Assessing Seed Breeders Recommended Maize Varieties for Southern Zambia: How Small-Scale Farmers Have Adapted

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***Abstract*—**The study conducted in Choma's Mbabala and Singani area assessed the recommended maize varieties for Southern Zambia by seed breeders for purposes of ascertaining the best variety for cultivation in the region. Data on recommended maize varieties was collected through key informant interviews with private seed breeders including The Zambia Seed Company, Seed Company, Pannar Seed Company and The Maize Research Institute as well as government officials from the Ministry of Agriculture. A total of 112 randomly sampled small-scale farmers from Mbabala and Singani areas were also interviewed on their adaptation measures, coping strategies as well as their preferred maize varieties. Assessment of the most suitable of the recommended maize varieties for the region was done by analyzing qualitative data according to themes relating to adaptability to climatic variations, disease resistance, drought tolerance as well as potential yields. The results showed that ZAMSEED's ZMS 616 was the most agronomically suited maize variety for cultivation in the region due to its range of climatic conditions, disease resistance, drought tolerance and high yield potential. However, effort is required to help farmers appreciate the need to use agro-ecologically specific maize varieties as well as adopt conservation agriculture as a long-term measure to reduce adverse impacts of climate variability and change.

***Keywords*—**Adaptation, climate variability, conservation agriculture, seed breeding, Southern Zambia.

I. Introduction

A vibrant seed industry is the key to agricultural progress [1]. The process of seed breeding is an important agricultural development process likely to improve yields. Seeds are the most essential input in crop agriculture as they carry genetic potential of plants and are yield determinants [2]. Farmers require regular supplies of good quality seed varieties to satisfy both their own consumption. Hence the need for local seed breeding programmes to respond to such farmer demands.

Zambia has not been immune from the adverse impacts of climate change [3]. Recent studies show the country has been experiencing an increase in temperatures and rainfall over the last four decades [4] - [7]. It has also experienced an increase in the frequency and intensity of droughts and floods [8], [9], [7]. These extreme climatic events have impacted both small-scale agriculture and the country's economy. For example, the droughts of 1991/1992 and 1995/1996 proved to be very devastating and costly to Zambia as the country had to depend on the international community to provide food aid amounting to 970,000 tons (for the 1991/1992 drought) and 81,274 metric tons (for the 1995/1996 drought) of grain [10].

Droughts can also be very expensive as was seen for the 1991/1992 drought which was valued at US$70 million. In that year, Zambia only managed to harvest 4.5 million 50kg bags of maize (Zea mays L.) instead of 12 million bags [10],[11] resulting in corn importation to offset the deficit. Losses in maize yields of up to 60% were reported after the 2004/2005 drought [12]. This affected even the next agricultural year when maize production recorded a drastic decrease of about 233,234 tons (22%) from the previous year [13]. During the 2003/2004 farming season, 1,134,319 tons of maize was produced compared to the 884,575 tons produced in 2004/2005 season. The decline was due to droughts experienced during the 2004/2005 farming season. Flooding incidences were reported during the 2006/2007, 2007/2008 and 2008/2009 farming seasons [14]. A study conducted in 2011 [15] showed that the floods of 2007/2008 highly affected the small-scale farmers food security in that maize yields significantly reduced from 3.4 ton ha-1 in the 2006/2007 farming season to 0.77 ton ha-1 in the 2007/2008 farming season. Even though both seasons had above normal rainfall, the 2006/2007 maize yields were not significantly affected by the rainfall as was the 2007/2008 maize yields. This implies that it's not only the average rainfall which affects yield but also the time of rainfall onset and its distribution.

Extreme climatic events have spurred research on agro-ecologically suitable maize varieties. Model simulations have predicted reduced maize yields if traditional static sowing practices are continued, while adopting dynamic planting strategies will result in highest maize yields for short season cultivars [16]. This has led to increased public and private sector involvement in plant breeding. Currently, three public institutions namely Zambia Agricultural Research Institute; The National Institute for Scientific and Industrial Research; and the University of Zambia's School of Agricultural Sciences are engaged in maize breeding. These are complemented by the private seed companies such as The

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Zambia Seed Company (ZAMSEED), The Seed Company (SEEDCO), The Maize Research Institute (MRI) and Pannar Seed Company (PANNAR).

The government involvement in seed breeding was in part an effort to achieve the first Millennium Development Goal (MDG) of 'Reducing Poverty and Hunger by 2015 [17]. Agro-ecological specific maize varieties are expected to assist in poverty reduction [18] due to increased maize yields hence increased agriculture sector contributions to the country's GDP. Agriculture contributes 18-20% of Zambia's total GDP with over 60% of the population employed in agriculture [19], [5]. Hence, agriculture remains the priority sector in achieving sustainable economic growth and reducing poverty in Zambia [20]. However, climate change and variability stands in the way of such economic growth. Agriculture is the mainstay for the majority of people in Zambia and has been since the mineral sector whose importance drastically reduced in the late 1980s [5]. Small-scale farmers, representing 79% of the Zambian farming communities, largely depend on maize production for their survival [21]. These farmers cultivate between 0.5 to 4 hectares of customary land using their own family labor for farming [22]. Maize yield stands at 1.5-2.0t/ha each year in most of Zambia's ten provinces [21]. The report estimated that 73% of the farming households in Zambia plant maize, out of whom 97% are small-scale farmers who account for 61% of total maize production.

The study investigated the recommended maize varieties by seed breeders for the purpose of determining the best maize varieties for cultivation in Southern Zambia. It also explored coping strategies employed by small-scale farmers to combat extreme impacts of climate change and variability.

II. Description Of Study Areas

Choma District (Fig. 1) is located in the Southern Province of Zambia within the latitudes 16°50'S to 16º83'S [25] and between longitudes 26º30' to 27°30' E [26]. It lays at an altitude of about 1100m to 1300m and experiences tropical conditions moderated by altitude and a rainy season that runs from October to April. Three (3) seasons can broadly be identified in the region; a warm wet season (November – April); a cool dry season (May-July); and a hot dry season (August-October). Mean temperature ranges from 18.3 °C to 26.6°C. Mbabala and Singani located about 30km North and 15km south of Choma town, respectively (Fig. 1) where selected. The two sites were assumed to be representative of Choma town as they were not just located on the opposite ends of the town but they represented the largest farming blocks in the area. Arable agriculture is maize centric. The study sites are in Agro-Ecological Region II (AER II) of Zambia and so has climatic and soil conditions typical of the region (Table I).

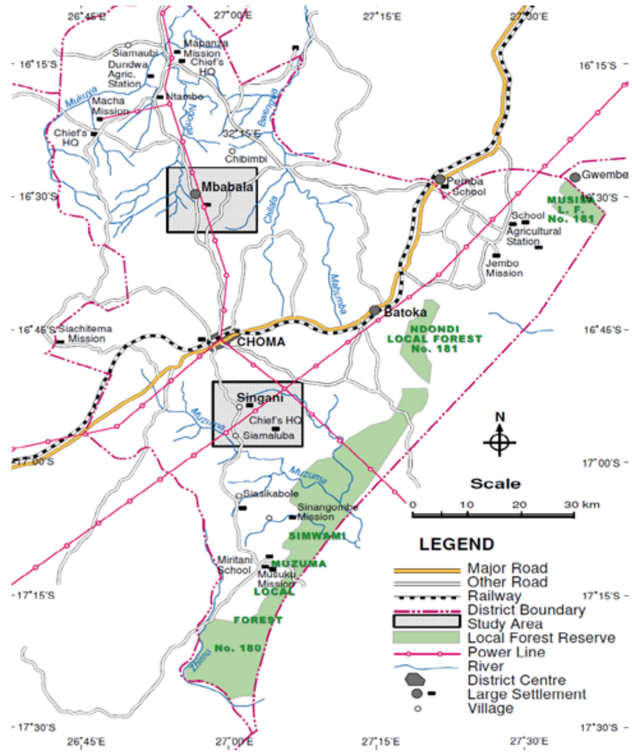

Fig. 1 Location of Choma District, Southern Zambia

TABLE I
CHARACTERISTICS OF AGRO-ECOLOGICAL REGIONS OF ZAMBIA

AER	Average Rainfall (mm)	Growing Period (Days)	Dominant Soil Types
I	less than 800	80-120	Haptic Luvisols, Haptic solonetz, Dystric Leptosols, Nitosols, Vertisols, Arenosols, Solonetz
IIa	800-1000	120-150	Haplic Lixisols, Haplic Luvisols, Haplic Acrisols, Alisols, Leptosols, Vertosols
IIb	800-1000	120-150	Ferrallic Arenosols, Course sands
III	Above 1000	150-190	Haptic Acrisols,red to brown Clayey Loamy, coarse sand

SOURCE: [23], [24]

III. Data Collection And Analysis

A. Semi- structured interviews

A total of 112 farming householders in Mbabala and Singani were interviewed. The farmers were interviewed on their planed and preferred maize varieties and their adaptation measures and coping strategies.

B. Key informant interviews

Key informants from ZAMSEED, SEEDCO, MRI Seed and PANNAR seed breeding companies were interviewed on the agronomic characteristics of their recommended maize varieties for Southern Zambia. These companies together command 72 % of the seed market in Zambia [27].

C. Desk studies

The desk research included a review of published material on seed breeding and maize varieties in Zambia [1], [17], [21], [28], [18], [2], [16] focusing on characteristics of the maize varieties recommended for southern Zambia. Beside this, a review of the climate status was done [29], [9], [6], [14], [30], [31], [7], [16]. Literature on the impacts of climate variability and food security was also reviewed [10], [32], [12], [31], [7] As was literature on conservation agriculture (CA) as an adaptation measure [33], [30], [31], [34].

D. Data Analysis

Descriptive statistical analyses helped analyze responses from small-scale farmers. Analyses involving graphs were done using Minitab 14 [35], SPSS 17 [36]. Further analyses involved grouping responses into emerging themes.

IV. Results And Findings

A. Crops Cultivated by Small-scale Farmers in the Study Sites

All the 112 respondents cultivated at least one variety of maize. Other crops cultivated in the study sites included Sunflower (*Helianthus annuus*), Beans (*Phaseolus vulgaris*), Groundnuts (*Arachis hypogea*), Sweet Potatoes (*Ipomoea batatas*), Soya Beans (*Glycine max*), Cotton (*Gossypium barbadense*), Cassava (*Manihot esculenta Crantz*), Sorghum (*Sorghum bicolor L*), Finger Millet (*Eleusine coracana*), Tobacco (*Nicotiana tabacum*), Irish potatoes (*Solanum tuberosum*), Carrots (*Daucus carota*), Paprika (*Capsicum annuum*) and Okra (*Abelmoschus esculentus*). There was more crop diversification in Mbabala as compared to Singani.

B. Adaptation Measures by small-scale Farmers in the Study Sites

Several adaptation measures where employed by farmers to combat impacts of extreme climates (Table II).

TABLE II
CHARACTERISTICS OF AGRO-ECOLOGICAL REGIONS OF ZAMBIA

Singani (%)	Mbabala (%)	Adaptation Measure
100	100	Use of early maturing maize varieties
76	81	Use of drought tolerant varieties
28	17	Conservation Agriculture (use of basins)
55	23	Use of substitute/complementary crops e.g. Cassava, Sorghum, Beans
10	2.4	Just grow whatever is available

The use of early maturing varieties was the most popular adaptation measure among the farmers in the study area and so where drought tolerant maize varieties. However, not many farmers appreciated the use of Conservation Agriculture (CA) during the period of study just as not many used substitute and complementary crops as cover for maize (Table 1). This trend in adaptation measures showed the farmers' affinity towards maize monocropping as their most popular measures involved use of maize. This was shown by the fewer number of farmers using substitute and complementary crops as well as CA.

C. Maize Varieties Cultivated in the Study Sites

Some small-scale farmers in Mbabala (30%) planted MM 604 in the 2010/2011 agriculture season with MM 601 (15%) and MM 603 (10%) also being planted by a number of farmers. In Singani, many varieties were planted with the highest percentage being 9% for MRI 634 while 8% planted SEEDCO (SC) 513 (Fig. 2). Farmers in Singani preferred a wider range of varieties compared to those in Mbabala where MM 604 was largely preferred.

D. Preferred Maize Varieties by Small-scale Farmers in Mbabala and Singani

Small-scale farmers in the study sites had preferences for particular maize varieties (Fig. 3). Of the sampled farmers, 31% preferred to cultivate MM 604 while 45% in Singani preferred to plant MRI 634. This meant that the farmers in Mbabala generally planted what they preferred while many farmers in Singani did not plant their preference. This was because these farmers were depending on the seeds given to them by the cooperatives to which they belonged. These cooperatives decided which seed varieties to give the farmers and in most instances farmers were not consulted.

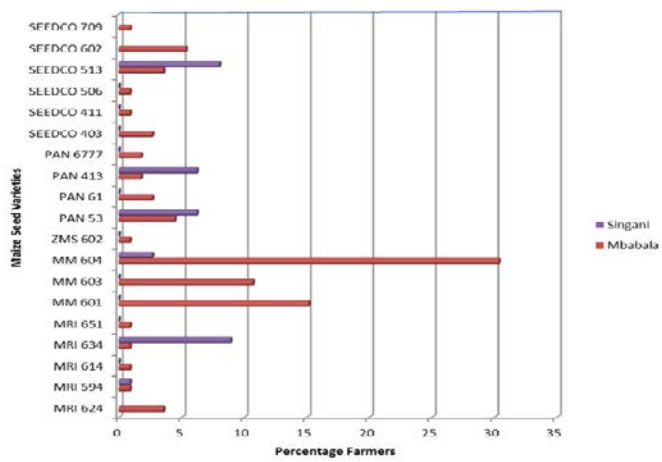

Fig. 2 Maize Varieties Grown in Mbabala and Singani

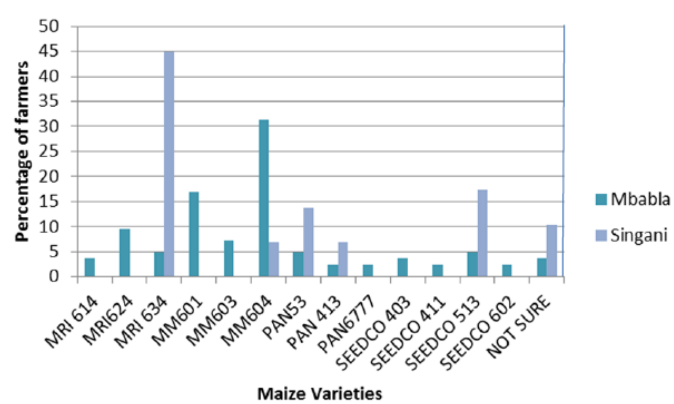

Fig. 3: Preferred Maize Varieties in Mbabala and Singani

The farmers gave varied reasons for their preferred maize varieties (Table III).

TABLE III
REASONS FOR PREFERRED MAIZE VARIETIES BY SMALL-SCALE FARMERS IN SINGANI AND MBABALA

Preferred Maize Variety	Reasons for Preference
MRI 634	☐ It is drought tolerant ☐ It's a high yielder because of its ability to bear 2 cobs ☐ It is cheaper
SC 513	☐ It is drought tolerant ☐ Requires minimal fertilizer ☐ It's a high yielder ☐ It can stay for a long time without rotting after being harvested.
MM 604 and MM 603	☐ It requires less fertilizer ☐ Friends say it is a high yielder (first time planting it) ☐ Not easily affected by droughts ☐ It is what we were given by the cooperative so it has to be good ☐ MM 604 weighs more than the other varieties hence fetches a bigger profit when sold to the Food Reserve Agency (FRA)
PAN 413 and PAN 53	☐ It has big cobs and is early maturing ☐ It was cheaper on the market

Farmers preferred particular varieties for a range of reasons such as a variety being drought tolerant or requiring less fertilizer and being a high yielding variety.

E. Seed Breeders' Recommended Maize Varieties for Southern Zambia

Seed breeders recommend that farmers in drought prone areas plant early to medium maturing maize varieties with high yield potential. These varieties have been found to have high water use efficiency. For this region a variety with an average yield potential of 8 t/ha is ideal cultivation [28]. However, due to agronomical and financial challenges, farmers usually produce far less than the expected 8 t/ha even for the hybrid seed varieties. The different varieties recommended by the seed breeder exhibited varied characteristics (Tables IV).

ZAMSEED's ZMS 616 had the highest yield potential of 10-12 t/ha while ZMS 606 and 602 had a yield potentials of 8-10 t/ha (Table IV). ZMS 616 was found to be the ideal choice considering not only its yield potential but also its adaptability, stability, disease resistance, and drought tolerance.

SEEDCO Company's SC 637 had the highest yield potential among SEEDCO varieties (6-13t/ha). SC 403 had the lowest (1-5t/ha). However, SC 637 would not be a good choice for Southern Zambia due to its high maturity days (148). (Table IV). Instead, SC 525 would be more ideal for the region among the SEEDCO varieties.

PANNAR's PAN 6966 which is a yellow variety is a high yielder with a potential yield of 9-12 t/ha (Table IV). It would be the most agronomically suitable variety for planting if one prefers yellow varieties while PAN 6823 would be suitable for those who prefer white maize varieties.

MRI Seed Company's promoted varieties mature just a few days short of the growing period of 150 days for Southern Zambia (Table IV). However, MRI 514's high adaptability to climatic conditions of Southern Zambia (Table V) makes suitable for the region.

TABLE IV (A)
RECOMMENDED MAIZE VARIETIES BY SELECTED SEED BREEDING COMPANIES

Maize Variety	Maturity Days	Recommended Region for Production	Potential Yield (t/ha)
ZMS 402	105-110	I,II	6-8
GV412	105-110	I,II	6-7
MM 441	110-115	I,II	6-7
MM 502	120-125	II,III	8-9
ZMS 510	120-125	I,II	8-9
ZMS 528	120-125	I,II	8-9
ZMS 602	130-135	II,III	8-10
MM 603	125-130	II,III	6-8
MM 604	125-130	II,III	6-8

F. Coping Strategies by Small-scale Farmers in Mbabala and Singani to Impacts of Extreme Climate Variability

The dependence on gardens during periods of droughts is the most common form of coping among the farmers in the study area (Table V). This coupled with off-farm activities like craft making have been the default coping strategies among the small-scale farmers in the region. However, these forms of coping have proved inefficient in the long-run to sustain these farmers. The crops grown in these gardens are not even enough to sustain these farmers up to the next harvest season.

V. DISCUSSION

Farmers in Choma have been coping with extreme climates by using early maturing, drought tolerant maize seed varieties. Most farmers have been supplementing and complementing their maize with crops such as Okra, Beans, Soya beans, Sorghum, Finger Millet and Cassava. These are used as a fall back when maize yields stall. These adaptation measures were used in combinations and were not mutually exclusive as one farmer would use more than one adaptation measure. Few farmers had been practicing conservation agriculture (CA).This farming system conserves both soil organic matter and soil moisture making it an important adaptation measure to climate variability. It involves a series of sound land husbandry practices which minimize soil disturbance by promoting minimum tillage, retain crop residues and use crop rotations to reduce impacts of pests and diseases [37],[31],[33]. Use of basin farming, ripping or pot holing is common in CA.

TABLE IV (B)
RECOMMENDED MAIZE VARIETIES BY SELECTED SEED BREEDING COMPANIES

Maize Variety	Maturity Days	Recommended Region for Production	Potential Yield (t/ha)
ZMS 606	125-130	II,III	8-10
ZMS 616	125-130	I,II	10-12
SC 403	131	I,II	1-5
SC 411	132	I,II	4-8
SC 513	137	I,II	4-8
**SC 506*	132	I,II	1-6
SC 525	134	I,II	5-10
**SC 608*	148	I,II	5-14
SC 621	148	II,III	3-8
SC 627	144	II,III	5-10
**SC 602*	148	II,III	5-13
SC 633	140	II,III	6-12
SC 637	148	II,III	6-13
PAN 4M-19	100-110	I,II	-
PAN 413	110-115	I,II	-
PAN 6823	120-130	I,II	8-10
PAN 67	120-130	II,III	7-9
**PAN 6966*	125-140	II,III	9-12
PAN 53	125-135	II,III	8-10
PAN 6243	130-140	II,III	8-10
PAN 14	130-145	II,III	7-9
MRI 455	90-110	I,II	8
MRI 514	90-110	I,II	10
MRI 614	110-135	II,III	10
MRI 594	110-135	II,III	10
MRI 634	110-135	II,III	10
MRI 624	110-135	II,III	11
**MRI 651*	110-135	II,III	12
MRI 534	110-135	II,III	10
MRI 694	110-135	II,III	13
MRI 644	110-135	II,III	13
MRI 734	110-135	II,III	11

The thematic analysis of recommended maize varieties in Table IV isolated six varieties suitable for cultivation in Southern Zambia (Table VI); ZAMSEED's ZMS 616, ZMS 606, SEEDCO's SC 525, PANNAR's PAN 6966 or PAN 6823 and MRI Seed's MRI 514. The analysis was based on the yield potential of particular varieties and adaptability to AER II climatic conditions.

TABLE V
COPING STRATEGIES BY SMALL-SCALE FARMERS IN MBABALA AND SINGANI

Singani (%)	Mbabala (%)	Response
44	62	Increased cultivating of complementary crops such as Okra, Cassava and Beans which are not adversely affected by droughts and/or floods.
96	100	Owned gardens near the stream where they grew crops such as maize, tomatoes (*Solanum lycopersicum*), cabbage (*Brassica oleracea*), rape (*Brassica napus*) and pumpkins (*Cucurbita maxima*) during the dry season for sale.
25	13	Diversified their income generating ventures to include charcoal production.
8	30	Cultivation of sugarcane (*Saccharum officinarum*) which is later sold to raise money for maize flour.
56	41	Some farmers hire themselves out as casual labor and either work for food from fellow farmers who at least managed to harvest or they move to Choma town to look for work.
5	15	Some farmers engage themselves in fish trade or even become fishermen in order to cope.
73	95	Depend on off-farm activities such as crafts making, and trading

All these varieties can do well in Southern Zambia. However, the agronomical characteristics showed that ZMS 616 is the best variety for planting in the region as had a high yield potential (10-12 t/ha) and its adaptability to a range of climates was excellent. Its disease resistance was also excellent while its tolerance to droughts was reported to be very good (pers comm. ZAMSEED official). The variety was also flexible and behaved like an early maturing variety when insufficient rainfall was received for that particular season. However, no farmers in the study area had used this variety before and were even skeptical about it. This highlights the need for farmers to see a demonstration of a variety before planting it. The farmers were not willing to take a risk on a variety they were not familiar with. Hence seed breeders should establish more demo plots among the farmers so as to introduce new varieties and demonstrate methods of management necessary to attain maximum yields from recommended varieties.

VI. CONCLUSION

The study concluded that farmers preferred coping strategies which involved use of one or more maize varieties such as crop diversification or use of early maturing maize varieties rather than substituting the maize. This was due to prevalent maize monocropping. Hence the need to encourage adoption of CA as a response to climatic variations. The maize variety ZMS 616 was found to be more adaptable to the climatic conditions of AER II with higher potential yields.

TABLE VI
CHARACTERISTICS OF RECOMMENDED MAIZE VARIETIES FOR AER II

Maize Variety	Maturity Days	Adaptability	Disease Resistance			Drought Tolerance	Potential Yield (t/ha)	Climatic Conditions	
			Grey Leaf Spot	Leaf Blight	Cob Rot			Rainfall (mm)	Mean Temperature (◦C)
ZMS 606	125-130	VG	VG	VG	EX	VG	8 to 10	800-1000	18-24
ZMS 616	125-130	EX	EX	EX	EX	VG	10 to 12	800-1000	18-24
PAN 6966	125-140	EX	G	VG	VG	VG	9 to 12	750-1000	18-24
PAN 6823	120-130	EX	VG	EX	EX	G	8 to 10	750-1000	18-24
MRI 514	125-130	VG	VG	VG	VG	EX	10	750-1000	18-24
SC 525	130-135	VG	G	VG	G	VG	5 to 10	800-1000	18-24
	Key: G=Good; VG=Very Good; EX=Excellent								

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