ADAPTATION TO CLIMATE VARIABILITY IN SADC FARMING SYSTEMS

ADAPTATION A LA VARIABILITE CLIMATIQUE DANS LES SYSTEMES AGRICOLES DE LA SADC

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ABSTRACT

Southern African Development Community (SADC) is a semi-arid region with scarcity of water for crop production each year, so coping strategies have been developed by local small farmers over many years. But, these may not hold under climate change scenarios, unless adaptation strategies are evolved. Adaptations incur costs; to farmers, governments and societies or communities and may not be able to prevent damages occurring at a range of inter-linking scales. One of the most important aspects is to manage natural resources and maintain a sustainable farming system. A range of interventions are possible in any farming system, but they usually all hinge on the feasibility of alternative choices in weather sensitive decisions at several levels – strategic for long-term planning, tactical for seasonal period planning, or operational for day to day activities.

A range of alternative technical adaptations that have been used in SADC countries such as alternative cropping patterns and planting dates, community participatory agrometeorological extension services and the use of action research cycle to introduce alternatives to communities. If there are climate forecasts at different time scales and farmers know how to use them to select from range of options available, then there is always a way to develop an alternative sustainable farming system. However, these different ways of managing the natural resources under a more variable climate do need to be tested for local acceptability as an intervention. As many of the livelihoods of farmers in SADC countries are threatened due to low soil fertility and low crop production there is a desire for change. Therefore it is vital that there is a good group of multidisciplinary intermediaries that can work together to help the farmers to use the available climate and agrometeorological information to develop alternative interventions that are viable in their own farming systems.

Key words: *Climate change, Adaptation, Water scarcity, Agrometeorology, South Africa.*

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RESUME

La Communauté de développement Sud-Africaine (SADC) s'est formée dans une région semi-aride avec la rareté de l'eau chaque année pour la production de cultures. Donc des stratégies afin d'adaptation ont été développées par les petits agriculteurs locaux depuis de nombreuses années. Mais, elles ne peuvent pas tenir sous les scénarios de changement climatique, à moins que ces stratégies d'adaptation évoluent. Les adaptations encourent des coûts aux agriculteurs, aux gouvernements, aux sociétés ou aux communautés et peuvent ne pas être en mesure de prévenir les dommages survenant à une gamme des échelles inter-liées. Un des aspects les plus importants est de gérer les ressources naturelles et de maintenir un système d'agriculture durable. Une série d'interventions sont possibles dans n'importe quel système d'exploitation, mais ils sont généralement tous les charnières sur la faisabilité des choix alternatifs dans les décisions sensibles aux conditions météorologiques à plusieurs niveaux – ils sont stratégiques pour planifier à long terme, tactiques pour la période de planification saisonnière, ou opérationnels pour les activités quotidiennes.

Une gamme d'alternatives adaptations techniques qui ont été utilisés dans les pays de la SADC comme les modes alternatifs de culture et les dates de plantation alternatives, la communauté des services de vulgarisation participative agro-météorologiques et l'utilisation de cycle de recherche-action pour introduire des alternatives pour les communautés. S'il y a des prévisions climatiques à différentes échelles temporelles et les agriculteurs savent les utiliser parmi la sélection des options disponibles, alors il y a toujours un moyen de développer un système d'agriculture alternative durable. Cependant, ces différentes façons de gérer les ressources naturelles sous un climat plus variable, doivent être testés pour l'acceptabilité locale comme une intervention. Comme de nombreux moyens de subsistance des agriculteurs dans les pays de la SADC sont menacés en raison de faible fertilité des sols et la production agricole faible, il y a un désir de changement. Par conséquent, il est important qu'il y ait un bon groupe d'intermédiaires multidisciplinaire qui peuvent travailler ensemble pour aider les agriculteurs à utiliser le climat et les informations agro-météorologiques disponibles pour développer des interventions alternatives qui sont viables dans leurs propres systèmes agricoles.

Mots clés: *Changement climatique, adaptation, rareté de l'eau, agro-météorologie, Afrique du Sud.*

1. INTRODUCTION

Much of Southern Africa receives erratic rainfall and has high evaporative demand, making it a semi-arid region. There are millions of small-scale farmers in SADC (Southern African Development Community) that rely on rain-fed crop production as main source of income to survive (Cooper *et al*., 2008; Bryan *et al*., 2009). The same cropping systems have been used for many years and focus on maize as a staple crop with some legume as intercrop but continuously planted on the same lands each year. This has resulted in low soil fertility and depletion of the soil organic matter. Therefore the general production of maize in SADC is very low and this leads to food insecurity and malnutrition.

Predictions for climate change over the SADC area have been made by the IPCC (2007) from General Circulation Models (GCMs). The mean regional predictions for each of the three month seasons are given in Table 1. All the models agree that it will become warmer in each of the seasons across Southern Africa, but with some variability. The uncertainty is larger for the rainfall and some of the models do not agree on whether the changes will be positive or negative. There is consensus about the decrease in rainfall during winter across southern Africa.

Table 1 Southern Africa regional response of projections from multi-models for each three month season for climate change by the end of 21st century for temperature and rainfall change (Cooper et al., 2008; IPCC, 2007)

Season	Temperature response			Precipitation response		
	Min	Median	Max	Min	Median	Max
Dec, Jan, Feb	1.8	3.1	4.7	-6	0	10
Mar, Apr, May	1.7	3.4	4.7	-25	0	12
Jun, Jul, Aug	1.9	3.7	4.8	-43	-23	-3
Sep, Oct, Nov	2.1	3.7	5.0	-43	-13	3
Annual	1.9	3.4	4.8	-12	-4	6

Most stakeholders in Third World agree that the poorest of the poor are most vulnerable and most susceptible to change and it is also true that many of these subsistence farmers have developed coping strategies in the past (Cooper *et al*., 2008) which actually have proved to be highly adaptable (Challinor *et al*., 2007) as they have managed to continue production. However, many of the farm-level adaptation strategies appear to be insufficient, say when droughts are prolonged, severe or widespread. This then results in loss of seed stocks and biodiversity as well as draught animals, which further delays any recovery from such extreme events (Challinor *et al*., 2007). However in recent times in Zimbabwe, it has been interesting to note that both climate, and political-economic stressors (Rufino *et al*., 2011) that continued for many years, have built more resilience into the communities. Adaptation has certain costs to farmers, governments and society or communities and may not be able to prevent damage at a range of interlinking scales. Governments however should take responsibility for maintaining a seed bank of major and minor crops as well as strategic seed stocks and be committed to implement practical seed policies and trading laws (Challinor *et al*., 2007). This would constitute part of the mainstreaming of climate adaptation (Sietz *et al*., 2011).

2. ADAPTATION

Adaptation is defined as an adjustment in natural or human systems to a new or changing environment (Millennium Ecosystem Assessment Glossary: MESG, 2009). The various types of adaptation include anticipatory or reactive adaptation; private or public adaptation; autonomous or planed adaptation according to the type or stakeholders or initiators (MESG, 2009). The adaptive interventions consist of a wide variety of measures that should reduce the vulnerability of the natural and human systems to projected climate change. Hence they have the potential to reduce adverse impacts of higher temperatures and more variable rainfall, as well as enhancing the beneficial opportunities or impacts. These adaptations need to be managed through time and this can take the form of either active adaptation resulting from a deliberate designed choice and planned best practice's or it can be passive adaptation where managers have made assumptions that the model predictions are correct (Greenfacts, 2009). Therefore active adaptive management usually allows more reliable and scientific interpretation of results and leads to more rapid learning. The other factor that needs to be considered and can vary widely, is the adaptive capacity

Changes in marketing, agricultural support or extension systems, land tenure or privatization of agribusiness are all factors that affect the adaptation capacity of the community. These changes will influences, capital and household labour availability relative to employment opportunities (Eriksen & Silva, 2009). As one can see, this all points to the fact that there is probably no single 'best bet' solution (Giller *et al*., 2011), which is largely due to the large heterogeneous farming systems even within a single agro-climate zone, due to different levels of farmers (Walker & Stigter, 2010). This means that a good system analysis is necessary to describe and explore all the inter-linkages and feedbacks in the dynamic diverse African farming systems (Giller *et al*., 2011). Some of the most important aspects are to be able to manage the natural resources or natural capital in such a way as to maintain a sustainable farming system. However, this is also dependent on the social capital and indigenous knowledge within the local constraints.

Systems analytical thinking and modelling can assist in designing climate robust sustainable systems that include biophysical and socio-economical aspects of operational farm decision making. Thus the range of possible adaptation interventions need to be developed from practical decision trees and various scenarios to help choose the best alternative future practices or management options based on the farmers objectives or purpose. Therefore it is important to review the facts necessary for sustainable livelihoods :

- resilient in face of external shocks and stress;
- not dependent on external inputs/support;
- able to maintain long-term productivity level of natural resources; and
- not undermine resources or livelihoods of others (Ashby & Carney,1999).

Livelihoods are not only dependent on natural, physical and financial assets or capital but also social and human capital, including kinship, networks, nutrition and health (Warner, 2000).

There are a wide range of adaptive interventions that have or are being used in SADC farming systems. They usually hinge on the feasibility of various alternative choices that are available to the farmers when making weather or climate sensitive decisions at different levels. Basically the alternatives then depend on the flexibility of the farming system and the amount of risk they can be exposed to and still maintain sustainability livelihoods in the long run. The decisions could be divided into several levels namely:-

- strategic decisions for long-term planning;
- tactical decision affecting the planning for the upcoming seasoning; and
- operational decisions relating to the daily or weekly short-term activities.

As there are such a wide variety of intervention options that have been used for adaptation, only a few will be named and described in detail as case studies.

3. STRATEGIC INTERVENTIONS

The strategic alternatives are mostly the concern of the national governments and trans-border agreements, but can also include aspects such as introducing or breeding new crops or cultivars to match the expected climate which are more in the realm of the CIGAR institutes; or can include large scale developments by such as new dams (e.g. Lesotho Highlands Water Scheme).

For example, degradation of all kinds of land is being hastened by the increase in climate variability. Therefore, the climate-land-water connection needs to be on the forefront of the strategic decisions concerning resource-conserving agricultural interventions (Bossio *et al*., 2010). There are many examples as illustrated in Table 2 ranging from organic and water harvesting farming to aquaculture and agroforestry (Bossio *et al*., 2010). Other examples include the practices and policies affecting the management of soil organic carbon as it influences many soil properties relevant to sustainable agriculture and ecosystems services (Powlson *et al*., 2011). These interventions can be divided into those concerned with increasing organic matter (e.g. reduced tillage practices) and provision of crop nutrients (e.g. micro-dosing fertiliser applications) or management of soil biological processes and root/soil interactions (Powlson *et al*., 2011).

Table 2. Resource-conserving agricultural practices that increase water productivity and enhance other water related ecosystem services (Bossio et al., 2010)

Resource-conserving practices[a]	Primary water benefit[b]
Organic farming, where artificial additions to the farming system (inorganic fertilizers and agrochemicals) are avoided, and soil organic matter is increased	Increased soil water holding capacity
Conservation agriculture, which combines non-inversion tillage (minimum or zero tillage in place of plowing) with mulching or cover cropping and crop rotation	Reduced evaporation Reduced runoff and erosion
Ecoagriculture, which emphasizes managing agricultural landscapes to enhance production while conserving or restoring ecosystem services and biodiversity	Increased regulating and supporting water related ecosystem services
Agroforestry, which incorporates trees into agricultural systems and stresses the multifunctional value of trees within those systems	Multiple water uses increase water productivity Increased regulating and supporting water related ecosystem services
Integrated pest management, which uses ecosystem resilience and diversity for pest, disease, and weed control and seeks to use pesticides only when other options are ineffective	Reduced water pollution
Integrated nutrient management, which seeks both to balance the need to fix nitrogen within farm systems with the need to import inorganic and organic sources of nutrients and to reduce nutrient losses through erosion control	Increased water productivity by reducing nutrient constraints
Integrated livestock systems, especially those that incorporate stall-fed dairy cattle, small stock, and poultry, which raise overall productivity, diversify production, use crop by-products, and produce manure	Multiple water uses increase water productivity
Aquaculture, which brings fish, shrimp, and other aquatic resources into farm systems – irrigated rice fields and fishponds – and increases protein production	Multiple water uses increase water productivity
Water harvesting in dryland areas, which maximizes the use of scarce rainfall by capturing runoff (and sediments) for productive purposes	Reduced unproductive losses of water Reduced runoff and erosion
Water saving irrigation, including small scale micro-irrigation and reduced-water rice production to increase returns to applied water and diversify smallholder farming systems	Reduced unproductive losses of water Increased water productivity

[a] *Resource-conserving agriculture* covers farming systems that aim to conserve natural resources and minimize negative environmental impacts. Approaches include plant diversification, plant and animal integration, and an emphasis on soil quality, especially soil organic matter, and on biological solutions to fertility and pest control. Multiple practices are often adopted in an integrated system.
[b] Benefits from integrated systems are multiple, listed here are one or two of the primary benefits related to specific land degradation and water issues highlighted in this chapter.

An alternative view of the strategic decisions is to develop new strategies adaptable to the future climates. These would then cope up with the inherent uncertainties of climate change and based on scenario analysis in which one can choose the most robust solution or intervention that is least sensitive to future climate conditions (Hallegatte, 2009). Therefore, new decision making frameworks or choices need to be developed whereby other aspects can be used in the multi-criteria decision-making processes. The categories that need to be included are a “no regrets” strategy which would also give benefits even without climate change (Hallegatte, 2009). The second category would be the “reversible” strategies that are more flexible and sustainable than un-reversible choices (Hallegatte, 2009) for example with crop insurance. Thirdly, a “safety margin” strategy will reduce the vulnerability of the community by building in a sort of insurance clause with a marginally more expensive option (Hallegatte, 2009) for example by using supplementary irrigation. The fourth strategy includes all “soft solutions” from a social, institutional or financial perspective and often involves planning of policies to deal with extreme events such as droughts and floods (Hallegatte, 2009). Fifthly, are the strategies that reduce the decision-making time horizons such as changing the species planted in a forest or plantation which is a decision that cannot be changed later (Hallegatte, 2009). As climate scientists cannot give highly accurate climate forecasts and by its very nature there will always be natural variability, so the end-users need to learn to change the way they make decisions. This then would consider the many uncertainties and be a form of anticipatory adaptation.

4. TACTICAL INTERVENTIONS

The medium-term decisions are considered to be tactical in that they are applicable on-farm but usually cannot be reversed until the next season, as they change some of the traditional or usual farming practices or methods or approaches. These interventions then include decisions to change the type of tillage for example changing from conventional to low-till or to conservation agriculture according to the eco-region and type of soil (Mupungwa, 2008). Another alternative would be to constrict or implement some infield rainwater harvesting to increase the plant available water and decrease the run-off losses (Tsubo *et al*., 2007). Some of the tactical decisions need to be approached with caution with a large number of options so as to be able to consider the balance between and the interaction between different choices. For example, assessing the impact of water harvesting and fertilization of a maize crop in the Thukela Basin (Andersson *et al*., 2011). There are a number of such technologies that need to take into consideration the exact natural resources on the farm to enable making an informed decision.

The use of rainfall and temperature seasonal forecast for a three month period with anything from 1 to 6 months lead time has assisted with tactical decisions. However, in order for these climate parameter forecasts to be used they need to have added value for the specific end users. Thus although GCMs can generate rainfall probabilities per season, the agrometeorologist needs to relate that forecast to the reality of the specific place and for a particular crop (Everingham *et al*., 2002; Hansen *et al*., 2009). This type of seasonal forecasts has been endorsed by farmers where they gave an estimated 15-30% average increase in gross production (Hansen *et al*., 2009). The decisions around crop rotation and selection of perennial crops would also form part of the tactical decision-making.

Tadross et al. (2007) calculated rainfall indices that are related to maize cropping over southeastern southern Africa and related them to SOI. They showed that there are weak trends for later planting and earlier cessation dates in the northern parts, leading to shorter rainfall seasons. Over southern Zambia the duration of the rainfall season is close to a critical thresholds (for planting 130-day maize cultivars), providing an incentive for farmers to plant as early possible to prevent crop failure. Figure 1 shows the correlation between September SOI and mean planting dates assuming 25 mm after 1 August, indicating that possibility of use as a forecasting tool.

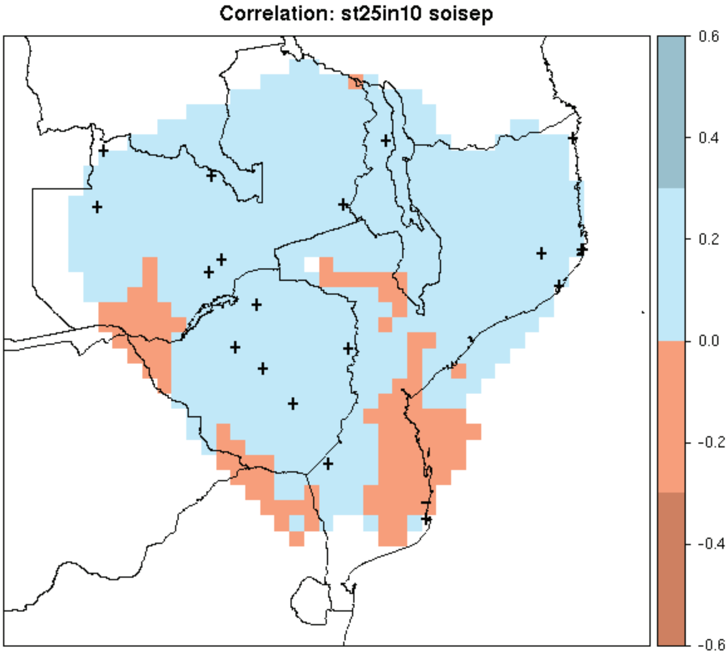

Fig. 1. Correlations between a) September SOI and planting after receiving 25 mm of rain after 1 August. Significant correlations marked with "+"/"-" (Tadross et al., 2007)

One may decide on the planting date from the available energy perspective – namely that in SADC one wants to have a full leaf area canopy before the December solstice so as to optimize the absorption of solar radiation to produce a good maize crop. The maize grain yield can be seen to decline for planting dates after the middle of December (Fig. 2).

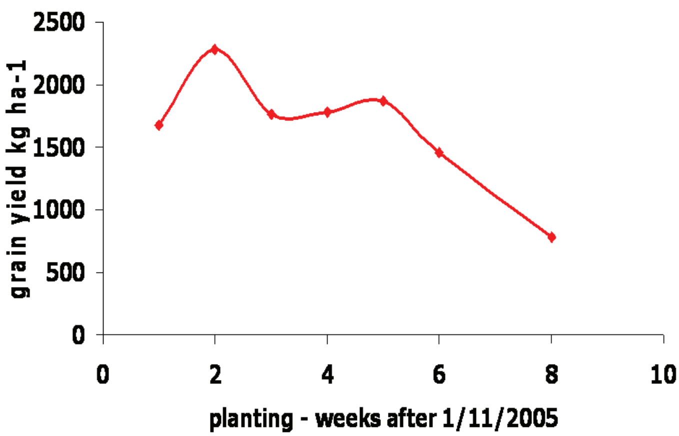

Fig. 2. Maize grain yield as a function of planting dates after 1 November.

One of the decisions that must be made before each season is that of which crops to plant where and when. The indigenous knowledge surrounding these types of decisions rests with the elderly, however under changing climate they may not remain the same over many years. Therefore, crop simulation models have been used to compare the production of a range of crops under different scenarios. For example using APSIM, the sorghum total biomass production declined, but the harvest index increased showing that the crop produced grain more efficiently than maize grown under similar conditions (Table 3: Dimes personal communication). In contrast, despite a shorter growing season under the climate change scenario (136d vs 165d) pigeon peas produced more biomass whereas groundnuts showed a lower production (Table 3). This illustrates that the decision on which crops to plant will change with a changing climate and one cannot always rely on the traditional knowledge.

Table 3. Comparison of production of Maize, sorghum, groundnuts and pigeon pea under current baseline and climate change scenarios (Dimes personal communication)

	Baseline				**Climate change**			
Crop	Total biomass (Mg ha^{-1})	Duration (d)	In-crop rain (mm)	HI	Total biomass (Mg ha^{-1})	Duration (d)	In-crop rain (mm)	HI
Sorghum	6.4	107	396	0.41	4.7	88	320	0.44
Maize	6.4	129	433	0.29	4.7	107	352	0.28
Groundnut	4.6	122	416	0.42	3.7	106	345	0.37
Pigeon pea	4.3	165	463	0.27	4.4	136	397	0.24

5. OPERATIONAL INTERVENTIONS

These decisions are more like those that can be made using the 7-days or 10 day or 14 day weather forecasts distributed by the NMS. These are the weather sensitive decisions that need to be made on an operational basis such as the actual planning date according to the specific cultivar (characteristics and the length of the available rainy or growing season (Tadross *et al*., 2009). The first and last frost dates and risk probability levels could also be used to help make decisions concerning these matters of cultivar X planting date (Moeletsi, 2010). Some of the possibilities for long-term analysis of specific operational decisions can be made using a calibrated crop model and a long-term weather dataset. (Carberry *et al*.,2002).

Land preparation operations are sensitive to the climate and any changes in the climate variability, particularly rainfall will need to be taken into consideration when planning the tillage operations. Whether winter ploughing to collect the first rains or deep ripping to break the plough pan, is to be used, one will need to consider the medium term rainfall forecast to make a wise decision (Mupangwa, 2008). The type of tillage operations to be used can also vary according to the seasonal rainfall forecast, such that while conservation agricultural principles are applied, the use of planting basins or pits for the collection of runoff will not be necessary during above normal rainfall seasons.

Crop models can also be used to find optimal planting densities, and to match planting dates for different combinations of rainfall seasons. Using APSIM for central Free State, Nape (2011) showed lower risk and highest yields when maize was planting during the first half of November compared with that planted during the first half of January (Fig. 3).

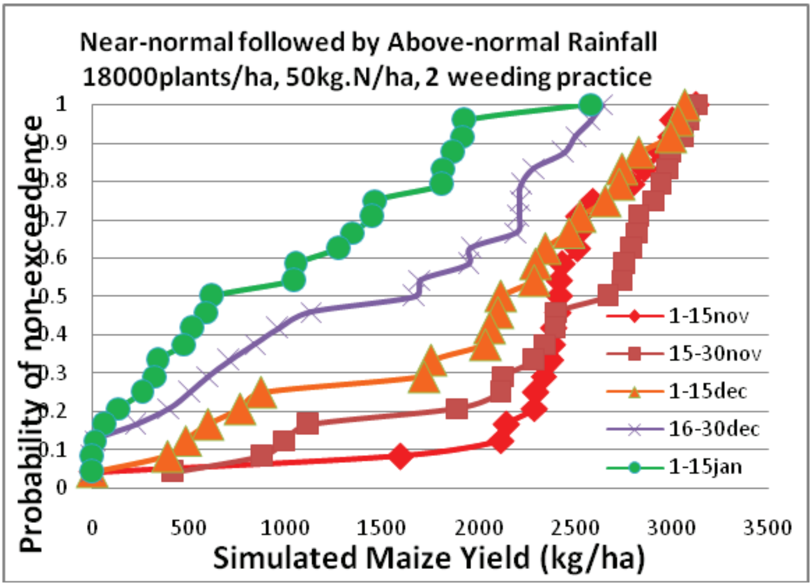

Fig. 3. Maize yield predictions from APSIM runs for central Free State in years with near normal rainfall received during October-November-December and above normal rainfall received during January-February-March, with 50kgN/ha fertilizer and 18000 plants/ha (Nape, 2011)

The community in Gladstone, Thaba Nchu, Central Free State had a number of strategies that they could use for the variable climate conditions that they were experiencing (Table 4) (Gandure et al., 2010).

Table 4. Gladstone farmer strategies for changing climates (Gandure eta al., 2010)

Strategy type	Properties	Supported by
In-field Rain Water Harvesting	Water and soil conservation	ARC and Partners
Changes in planting dates	Spreading risk by planting twice a year Plant only when it rains	Farmer driven
Changes in crops grown	From largely cereal to vegetables	Farmer driven
Agriculture practices	Build shelters for crops Soil conservation methods Broad casting to drop and line method	ARC & Farmer driven
Use of municipal water	Irrigate using free municipality water	Government

6. CONCLUSIONS

A range of alternative technical adaptations that have been used in SADC countries as discussed above such as alternative cropping patterns and selection of planting dates, and the use of action research cycle to introduce alternatives to communities. If there are climate forecasts at different time scales and farmers know how to use them to select from the range of options available, then there is always a way to develop an alternative sustainable farming system. The alternatives can be tested using crop simulation models with long-term climate data to produce risk assessments. However, these different ways of managing the natural resources under a more variable climate also need to be tested for local acceptability. As many of the livelihoods of farmers in SADC countries are threatened due to low soil fertility and low crop production there is a desire for change. Therefore it is vital that there is a good group of multidisciplinary intermediaries that can work together to help the farmers to use the available climate and agrometeorological information to develop alternative interventions that are viable in their own farming systems.

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