

Review

Increasing resilience and reducing vulnerability in sub-Saharan African agriculture: Strategies for risk coping and management

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The agricultural sector in Sub-Saharan Africa (SSA) continues to be confronted with multiple shocks and crises, threatening the endowments of the sector and impeding efforts at attaining the Millennium Development Goals (MDGs) in the region via the sector. We note that shocks to the agricultural sector are precipitated by a system of multiscalar stressors. These include; climate change, natural disasters, volatility of commodity prices, regional conflicts, policy shocks and the effects of globalization. These stressors interact in complex and messy ways to increase the vulnerability and reduce the resilience of agricultural agents to crises. This paper presents a descriptive and distinctive framework on the concepts of vulnerability, resilience, adaptive capacity and risks in agriculture, putting sub-Saharan Africa in context. In addition, the paper identifies four broad domains of opportunities available to farm agents to use risk coping and management strategies to increase their resilience and reduce their vulnerability to shocks and crises. They include; income and asset management strategies, farm production strategies, government programmes and support strategies and technological development strategies. Drawing from the experiences of developed countries and the information obtained from workshops and research works conducted in SSA, we identify policy directions that require urgent attention in reducing the vulnerability and increasing the resilience of SSA agricultural agents.

Key words: Vulnerability, risk coping, risk management, agriculture, crises, sub-Saharan Africa.

INTRODUCTION AND MOTIVATION

The agricultural sector in most sub-Saharan African (SSA) countries remains the crucial mainstay of local livelihoods and the primary contributor to national gross domestic product (GDP) (Chuku, 2007). The contributions of agriculture to GDP vary across SSA countries. Recent assessments suggest an average contribution of 21%, ranging between 10 to 70% of GDP (Mendelsohn et al., 2000; Devereux and Maxwell, 2001). Moreover, agriculture employs more than half of the labour force and serves as the main base for food security in the region. Despite its economic significance, the agricultural sector in SSA countries has performed very poorly over the decades. A large part of the literature that has addressed this issue has pinpointed poor policies and institutional failures as the primary culprits.

See Sachs and Warner (1998), Collier and Gunning (1999) and Binswanger and Townshend (2000) for a review of possible causes of the poor performance of African agriculture. Some authors have also argued that adverse natural resource endowments, such as low population density, land abundance and inherent geo-graphic conditions including slow technological change may also have been important in explaining the weak contribution of agriculture to development in SSA (See for instance Bloom and Sachs, 1998, Gallup and Sachs, 2000 and Barrios et al., 2008).

While these aforementioned factors are undisputedly vital in solving the SSA agriculture poor performance puzzle, there is yet another largely neglected factor to be considered. That is, the fact that the agricultural sector in SSA is particularly sensitive to a system of multiscalar stressors. These includes the treats of climate change, volatility of commodity prices, regional conflicts, policy shocks and the harmful effects of globalization (Devereux

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and Maxwell, 2001; OECD, 2004/2005; Ferguson, 2006). These shockers do not operate in isolation; they interact in complex and 'messy' ways to increase the risk exposure and vulnerability of smallholders to further shocks, hence undermining attempts to reduce vulnerability and drive development through the agricultural sector (IPCC, 2007).

In recent times, there has been an emerging awareness in agricultural development literature that for agriculture to drive development and hence alleviate poverty in developing countries, issues bordering on the vulnerability, resilience, adaptive capacity, effective risk management and coping strategies of smallholders to economic shocks and natural disasters will have to be addressed *ex-ante* (e.g. Eriksen and Silva, 2009, Ziervogel et al., 2006, O'Brien et al., 2009 and Eakin, 2005).

This paper seeks to address these issues by proposing *ex-ante*, contemporaneous and *ex-post* strategies available to households, formal and informal groups and governments for accelerated regional development, catalyzed by the agricultural sector.

To appreciate the problem that this paper seeks to address, it is useful to go over briefly, how economic crises (slowdown in economic activity, increase in the prices of staple products, removal of subsidies, devaluation of local currency, fall in the value and returns to assets) and environmental events (floods, droughts, El Niño events, poor soil fertility, pest invasion, crop disease etc) interact to shock smallholder agriculture. Economic crises can affect smallholders through a variety of channels, including: income risks and consumption fluctuation which affects nutrition, health and education (Dercon, 1999); the Prebisch-Singer effect which deteriorates commodity terms of trade (Todaro, 2000); and decreases the purchasing power of smallholders (Saldana, 2001); the weakening effect it has on informal safety nets (Dercon, 1999; Adger, 1999) and fluctuations in the value and returns to assets (Skoufias, 2003), among others. In contrast, climate change and environmental events can affect smallholders through perturbations and its destructive effects on their environmental capital, physical capital and human capital stock.

Recent agronomic studies suggest that the SSA agricultural sector is the worst affected and remains the most vulnerable to the vagaries of weather and climate risks, volatile agricultural commodity prices, unstable policies, weak institutions, and the harmful effects of globalization (Mendelsohn, 2000; OECD, 2004, 2005; WDR, 2008, IPCC, 2007). Certain countries have been observed to suffer from deteriorating food security, decline in overall real wealth and increased estimates of poverty, with recent estimates revealing that the average person in SSA becomes poorer by the factor of two every 25 years (Arrow et al., 2004; Sachs, 2005; Collier and Gunning, 1999).

Given increasing pessimistic forecasts of climate con-

ditions in the region which is chiefly attributed to climate change (Mendelsohn, 2000; Conde and Gay, 1999; Hulme, 2001); along with uncertain economic conditions resulting from policy shocks, agricultural commodity price volatility, market uncertainty and increased globalization, smallholders are becoming more vulnerable and have increasingly been adopting off-farm coping strategies including; emigration, seeking semi-urban employment, diversification, conservation agriculture, etc (Cooper et al., 2008; Barrios et al., 2008; WDR, 2008). These strategies have been viewed as not necessarily viable long-term solutions to the problem, but as immediate relief measures.

There is thus the need for exploring feasible vulnerability reduction and resilience boosting options through risk coping and management strategies that take into account, the peculiar climatic, environmental and economic circumstances faced by SSA in a holistic manner.

On a general note, this paper focuses on two core objectives: (1) To throw insightful light on the concept of vulnerability, resilience, adaptive capacity and risk; in the context of SSA agriculture; (2) To identify the opportunities available to farm agents to use risk coping and management strategies to reduce their vulnerability and increase their resilience to shocks and crises.

CONCEPTUAL SURVEY: VULNERABILITY, ADAPTIVE CAPACITY, RESILIENCE AND RISKS

In recent times, there has been a growing body of literature on the vulnerability and adaptation of human and biophysical systems to common and idiosyncratic shocks. Some bewildering arrays of terms have featured prominently in the literature. They include: vulnerability, sensitivity, resilience, adaptation, adaptive capacity, risks hazards, coping range, adaptation baseline and so on (IPCC, 2007; Adger et al., 2002; Burton et al., 2002; Brooks, 2003). The relationships between these terms are often unclear, and the same term may have different meanings depending on the context and the background of the author who is using it. The aim of this section therefore, is to present a conceptual framework that can be applied consistently to studies on vulnerability and adaptation in agriculture from a wide range of contexts, and by a wide range of disciplines.

The concept of vulnerability

The concept of vulnerability has its roots in the social sciences (Adger, 1999). It has a particularly long history in the risk-hazards and geography literature (Kasperson et al., 2003). Smit et al. (1999) describe vulnerability as the "degree to which a system is susceptible to injury, damage or harm." Vulnerability has also been defined simply as the potential for loss (Luers et al., 2003), and is

often understood to have two sides: an external side of shocks and perturbations to which a system is exposed, and an internal side which represents the ability or lack of ability to adequately respond to and recover from external stresses (Chambers, 1989).

Focus on vulnerability shaped by combined exposure to “double” risk factors, such as climate change and market fluctuations have been shown to aggravate stress to SSA smallholders (e.g O'Brien and Leichenko, 2000, 2002). This is because lack of access to technological infrastructure such as early warning information, for exam-ple, can often aggravate local vulnerability, particularly at times of heightened climate stress (e.g O'Brien and Vogel, 2003). Recently, researchers have been drawing attention to the role of social capital and physical assets in shaping the vulnerability context of SSA farm agents (Reid and Vogel, 2006; Pelling and High, 2005). For example, Reid and Vogel (2006) show that farmholders' relative vulnerability in South Africa is affected by the farmers' access or otherwise to basic infrastructure, the persons social connectedness, membership of formalized groups, relationships of trust, reciprocity and exchange.

In examining the vulnerability of SSA agricultural system to shocks and crises, it is essential to explore both the 'internal' and 'external' dimensions that shape vulnerability. This is what Fussel and Klein (2005), term “second-generation” vulnerability assessments. Here, the assessment is done based on its capacity to estimate realistically, the vulnerability of certain sectors to climate change in concert with other stress factors (economic crises). The prominent factors that have been highlighted to configure the vulnerability of SSA smallholders to shocks and crises include: their capacity to anticipate, cope with, resist, as well as their ability to recover from stresses (Kasperson and Kasperson, 2001). Cannon (2000) expressly identified five key components of vulnerability, including: (1) Initial well-being, (2) livelihood resilience, (3) self protection, (4) societal protection and (5) Social Capital (Social Safety Nets).

To utilize the concept of vulnerability in policy-driven strategies for development, researchers need to be able to measure it. However, defining the parameters for quantifying vulnerability has proven difficult, particularly because of the fact that vulnerability is often not a directly observable phenomenon (Downing et al., 2001). Despite the many challenges that exist in quantifying vulnerability, several quantitative and semi-quantitative metrics have been proposed and applied. For example, Udry (1994) among other indicators used changes in access to state contingent loans to measure smallholder vulnerability in Northern Nigeria. Asimwe and Mpuga (2007) among other indicators, used access to crop insurance in Uganda, while Eriksen and Silva (2009) used the proximity and access of smallholders in Matidze and Massavasse in Mozambique to specialized markets as a indicator.

Perhaps the most common method of quantifying vulnerability in the global change community is by using a

set of composite proxy indicators (e.g. Moss et al., 2002; Kaly et al., 2002). Table 1 summarizes some of the most common indices used to measure vulnerability.

While the indicator approach is valuable for monitoring trends and exploring conceptual frameworks, it often leads to a lack of correspondence between the conceptual definitions of vulnerability and the matrices of the indicators. Hence, the need to develop a quantitative framework that fills this gap. Following the works of Luers et al. (2003), Stephen and Downing (2001) and Pritchett et al. (2000), we describe a new approach for quantifying SSA smallholder vulnerability to shocks and crisis thus:

$$V = f\left(\frac{\text{sensitivity}}{\text{contemporaneous state, relative to threshold}}\right) \quad 1$$

That is, the vulnerability of a smallholder/system to shocks and crises is a function of the smallholder/system's sensitivity to a given degree of perturbation, and the relative proximity of the smallholder/system to its damage threshold. Thus:

$$V = f\left(\frac{|\delta W/\delta X|}{W/W_0}\right) \quad 2$$

Where W_0 represents a threshold value of well-being below which the system is said to be damaged. While $|\delta W/\delta X|$ is the sensitivity of smallholders, represented as the absolute value of the derivate of the well being with respect to the stressor X.

Taking cognizance of the fact that different countries and ecosystems in the SSA region are exposed to varying magnitudes and frequencies of shocks and crises, often resulting in differential vulnerabilities (IPCC, 2007; Turner et al., 2003). We describe a means by which the differences in exposure can be captured. That is, by calculating the expected value of the ratio of sensitivity to the contemporaneous state, relative to a threshold based on the observed frequency distribution of the stressors. Thus:

$$V = EV\left(\frac{\text{sensitivity}}{\text{contemporaneous state, relative to threshold}}\right) \quad 3$$

Where EV is the expected value of the ratio of sensitivity to the present state, relative to a threshold, and PX refers to the probability of occurrence to stressor X. Hence:

$$V = \int \left(\frac{|\delta W/\delta X|}{W/W_0}\right) PX dX \quad 4$$

Although it is impossible to determine the precise functional relationship that includes all of the stressors and

Table 1. Indicators of dynamic vulnerability in agriculture.

1	Changes in access to infrastructure.
2	Variability of agricultural production.
3	Changes in rainfall index.
4	Changes in population density.
5	Changes in average cash income.
6	Frequency of civil insecurity.
7	Changes in availability of marketing facilities.
8	Changes in access to credit.
9	Changes in crop subsidy prices changes in national trade and investment policies.
10	Changes in soil fertility.
11	Changes in climate.
12	Changes in rates of exposure to diseases.

variables of concern, Luers et al. (2003) show that analysis based on simple theoretical models and multivariate regressions from empirical data can provide valuable information about functional relationships that can be applied in this measure.

The concept of adaptive capacity

Many definitions of adaptive capacity exist in the literature (for example, see IPCC, 2007, Burton et al., 2002, Adger et al., 2004 and Luers et al., 2003); generally speaking, adaptive capacity may be described as the ability or capacity of a system to modify or change its circumstances or behavior so as to cope better with existing and anticipated external shocks (Brooks, 2003). Adaptive capacity represents potential rather than actual adaptation. The process through which adjustments take place in the behavior of a social or biophysical system to enhance its ability to cope with shocks and crises is termed adaptation. The potential for a smallholder or system to successfully respond to a set of new (especially adverse) circumstances is a function of its initial endowment, including technology, knowledge, wealth and socio-ecological attributes. Cooper et al. (2008) refer to these endowments as components of the livelihood assets.

Livelihood assets are the means of production available to a given individual, household or group. Development economists have identified five kinds of livelihood assets that are capable of serving as buffers in times of shocks and crises. They include: (1) Natural capital, (2) Socio-political capital, (3) Physical capital, and (5) Financial capital (DFID, 1999). In general, the higher and more varied the asset base, the greater is the smallholder/system's adaptive capacity and potential for sustainability. Table 2, summarizes some robust determinants of adaptive capacity as described in IPCC (2007).

There is arguably as much uncertainty in adaptive capacity as there is in climate change science (Adger and

Vincent, 2005). This is because adaptive capacity cannot be easily measured, since it is directly connected to the levels of economic, social and biophysical endowments of agents. For example, some parts of South Africa like KwaZulu-Natal may rank positively in terms of adaptive capacity because smallholders have relatively higher livelihood assets, access to social security and improved institutions (Reid and Vogel, 2006). However, in countries like Mozambique, adaptive capacity is currently extremely stressed and dynamic adaptive capacity is at risk of being further weakened by a lack of and an inadequacy of similar factors present in South Africa (see Osbahr et al., 2008, Bingen et al., 2003, Eriksen and Silva, 2009 for evidence).

The concept of resilience and resistance

As a technical term, the idea of 'resilience' originated in the field of ecology (Holling, 1973). However, in recent times, it has gained interdisciplinary popularity, especially in the economics literature (see for example Ludwig et al., 1997). In the economics literature, resilience is often used to describe the characteristic features of a socio-ecological system (SES) that are related to sustainability and is often used in conjunction with the concept of adaptive capacity. Gunderson and Holling (2001) defined resilience as the capacity of a system to undergo disturbance and maintain its functions and controls. Thinking along the same line, Carpenter et al. (2001) describe resilience as the magnitude of disturbance that can be tolerated before a Socioecological system moves to a different region of state space, controlled by a different set of processes.

These definitions contrast with that proposed by Pimm (1984), who proposed using the ability of a system to resist disturbance and the rate at which it returns to equilibrium after a shock to describe the level of resilience. The distinction between these two definitions has been useful in encouraging the consideration of the com-

Table 2. Determinants of adaptive capacity.

Determinant	Description
Economic resources	Greater economic resources increase adaptive capacity. Lack of financial resources limits adaptive capacity.
Technology	Lack of technology limits range of potential adaptation options. Less technologically advanced regions have higher vulnerability.
Information and Technical Know how	Lack of informed, skilled and trained personnel reduces adaptive capacity greater access to information increases likelihood of timely and appropriate adaptation
Infrastructure	Greater variety of infrastructure can enhance adaptive capacity, since it provides more options. Characteristics and location of infrastructure also affect adaptive capacity.
Institutions	Well-developed social institutions help to reduce impacts of risk, and therefore increase adaptive capacity. Policies and regulations constrain or enhance adaptive capacity.
Equity	Equitable distribution of resources increases adaptive capacity Both availability of, and entitlements to resources is important.

plementary aspect of resilience, which is, resistance. Carpenter et al. (2001) have defined resistance as the amount of external pressure needed to bring about a given amount of disturbance (crises) in the system. Consider for example those agricultural systems that are particularly resilient because they are intrinsically resistant, that is, they absorb high levels of shock and crises and nevertheless, persist. Some examples include self-mulching clay soils and lengthened crop seasons in Ethiopia, Southern Africa and Mozambique (Thornton et al., 2006).

In studying the resilience of SSA smallholder agriculture to shocks and crises, we are concerned about the magnitude of stress (disturbance) that can be tolerated by the system (social and biophysical) before it moves into a different socioecological state. Based on this, we point out three properties of a SES that determines its tolerance. They are: (a) the elasticity of the system (this represents the amount of shock the system can absorb and still remain within the same SES state), (b) the speed of adjustment of the system (this is the time horizon within which the system returns to its prior state after a shock or crises), and (c) the adaptive capacity of the system. This description is similar to what Gunderson and Holling (2001) term the theory of “adaptive cycle and resilience,” which posits that human, ecological and economic systems do not tend towards an equilibrium condition after a shock, but instead, they pass through a cyclical process, including: rapid growth and exploitation, conservation, collapse or release and renewal or reorganization.

Research has shown that some indicators of SES resilience to shocks and crises tend to be more robust than others. For example; the level of economic growth, social connectedness, environmental stability, equitable

income distribution, global connectedness, stability of livelihoods, crime rates and effectiveness of institutions, features prominently as robust indicators (see for example Adger, 2000; Carpenter et al., 2001; Freudenburg, 1992).

The concept of socioecological resilience as opposed to the separate assessment of social and ecological resilience is a consolidated assessment of the resilience of SSA smallholders and the SSA ecological system to shocks and crises.

The concept of risks and risk management

Agricultural activities are a risky means of livelihood. Smallholders are constantly being confronted with uncertain economic, environmental, social and climatic outcomes on a daily basis. These outcomes define the riskiness or otherwise of the agricultural sector in SSA. Risk is defined as uncertainty that affects an individual’s welfare and is often associated with adversity and loss (Bodie and Robert, 1998). Harwood et al. (1999) simply describe risk as the possibility of adversity and refer to it as the “uncertainty that matters.” Among the many definitions of risk in the literature, three properties emerge as common factors. They are: (1) the chance of a bad outcome, (2) the variability of outcomes and (3) the uncertainty of outcomes (Hardaker, 2000).

Distinguishing the different types of risks that an agricultural stakeholder confronts is useful to explore the different actions required for managing them. The most important risk faced by stakeholders in Agriculture is production or yield risk. This occurs because agriculture is subject to uncontrollable events usually related to climate such as changes in precipitation, floods, hail,

insects, diseases etc. This kind of risk requires the deployment of high-tech infrastructure (especially irrigation) to manage, and these infrastructural amenities are not readily available in the region. A second and very important kind of risk faced by stakeholders is the price/market risk, which is incurred when prices of output or even inputs collapse or rise below or above the rational expectations of farmers. Other risks that need to be considered are institutional risks which occurs as a result of changes in policies and regulations that affects agricultural practices and stakeholders' well being, asset risks which can be incurred when there is damage to the means of livelihood (land, equipment, livestock etc), and financial risks which involves fluctuations in interest rates, cash flow difficulties etc.

Understanding the nature of these different kinds of risks is crucial because the actions required to manage them are different. Risk management for a farmholder involves choosing among alternatives for reducing the effects of risk on a farm and in so doing, affecting the farmer's welfare position (Harwood et al., 1999). Risk management strategies have the potential to (1) Reduce risk within the operations, such as product diversification, (2) Transfer risks outside the operations, by product contracting for example and, (3) Build the agent's capacity to bear risk, by for instance maintaining some liquid assets. Harnessing these potentials of risk management to effectively cope and adapt in times of shocks and crises depends on the understanding of the different types of risks that an agricultural agent is confronted with.

Farmers, farm associations and governments' decisions to manage risks depend on their subjective assessments of risks, their risk behavior and the extent of vulnerability and their levels of adaptive capacity. Their perceptions about risk inform the strategies they adopt towards risk management. These strategies can be grouped into three categories thus: (1) Ex-ante risk management, which is done before the risky outcome occurs. It involves options such as choice of risk-tolerant varieties, investments in water management, on-farm and off-farm diversification etc. (2) Contemporaneous risk management options which are actions that are taken concurrently as shocks or crises occur. They involve in-season adjustments to crops and operations. (3) Ex-post risk management options, which involves minimizing the impact of shocks through coping strategies such as depleting savings, selling assets, borrowing from social networks, cutting consumption etc (Eakin, 2005; Reid and Vogel, 2006).

STRATEGIES FOR RISK COPING AND MANAGEMENT IN SSA AGRICULTURE

This strategies identifies options for risk coping, management and adaptation to social, economic and climatic stimuli, in the SSA agricultural sector. While the options

are rather generic, we site examples and applications that suite the peculiar circumstances of SSA agriculture. Agricultural adaptation (risk coping and management) strategies are grouped into four main categories that are not mutually exclusive: (1) Income/asset management, (2) Government programmes and insurance, (3) Farm production practices and (4) Technological development. This categorization can be characterized by two operational factors. Firstly, the scale at which the adaptations are being undertaken and secondly, the agents or stakeholders who are involved in the implementation. The main strategies for adaptation are summarized in Table 3, with examples considered in light of the distinctions and characterizations discussed earlier.

Income/asset management strategies

Asset management options are smallholder responses using their livelihood assets (both government, community and privately supported) to reduce the impact of shocks and crises. Asset management options involve decisions with respect to crop insurance, crop shares, options and futures, asset smoothing (stabilization) programmes and household income (Table 3)

Buying crop insurance policies reduces or eliminates the tendency for asset loss as a result of reduced crop yield or sales from droughts, floods or market fluctuations. This is an adaptation strategy that will enable agricultural risks to be shared by the financial system, and in cases where these insurance policies are subsidized, the risk will be shared publicly (Smit, 1993; de Loe et al., 1999). This type of adaptation involves smallholder participation in established community, state and federal social security programmes. For example, Udry (1994) reported that informal compensation in rural Nigeria, took the form of state contingent loans, and beneficiaries had to be contributory members of registered traditional credit systems (ESUSU). Similar informal crop insurance systems were observed in Mozambique (Nwadjahance) (Osbahe et al., 2008; Eriksen and Silva, 2009), and Uganda (Asiimw and Mpuga, 2007).

Investments in crop shares, futures and options by agricultural stakeholders, has been proposed as a veritable means of spreading exposure to risks by farmers, and reducing vulnerability to shocks and crises (Mahul and Vermersch, 2000). This risk management option involves the use of securities, shares and other financial instruments developed by banks, governments and other social institutions to spread risks and smoothen income fluctuations (Chiotti et al., 1997). The efficacy of this option has been proven to be veritable in some advanced economies like Canada (Smit and Skinner, 2002). However, in developing countries, it is more or less inexistent because of the underdeveloped nature of the existing financial markets (for a survey, see Basley, 1994).

Table 3. Strategies for risk coping and management in SSA agriculture.

Income and asset management strategies	<p>Crop insurance: Purchase crop insurance to reduce the risks of climate and market related income loss</p> <p>Crop shares and futures: Invest in crop shares and futures to reduce the risks of climate and market related income loss</p> <p>Income stabilization programs: Participate in income stabilization programs to reduce the risk of income loss due to changing climate and market conditions.</p> <p>Household income: Diversify sources of household income in order to address the risk of climate and market related income loss.</p>
Government programs and support	<p>Agricultural subsidy and support programs: Modify crop insurance programs to influence farm-level risk management strategies with respect to climate and market related losses Change investment in established income stabilization programs to influence farm-level risk management strategies with respect to climate and market related income loss Modify subsidy, support and incentive programs to influence farm-level production practices and financial management. Change <i>ad hoc</i> compensation and assistance programs to share publicly the risk of farm- level income loss associated with disasters and extreme economic crises.</p> <p>Private insurance: Develop private insurance to reduce climate and market related risks to farm-level production, infra- structure and income</p> <p>Resource management programs: Develop and implement policies and programs to influence farm-level land and water resource use and management practices in light of changing climate and market conditions.</p>
Farm production practices	<p>Farm production: Diversify crop types and varieties, including crop substitution, to address the environmental variations and economic risks associated with agricultural production Diversify livestock types and varieties to address the environmental variations and economic risks associated with agricultural production. Change the intensification of production to address the environmental variations and economic risks associated with agricultural production.</p> <p>Land Use: Change the location of crop and livestock production to address the environmental variations and economic risks associated with agricultural production. Use alternative fallow and tillage practices to address climate change-related moisture and nutrient deficiencies</p> <p>Land topography: Change land topography to address the moisture deficiencies associated with climate change and reduce the risk of farm land degradation.</p> <p>Irrigation: Implement irrigation practices to address the moisture deficiencies associated with climate change and reduce the risk of income loss due to recurring drought.</p>

Table 3. Contd.

Technological developments	Timing of operations: Change timing of farm operations to address the changing duration of growing seasons and associated changes in temperature and moisture
	Crop development: Develop new crop varieties, including hybrids, to increase the tolerance and suitability of plants to temperature, moisture and other relevant climatic conditions.
	Weather and climate information systems: Develop early warning systems that provide daily weather predictions and seasonal forecasts
	Resource management innovations: Develop water management innovations, including irrigation, to address the risk of moisture deficiencies and increasing frequency of droughts
	Develop farm-level resource management innovations to address the risk associated with changing temperature, moisture and other relevant climatic conditions

Diversification with and beyond agriculture is a widely recognized strategy for reducing risks and improving the well being of freeholders through income and asset management (O Laughlin, 2002; Ellis and Allison, 2005; Oshahr et al., 2008). Diversification contributes to freeholder's resilience by spreading risk. Since diversification has the potential to spread risk, freeholders should be encouraged to diversify their sources of livelihood within and beyond agriculture to reduce their vulnerability to shocks. This adaptation strategy is theoretically valid because as long as the different income sources are not perfectly covariate (that is, they have a correlation coefficient below 1), then there will be a reduction in total risk from combing two income sources with the same mean and variance (Dercon, 1999). Some of the commonly observed farmholder portfolio diversification options practiced in SSA include: petty trading, tailoring, construction work, wage labour, etc. (Oshahr et al., 2008 and Cooper et al., 2008).

Government programs and support strategies

Government programmes and support strategies are institutional responses to the economic, ecological and social risk and crises associated with agri-businesses, and that have the potential to reduce the vulnerability, and increase the resilience of agricultural stake-holders to shocks and crises. These include among others, governments subsidy and trans-fers, governments insurance and natural resource management programs.

Agricultural subsidy and transfer programs involve government's investments in the agricultural sector which seeks to provide incentives and increase the resilience of farm agents who participate in agri-business. However, it is difficult to determine the effectiveness of these programmes in SSA, because they are usually marred with corruption by government officials or are high-jacked before they arrive at the target beneficiaries (Collier and Gunning, 1999). This

risk management strategy has been shown to be very effective especially when it is implemented in collaboration with traditional credit systems (that is Public-Private-Partnership) (Udry, 1994, Dercom, 1999 and Attanasio and Rios-Rull, 1999).

The development of government insurance products represents an adaptation to agricultural risks that is primarily the responsibility of the financial services sector, which is heavily influenced by government programmes. Government insurance schemes are schemes that address risks associated with crop or property loss as a result of extreme climatic events or economic glooms. Although this risk management option has the potential to reduce vulnerability (Smit and Skinner, 2002), its implementation in SSA is impeded by the smallness (subsistence) of most farm agents, making its administration difficult to operate.

Another option for risk management in agriculture under government programmes and support is the formulation of natural resource

management policies. These policies involve the development of government programmes that encourage best practices in land and water use regimes. This type of agricultural risk management strategy involves the development and modification of land use regulations (Chiotti and Johnston, 1995), water use permits (Easterling, 1996), and “optimal resource control” practices (Smit and Skinner, 2002). Implementation of these programmes will involve an assessment of current practices, with a view to modifying the institutional and economic foundations upon which the policies will run smoothly. In most cases, it may even involve amendments to existing legislations (de Loe et al., 1999; Smit and Skinner, 2002). All government programmes and supportive schemes as mentioned, represent adaptation strategies at an aggregate scale and should be considered as prerequisite actions for effective and sustainable risk management in agriculture.

Farm production practices

Farm production practices are useful ways to manage potential agricultural risks. It involves changes in operations and methods of carrying out agri-business. Decisions on production methods, land use, land topography, irrigation and timing of operations are key variables to consider (Table 3). Changing farm production methods has the potential to reduce vulnerability to socioecological risks, and increase adaptability of farm production to changing climate conditions. Adaptations in production methods could include the diversification of crop and livestock varieties (Skoufias, 2003), the substitution of plant types, cultivars and hybrids (Saldana, 2008) and the substitution of animal breeds designed for higher drought and heat tolerance (Smit and Skinner, 2002; Chiotti et al., 1997). Also, altering the composition of chemical (fertilizers and pesticides) and synthetic inputs has the potential of reducing the risks in farm production in the light of multiple climate stress (Hucq et al., 2000). Successful examples of the use of alterations in chemical and synthetic composition of farming operations include the experience of semi-arid Zimbabwe, where nitrogen deficiency is widespread.

Dimes' (2005) study revealed that in the 2003/2004 cropping season, the introduction of nitrogen fertilizer at the rate of 52 kg ha⁻¹ substantially improved crop yield despite adverse climate conditions.

Changing land use practices involves altering the location and nature of crop and livestock production engaged by farmholders. It involves rotating or shifting production between crops and livestock and shifting production away from marginal areas to more climate resilient areas. This risk management strategy reduces soil erosion and improves moisture in the soil and the soils ability to maintain nutrients (Smit and Skinner, 2002). Another way of conserving soil moisture and nu-

trients can be by using alternative fallow and tillage practices (Chiotti et al., 1997; Hucq et al., 2000).

Risk management in agriculture through land topography involves heavy investments in providing public goods like land contouring and terracing, construction of diversions, reservoirs and water storage (Easterling, 1996). This type of adaption though expensive, can reduce on an aggregate scale the vulnerability of farm production by decreasing runoffs and erosion, improving moisture and nutrient retention, and improving water uptake (de Loe et al., 1999).

Irrigation practices involve the introduction of artificial enhancements of water supply to farms. In recent times, innovative irrigation management approaches have been adopted widely in SSA. They include: centre pivot irrigation, dormant season irrigation, drip irrigation, gravity irrigation, pipe irrigation and sprinkler irrigation (Smit, 1993; Chiotti et al., 1997). This type of adaptation maintains adequate moisture in the light of decreasing precipitation and increasing evaporation. It also improves farm productivity and enables diversification of production practices (Brklacich et al., 1997).

Changing the timing of operations involves risk management approaches that reschedule production activities such as planting, spraying, fertilizing and harvesting to take advantage of or at least minimize the impact of climate and market shocks. Typically, this type of adaptation involves scheduling and rescheduling crop and livestock production activities such as chemical inputs (Chiotti and Johnston, 1995), grazing (Chiotti et al., 1997), irrigation (de Loe et al., 1999), harvesting, mulching, planting, seeding and tillage (Smit and Skinner, 2002). Rescheduling the timing of these farm practices has the potential to maximize farm productivity during the growing seasons and to avoid heat stresses and moisture deficiencies during times of increased climate perturbations (Smit and Skinners, 2002).

Technological developments

Technological development is one of the most effective and sustainable ways of managing risk in agriculture. As summarized in Table 3 technological adaptation options are innovations that seek to improve biotechnology (to increase crop yield and increase tolerance), provide weather and climate information systems (to generate forecasts) and develop resource management methods (to deal with climate related risk).

The development of new crop varieties including types, cultivars and hybrids has the potential to provide crop choices that are better suited to the temperature, moisture and other conditions associated with the peculiar ecology of SSA. Biotechnology for adaptation focuses on the development of plant varieties with higher yield, and that are more tolerant to adverse climatic conditions such as heat or drought, through conventional breeding,

cloning and genetic engineering (Smitters and Blay-Palmers). In SSA, most biotechnological research projects are undertaken by governments and donor agencies, with the private sector nearly non-participatory. This trend needs to be corrected by providing incentives and the necessary framework that guarantees the protection of property rights in agri-biotechnological discoveries. Also, the crop development community should target “robustness” (that is, crop stability and resilience) as against productivity as the objective of biotechnological research.

Another type of technological advancement that can reduce vulnerability to shocks in agriculture is the development of information systems, capable of forecasting weather, climatic and market conditions associated with agricultural production. Availability of weather predictions over weeks months and years to farmholders has a special relevance to the scheduling of production operations like planting, spraying harvesting etc. Seasonal weather forecasts, such as estimates of the likelihood of conditions associated with El Nino events, have the potential to aid risk assessment and management decisions over several seasons. Fundamental and technical information on longer term market trends, can inform farmers about future expectations and the probability of extreme volatile movements, while seasonal forecasts have the potential to inform farm-level production decisions (Murphy, 1994). Studies on farmers perception and acceptability of such forecasts for decision-making are low, suggesting that their reliability would have to be greatly improved before these forecasts can enter as a major variable in producer risk management choices (Brklacich et al., 1997).

Technological innovations are also required in natural resource management to enhance the resilience of farmholders to shocks. For example, broad scale water resource management innovations address the risk of water (moisture) deficiencies or surpluses associated with shifting precipitation patterns and the proximity of more frequent floods and/or droughts (Smit and Skinner, 2002). Typically, these innovations are undertaken by public agencies at the national level, may also involve desalination technologies (Easterling, 1996; de Loe et al., 1999). At the community or individual farm-levels, resource management innovations could take the form of the development of integrated drainage system, land contouring, and alternative tillage systems (Easterling, 1996; Smit and Skinner, 2002). Technological, risk management options are cost and knowledge intensive thereby requiring the support of government and development agencies.

CONCLUDING REMARKS AND DIRECTIONS FOR POLICY

The social and biophysical agricultural system in SSA continue to face multiple shocks, threatening its endow-

ments (livelihoods) and impeding efforts at attaining the Millennium Development Goals (MDGs) and driving development using agriculture in the region. This paper illustrates the myriad of agricultural risk management options, available to governments, agri-businesses and smallholders to reduce vulnerability and increase resilience to multiple shocks and crises in agriculture. The peculiar situational vulnerability of SSA livelihoods draws attention to the range of factors configuring the local vulnerability to which people live, (poor governance, climate stress, social conflicts, underdeveloped markets, poor economic policies, poor technology, weak institution and slow growth etc). These factors must be considered in implementing adoptable and veritable agricultural risk management strategies for the region.

Since risk management in agriculture involves various ‘stakeholders’ with different and yet often inter-related vulnerability, resilience and adaptive capacity, it is necessary to recognize which players are involved and what their roles are with respect to the risk management strategies highlighted above. As illustrated, significant distinctions exist between risk management options that are employed by private decision makers, including industry and individual producers (farmers) and public decision-makers (governments and public decision-makers (governments and public agencies) . However, private and public adaptation options are not necessarily independent of each other, but most often have reinforcing effects.

Ultimately, risk management in agriculture occurs via decisions of producers to employ a technology, choose a crop variety, change a practice, reschedule production timing, modify inputs, purchase insurance, enroll in a safety net, register for a stabilization policy etc. These decisions are articulated through the institutional and regulatory mechanisms prevailing in the agricultural, economic, financial, social, political and technological systems operational in the region.

The implementation of sound economic, agricultural, financial and technological policies in SSA is a prerequisite for the successful adaptation of the agricultural sector to shocks and crises. Drawing from the experiences of developed countries (Dercon, 1999; Smit and Skinner, 2002; Smit et al., 2000; Saldana, 2008) and information from workshops and research works conducted in SSA (Dietz et al., 2004a, 2004b; Thomas, 2008; Urdu, 1994; Twomlow et al., 2008; Barrios et al., 2008; Eriksen and Silva, 2009; Reid and Vogel, 2006), we identify directions that require urgent policy attention in the region as follows;

Income/Asset management

- (1) Granting government direct credits to farmers in the face of shocks and crises.
- (2) Improving the operations of asset markets.
- (3) Improving macroeconomic stability which enhances

self-insurance.

- (4) Removal of restrictions and increasing access to off farm economic activities.
- (5) Developing public safety nets (even though this has been shown to have some form of crowding-out effect through its effects on the incentive structure of informal or private safety nets)
- (6) Empowering informal safety nets to be able to cope with idiosyncratic and especially common shocks.

Government programmes and support

- (1) Training and capacity building on risk management and coping strategies.
- (2) Payment for environmental services to encourage "best practices" in natural resource management.
- (3) Provision of risk mitigating infrastructure (dams, irrigation, drainage etc).
- (4) Provision and dissemination of high quality information on market and climate forecasts.
- (5) Decentralization of agric-policies in favour of local and regional authorities (this will ensure temporal and spatial specific implementation of adaptation options).

Farm production practices

- (1) Formulation of policies on appropriate professionally recommended combination of chemical inputs to be used by farm agents to increase resilience.
- (2) Introduction of topological inspection of farm lands before operations commence (this will ensure that relatively unproductive areas are not cultivated at the expense of more productive areas).
- (3) Sustainability policies on fallow and tillage methods to be adopted etc.

Technological developments

- (1) Mandatory provision and dissemination of early warning information for stakeholders.
- (2) Aggressive prospecting for new plant and animal varieties and hybrids with higher yield and increased tolerance to climate and market shocks.
- (3) Generous funding for agri-biotechnological research with robustness (crop/livestock stability and resilience) rather than productivity as the objective.

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