and standards in production and postharvest handling of the seed have to be observed. Few smallholder farmers have been involved in crop seed production due to limited land size, low input supply and general incapability to access the required resources and lack of enabling regulations[13]. Smallholder farmers instead undertake their own, informal seed development or buy from other informal sources. Seeds sourced in these ways account for 90-100 % of seed planted depending on crop type[14]. Crops such as bambara nuts, rapoko, cowpeas and sugar beans fall into that category. The seed supplied in the informal market is not regulated and has no guarantee of quality.

The goal of the ZSS model is to increase its capacity to contribute to a transition of current farming systems towards climate resilience, by expanding its services into three new regions (Mberengwa, Mwenezi and Bikita). These services will benefit smallholders in those geographies by improving the availability at affordable prices, of the relevant, stress tolerant, but high yielding seed that can withstand some of the key challenges from a changing climate.

Due to the increasing frequency and intensity of droughts in most parts of Zimbabwe and changes in the rainfall patterns, significant research and development investments have focused on producing drought-tolerant, as well as short-season seed varieties. Commercialisation of these has, however, been limited to a few maize hybrids. The performance of these hybrids has also been unsatisfactory in semi-arid regions. ZSS's seed multiplication and marketing model focuses on scaling up local production of stress tolerant OPVs of maize, small grains like sorghum and millet, and self-pollinating legumes such as beans and cowpeas.

2.2 The innovation model

The ZSS model is anchored on a partnership that brings smallholder farmers into the seed value chain (Figure 1). In Zimbabwe, this is a new approach as seed companies have until now overlooked smallholders in favour of large-scale farmers in seed multiplication due to perceptions of the higher risk and complexity of commercial partnerships in smallholder systems. As such, the ZSS business model looks at smallholder farmers not just as customers of seed, but also key partners in seed multiplication. In addition to improving access to climate resilient seed in semi-arid regions, this business model creates a new dimension to resilience building for participating smallholder farmers through access to a high-value seed multiplication opportunity, with a guaranteed market and enhanced income prospects.

ZSS was registered as a seed company in 2014. Its majority shareholding is 322 smallholder seed farmers who own 99% of the company. Prior to its incorporation, the organisation had been operating as Zaka Super Seed, a trust working with farmers since 2011. To date, it grows climate smart seed OPV maize, cowpeas, sorghum, sugar beans and pearl millet. With support from Vuna through a project titled 'Zimbabwe Seed Systems for Semi-Arid Areas', ZSS has expanded its

13 Munyaka *et al*., 2015
14 Maredia *et al*., 1999; CIAT *et al*, 2009

operations from three to six districts in two provinces in Zimbabwe - Mwenezi and Bikita districts in Masvingo province and Mberengwa in Midlands province. The Vuna funded project aimed to scale-up and strengthen smallholder farmer cooperative-based drought-tolerant seed multiplication and marketing to increase farmers' access to affordable, locally and readily available, climate and market adapted seed in semi-arid areas in Zimbabwe. The business is now focusing on improving farmer yields and quality of certified seed, and also improving its operational efficiency and logistics, as well as relationship management with key stakeholders. The company is also working on attaining greater product diversity and growing their customer base. The company now works with a total of 1500 smallholder seed growers and sells its seed to approximately over 70 000 others.

To complement the availability of high-quality adaptable seed, ZSS is also supporting the adoption of other CSA practices such as minimum tillage, water harvesting and irrigation to improve soil and water management in semi-arid areas. This is done through various capacity building programmes and ongoing farmer support through ZSS field offers in collaboration with AGRITEX (Box 1). The ZSS business model also encompasses upstream partnerships with agro-dealers for seed distribution and sales (Box 2).

"Our Partnerships with ZSS is pioneering in many ways, but it wasn't easy in the beginning as this is new to all of us. In Masvingo province, we now have a formal relationship that allows all our officers to work freely with ZSS wherever they operate. We support their operations mostly through capacity building activities, targeted training of seed growers and promotion of good practices more broadly.

We conduct training for all seed growers when they join the ZSS programme. This is a joint effort between ourselves, ZSS and the Seed Services who oversee all production of certified seed in the country. Training covers all aspects of good agronomic practices but also seed production related requirements such maintaining correct isolation distances and post-harvest processes. The ZSS programme also includes training on various CSA practices. These are tailored to each location but generally include, CA techniques (minimum tillage, rotations, mulching), in-situ water harvesting, small-scale irrigation. Our approach is based on cascading of trainings, i.e. we do training of trainers (ToTs) who go on to train farmers in their areas.

We also hold farmers' days and field days that target local farmers to improve their knowledge on climate resilient seed and its advantages for their areas. Agro-dealers also undergo on CSA training to strengthen the quality of advice they offer to farmers in seed selection.

Overall our partnership has been very successful and the results are clear when you look at the performance of farmers. Even our officers are very excited about this partnership."

Ms Pachipo, Provincial AGRITEX Officer, Masvingo

The company currently has three marketing officers covering: Midlands and Mashonaland West; Harare, Mashonaland East and Central as well as Matabeleland. Within each of the three regions, ZSS supplies registered agro-dealers with certified seeds packs in 2-kilogram, 5-kilograms, and 10-kilogram units for sale. Stocks are supplied on consignment terms, meaning it is only upon sales that payments are remitted to the seed company.

This marketing arrangement allows agro-dealers to stock ZSS products without tying a lot of resources in working capital, which enables small businesses to participate. ZSS merchandisers manage seed stocks in the bigger retail chains and maintain a day-to-day presence during the seed marketing season which generally commences on July 1, every year. Given the seasonality of dryland agriculture, recruitment of merchandisers and marketing personnel is seasonal.

Merchandisers are able to engage consumers as well as address farmers' questions on the seed products on offer. To date, more than 90 agro-dealers have been registered as part of the ZSS distribution network for certified seed.

Box 2: Partnership for dissemination

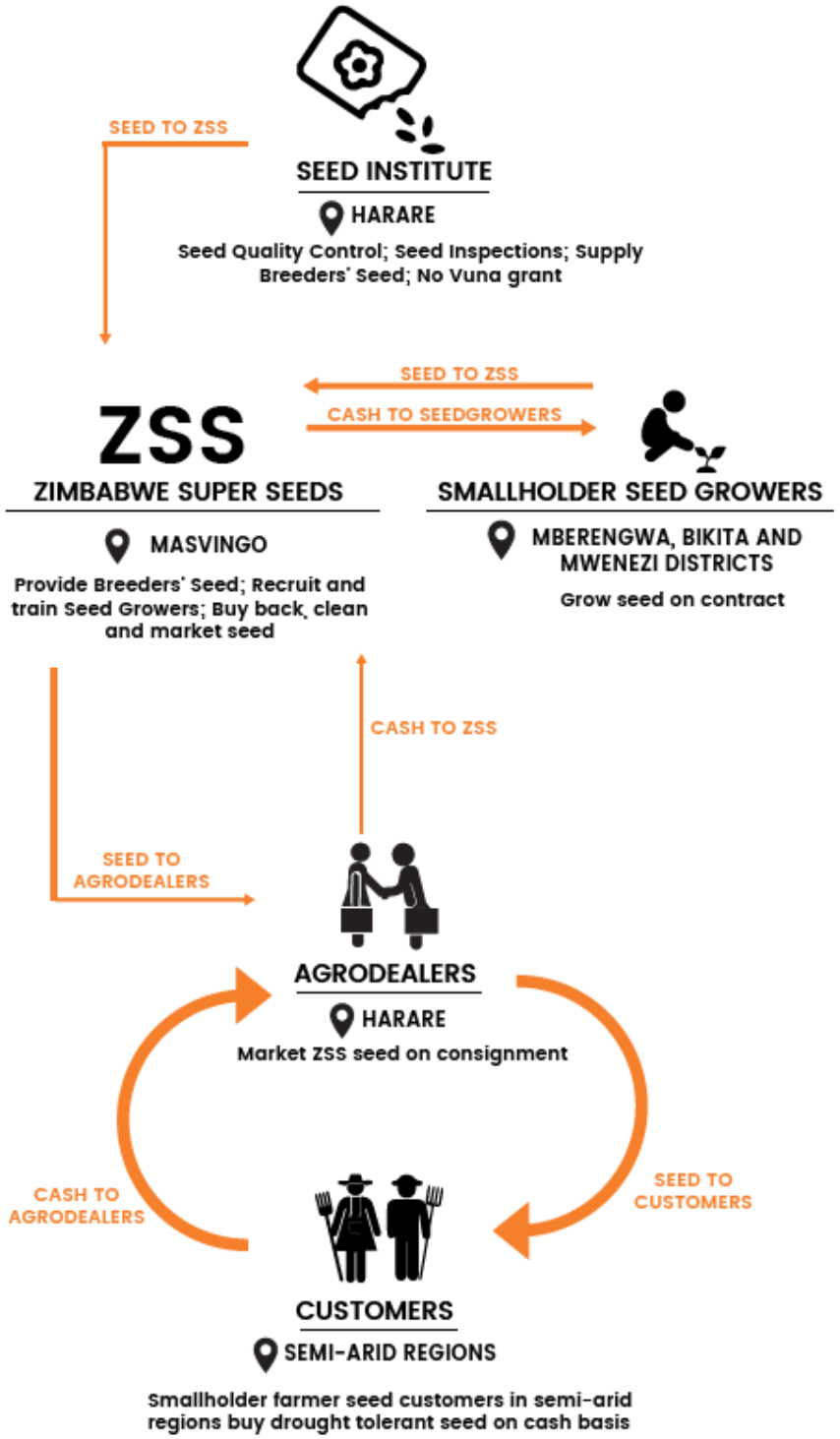

Figure 2: ZSS business model.[15] (Adapted from Vuna 2016)

2.2.1 Key stakeholders and their roles

The ZSS model builds a partnership between a number of critical market players from among NGOs, private and public institutions. Table 1 below summarises the model's key stakeholders and their roles.

15 Adapted from VUNA programme report, 2016

Table 1: Stakeholders within the ZSS business model

Stakeholder	Type of organisation	Roles
ZSS	Private Company	• Provides participating smallholder seed multipliers with seed stock • Recruits and deploys field officers to supervise farmer practices during the cropping season • Runs the seed collection and processing plant • Conducts germination tests and grading on aggregated seed crop • Guarantees farmer input loans with commercial banks • Provides the market for the seed • Distributes seed packs to provincial warehouses for on-distribution to agro-dealers.
SSI	Parastatal	• Registers seed growers each year • Inspect seed crop in the field • Inspects seed post-harvest and conducts purity and germination tests • Certifies the seed for market • Trains farmers jointly with ZSS and Agritex on seed production standards
AGRITEX	Government Department	• Provides day-to-day extension support to seed growers • Conduct training of lead farmers and farmers in seed husbandry • Coordinates ZSS activities with the relevant district offices to ensure buy-in from the community and political leadership
Agribank	Bank	• Provides input loans to farmer groups
Farmer groups	Seed growers	• Provide group guarantees against default on loans • Do the seed multiplication • Ward level farmer committees recruit new growers • Pay interests on input loans
	Ward & district level committees	• Conduct pre-SSI field inspections which help guarantee high crop quality at individual farmer level
Agro-dealers	Input retailer	• Sell certified seeds for maize, cowpeas, sugar beans, pearl millet and sorghum through consignment agreements with ZSS

2.2.2 Model theory of change/results chain

How the model is designed to build resilience

The ZSS model is expected to build resilience of smallholder farmers in semi-arid areas on two levels: (i) the improved availability of locally adapted high yielding, drought-tolerant seed varieties at affordable prices is expected to increase the use of such seed, leading to higher and more stable yields and incomes of farming households in semi-arid regions; (ii) the participation of smallholder farmers in seed multiplication is expected to open a new income opportunity through participation in high-value (seed) crop production, which guarantees them premium prices and market opportunities. Participation in seed multiplication is also expected to elevate farmers' technical, managerial and organisational competencies in various aspects of production and marketing as well as enable them to self-finance future farming operations.

To complement these two aspects, capacity building through dedicated training and technical support on CSA and other good agricultural practices as well as on-going farmer support, is expected to increase the adoption of CSA practices and technologies that further build the resilience of the farming system. The cooperation with AGRITEX and other farmer

support agencies, is intended to broaden the base of support services to reach more farmers and ensure institutionalisation of such interventions both improving prospects for sustainability and scaling up successes.

How the model is designed for sustainability and scalability

A commercial partnership between farmers and the private sector is at the core of ensuring the sustainability of the ZSS model. On one hand, ZSS as the guaranteed buyer of the seed produced by farmers relies on those farmers to produce efficiently and viably so that they have continued access to high-quality seed. On the other hand, multiplying farmers have to ensure quality seed is produced to enable them to sell at the quality required by ZSS. Farmers planting the improved seed will, in turn, benefit from greater productivity. In that sense, both sides of the demand-supply equation are motivated to ensure the sustainability of the relationship.

Premium prices, improved and predictable marketing arrangements, as well as access to training and other support services, provide significant incentives for continued farmer participation in the multiplication process. Farmers enter into binding contracts with ZSS for the multiplication of seed that is then bought by ZSS. Incidences of default are minimal, a function of the intense competition to take part in seed growing due to the good returns. For additional working capital support, farmers have been able to borrow (in groups) from banks and provide cross guarantees, which reduces the risk of defaults on debt repayments.

To ensure sustainable support for farmers, ZSS also cooperates with the state extension service provider-AGRITEX, leveraging their extensive network of field officers including in all the areas of ZSS operation. This collaboration extends the field level presence of ZSS representatives allowing them to cover larger areas. Through training and day to day interactions with ZSS staff, AGRITEX officers also improve their capacity to support farmers on CSA beyond ZSS focus areas.

The SSI, a state entity that registers all seed growers, helps to ensure seed quality. They also conduct field inspections as well as various tests to ensure adherence to minimum standards before the seed can be certified for commercial use. Quality testing is done at two levels; at community (bulking) stage using a rapid probe sampling technique to assess pest infestation (or damage, except in cowpeas), grain size uniformity and the purity, followed by the germination and purity test upon arrival at the seed processing plant. The SSI is funded from revenues received as payment by seed houses for their services. As such, they are a sustainable entity that is greatly supportive of a growing seed sector.

Important with respect to its broader business model, ZSS cooperates with a national network of agro-dealers and large retail chains who sell ZSS products, earning an agreed margin on sales. This is a commercial relationship that benefits all the players involved and is proving to be sustainable. Agro-dealers also benefit from the additional customer traffic that is generated by stocking seed as these customers also end up buying other goods on their shelves.

3 Assessing the success of the innovation model adoption

3.1 Model success in delivering intended support services

The intended expansion of ZSS into three additional districts (Mberengwa, Mwenezi and Bikita) has largely been a success. With a combined production target of 300 tonnes for the 2016-17 season, ZSS had already surpassed this milestone by October 2017, with 308 tonnes of maize, beans and sorghum seed multiplied. The recruitment of nine merchandisers and improved ZSS product visibility through the weekly radio programme that promotes the company's seeds to the rest of the country, were also some of the important milestones. At the time of writing, 275 tonnes of seed had been sold since the opening of the 2017 marketing season.

The impact of farmer training and on-going support has been significant. Farmers' yields have grown from an average of 0.638 tonnes to 2 tonnes (maize) and 0.6 tonnes to 1 tonne (sugar beans)[16]. Many aspects of crop management are reported to have seen significant improvement due to farmer support services through ZSS and AGRITEX partnership. ZSS's smallholder seed producers have been enjoying premium prices of $1400 per tonne for beans, and $600 for a tonne of maize compared to the commercial crop prices averaging $900 and $390 per tonne for beans and maize, respectively. These financial benefits have also brought some secondary increase in productivity as farmers set high-performance targets each successive season and can afford the required inputs.

According to SSI, the quality of seed crops produced by smallholder farmers under the ZSS programme has continued to improve each year. The proportion of seed crop rejected during crop and grain inspection is negligible, demonstrating the high-quality of crop the farmers are producing and the growing competencies of ward and district level farmer committees who are the first line of seed quality assurance.

3.2 Signs of model impact on sensitivity and adaptive capacity of farmers and other market players

3.2.1 Changes in level of sensitivity of current production/market systems

The notable increase in yields of target crops is the main indicator of success of the ZSS model in reducing sensitivity of key crops to climate risk in these regions. Although more time is needed to ascertain the tolerance of ZSS products to moisture stress, current indications are that yields are either increasing or stable across years. For ZSS, this stability has been key to their business as their forecast seed production levels are consistently being surpassed.

Feedback from farmers and agro-dealers suggest a growing popularity of ZSS seeds in the target regions and confirms that ZSS seed varieties are in strong demand, especially in drier districts where good performance has been reported even during a poor season. Availability of legume seeds including sugar beans and cowpeas has also been reported to have improved and more farmers are including these in their rotations. This is expected to improve soil fertility management as legumes fix the much-needed nitrogen in these fragile environments characterised by poor soils with high levels of nutrient leaching. Based on reported sales, farmer testimonies and general commentary, one can conclude that the ZSS seed varieties are performing to expectation and farmers are reaping the intended benefits.

3.2.2 Impact on level and diversity of income profiles

The positive impact of the ZSS model on farmers' incomes is clear, particularly for those participating in seed multiplication. Testimonies and actual investments in assets confirm this. Evidence of capital formation and savings as a result of increased incomes included significant investment on higher education, widespread investments in water management related assets such as water pumps and other irrigation equipment, building of small water reservoirs for small-scale irrigation, and purchase of livestock which tend to be generally more resilient to adverse effects of climate change.

The introduction of legumes is an important means of diversifying production systems in target regions. Not only do they enhance soil fertility management, they also bring a different nutritional dimension to food security given their high protein content and widely favoured taste. Particularly, ZSS' bio-fortified Nua 45 sugar bean variety is high in calcium and iron minerals. With relatively high prices and consistently high demand, ZSS introduced legumes like sugar beans have had a significant impact on farmers' income profiles.

Another dimension of diversification related to the ZSS intervention related to investment in other enterprises from higher incomes generated from seed production. Farmers attribute reported investments in commercial livestock-based

16 ZSS, 2017

enterprises such as poultry and pig production and irrigation development to the benefits of ZSS engagement. These investments are significant in diversifying household income profiles, especially as some of them have a different climate risk profile to mainstream crop production. Although investments in human capital (e.g. higher education) are long-term, they are equally important in long-term resilience building of rural households as they improve chances of off-farm livelihoods and remittances that strengthen local production.

3.2.3 Changes in market integration

Challenges for smallholders in accessing seed multiplication markets hinge on the dual factors of seed quantity and quality. The ZSS model addresses this by focusing on crops that do not require large quantities of seed production, e.g. millet, sorghum and beans. This increases the likelihood that smallholder-based production will be sufficient to meet market demand. On the quality side, the engagement of corporate extension officers, in addition to public extension officers, working in constant liaison with the SSI, has ensured that the quality of seed from smallholders is of the required standard. Consequently, the integration of smallholders into the mainstream seed market systems has been possible, with ZSS as the key link in this model.

The ZSS model has been highly successful in improving market integration for smallholder farmers, particularly those involved in seed multiplication. In an environment where markets for most agricultural commodities are highly unpredictable, the comfort of an offtake agreement is a rare luxury for farmers. Not only does the ZSS model guarantee offtake, it also guarantees a purchase price that farmers can use in their decision making and income projections.

Nevertheless, ZSS recognizes the need to continue facilitating capacity building of ward committees in good governance, to allow the committees to continue administering the pool of funds raised through new membership and subscriptions.

Selling through a network of village-based agro-dealers, ZSS has given farmers access to and awareness of new drought-tolerant seed varieties. For legumes such as beans and cowpeas, there was virtually no supply of certified seed in most regions before these were introduced by ZSS.

3.2.4 Institutional changes as a result of innovation model

The ZSS model has energised a number of partners providing supporting services around the business model. AGRITEX has recognised the role played by ZSS and have formally agreed to a partnership through a Memorandum of Understanding (MoU) in the relevant provinces. A joint programme of training on CSA is on-going, targeting seed farmers and demonstrating good practices and showcasing the results to the broader farming community. This strengthens the level of cooperation between ZSS and AGRITEX and enhances sustainability and prospects for scaling up the interventions.

The SSI has strengthened its team in Masvingo province, which oversees ZSS seed producers. They are planning to further enhance their capacity to have a presence in each district. This will improve their service and keep up with the rapid expansion of smallholder farmers undertaking seed multiplication.

3.3 Local sentiment and perspectives on the success of the innovation model

The general sentiment among players in ZSS seed system is very positive and optimistic. Key players are very satisfied with the ZSS approach and there is overwhelming demand for scaling up the operations both by current seed producers and non-participating farmers who also want to be part of the intervention. Key drivers of this interest hinge on both the high premiums seed farmers are receiving as well and the assured market. Other acknowledged benefits include the training and support in CSA and general good agriculture practices, as well as the better organisational structures of seed farmers that ensure cooperation and co-learning. Other farmers also highlighted the opportunity to access financing through the use of ZSS contracts as a key advantage that can support critical investments.

Agro-dealers that are part of the ZSS network also expressed satisfaction with the ZSS partnership, emphasising that it is good for business. Although the margins on seed sales were said to be small, the dealers were happy with the arrangement for them to pay after making sales as this frees up their working capital. The seed was described as a crowd puller particularly during the agricultural season. This was said to be very good for business as seed buyers usually end up buying other commodities as well. Potential areas of improvement were identified with respect to consignment management and communication with agro-dealers to reduce turn-around time between orders for seed and deliveries. Matching the size of seed packs with location and specific times of the season was also identified as an area of improvement.

Both the state extension service AGRITEX and the SSI concurred that the ZSS model had been a success. They expressed great optimism on the cooperation into the future. They also highlight that the programme had empowered the farming community and there is a great sense of purpose and positivity particularly among farmers which makes them a joy to work with. Even the morale of staff assigned to work on ZSS programmes was described to be very high as many felt they are a part of a progressive development agenda.

4 Assessing model adaptation and potential for sustainability

4.1 Extent of model adaptation

The ZSS model is relatively new, but already adaptations of the model are emerging to enhance its effectiveness and to ensure it unlocks opportunities elsewhere. For example, ZSS is currently pre-financing foundation seed to farmers. As such, they can only provide limited quantities to each farmer or farmer group. To overcome this constraint, a lot of farmers have now expressed interest in paying cash for their foundation seed to guarantee that they get the quantities they require. ZSS will, however, need to balance these interests with the capacity of each farmer to maintain the required quality standards as they expand their scale. In addition, some farmers pointed out that they now prefer to collect seed from ZSS premises at their own cost rather than wait for delivery to their areas to ensure timeliness despite the additional costs.

Importantly, the model itself is inherently flexible in terms of its adaptability to a range of different seed crops and the nature of associated extension support developed in partnership with AGRITEX.

4.2 Model's commercial viability

As discussed elsewhere in the paper, there are clear commercial incentives for farmers, agro-dealers and ZSS itself (Table 2) in sustaining this partnership. Even farmers who are not producing seed have benefited from the use of ZSS seed, some of which was not available before this intervention. The close proximity of agro-dealers to farmers has also brought significant savings financially and in terms of time and convenience as farmers do not need to travel to town to buy seed.

Table 2: ZSS Profit and Loss (USD), 2015-2017

Details	2015	2016	2017
Revenue	363 315.00	563 846.00	863 853.00
Cost of Sales	177 300.00	353 333.00	552 865.00
Gross profit	186 015.00	210 513.00	310 988.00
Other income	30 638.00	339 959.00	602 139.48
Operating and other expenses	113 047.00	385 487.00	808 784.98
Profit before tax	103 606.00	164 985.00	104 342.50
Taxation	26 678.55	42 483.64	26 867.96
Net Profit	76 927.45	122 501.36	77 474.54[17]

4.3 Expansion and wider adoption and benefits

It remains too early to attribute any changes in the wider seed market system as a result of the ZSS model expansion. It is however, evident that the smallholder cooperative approach in seed multiplication is gaining traction in the country. A number of new entrants are also now engaging smallholder farmers in seed multiplication and working with networks of agro-dealers to sell their certified seed, although an explicit focus on producing climate resilient seed and on semi-arid areas, however, remain a niche for ZSS. Crowding-in of others to this niche, but critical market remains limited.

It is important to note that ZSS has been substantially subsidised by donor funding since its establishment in 2011 under the DFID-funded Protracted Relief Programme (PRP). External funding has to-date played a crucial role in both initial set-up and, under Vuna, expansion into new districts. It is positive, therefore, that ZSS themselves have now put in-place plans to independently expand into two further districts based on the success and profits realised in those districts. This represents a critical and necessary move toward a more sustainable reality for the ZSS model and offers hope for its outreach in the long-term.

5 Findings and lessons for model improvement

A number of lessons emerge for the experience of the ZSS initiative in Zimbabwe and these are summarised below.

- **Establishing a commercial case for CSA:** The success of the ZSS model hinges on its ability to leverage and align the strong commercial incentives that have underpinned adoption by ZSS itself, participating farmers, and also agro-dealers. The involvement of smallholders in seed multiplication not only offers them CSA-linked benefits but also direct income benefits from a new commercial opportunity. The case underlines the fact that commercial sustainability is an inherent part of overall resilience amongst smallholders.

  Lesson: CSA innovations must be based upon a strong commercially viable business case for each partner involved. Farmers and agri-businesses are incentivised primarily by clear and sufficiently attractive commercial incentives.

17 Figures for 2017 incomplete as the assessment was conducted at the beginning of the seed marketing season before ZSS received most of its income from sales.

- **Potential of smallholders to drive CSA innovation:** The ZSS model challenges conventional thinking with respect to prevailing seed multiplication models. While the transaction costs of working with and through smallholder multipliers may be relatively high, the ZSS model indicates these can be adequately offset by the market opportunities offered for locally bred, climate adapted seeds. The model provides confirmation that smallholders can contribute to, as well as benefit from, CSA innovation and that they can supply high-quality seed multiplication services.

  The inherently higher transaction costs nevertheless require a longer-term investment horizon than may be necessary with fewer, larger scale multipliers. The ZSS model has emerged on the basis of long-term external funding support and, critically, strong partnerships with quality government extension providers in order to build the capacity of smallholder seed multipliers.

  Lesson: Climate smart, drought tolerant quality seed varieties can be commercially produced by smallholders in order to maximise local climate and eco-system relevance and adaptability.

  Lesson: Viable smallholder-based multiplication models require relatively high investment and technical support in the short- to medium-term.

- **The potential for public-private partnership in service delivery**: The engagement of smallholders in seed multiplication has been made possible through the effective partnership between ZSS and AGRITEX in delivering quality extension support, and with SSI in seed certification. The project demonstrates the potential for such partnerships to work, as well as how important those public-sector partnerships are with regards future sustainability and scale.

  Lesson: Robust partnerships between private and public entities with clearly defined roles and responsibilities can add significant value to the sustainability and scalability of CSA delivery models.

- **Business management capacity:** Going forward, ZSS aims to divest itself of external funding support having proven the viability of its business model. This transition from subsidised to fully commercial business will be predicated on its internal capacity, systems and financial model being 'fit for purpose'. In particular, their financing architecture needs to provide for operations expansion and increasing numbers of smallholder partnerships.

  Lesson: Where the length and risk profile of CSA investment warrants external support and/or seed financing, that investment should contribute to institutional capacity strengthening to support a long-term exit strategy and model sustainability.

ANNEX 1:

Climate trends and risks for seed multiplication in Zimbabwe

Extreme weather events

Zimbabwe has suffered widespread incidents of droughts. An assessment of historic drought events over 20 years (from 1980-2000) indicates that highest incidents occurred in Matabeleland South and Mashonaland Central provinces, with ten events recorded; while other provinces had incidence ranging from one (lowest) to eight (Figure A1 middle). The pilot study areas of Bikita and Mberengwa had the highest drought occurrence with drought lasting 3, 6, 12 and 24 months within 2 to 4-year intervals, over the past 10 years, while 48-month long droughts recur in intervals of 8 to 16 years[18]. The frequency and intensity of droughts are projected to increase across much of southern and western Zimbabwe[19].

The southwest areas of Masvingo and parts of Matabeleland South experienced the highest number of flooding incidents in the 18-year period, from 1985 to 2003 (Figure 3, right). Mwenezi (yellow star on map) experienced approximately eight incidents of flooding; while Bikita and Mberengwa experienced between five to six incidents. Similar to droughts, floods are expected to increase in frequency and intensity in the future[18]. Floods are also influenced by cyclones that occur in the region such as Cyclone Eline in 2000 and Cyclone Dineo in 2017. Cyclones are expected to increase leading to more intense flooding incidents[20].

Annual rainfall across Zimbabwe averages 650mm while the southern Lowveld averages 350 to 450mm[19]. These areas will suffer some of the worst impacts of climate change, with precipitation projected to decline by as much as 15% in some areas. Rainfall projections suggest decreases in rainfall will result in drier conditions[1]. Mean annual temperature varies from 18°C on the Highveld to 23°C in the Lowveld[19]. The country experienced warming trends towards the end of the 20th century, with estimated average temperatures increasing by 0.4°C since the 1900s. Temperature changes between 1975 to 2012 in Mberengwa and Mwenezi range from 0.96°C to 1.96°C, while Bikita has temperature changes ranging of 0.86°C to 0.9°C (Figure 3, left).

18 Brown *et al*., 2012
19 MEWC, 2012
20 Davis-Reddy *et al*., 2017

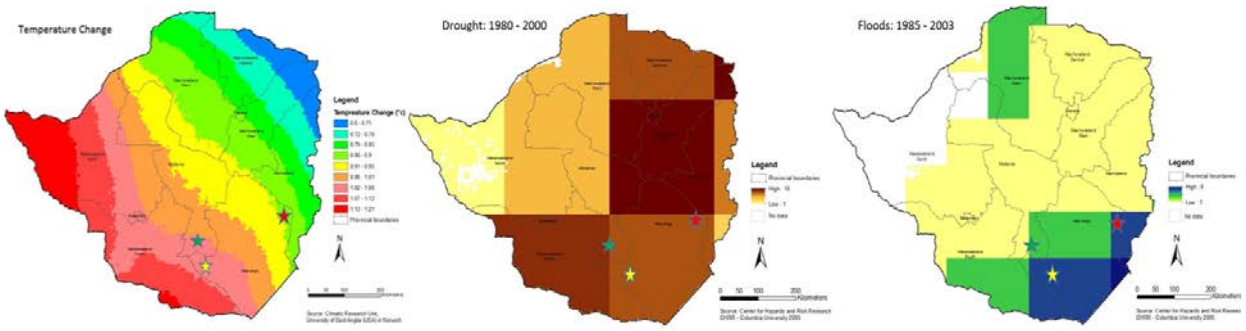

Figure A1:. Climate trends in Zimbabwe. Temperature (Left) Drought (middle) and Flood Incidents (right) in Zimbabwe. The pilot project districts are marked with stars; Bikita – red, Mwenezi – yellow and Mberengwa – green.

Impacts of rainfall changes on agriculture and seed multiplication production

The projected rainfall variability and possible reduction in water availability will result in water stress and will be detrimental to communal farmers who depend on rainfed agriculture and communal land, increasing their vulnerability to climate change[18].

Impacts of temperature changes on agriculture and seed multiplication production

The general warming trends as a result of increasing temperatures will impact crop production and will result in decreased crop yields and crop failures.

Increases in average temperature could result in more pests and pathogens threatening crop yields and cost of production, therefore seed varieties promoted as well as seed processing chemicals should keep up with this. Further, maize-suitable areas will decrease by 2080, while cotton- and sorghum-suitable areas will increase by 2080, particularly in south western parts of the country. Legumes such as cow peas, will do well in regions III, IV and V since they grow well in well drained sandy soils with approximately 250 to 500mm and under 25 to 35°C. Seed multiplication and marketing activities should focus on promoting more climate-suitable crops.

Quick facts:

Climate Change Projections in Zimbabwe

Rainfall

- Projections indicate reduced rainfall across the whole country

Temperature

- Increase in temperatures will result in the warming of the interior at a rate higher than the global increase of between 1.3-4.6°C by 2100 [2].
- Changes in annual surface temperature will increase by 1.5-3.5°C between 2045-2065 across some districts[18].

Extreme Weather Events

- Drought and flood are expected to increase in frequency and intensity across the country.
- Zimbabwe is generally arid – so increases in extreme temperatures will likely increase the incidences of drought
- Flooding events will likely increase as a result of an increase in cyclones that will affect region including Zimbabwe.

Box A1: Quick facts on climate change projections in Zimbabwe

Impacts of extreme weather events on agriculture and seed multiplication

Projected increase in incidences of drought mean that farmers have to make use of agricultural techniques that improve water-holding capacity of soil, conserve water and also depend less on rainfed agriculture. Increase in flooding events mean that farmers have to understand the hydrology of their farming land so they can channel flood water away from their fields. Seasonal forecasts and early warning systems become essential for preparedness of flooding events.

Climate change will impact on the cost of production and yield of the seed produced by companies such as ZSS, therefore the production of the seed for the future should consider these vulnerabilities as well as changes in crop suitability, especially the regions that will become drier. Further, consideration of pest and pathogens in future seed production is essential to ensure sustainable seed production for sustainable agriculture.

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