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Review

Potential impact of climate change in sugarcane and mitigation strategies in Zimbabwe

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Sugarcane production is important to the economy of Zimbabwe by contributing to Gross Domestic Product (GDP), employment creation and foreign currency generation. However, its production is likely to be affected by climate change due to projected increase in temperature and changing rainfall patterns. This paper reviews the possible effects of climate change in the agronomy of sugarcane. Temperature rise due to climate change is projected to increase cane growth during winter although it may result in increased irrigation needs. Increased temperature will also alter the prevalence of weeds, diseases and insect pests in sugarcane production. The changing rainfall patterns due to climate change may result in water stress induced by drought although harversting efficiency is expected to increase. The paper also expounds on the mitigation and adaptation strategies that can be employed in the sugarcane industry as a way of reducing losses in sugarcane production.

Key words: Climate change effects, temperature, rainfall, adaptation, mitigation and sugarcane.

INTRODUCTION

Sugarcane is mainly grown in the South Eastern Lowveld of Zimbabwe for sugar, ethanol and other by products like molasses, filter cake and bagasse (Clowes and Breakwell, 1998; Esterhuzein, 2012). Sugar industry in Zimbabwe is contributing significantly to the economy of the country, for example in 2005 sugarcane contributed 1.4% of Gross Domestic Product (Annual Action Programme, 2009). In addition, it is estimated that sugar industry in Zimbabwe employs 25,000 people directly and 125,000 people indirectly (Esterhuzein, 2012). The livelihood of people in the South Eastern Lowveld of Zimbabwe and surrounding areas relies much on sugar industry. More than 60% of sugar produced in this part of the country is exported to neighbouring countries and European Union, generating foreign currency substantially. Despite all these benefits associated with sugar industry in Zimbabwe, just like other crops the production of sugarcane has not been spared from the potential effects of climate change. According to Challinor et al. (2007), climate change is anticipated to increase temperature and vary rainfall patters. To date global mean temperatures have increased by about 0.7°C since mid-1800s although the temperature increase is not uniform (IPCC, 2007). Sugarcane production is mainly situated in South Eastern Lowveld because the area experience high temperatures favoured by the crop (Clowes and Breakwell, 1998). Therefore, the increase in temperature is likely to impact sugarcane production. Global warming due to influx of greenhouse gases is also expected to alter the precipitation pattern and again have an effect in sugarcane production in the South Eastern Lowveld of Zimbabwe since the crop require large quantities of water. Therefore, the objective of the research is to look at the potential effects of climate change in sugarcane production of Zimbabwe and suggest mitigation and adaptation strategies for the country.

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CLIMATIC FACTORS AFFECTING SUGARCANE PRODUCTION

Temperature

United Nations Framework Convention on Climate Change 2007) coined that if nothing is done on Green House Gases (GHG), the temperature is expected to increase by about 3°C by 2030. This temperature increase is likely to have an effect on physiological processes of sugarcane plant. Since sugarcane is a C_4 plant species whose photosynthetic pathway increases carbon dioxide assimilation with increase in temperature in the range of 8 to 34°C (Gawander, 2007; Sage and Kubien, 2007). The temperature increase due to climate change is likely to improve cane growth during winter since very low temperatures constrain leaf growth rate and photosynthesis although this increases sucrose accumulation (Gawander, 2007). Ebrahim et al. (1998) revealed that low temperatures of 15°C limited cultivation of sugarcane. Hypothetically, temperature increase due to climate change during this period of low temperature is likely to increase sugarcane yields. Furthermore, Mathieson (2007) reported that high temperatures are likely to reduce incidence and severity of frost, extending growth during winter months. Frost is known to reduce pol percentage in sugarcane and thus poor quality (Clowes and Breakwell, 1998).

However, high temperatures is likely to negatively affect sprouting and emergence of sugarcane (Rasheed et al., 2011). Poor emergence of sugarcane will result in significantly low plant population. In addition, temperatures above 32°C result in short internodes, increased number of nodes, higher stalk fibre and lower sucrose (Bonnett et al., 2006). The temperature in the South Eastern Lowveld can sour up to 42°C during the period of August to March. Climate change if unabated is likely to reduce sugarcane and sucrose yields. Furthermore, Clowes and Breakwell (1998) revealed that high temperatures especially at night usually result in more flowering of sugarcane. Flowering in sugarcane ceases growth of leaves and internodes, this reduces cane and sucrose yields.

The increase in temperature due to climate change is also likely to alter the net daily evaporation which is essential in irrigation scheduling. Climate change is likely to pose a challenge in irrigation since the designing does not cater for anticipated increase in net daily evaporation. High net daily evaporation due to high temperatures may cause water stress in sugarcane.It is highly likely that more frequent irrigation cycles will be done to meet the demand of the crop and evaporation. Frequent irrigation cycles are likely to pose a problem of over irrigation. Over irrigation in sugarcane can potentially create waterlogging and salinity problems which can depress sugarcane yields (Kahlown and Azam, 2002). Frequent irrigation cycles to meet high evaporation rates is likely to require more irrigation water from the storage reservoir, intensifying the competition for water between sugarcane production and other sectors.

It is also projected that a shift in temperature due to climate change will have an effect on some of biotic factors like diseases, insect pests and weeds in sugarcane production (Neumeister, 2010). For example, Matthieson (2007) reported that the incidence of smut disease is likely to increase due to high temperatures. The prolific of dry weather exacerbate the symptoms of Ratoon Stunting Disease (RSD). Smut and Ratoon Stunting Diseases are among the biotic stresses which considerably reduce cane in the South Eastern Lowveld of Zimbabwe (Clowes and Breakwell, 1998). Apart from smut and RSD, some difficult weeds in cane that grows in summer like shamva grass (*Rottboelia conchincinensis*), *Ipomoea plebia* and finger grass (*Digitarias angunalis*) are expected to increase with high temperatures. While some winter weeds like onion weed (*Dipcadi spp*) may be seen reducing due to elevated temperatures. High temperatures due to climate change may cause genotypes of some of these weeds to mutate, making it difficult to control them. The temperature increases during winter may cause some weeds that commonly grow in summer to appear in winter since their dormancy will have been broken by temperature changes. Insect pests which are problematic to sugarcane like Black Maize Beetle (*Heteroncychus licas*) and pearly scale (*Margarodes spp*) populations will not be spared by temperature changes. For example, the emergence of black maize beetle is triggered by high temperatures among other factors. Matthieson (2007) reported that temperature changes are likely to introduce new pests and diseases in sugarcane growing areas.

Temperature changes due to climate change will affect the ripening of sugarcane. Gawander (2007) reported that lower temperatures during winter are very important for natural ripening of sugarcane. Sugarcane ripening is important in increasing quality of sugarcane. Elevated temperatures due to climate change are likely to reduce natural ripening and quality of sugarcane. Besides natural ripening, chemicals like ethrel, fusillade super and roundup may be used for ripening sugarcane, although, this may carry an extra cost in sugarcane production.

Rainfall

Climate change is expected to shift precipitation patterns in the next century (Intergovernmental Panel on Climate Change Secretariat, 2007). Some scientists are predicting more frequent droughts (Held et al., 2005), while others project more wetter conditions (Kamga et al., 2005) and yet other authors (Huntingford et al., 2005) predict small changes in rainfall in the next century.

However, it is now acceptable that climate change may be characterized by extreme values (wet and dry years)

(Challinor et al., 2007). Extreme values in rainfall will have an impact on cane and sucrose yield in the South Eastern Lowveld of Zimbabwe (Wheeler et al., 2000; Porter and Semenov, 2005).Frequent droughts due to climate change will have a negative effect on sugarcane as the crop requires a lot of water. It is projected that more dry years are likely to cause greater competition for water resources between sugarcane production and other sectors like mining, domestic use resulting in the decrease in amount of available water (Matthieson, 2007; USGCRP, 2009). Any decrease in amount of available water to sugarcane will cause water stress which is likely to alter physiological processes like photosynthesis, stomatal conductance, respiration and photo-assimilate partitioning (Gardener et al., 1984). The adjustment of these physiological processes is thought to reduce crop growth and yield of sugarcane (De Silva et al., 2007). In order to mitigate moisture deficit in sugarcane, farmers are likely to irrigate more and this may increase problems of salinity and rising water table. However, reduced precipitation during “dry off” and harvesting period is likely to increase efficiency of harvesting and quality of cane (Matthieson, 2007). Increased harvesting efficiency of sugarcane will curtail harvesting costs, usually associated with sugarcane production.

On the contrary, wetter years are likely to cause floods which may leach away essential nutrients like nitrogen, phosphorus and potassium. Nitrogen is one of the most limiting factors in sugarcane production (Wiedenfeld and Enciso, 2008). The farmers are likely to use high rates of fertilizer during wetter years. Floods and adoption of high fertilizer rates is likely to exacerbate water logging, salinity and high water table. Waterlogging may deprive sugarcane root system of oxygen, facilitate formation of toxic compounds and inhibit uptake of nutrients (Glover et al., 2008). While salinity is characterised by accumulation of salts in the soil solution and these are toxic to plants. Increased precipitation is likely to reduce the efficiency of harvesting sugarcane and also quality of cane due to inadequate “dry off” period.A shift in precipitation due to a change in climate is also likely to have an impact on prevalence of diseases, insect pests and weeds of sugarcane. There are some weeds like *Cyperus* spp. which decrease with more frequent of droughts. While termite and nematode populations is expected to increase due to warm and dry conditions associated with climate change (Clowes and Breakwell, 1998). The change in precipitation is likely to alter genes of some weeds, pathogens and insect pests, making them difficult to control (Harmon et al., 2009).

MITIGATION AND ADAPTATION STRATEGIES OF SUGARCANE TO CLIMATE CHANGE

Since climate change is projected to reduce sugarcane yields in the next century, it is vital to come up with mitigation strategies that can lower the effects. A number of mitigation measures can be drawn from understanding the potential effects of climate change relying much on climate models. However, the projections of climate change using models are uncertain because of errors that may be encountered in these models (Mall et al., 2004).

Water stress generated by high temperatures and low rainfall can be mitigated by growing varieties that are tolerant or resistant to drought. Inman-Bamber et al., (2012) reported that sugarcane cultivar differences in drought adaptation exist. Researchers should thereforecontinue to breed sugarcane varieties or cultivars that adapt to drought conditions or greater water use efficiency (Matthieson, 2007). Clowes and Breakwell (1998) reported that *Saccharum officiranum* is the widely grown cultivar in Zimbabwe although *S. barberi and S. sinense* cultivars have been found to tolerate environmental stress despite low cane yield. It is also important that farmers grow a number of varieties than relying on a single variety (Challinor et al., 2007). This will reduce the risk of failure in the event that one variety fails due to excessive moisture stress.

Besides breeding new varieties of sugarcane to mitigate effects of climate change, scientists can also use biotechnology to reduce abiotic and biotic stresses associated with sugarcane (Cheavegatti-Gianotto et al., 2011). Genetically modified sugarcane has a potential of increasing yield, drought tolerance and insect resistance of sugarcane. Biotechnology also releases varieties faster than conventional breeding of sugarcane. However, in Zimbabwe the technology have not yet been accepted as there are concerns on health and environmental issues. Also biotechnology requires highly skilled researchers and capitol to procure the equipment to be used which may be limiting in Zimbabwe.

Another adaptation strategy to low rainfall due to climate change is to invest in irrigation infrastructure like dams, canals and pumps (Matthieson, 2007; Parry et al., 2004). Zimbabwe like other developing countries is trailing behind in irrigation development as most of its infrastructure is not working after its land reform due to theft, dilapidation and vandalism (Nhundu and Mushunje, 2010). However, investment in irrigation development will reduce the likely competition of water resource between sugarcane production and other sectors. Besides increasing irrigation infrastructure, it is essential to increase the efficiency of irrigation (Matthieson, 2007). This encompasses reducing losses of water due to leaks, properly scheduling irrigation and investing in irrigation technologies like trickle tape. High irrigation efficiency will save water in the midst of low rainfall and also reduce cost of production when yields are expected to be low due to moisture stress.

Climate change is projected to result in floods in some areas or years. Since floods result in waterlogging conditions, salinity and raised water table, reducing yields significantly (Glaz et al., 2004), it is therefore important to adapt sugarcane production to such conditions. Drainage systems in the fields that are likely to be affected (flat) areas may need to be installed. Once the drainage improves, excessive salts causing salinity can be leached by irrigation (Clowes and Breakwell, 1998). Varieties that adapt to waterlogging and saline conditions may be grown.

Besides mitigating the direct effects of climate change, cultural practices that exacerbate climate change may be reduced for example sugarcane burning prior to harvest. Sugarcane burning before harvesting, a common practise in Zimbabwe is important for removing leaves and insects to facilitate manual cutting of cane. However, Levine (2000) argued that this practice releases greenhouse gases like carbon dioxide, methane, non-methane volatile organic compounds and nitrogen gases which increases effects of climate change. Alternatively, sugarcane can be harvested without burning as it was the practice until 1940s (De Resende et al., 2006). Burning practices prior to harvesting has been phased out in São Paulo State due to protocol that was signed to eliminate this practice by 2014 (Goldemberg et al., 2008). In order to complement harvesting without burning, self-trashing varieties may be adopted (Clowes and Breakwell, 1998). According to De Figueiredon and La Scala (2011), conversion from burning to green harvest can increase the amount of sugarcane residue and this may have an impact on soil properties. Sugarcane residue is important in weed suppression, increases the content of organic matter in the soil which increases water holding capacity; improve soil structure and biological activity in the soil. However, no burning of sugarcane prior to harvesting have got its problems like reduced tillering, reduced available nitrogen during wetter years and increase in certain pests and diseases (Clowes and Breakwell, 1998).

Another cultural practice that increases the effects of climate change is burning sugarcane trash. In Zimbabwe, after harvesting sugarcane, tops, burned and unburned leaves which make up trash is cleared from all ridges and placed in every eighth of the ridge in the field. This is done to allow free flow of irrigation and to reduce interference of trash with land preparation. The trash in every eighth of the ridge is burned. This practice exacerbates the effects of climate change since burning trash releases greenhouse gases. Alternatively, trash may act as mulch and can be windrowed to control wind and water erosion (Clowes and Breakwell, 1998). Trash when decomposed may release essential nutrients like nitrogen that may be taken by the crop (Vallis et al., 1996). Therefore, use of organic nitrogen sources like sugarcane residues can improve the nitrogen content of the soil (Giller, 2001).

However, N present in sugarcane residues are released slowly (Vitti, 2003). Potentially, use of trash can reduce nitrogen requirement of the crop from inorganic sources. Use of high rates of inorganic nitrogen increases the effects of climate change (UNESCO and SCOPE, 2007; Keating et al., 1997). Also salinity is associated with use of high rates of inorganic nitrogen.

Furthermore, in Zimbabwe, when sugarcane is ploughed out in preparation for a new crop, many operations which make up land preparation are involved. The operations may include pre-discing, ripping, ploughing, post-discing, land planning and ridging (Clowes and Breakwell, 1998). Many operations of land preparation usually result in more fuel being used. Since most of the fuel used in sugarcane production at South Eastern Lowveld of Zimbabwe is produced from fossil fuel. Using large quantities of such fuel releases more greenhouse gases that exacerbate the effects of climate change. Therefore it is vital, that operations for Land preparation be kept at minimum. This also reduces the cost of production in the midst of sugarcane yield declining as projected by climate change.In addition, fossil fuel can be replaced by bio fuel to power transport vehicles in the sugarcane industry (Shumba et al., 2011).

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