An assessment of Swaziland sugarcane farmer associations’ vulnerability to climate change

Bon’sile Faith Nicollete Mhlanga-Ndlovu and Godwell Nhamo

Department of Environmental Science and Institute for Corporate Citizenship, University of South Africa, Pretoria, South Africa

ABSTRACT
The study investigated the vulnerability of Swaziland’s sugarcane small scale farmer associations (SSFAs) to climate change through the Sustainable Livelihoods Framework. From a survey of 45 SSFAs, representing +2700 farmers, drought emerged as the most significant stress. Droughts result in failed cane germination, increased pests and increased diseases. Farmers indicated that there had no land title deeds and were concerned about the poor state of infield and feeder roads damaged during heavy rainfall and floods. It emerged that the bulk of the SSFAs irrigate during the day, a scenario that leaves them vulnerable to high temperatures leading to high evapotranspiration. In addition, 97% of the SSFAs sampled did not have drought preparedness plans and likewise, all did not have a flood management plan. About 76% of SSFAs operation costs goes to crop upkeep and harvesting, with labour cost increases attributed to extreme weather events. All sampled SSFAs had no insurance against loss from extreme weather events. Given the foregone, the paper recommends that the government fast tracks the 1999 Draft Land Policy intended to address the issue of title deeds. The paper further suggest that extension officers and farmers be trained to sharpen skills on understanding climate change.

Introduction
The climate change phenomenon has received growing attention in recent times. The African continent, where Swaziland is located remains vulnerable to future climate change due to its low adaptive capacity (IPCC 2007). The economy of Swaziland is largely agro-based, making it more vulnerable to climate change. Small-scale sugarcane farming is extensively practiced by many rural households in the poverty-stricken Lowveld. These farmers are organised into small scale farmer associations (SSFAs) averaging 60 individual farmers (SSA 2008). Sugarcane production offers substantial employment presenting a good opportunity for poverty reduction. The sugar industry further contributes to other national developments realised through its major contribution to government revenues such as the sugar levy and income taxes (Ibid.).

© 2017 the author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.
This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.
Several studies conducted to determine the impact of climate change in Swaziland have not included a holistic approach to examine how vulnerable the SSFAs are and what coping measures they are putting in place. Previous studies conducted in the country focused on the impacts of climate change on the sugarcane yields (Knox et al. 2010), on water resources (Matondo et al. 2005; Mhlanga 2010), climate change perceptions by communities (Manyatsi et al. 2010) and adaptation measures employed by large-scale farmers (Simelane 2009). Climate change in Swaziland has become more apparent, and is experienced through extreme weather events (Manyatsi et al. 2010). Some of the severe weather events included droughts and floods experienced in the years 1983, 1984, 1992, 2000, 2001, 2004, 2005 2007 and 2008 (GoS-UNDP 2014). The worst drought conditions experienced in the country were in 2004/2005 with the worst year being 2007. The years 1984 and 2000 were characterised by extreme floods.

Situated in Swaziland’s Lowveld, this study investigates the SSFAs’ vulnerability to climate change through the application of the Sustainability Livelihoods Framework (SLF) developed by the Department for International Development (DFID) (DFID 1999). Although climate change impacts to the sugar sector are generally known as well as the associated adaptation measures employed, the SSFAs’ vulnerability to climate change and the factors that drive this vulnerability are unknown. To this end, understanding the SSFAs’ exposure to climate change helps to improve their adaptive capacity and enhance relevant adaptation measures. This study is therefore important to close the gap between the climate change impacts studies and climate change adaptation studies by providing some understanding on the underlying factors that shape SSFAs’ vulnerability to climate change.

The rest of the paper is organised as follows: the next section presents the literature review. This is followed by the methodology used, that in turn is followed by the presentation and discussion of results. The last part is the conclusion, which summarises key findings and makes some suggestions.

**Literature review**

Swaziland faces a major decline in the gross domestic product (GDP) as a result of climate change impacts. This is so because the main economic growth and development contributing sectors such as agriculture, water resources and health are also climate sensitive and heavily reliant on natural resources (SSA 2013). In Swaziland, the sugar industry is vital in that it provides 59% of agricultural output, 35% of agricultural wage employment and about 8% to the country’s GDP output (SSA 2011). The projected impacts such as reduced water availability, health effects on the labour force and natural resources degradation will therefore affect the sector’s contribution towards GDP (Deressa et al. 2005). The major issue therefore is whether farmers in the sugar industry have the required adaptive capacity to climate change and whether these farmers possess the ability to cope and adapt to climate changes and the accompanying consequences.

Vulnerability is a contested term despite its wide use in climate change impact studies. Studies have revealed that vulnerability is an ever-evolving field of academic enquiry that is currently fragmented as it is defined by conflicting paradigms, theories and terminologies including a lack of comparative analysis and findings (Vincent 2004). An analysis of the literature reflects that vulnerability has several meanings and these definitions are often contradictory and the term is used to mean different things by different scholars (Adger et al.
What is clear though is that the term is applied in various disciplines resulting in many conceptual and methodological approaches to its definition, interpretation and analysis as is reflected in the paragraphs that follow.

According to Kelly and Adger (2000), Sen's Entitlement Approach (1981), is often cited as having built the foundations for examining causality in a systematic way and for laying the groundwork for vulnerability analysis. On the other hand, Cutter (1996) and Blaikie et al. (1994), described vulnerability as the aspects of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impacts of natural and other hazards. Niranjan and Jayatilaka (2013), further postulated that vulnerability can be observed along a continuum from resilience to susceptibility. Vulnerability therefore measures a person or group's exposure to natural hazard effects, as well as the level to which they are able to recover from an impact. With regard to climate change, and in line with this study, vulnerability was defined by Watson et al. (1996), as the degree to which climate change may cause harm or injure a system, which depends not only on a system's sensitivity, but also on its capacity to adapt to new climatic conditions.

Chambers (1998) supports views from Watson et al. (1996) and defines vulnerability based on human perspectives and from a two-side perspective. The one side is said to be an external side to which an individual or household is exposed to climate change, and the other side is the internal side which refers to defencelessness due to a lack resources to cope without incurring loss. Cutter (1996) identified up to eighteen definitions of vulnerability offered in the literature and put such into three broad themes. The first theme has authors who consider vulnerability as a pre-existing condition related to the biophysical aspects for a community at risk. By contrast, there are those who define vulnerability as a tempered response and place greater emphasis on the resistance and resilience that societies show in the face of threats. A third type of definitions, are those that Cutter labels hazard of place that contains elements of the other two, with more explicit geographic references.

One remarkable distinction in the way social scientists and climate scientists view vulnerability. Social scientists consider vulnerability as a phenomenon that represents the set of socio-economic factors that influence people's ability to cope with stress or change (Allen 2003). Climate scientists on the other hand define vulnerability with regards to the likelihood that weather and climate related impacts would occur (Nicholls et al. 1999). Natural scientists usually focus on biophysical determinants of climate change and thus assess future vulnerability as the end-point of the analysis.

Water is the key driver and a precious input to sugarcane production (Fischer et al. 2007). All SSFAs sugarcane produced is irrigated. Irrigation is the key water user in Swaziland as it takes up to 96% of total water consumption (Matondo et al. 2005). The projections of climate change on water, as an input for agriculture, are that water will decrease, particularly with warmer climates, thereby increasing its demand. The fact that Swaziland shares all of her rivers with neighbouring countries (South Africa and Mozambique) implies the need for improved management of water resources and adaptation to predicted reduced stream flows.

As suggested by Gawander (2007), temperature changes due to climate change is projected to affect the ripening of sugarcane in that elevated temperatures are likely to hamper natural ripening and quality of sugarcane. Studies on sugarcane response to extreme changes in temperature indicate that both very high and very low extremes are damaging to the sugarcane crop (Chandiposha 2013). High temperatures and patterns of rainfall will
lead to the reduction of sugarcane yields, proliferation of pests and weeds and increased crop failures coupled with production declines (Nelson et al. 2009). Other studies (Rasheed et al. 2011), indicate that very high temperatures are likely to negatively affect sprouting and emergence of sugarcane. In addition, temperatures above 32 °C result in short internodes, increased number of nodes, higher stalk fibre and lower sucrose (Bonnett et al. 2006). According to Clowes and Breakwell (1998), high temperatures, especially at night result in more flowering of sugarcane, which ceases growth of leaves and internodes resulting in reduced cane and sucrose yields.

In fact, in the early 1960s, Humbert (1963) revealed that very cold periods were not conducive to sugarcane germination and that whenever temperatures drop below 21 °C, germination is either very slow or fails. A study by Ebrahim et al. (1998), confirmed that low temperatures of about 15 °C limit the cultivation of sugarcane while temperature increase resulting from climate change is likely to favour cane growth especially during winter months when very low temperatures constrain leaf growth rate and photosynthesis (Gawander 2007). High temperatures and droughts are likely to pose a challenge in irrigation management due to the fact that irrigation systems designs currently do not cater for anticipated increases in net daily evaporation (Schulze & Dlamini 2005). It is highly likely that more frequent irrigation cycles will be needed to meet the demand of the crop and evaporation, intensifying the competition for water between sugarcane production and other sectors (Schulze & Dlamini 2005). The effects of water stress have the greatest impact on yield during summer when potential growth is at a maximum.

In general, at least 1200 mm of rainfall per year is needed to produce sugarcane, tolerance to drought is favoured in soils which allow deep rooting and plants vary in their susceptibility to drought at different growth stages (Blackburn 1984). On effects of water shortage, Robertson et al. (1999) state that sugarcane can tolerate early season water deficits quite effectively, partly through the plant’s ability to produce new shoots. However, once the crop canopy has become well established shortage of water will lead to reduced plant growth and a reduction in sucrose yield in stalks. This therefore implies that the projected future changes in climatic conditions will render sugarcane plants more susceptible to damage from some pests and diseases (Robertson et al. 1999). Moisture deficit in sugarcane is likely to necessitate increased irrigation resulting in increased problems of salinity and rising water table. According to Harb and Columba (2010) and Matthieson (2007), the harvesting operation affects farm profitability through influencing sucrose quality since sucrose quality is a very sensitive factor that requires that the time lag between cutting and crushing at the mill is kept to the minimum to avoid quality experienced after cutting of the crop.

If flooding occurs 18 days after planting, germination is slowed or stalled resulting in reduced cane yields and sucrose content (Deren & Raid 1995). On the same token, floods leach away essential nutrients like nitrogen, phosphorus and potassium prompting farmers to use high rates of fertilizer resulting in water logging, salinity and high water table (Wiedenfeld & Enciso 2008). Sediment resulting from flooding events will cause the disruption of the normal functioning of irrigation pump house intakes and also the irrigation system. Deposition in canal systems will lead to high costs for the farmers requiring dredging to remove surplus sediment. Sediment deposition will also result in blockages or inefficiencies in irrigation infrastructure (including pumps and distribution networks) and even impact upon the produce (UNESCO-IRTCES 2011).
In assessing Swaziland sugar industry sensitivity to climate change impacts (the level upon which the industry is affected) this study employed the Sustainable Livelihoods Framework (SLF) (DFID 1999). The SLF has five livelihood asset lenses namely: natural, physical, financial, social and human assets.

**Methodological underpinnings**

**Research questions, objectives and framework**

The study responded to the question: to what extent are Swaziland’s SSFAs involved in sugarcane growing vulnerable to climate change? To address the question, a sole objective was established to assess the vulnerability of Swaziland’s SSFAs to climate change. The enquiry was carried out through utilising the DFID five SLF assets namely: natural, physical, financial, social and human assets (DFID 1999). The SLF was selected ahead of other generic vulnerability studies framework as it was deemed to be able to provide a holistic framework and picture in terms of assessing SSFAs vulnerability that could result from other non-climate variability and climate change aspects like the availability or lack thereof, of financial, social and human assets. In many instances, climate change vulnerability come in as an additional layer to already existing challenges that manifest in communities that are vulnerable like the existence of (extreme) poverty in a particular community.

**Study area**

The Lowveld region in the eastern part of the country is where the sugar industry is concentrated even though some few farms exist within the Middleveld. The main reason behind selecting the Lowveld as the study area was because it has about 70% of the 400 sugar cane farmers in the country and studies indicate that climate change will be more severe in this region (Matondo et al. 2004). Rainfall received in the study area is highly erratic, rendering the Lowveld region the most drought-prone area in the country. The region receives low rainfall (500–700 mm annually) and also experiences high temperatures (Ibid.).

The Lowveld of Swaziland was selected because it is the main area (>70%) where sugarcane is grown. Furthermore, climate change studies cited earlier revealed that the Lowveld region will experience significant impacts from climate change. Rainfall received in the study area is highly erratic, rendering the Lowveld region the most drought-prone area in the country. The region receives low rainfall (500–700 mm annually) and also experiences high temperatures (Matondo et al. 2004) compared to other regions in the country. The study area also provides a good platform for research because of the large number of emerging small-scale farmers promoted mainly by the Government towards achieving poverty eradication (SSA 2014). From the Lowveld, the study considered small-scale growers from the Komati Downstream Development Project (KDDP) managed by the Swaziland Water and Agricultural Enterprise (SWADE) and those from out-growers managed by Royal Swaziland Sugar Corporation (RSSC) and Ubombo. The final realised sample was 14 supervisors from the KDDP, 16 from the RSSC out-growers and 15 from the Ubombo Sugar out-growers SSFAs totalling to 45 respondents. Key informants were sourced from the Ministry of Agriculture (MoA), UNDP, Ministry of Natural Resources and Energy (MNRE), Meteorology Department,
Ministry of Economic Planning and Development (MEPD), senior managers within the (RSSC), Ubombo Sugar (Ltd) and Swaziland Water and Agricultural Development Enterprise (SWADE).

**Data generation instruments and sampling**

A questionnaire was used with 167 SSFAs identified in the Lowveld. From the identified SSFAs that represented more than 2700 individual farmers, a total of 45 SSFAs were systematically sampled. The main criterion was to identify SSFAs with respondents (in the form of supervisors) that would have been in the area for 10 years and above. On average, a SSFA is made up of 60 individual farmers who bring together their small portions of land. Each SSFA has a supervisor(s) who are part of committees that run the SSFA. Given the hands-on approach from the supervisors, the researchers purposively sampled them as respondents. The farming operations affected by the identified climate change hazards included; ripping and land preparation; irrigation scheduling; water management issues; harvesting; burning, ripening; dry-off; yield estimates; pest control; haulage and transportation and crushing or sugar processing.

The study also employed observations (Creswell 2006) and conducted interviews with key informants and SSFAs supervisors. Activities observed included methods of farming, farm infrastructure and the general operations and management that are performed on the farms. Secondary data was used and consisted of information obtained from readily accessible public and official documents as well as private documents which are referred to in the literature review. Information and data was collected on yields, price per ton, labour costs, fertilizer amount and cost, fuels and lubricants, equipment maintenance costs, as well as irrigation amount and cost, tonnes of sugarcane produced per hectare over the past 10 years, haulage and harvesting costs. Temperature and rainfall figures (maximum and minimum) including data on drought and flood frequencies recorded over the past 35 years for the Lowveld region were obtained from the Swaziland Meteorology Department.

**Results and discussions**

This section presents the result and discussions on the vulnerability assessment done on SSFAs in Swaziland sugarcane industry. As indicated elsewhere, the assessment followed the five assets from the SLF. The underlying assumption is that for SSFAs to adapt and build resilience to climate change, they need to fully understand their vulnerability to the phenomenon.

**Natural assets**

This is the natural resources stock where the SSFAs obtain resources needed for their agricultural strategies. The resources available reflect the features of the local natural resource base and the degree to which the SSFAs can gain access to such resources. The natural assets include land, water, clean air, forests, erosion protection and biodiversity which the communities utilise for a livelihood. The availability and access to land and water resources are discussed at length in the following paragraphs.

The results indicated that sugarcane production has been prone to multiple and frequent drought and flood stresses, accompanied by extreme temperature as a result of climate
change. Serious droughts were recorded during the following seasons: 1991–1996; 2001–2005 and 2010–2011. An interview with a small-scale farmer in the KDDP revealed that during the 2005 drought farmers made huge losses because planted seed-cane did not germinate and as a result the field had to be replanted in the next season. In the respondent’s own words:

Drought and high temperatures are our main concern as they affect cane germination and the resultant reduced yield and income. In 2005 we had to replant a field because our cane germinated but the shoot was immediately burnt out by the scorching sun. The drought situation increased the debt burden because replanting required an additional loan, and additional labour costs. (Personal Interview, February 2014)

As discussed earlier drought is the most significant stress, followed by high temperature that affects sucrose content and quality. Sucrose content is the critical determinant for income generated in sugarcane production. Key informants claimed that drought further contributed to soil erosion and water pollution of nearby water sources used for irrigation and drinking. Droughts also open opportunities for pest and disease attacks, a phenomenon confirmed earlier in the literature (Nelson et al. 2009). The pests and diseases observed include aphids, thrips, African rust, locusts and the constant threat of Chilo species. The protection of sugarcane against these pestilences requires increased money to be spent on purchasing additional herbicides and pesticides. As a result, there has been a reduction in net income. The interviewed small-scale farmer, like many who operate small farms on 100% loan with high interests suffer the most. However, during the time of fieldwork in 2015, some SSFAs seemed to be doing well (Figure 1).

Respondents further indicated that there has been increased incidence of erratic or extreme rains leading to droughts and flash flooding respectively. The impact of both flooding and drought was unquestionable, as these led to severe crop damages resulting in low yields. The farmers noted declines in seasonal rainfall, as well as an increase in temperatures, conditions which are not favourable to the sugarcane crop and the production operations. When asked about the sugarcane varieties farmers grow in the study area, 100% of them grow cultivars N19, N23 and N25. In addition N36 and N46 are grown by less than 2% of the SSFAs sampled. The farmers, however, indicated that with climate change, the N23 is facing reduced quantities as the variety does not germinate well under wet and cold conditions.

Figure 1. Photo of sugarcane fields and irrigation equipment at one of the SSFAs. Source: Fieldwork August 2014.
The N25 variety is susceptible to diseases and promotes the rapid spread of pests and diseases, leading to reduced yields and increased treatment. The brittle stalks of the N25 were noted as making it difficult for small-scale farmers to harvest effectively.

A greater portion of soils in the study area are vertisols. These are clay-rich soils associated with high water logging. The soils also shrink and swell as a result of changes in the soil moisture content. Shrinking and swelling cause serious engineering and agronomic challenges including water management and irrigation scheduling in sugarcane production. The management of such soils has been difficult even for large-scale commercial farmers.

Key informants claimed that drought and high rainfall have contributed to soil erosion and land degradation resulting in increased fertilizer demand. Sugarcane production requires land clearing and therefore soil is left bare for a considerable period rendering it susceptible to being washed away by flowing water and blown away by strong winds into nearby water sources. The SSFAs hold land under traditional management that is already characterised by high deforestation, loss of biodiversity, overgrazing, soil erosion, increased competition for scarce resources and food insecurity, adding more pressure in the face of climate change.

Key informant discussions revealed that the introduction of commercial sugarcane production through SSFAs has sparked social conflict among farmers in certain communities over land ownership, land boundaries, and access to natural resources. The commercialisation of sugarcane within tribal land areas raised the question on who belongs to which community and what the land demarcations were per each community. These conflicts have resulted in delayed operations, reduced sugarcane production, and reduced income. This is so because resolving the conflicts required the use of the already limited financial, human and time resources and delayed carrying out farming operations at the right time (Tsabedze 2005). This points to a need for a land policy, which has remained in draft form for a very long time and has not been implemented.

The farmers in the western Lowveld use irrigation water from the Komati and Mbuluzi River basins, while those from the eastern Lowveld use irrigation water from the Usutu River Basin. These are all important internationally shared river basins. The utilisation of the water therefore is regulated by bilateral and trilateral agreements such as the Joint Water Commission (JWC) (1992), Interim IncoMaputo Agreement (IIMA) (2002) and the Incomati System Operations Task Group (ISOTG) rules, implying that adherence to these at all times and by all users is important. Nevertheless, the study revealed that the impact of high temperatures has led to rapid evaporation and drying up of water in the rivers, irrigation canals and reservoirs, including irrigated fields (Figure 2). Hence flood irrigation is the main form and this has its challenges regarding water inefficiencies. In many occasions during drought conditions the river water levels are reduced leading to some sections drying up. This affects abstraction activities for sugarcane irrigation and resulting in increased pollution and over abstraction.

The high temperatures and droughts experienced in the study area affected sugarcane growth and soil moisture availability. Additionally, increased temperatures increase evaporation of water from water sources such as rivers, canals and reservoirs reducing water available for irrigation. The respondents revealed that diminishing river water resources have sparked serious concerns by Mozambique as a downstream user in recent years.

Interviews with small-scale farmers in the KDDP revealed that farmers feel that the allocated 12,000 m³ per hectare per year is not enough. It emerged that the allocation is
based on the actual sugarcane water consumption requirements, which does not cater for water losses incurred in the system from source to the field and high temperatures due to extreme weather events. This tight allocation requires efficient water management and use of efficient irrigation systems. These are aspects that even large scale farmers are grappling with. Water shortages have affected the other water dependent livelihood strategies for SSFAs such as other crop production activities, ecosystem services and livestock husbandry, thereby affecting overall income for small-scale farmers making them more vulnerable to climate change.

**Physical assets**

Physical assets analysed include the tools, machinery, roads, transport systems and infrastructure, water management systems, technology and/or communication systems, power lines, chemicals, water supply as well as sanitation and health care facilities.

Roads and transportation systems are crucial for the day to day operations and for taking the sugarcane crop from the farm to the mill. An effect on these systems results in a negative impact on the net returns received by the farmers. Results indicate that the farmers are concerned about accessibility of road infrastructure, affordability of tractors, relevant transportation equipment and the cost thereof. In as much as the main roads to the mills are tarred, the infield and feeder roads are not in a good condition due to poor maintenance and damage by heavy rainfall and floods. This situation makes transportation of sugarcane to the mills difficult and costly. Figure 3 depicts the conditions of roads to the nearest mill.

The respondents cited limitations on financial resources as the reason for spending less on roads and machinery maintenance. The heavy rainfall destroys roads and bridges including telephone lines. Roads, drains, bridges, electricity, telephones and other services are likely to be ignored until they become critical to production or a disaster triggers their need. However, not paying attention to operation and maintenance of physical assets contributes to huge losses in the long term as bad roads and unmaintained machinery and equipment affects net yields and timely delivery of good quality sugarcane at the mills which contributes to high costs of transport and haulage.

The cost of hauling and transporting harvested sugarcane from the farmers' loading zones to the sugar mill is charged on per tonne per kilometre basis by the haulage and transport
companies. Consequently, the differences in distance, puts farmers who are further away (±65 km) from the mill at a comparative disadvantage. This is in contrast to the large scale farmers who commonly travel ±15 km to the mill. At the mill, climate change has had implications for an accurate idea of the crop size expected to be crushed. The study also revealed that extreme climate events experienced in the past few years influence the start of the crushing season and the closure of the mills by at least 4–6 weeks of normal period.

The production of commercial sugarcane requires input supplies such as fertilizer, herbicides, chemical ripenners and fuel. Sugarcane production consumes large amounts of energy through irrigation and use of energy-intensive inputs, especially fertilizer. The production of sugarcane is therefore very sensitive to changes in energy prices. Consequently, energy prices affect the cost of sugarcane production which then affects SSFAs’ net returns. This is the second significant threat that could force them out of sugarcane production. Over the years the price of fuel, particularly farm diesel, has risen sharply and steadily due to a number of political and economic factors acting at the global oil markets. Increased fuel prices impact on the running of farm machinery as well as the transport of the sugarcane to the mill. For instance transport and haulage costs increased from E1.70/tonne/km in the year 2013/14 to E2.30/tonne/km in 2014/15. The increase in the fuel price meant an increase in the cost of sugarcane haulage, on farms, and an increase in costs associated with the delivery of sugarcane at the mill and input supplies needed for general on-farm activities resulting in reduced net income for farmers in the study area. Sugarcane crops are highly dependent on large amounts of inputs of fertilisers and pesticides required for high yields. Hence unfavourable climatic conditions like floods and droughts experienced in the study area have caused nutrient depletion, soil erosion, proliferation of weeds, pests and diseases resulting in an increased need for more fertilisers and pesticides.

Water storage infrastructure is very important for drought conditions, yet the results indicate that 89% of the SSFAs farmers surveyed had no on-farm water storage infrastructure. The remaining 11% claimed that the storage infrastructure they had was not enough to store water for use during drought conditions. In addition, the choice of the right irrigation system for the right climatic conditions and soils is also important in sugarcane. A range of irrigation equipment is available but SSFAs cannot afford it. Among the available equipment and irrigation systems are: drip, flood, centre pivot and sprinkler. Linked to irrigation are electricity costs incurred by the farmers for pumping water. The farmers indicated that they do not have financial and technical resources to use drip irrigation despite its water use
efficiency ideal for drought situations. About 86.6% of the respondents indicated that they practice irrigation during daytime. Other details are shown in Figure 4.

It was fascinating discovering that the bulk of the SSFAs irrigate during the day. This scenario leaves the SSFAs vulnerable to high temperatures leading to high evapotranspiration. Such a practice is not responsive to the changing climate. Farmers have also observed drastic modifications on the change of flow, quality, quantity, erosion rate and sedimentation in the river basins. This was confirmed by 34 out of the 45 respondents surveyed.

Although dams have been constructed, farmers indicated that they bring along both negative and positive impacts on their livelihoods. The positive impacts include water availability for basic human needs and irrigation for sugarcane production throughout the year. However, the negative impacts have been flood peaks that have increased downstream resulting in drowning irrigation equipment such as pumps. In addition, silt deposition was reported to have worsened over the years as the river flow lessens causing clogging of pipes thereby reducing the amount of water reaching the sugarcane crop and increasing operation and maintenance costs.

Financial assets

Financial assets are critical to SSFAs in that they can be converted into other types of capital and be used for direct achievement of livelihood outcomes and reduce climate change vulnerability. The financial assets in the form of grants, loans, profits received from sales, insurances, savings and credit are important sources for sustained livelihoods for sugarcane farmers in the study area. The unfavourable climatic conditions experienced in the study area have resulted in an increased time period taken between cutting and milling and has affected sucrose quality and net income.

Other findings were that all the SSFAs surveyed had no insurance policies against loss and damage cause by extreme weather events like droughts and floods. In addition, 97% of the SSFAs sampled did not have drought preparedness plans. Likewise, all SSFAs surveyed did not have a flood management plan. Climate change stresses will necessitate insurance cover which is currently not catered for by insurance companies and is not required by financial institutions. Taking up weather index based insurance covers will result in increased operational costs and further reduce farmer revenues.

The study indicates that currently the farm operation costs are too high and they affect profit margins SSFAs farmers. The operational costs related to sugarcane include crop upkeep (irrigation, water, electricity, maintenance of irrigation equipment, fertilizer, chemicals, drainage); Fixed Asset Maintenance (light and heavy equipment, fuel and lubricants, building and

![Figure 4. Access to irrigation by time zones (n = 45). Source: Fieldwork 2014.](image)
general repairs, depreciation and labour for maintenance); Overheads (administration, employee rations and provision of social services); and harvesting (cutting, loading and transportation). The small-scale farmers spent about 38% on upkeep of the sugarcane crop, 13% on labour costs, 38% on harvesting, 4% on maintenance and 7% on overheads. A comparison of operational costs with other categories of farmers is shown in Figure 5.

These results indicate that crop upkeep and harvesting are the twin costly aspects in operating the SSFAs’ sugar production. From interviews, it emerged that unexpected rains received during harvesting resulting from extreme weather events as a result of climate change lead to very high labour rates and costs as well as delayed arrival of cane to the mills. Harvesting costs are particularly high for SSFAs due to longer distances to the mills that come with further complications during flood events. For example, harvesting and haulage costs have skyrocketed from about E12,000.00 per hectare in 2005 to E22,000.00 per hectare in 2009.

The cost of fuel, inflation and exchange rate further impact negatively on the SSFAs. For example, crude oil prices affect the domestic price of petrol and diesel, thereby escalating operational costs related to crop upkeep. The Swaziland currency – the ‘Lilangeni’(E), its pegged to the South African Rand and any changes in exchange rate of the Rand against the US Dollar and other currencies have direct impacts to the SSFAs. An interview with a representative from the SSA revealed the following:

The combined effect of oil price changes and exchange rate movements experienced over the years has affected the costs of inputs such as fertilisers, chemicals, farm equipment and machinery. This is so because small-scale farmers are solely dependent on the availability and accessibility of finance through loans provided by from banks. The interest rate charge adds to the financial stress already experienced by the farmers though increased costs of inputs.

(Sources: Personal communication, February, 2014)

Sugar prices are of material value to the livelihoods of SSFAs. Since the Swaziland sugar market is too small to consume all the sugar produced, more than 90% of the sugar is exported to regional and international markets. The main markets supplied include: the European Union (EU), United States of America (USA) and South African Customs Union (SACU). Under the SACU, Swaziland enjoys preferential access to the EU under the Economic Partnership Agreement (EPA) and to the Common Market for Eastern and Southern Africa (COMESA). On the contrary, the USA market is accessed under a tariff rate quota and therefore contains some restrictions on sugar marketing by Swaziland. The sugar price paid to the

---

**Figure 5.** Operation costs across different growers categories. Source: Authors (Data from RSCC, 2013).
farmer is subject to a number of complex factors at the global scale that include high import tariffs, pressure from Brazil and other leading sugar producers, the reform of the European Common Market Agricultural Policy (CAP) and the European Union Sugar Regime. Usually the farmer’s net profit is calculated based on prevailing sugar prices on the market. In some instances the forecasted price is lower than the price actually paid and sometimes higher than the price actually paid due to the complexity of sugar markets (Figure 6). A lower price forecast is preferable than a high sugar forecast which result in the farmer receiving much less than was planned for. Ultimately, reduced market earnings due to price fluctuations expose SSFAs to limited resilience and adaptation strategies linked to disposable incomes that could support other livelihoods.

The frequent unfavourable climatic conditions increased input costs and fluctuating sucrose price all add up to the complex situations sugarcane farmers operate under. It is unfortunate that the farmers are paid on the basis of sucrose quality and content only without including the added benefits of the whole produce delivered at the mill which are bagasse, filter muds and molasses excluding cane tops that remain at the farm. For instance the millers use bagasse as a source of power generation and molasses sold to manufacturers internally and internationally. A situation where SSFAs become stakeholders in the use of bagasse for electricity generation needs to be followed up by the relevant government arms and farmer associations.

**Social assets**

Social assets are the social resources upon which the farmers draw on in pursuit of their livelihood strategies. They include networks that increase trust, connectedness, ability to work together, membership of more formalised groups and exchanges that facilitate co-operation, reduce transaction costs and may provide the basis for safety nets. Policies and institutions are an important set of social assets in the study area that influence the range of livelihood options and access to assets and vulnerability to shocks. The important social asset to the farmers in the study area include the farmers’ groups and associations, mill groups, input supply companies, membership in irrigation districts and river basin authorities, informal social networks formed within communities, policies, institutions and knowledge.

![Figure 6. Sugar pricing 2009–2013 seasons. Source: Authors (Data from RSSC, 2013).](image-url)
Farmer associations are the most important asset for the small-scale growers as such platforms permit farmers to meet and share information. This asset offers learning and problem solving opportunities. The study, however, revealed that the farmer associations have weak social cohesion caused by internal social conflicts and mistrust. It emerged during key informant discussions that the management structure within a farmer association is usually influenced by favouritism instead of merit. This often compromises the proper farm management especially in instances where the management committee lacks critical business skills. This system neglects the availability of skilled and experiences of not so popular personnel that could positively contribute towards the sustainability of SSFAs.

An estimated 86% of the respondents revealed that extension services are very crucial in the sugar industry for climate change knowledge and information support. The variability nature of the climate in the study area shows that extension services and farmers need to be abreast of projected changes. Nevertheless, the study identified the gap in information and advice required for understanding climate change and necessary relevant adaptation as an addition to the information on sugarcane production currently rendered to farmers. Since 86% of the farmers indicated that they rely on extension officers for climate extension officers, there is a need for regular training and capacity building to upgrade their skills and knowledge to help farmers improve their adaptive capacity to impacts of climate change.

The study also looked at policies. Key policies relevant to the study include the Livestock Development Policy (1995), Draft Land Policy (1999), Irrigation Policy (2006), the Water Act (2003), Environment Management Act (2002) and the Sugar Act (1967). The enforcement of the Water Act (2003) calls for the establishment of water user groups which would be responsible for water allocation and management. The study however, revealed that even though the water user organisations are in place as established by the Water Act (2003), major hurdles are experienced regarding financial, capacity and political aspects required to operationalise them. There is currently no established financial support afforded the newly established organisations to kick-start operations. Moreover, there is no appetite in devolving powers from the DWA to these organisations due to limited capacity. Needless to say operationalising these water user organisations would improve integrated water resources management at the local level and thereby improve adaptive capacity of the sugarcane farmers to the prevailing climatic stresses.

On the other hand, the 1999 Draft Land Policy remains as such and affects land and related resources management in the traditional land holdings – the Swazi Nation Land. There exists no land demarcation, the Chief’s powers and authorities are not clear and there are no clear land rights or entitlements which renders SSFAs vulnerable to unfavourable decisions by the Chiefs. Not having clear land rights or titles affects SSFAs in that they cannot use the land as collateral for attaining credit from financial institutions.

The study further revealed that banking institutions prohibit small-scale farmers from inter-cropping sugarcane with other crops, even though this would allow farmers to produce both food and cash crops and increase profit margins. An example was given where, one SSFA in the KDDP planted maize at the end of the sugarcane field in 2003 with the aim of attaining food security, but the financial institution officials directed it to remove it. The reason given was that the maize crop would compete with the sugarcane for nutrients and water affecting yields. As part of the financing agreement, the banking institutions have a clause that prohibits the intercropping of sugarcane. Although intercropping may be
permitted, the banks are of the view that the SSFAs do not have the high level skills needed on field management to safely practice it.

**Human assets**

An analysis of human assets in the study area indicates that they are necessary to make use of any of the other four assets described earlier to improve sugarcane production and livelihoods. It emerged that education, knowledge and skills were very critical in tackling climatic related stresses. The literacy and basic education rates vary among the farmers and SSFAs had the lowest compared to those medium and large scale farms. The skills challenge was aggravated by migration of such to better paying jobs in urban areas and/or through employment by large scale farms. To this end SSFAs remain vulnerable to extreme weather events as they are not able to manage such effectively and adapt.

Aspects on health and nutrition were investigated. Swaziland has one of the highest prevalence of HIV/AIDS in the world. Records indicate that the highest proportion of the HIV infected populations (32%) is in the age group 20–49 years (SHIMS, 2012). This age group is economically active and usually supply labour for sugarcane production. Although probing more on the HIV/AIDS status of SSFAs human asset was not part of this research, an attempt was made to understand other non-sensitive dimensions. It emerged that HIV/AIDS has led to the damage of social capital, weakening of institutions and heightened poverty levels through death or lost working days, especially during harvest time. While one respondent indicated that, unlike the large scale farmers that have functioning and within proximity health facilities that operate 24 h, SSFAs are located far away and serviced mainly by three health centres and/or clinics (Mangweni Clinic, Dvokolwako health centre and Mkhuzweni clinic). These only operate on a normal business eight-hour day and are located on average more than 20 kilometres away. The main public hospital (Good Shepherd Hospital) that operates 24 h and one which is affordable to SSFAs workers is located on average more than 60 km. Furthermore, food insecurity worsens the HIV/AIDS dilemma. People living with HIV/AIDS and its treatment require proper diet and adequate food to maintain strength, energy, and a healthy immune system.

**Summary of findings and conclusions**

Through the analysis lenses provided by the SLF, the study came up with a number of key findings. It emerged that the SSFAs sugarcane production has been prone to multiple and frequent drought and flood stresses, accompanied by extreme temperature as a result of climate change. Serious droughts were recorded during the following seasons: 1991–1996; 2001–2005 and 2010–2011 and flooding during 2000. Interviews showed that during the 2005 drought, farmers made huge losses as planted seed-cane did not germinate and they could only plant again the next season. Droughts further open opportunities for pest and disease attacks. Pests and diseases observed include aphids, thrips, African rust, locusts and the constant threat of *Chilo* species. All the SSFAs grow sugarcane cultivars that include N19, N23 and N25. An estimated 2% of SSFAs also grow N36 and N46 cultivars. The farmers, however, indicated that with extreme weather events recurring, the N23 cultivar is facing reduced quantities as it does not germinate well under wet and cold conditions. Furthermore, the
N25 variety is susceptible to diseases and promote to the rapid spread in pests and diseases, leading to reduced yields and increased treatment.

A total of 87% of the respondents from the surveyed SSFAs indicated that they did not have water storage and adequate irrigation infrastructure, an aspect that increased their vulnerability to drought and increased temperature. Among the available equipment and irrigation systems were: drip, flood, centre pivot and sprinkler. However, the farmers indicated that they did not have financial and technical resources to use drip irrigation despite its water use efficiency that is ideal for drought situations, with 86.6% of the respondents indicating that they flood irrigate during daytime. Irrigating during daytime leaves the SSFAs vulnerable to high temperatures leading to high evapotranspiration and such a practice is not responsive to the changing climate. Although dams have been constructed, farmers indicated that they bring along both negative and positive impacts on their livelihoods. The positive impacts include water availability for basic human needs and irrigation for sugarcane production throughout the year. However, the negative impacts have been flood peaks that increased downstream resulting in the drowning of irrigation equipment such as pumps. There is also silt deposition that was reported to have worsened over the years as the river flow lessens causing clogging of pipes thereby reducing the amount of water reaching the sugarcane crop and increasing operation and maintenance costs.

Other findings were that all the SSFAs surveyed had no insurance policies against loss and damage cause by extreme weather events like droughts and floods. In addition, 97% of the SSFAs sampled did not have drought preparedness plans and likewise, all SSFAs surveyed did not have flood management plans. These results further revealed that crop upkeep and harvesting are the twin costly aspects in operating the SSFAs’ sugar production. From interviews, it emerged that unexpected rains received during harvesting result in very high labour rates and costs as well as delayed arrival of cane to the mills. Furthermore, an estimated 86% of the respondents revealed that extension services were crucial in the sugar industry for climate change knowledge and information support. The variability nature of the climate in the study area shows that extension services and farmers need to be abreast of projected changes. Nevertheless, the study identified the gap in information and advice required for understanding climate change, presenting a vulnerability gap.

The study therefore concludes that SSFAs in Swaziland are vulnerable to the impacts of climate change. This conclusion is drawn from the fact that land and water resources which are the main resources for sugarcane production are poorly managed. This situation is made worse by incidences of droughts and floods which have increased over the years due to climate change. Unsustainable land use practices upstream of the farms affect soil productivity and with frequent floods resulting from climate change this situation is worsened. On the same token, physical assets are becoming very costly to the small-scale farmers and climate change is adding to this costs. The need for high volumes of water, high quantities of fertilizer and pest control is necessitated by frequent drought and flood incidences. To improve this situation the sugar industry of Swaziland requires to shift towards a highly productive and robust agricultural system which requires ameliorations and high efficiency in the management and use of natural resources such as land, water, soil nutrients, and genetic resources. The agriculture development policies and programs need to promote climate-smart agriculture from planning to implementation phases in order to reduce climate change vulnerability and promote adaptive capacity of the sugar industry. The 1999 Draft Land Policy needs to be fast tracked into finalisation so that matters regarding title deeds
and the promotion of sustainable land use mechanisms are addresses in order to improve SSFAs' adaptive capacity at the farm level and beyond. The findings of this study can provide additional insights to similar situations across Africa. This recommendation is made knowing well that climate change vulnerability issues are highly localised, an element that limits us to generalise the findings.

Note
1. As of 4 September 2013, the exchange rate was averaging $1 to E8.95.

Disclosure statement
No potential conflict of interest was reported by the authors.

ORCID
Bon'sile Faith Nicollete Mhlanga-Ndlovu http://orcid.org/0000-0002-8408-2132

References
Adger WN, Brooks N, Bentham G, Agnew M, Eriksen S. 2004. New indicators of vulnerability and adaptive capacity. Tyndall Centre Technical Report, No.7. Norwich, Tyndall Centre for Climate Change Research, University of East Anglia.
Allen K. 2003. Vulnerability reduction and the community-based approach. In: Pelling M., editor. Natural disasters and development in a globalising world, 170–184. New York (NY): Routledge
Blackburn F. 1984. Sugar-cane. 1st ed. London: Longman (Tropical Agriculture Series); p. 414. ISBN 0-582-46028X.
Blaikie P, Cannon T, Davis I, Wisner B. 1994. At risk: natural hazards, peoples vulnerability and disasters. London: Routledge.
Bonnett GT, Hewitt ML, Glassop D. 2006. Effects of high temperature on the growth and composition of sugarcane internodes. Australian J Agric Res. 57:1087–1095.
Chambers R. 1998. Editorial introduction: vulnerability, coping and policy. IDS Bulletin. 20:1–7.
Chandiposha M. 2013. Potential impact of climate change in sugarcane and mitigation strategies in Zimbabwe. African J Agri Res. 8:2814–2818.
Clowes MJ, Breakwell WL. 1998. Zimbabwe sugarcane production manual. Chiredzi: Zimbabwe Sugar Association.
Creswell JW. 2006. Qualitative inquiry and research design: choosing among five approaches. Thousand Oaks, CA: Sage.
Cutter S. 1996. ‘Vulnerability to environmental hazards’. Prog Human Geogr. 20(4):529–539.
Department for International Development (DFID). 1999. Sustainability livelihoods guidance sheets. London: DFID.
Deressa T, Hassan R, Poonyth D. 2005. Measuring the economic impact of climate change on South Africa's sugarcane growing regions. Agrekon. 44:524–542.
Deren CW, Raid RN. 1995. Yield components of sugarcane subjected to flood at planting. Belle Glade, FL: University of Florida/IFAS. Everglades Research and Education Center; p. 33430.
Ebrahim MKH, Vogg G, Osman MNEH, Kamor E. 1998. Photosynthetic performance and adaptation of sugarcane at suboptimal temperatures. J Plant Physiol. 153:587–692.
Fischer G, Tubiuello FN, van Velthuizen H, Wiberg DA. 2007. Climate change impacts on irrigation water requirements: effects of mitigation, 1990–2080. Technol Forecasting Soc Change. 74:1083–1107.
Gawander J. 2007. Impact of climate change on sugar-cane production in Fiji. WMO Bull. 56:34–39
Government of Swaziland (GoS)-UNDP. 2014. Water resources vulnerability assessment report.
Government of Swaziland. 1967. The Swaziland Sugar Act.
Government of Swaziland. 1995. Livestock Development Policy.
Government of Swaziland. 1999. Draft land policy.
Government of Swaziland. 2002. Environment Management Act.
Government of Swaziland. 2003. Swaziland Water Act. No. 5 of 2003.
Government of Swaziland. 2006. Irrigation policy.
Harb JC, Columba CH. 2010. Financial and economic feasibility of sugarcane production in northern Lapaz. Ottawa: Latin American and Caribbean Environmental Economics Program, International Development Research Centre (IDRC).
Humbert RP. 1963. The growing of sugar cane. New York (NY): Elsevier.
IPCC. 2007. Climate change 2007: impacts, adaptation and vulnerability. In Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, ML. Parry OF, Canziani JP, Palutikof PJ, van der Linden, Hanson CE, editors. Cambridge: Cambridge University Press; 976.
Kelly PM, Adger WN. 2000. Theory and practice in assessing vulnerability to climate change and facilitating adaptation. Clim Change. 47:325–352.
Knox J, Rodriguez W, Díaz JA, Nixon DJ, Mkwanazi M. 2010. A preliminary assessment of climate change impacts on sugarcane in Swaziland. Agric Syst. 103:63–72.
Manyatsi AM, Mhazo N, Masarirambi MT. 2010. Climate variability and changes as perceived by rural communities in Swaziland. Res J Environ Earth Sci. 2:165–170.
Mathieson L. 2007. Climate change and the Australian Sugar Industry: impacts, adaptation and R & D opportunities. Australia: Sugar Research and Development Corporation.
Matondo JI, Peter G, Msibi KM. 2004. Evaluation of the impacts of climate change on hydrology and water resources in Swaziland: Part II. Physics Chem Earth. 29:1193–1202.
Matondo JI, Peter G, Msibi KM. 2005. Managing water under climate change for peace and prosperity in Swaziland. Physics Chem Earth. 30:943–949.
Mhlanga NK. 2010. Evaluation of the impact of climate change on the inflow to Lubovane reservoir Case study of Usutu catchment, Swaziland. A Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of Master in Integrate Water Resources Management (IWRM) of the University of Dar Es Salaam, Tanzania.
Nelson G, Rosegrant M, Koo J, Robertson R, Sulser T, Zhu T, Ringler C, Msangi S, Palazzo A, Batka M, et al. 2009. Climate change: impacts on agriculture and costs of adaptation food policy report. Washington (DC): International Food Policy Research Institute.
Nicholls RJ, Hoozemans FMJ, Marchand M. 1999. Increasing flood risk and wetland losses due to global sea-level rise: regional and global analyses. Global Environ Change. 9:S69–S87.
Niranjan F, Jayatilaka W. 2013. Vulnerability to climate change: a comparative study of perceptions and capacities of selected villages in Sri Lanka. Working paper. Patancheru (AP): International Crops Research Institute for the Semi-Arid Tropics.
Rasheed R, Wahid A, Farooq M, Hussain I, Basra SMA. 2011. Role of proline and glycine betaine pretreatments in improving heat tolerance of sprouting sugarcane (Saccharum sp.) bud. Plant Growth Regul. 65:35–45.
Robertson MJ, Inman-Bamber NG, Muchow RC, Wood AW. 1999. Physiology and productivity of sugarcane with early and mid-season water deficit. Field Crops Res. 64:211–227.
Schulze RE, Dlamini DJM. 2005. Case study 3: potential impacts of a hypothetical, but plausible, climate change scenario on within country reservoir management for irrigation, and out-of-country flow obligations in the Mbuluzi Catchment, Swaziland. In: Schulze RE, editor. Climate change and water resources in Southern Africa: studies on scenarios, impacts, vulnerabilities and adaptation. Pretoria: Water Research Commission. Chapter 14, RSA, WRC Report 1430/1/05; p. 249–254.
Sen A. 1981. Resources, values, and development. Cambridge, MA: Harvard University Press.
Simelane L. 2009. Climate change adaptation within the sugar industry of Swaziland. A thesis submitted in partial fulfilment for the Degree of Master of Science in Environmental Studies at the University of the Witwatersrand, South Africa.
Swaziland Sugar Association (SSA). 2008. The marketing of Swazi Sugar and getting an allocation. Volume 24 March 2008.
Swaziland Sugar Association (SSA). 2011. Swaziland Sugar journal. Mbabane.
Swaziland Sugar Association (SSA). 2013. Swaziland Sugar journal. Mbabane.
Swaziland Sugar Association (SSA). 2014. Swaziland Sugar journal. Mbabane.
UNESCO-IRTCES. 2011. Sediment issues & sediment management in Large River Basins interim case study synthesis report. Beijing.
Tsabedze K. 2005. Factors affecting the viability of small-scale sugarcane businesses – a case study of KDDP: Unpublished report.
Vincent K. 2004. Creating an index of social vulnerability to climate change in Africa. Working Paper No. 56. Norwich: Tyndall Centre for Climate Research, University of East Anglia.
Watson RT, Zinyowera MC, Moss RH. 1996. Climate change 1995: impacts, adaptations and mitigation of climate change: scientific-technical analyses. Cambridge: Cambridge University Press.
Wiedenfeld B, Enciso J. 2008. Sugarcane responses to irrigation and Nitrogen in Semiarid South Texas. Agron J. 100:665–671.