Climatic Change, Its Likely Impact on Potato (*Solanum tuberosum* L.) Production in Kenya and Plausible Coping Measures

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**Abstract** Potato is a cool season crop and plays an important role in Kenya’s economy. The crop is mostly grown under rain-fed conditions. However, most parts of Kenya are warming up in line with global trends and, information on how climate change will impact on potato production is presently lacking. An analysis of the literature in this area shows that changes in climate will lead to shifts in areas suitable for potato production, reduced yields and poorer quality of tubers for processing while demand for potato irrigation is also expected to increase. Distribution of pests (e.g. aphids, potato tuber moth and leaf miners) and diseases (e.g. late blight, bacterial wilt and viruses) are expected to increase since high temperatures allow more cycles of multiplication leading to greater pressure of pests and diseases. Seed potato produced under high vector pressure may degenerate fast due to viral infections. To remain competitive, the potato industry needs to embrace innovative strategies in adapting to climate change. New varieties adapted to extreme weather conditions (heat and drought tolerant) and possessing other desirable traits such as short dormancy, early maturity, pest resistance and/or tolerance will need to be developed. Investments will be required in irrigation infrastructure and in improved storage for both seed and ware potatoes since higher temperatures will most likely make it difficult to keep both seed and ware potatoes from season to season. Agronomic technologies that conserve soil moisture and lower soil temperatures will need to be adopted.

**Keywords** Climate change; Potato production; Kenya

**1 Introduction**

Agriculture is an important sector in the Kenyan economy, contributing about 26% to the GDP (Gitau et al., 2009). More than 1/3 of Kenya’s agricultural produce is exported and this accounts for 65% of Kenya’s total exports (GOK, 2007). About 80% of Kenyans work in the agricultural sector; most of whom are small scale subsistence farmers that depend on rainfall for production of their staple foods (ANN, 2009; Gitau et al., 2009).

Kenya has seven agro-climatic zones, with only 12% of the land being suitable for rain-fed arable farming; the rest (88%) is semi arid, arid, and very arid and therefore unsuitable for arable farming (Figure 1; Table 1).

The high potential land for cultivation in Kenya is mainly concentrated in highlands on both sides of Rift valley and the former Central and Eastern provinces (Downing, 1992). The low potential areas are mainly constrained by lack of water (Downing, 1992). According to Kassam et al. (1991) growing seasons in Kenya are defined as the period during which rain exceeds 50% of potential of evapo-transpiration.

**2 Potato Production in Kenya**

Among the staple food crops, maize is the most important followed by potatoes in terms of volumes produced and consumption in Kenya (ANN, 2009). Potato is grown by about 800,000 farmers cultivating about 161,000 hectares per season with an annual production of about 3 million tonnes in two growing seasons (Lutaladio et al., 1995; GTZ-PSDA, 2011; MoALF, 2016). The annual potato crop is valued at KSh. 50 billion (USD 500 million) at farm gate prices (GTZ-PSDA, 2011; MoALF, 2016). Beyond the farm, the industry employs about 3.3 million
people as market agents, transporters, processors, vendors and exporters (ANN, 2009; MoALF, 2016). In addition potato is a vital source of calories, proteins, vitamins, potassium and fiber.

Figure 1 Agroclimatic zones in Kenya (FAO, 2008)

Table 1 Characteristics of agro-climatic zones in Kenya

| Agro-Climatic Zones | Classification          | Moisture Index (%) | Annual rainfall (mm) | Land Area (%) |
|---------------------|-------------------------|--------------------|----------------------|---------------|
| I                   | Humid                   | >80                | 1100-2700            | 2             |
| II                  | Sub-humid               | 65 - 80            | 1000-1600            | 5             |
| III                 | Semi humid              | 50 - 65            | 800-1400             | 5             |
| IV                  | Semi humid-Semi Arid    | 40 - 50            | 600-1100             | 5             |
| V                   | Semi Arid               | 25 - 40            | 450-900              | 15            |
| VI                  | Arid                    | 15 - 25            | 300-550              | 22            |
| VII                 | Very Arid               |                    | 150-350              | 46            |

Note: Modified from: Sombroek et al. (1982)

Potato production is concentrated in the highlands (1500-3000 masl) under rain-fed conditions in the former Central, Eastern and Rift valley provinces. These are areas surrounding Mt. Elgon, Mau escarpment, the Aberdare range, the edges of the rift valley and the slopes of Mt. Kenya (MOA, 2008; FAO, 2013). The former Central province produces over 37% of the national potato yields followed by Rift Valley Province (27%) and Eastern Province (19%) (MoA, 2008; FAO, 2013). In Central province, Nyandarua county is the largest potato producing area (MoA, 2008). In Eastern province, the main potato growing county is Meru; in the Rift Valley province, potatoes are grown in Kericho, Bomet, and Uasin Gishu counties (MoA, 2008).

Based on geographic location, production practices and variety preferences, the traditional major potato growing areas are divided into five regions (Figure 2):
Mt. Kenya region mainly comprising Meru Central and parts of Nyeri and Laikipia counties.
Aberdares and Eastern Rift Valley, mainly comprising of Nyandarua and parts of Nyeri, Kiambu and Nakuru counties.
Mau region comprising Bomet, Kericho, Narok and parts of Nakuru county.
Mt. Elgon, comprising Elgeyo Marakwet, Bungoma, West Pokot, Trans Nzoia and Uasin Gishu counties.
Others highlands, such as Taita hills in Taita Taveta county in the southern border of Kenya and Tanzania (Kaguongo, 2010).

Other emerging potato growing areas include Nandi, Baringo, Laikipia, Nyamira and Kisii counties (Figure 2). Due to increased demand, potato production has expanded to non-traditional potato growing areas such as Kirinyaga, Naivasha and Tana River. This is possibly due to availability of irrigation facilities (MoALF, 2016).

Despite the importance of potato in Kenya, its production has been declining in recent years (Figure 3); this is mainly due to lack of good quality seeds and, pests and diseases (Muthoni and Nyamongo, 2009; MoALF, 2016); low and erratic rainfall accompanied by high temperatures which are occasioned by climate change are also
Potato growing zones in Kenya have a bi-modal rainfall pattern with the long rains falling between March and June and the short rains from September to November. Exceptions are Meru which receive long rains in October to December while in Kisii and Kericho, long rains occur in January to March and short rains in July to October (Muthoni and Nyamongo, 2009). Because potato production in Kenya is mainly rainfed, the bi-modal rainfall pattern determines potato supply; consequently, this determines prices due to high perishability of the produce as well as lack of adequate storage facilities (MoALF, 2016). These potato growing areas also experience an average minimum temperature of 8°C and an average maximum temperature of 23°C (Kinyae et al., 2004; Jaetzold et al., 2006). These highlands also receive an annual rainfall of between 1050 to 1900 mm and have good soils (Guyton et al., 1994; MoA, 1998; Kinyae et al., 2004). However, in the recent past, parts of these regions have been experiencing low and erratic rainfall leading to a significant reduction in potato yield and quality (Figure 4).

3 Impact of Climate Change on Crop Production
Impacts of climate change might be positive or negative depending on regions. For many regions however, global warming will bring about a decrease in annual and seasonal rainfall, more erratic weather patterns and more intense and frequent extreme weather events such as heatwaves, drought, storms and floods (Spore, 2015). The low relative humidity due to decreased rainfall will favour increased insect vectors and viruses while high relative humidity due increased rainfall will favour increased bacterial and fungal infections (Spore, 2015).

Climate change might negatively affect crop production especially in developing countries (Nelson, 2009). For example, about 90% of the sub-Saharan African population depends on rainfed agriculture for food production and climate change could result in decreased crop yields of 18% for southern Africa and 22% across sub-Saharan Africa (Spore, 2015). The IPCC (2007) predicted a rise in global temperature by 1.8–4°C by the year 2100. In addition, Africa will very likely (with > 90% probability) experience warming in greater measure than the global average in all seasons (Lobell and Burke, 2010). Agricultural yields are not the only thing under threat from climate change; a warmer climate could also make staple food crops more toxic. For example, mycotoxins commonly found in maize, wheat sorghum and groundnuts are a real health concern in the hot, humid countries (Spore, 2016). In addition, when a plant is stressed and in poor health such as during a heat wave or drought, it can become more vulnerable to fungal infections (Spore, 2016).

4 Impact of Climate Change on Potato Production in Warm Areas like Kenya
Production of cool season crops like potatoes in the warm tropical areas will likely be a huge challenge in the face of global warming. Potato is a cool season crop and grows best between 15°C and 18°C (Haverkort, 1990). Potato is particularly vulnerable to heat due to its narrow production "window"; it requires mean daily temperatures of 18-20°C and night-time temperatures less than 15°C (Borah et al., 1962). High temperatures delay, impede or even inhibit tuber initiation (Minhas et al., 2006). It has also been suggested that high temperature reduces yield by inhibiting starch synthesis in tubers (Krauss and Marschner, 1984; Mohabir and
John, 1988). According to Foti et al. (1995) and Haverkort (1990), water stress and moderate rise in temperature generally leads to yield and tuber quality losses. Potato responds to any change of precipitation regime; excess or deficient soil moisture is said to cause significant yield losses (Saue and Kadaja, 2009). According to Mackerron and Jeffries (1986), water stress before tuber initiation reduces tuber set per stem.

5 Disease Incidences

Potato production in Kenya is affected by a number of diseases, chief among them being late blight (Kaguongo et al., 2008). It is highly destructive during the rainy season especially in the cool highlands (Kaguongo et al., 2008). With unpredictable weather, unprecedented heavy rains in potato growing areas are likely to create conditions favourable for serious late blight outbreaks. For example, in 2002, 2003 and 2006 unexpected heavy rains pounded Tigoni area (Kiambu county) leaving a trail of destruction on potato fields due to late blight. Although development of late blight resistant varieties has been a focus of the Kenya national potato programme in collaboration with the International Potato Centre (CIP) (KARI, 2000), durable resistance has been elusive.

In addition to late blight, bacterial wilt (caused by Ralstonia solanacearum) is a common disease contributing to potato yield reduction (Kaguongo et al., 2008). Although the cool-climate adapted race 3 of the pathogen is the principal cause of bacterial wilt of potatoes in the highlands (Smith et al., 1995) it also occurs in potato plants grown in warmer locations from seed tubers harvested from cool areas (French, 1994). With the expansion of potato production into warmer lowlands and the warming up of the cool highlands, cases of lowland bacterial wilt caused by race 1 (biovars 1, 3 and 4) have occurred (French, 1994; EPPO, 2004). In Kenya, both pathogen races are present causing an estimated yield loss of between 50% and 75% (Rotich et al., 2010).

Furthermore, the hot and dry conditions are likely to increase the incidences of insect vectors and viral diseases. The most common viruses in Kenya are Potato Virus X (PVX), Potato Virus Y (PVY), Potato Virus S (PVS) and Potato Leaf Roll Virus (PLRV) (KARI, 2000). Most potatoes in Kenya are grown from seed tubers retained by farmers from previous harvests, acquired from markets or from neighbours (Khurana and Garg, 2003). Viruses are spread by insects especially aphids; the incidences of which increase as conditions become warm and dry. Seed tubers from infected plant most likely pass the infection to the resultant plant upon planting; the rapid buildup of viruses in warm and dry conditions leads to rapid degeneration of seeds.

6 Possible Mitigation Measures

To mitigate against the effects of climate change, it is necessary to grow potatoes that are tolerant to high temperatures, common diseases and pests, and drought (IPCC, 2007). In addition, other measures such as minimum tillage and irrigation may have to be adopted. Coping strategies may be broadly grouped into breeding, seed, postharvest and agronomic interventions.

6.1 Breeding

The identification or the development of potato cultivars with increased heat and drought tolerance appears to be important in coping with climate change (Hijmans et al., 2003). Breeding for increased heat tolerance will need to focus on the effect of temperature on tuberization (Haverkort, 2008) since potato tuber initiation and development are much more sensitive to high temperature stress than photosynthesis. Development of early-maturing varieties with shorter growth cycles will allow the crop to 'escape' stresses such as drought (Robert, 2003; David, 2007). When breeding for heat tolerance, quality aspects such as susceptibility to secondary tuber growth, accumulation of reducing sugars and reduced glycol-alkaloids are other aspects that must also be factored in during development of new varieties (Haevekort, 2010). Since diseases are likely to intensify under high temperatures, it is necessary to breed for resistance to the most critical ones such as bacterial wilt, Erwinia and viruses. It is instructive that resistance to bacterial wilt (R. Solanacerum) has remained elusive (Wolfgang, 2009).

6.2 Seed

Hot and dry conditions favour rapid multiplication of insects especially aphids which are vectors of viruses in potatoes. Accumulation of viral load in seed tubers leads to rapid degenerating from one season to the next. The
situation is worsened by the fact that over 90% of the farmers plant seeds they save from previous harvests, or they acquire from markets or neighbours (Khurana and Garg, 2003; FAO, 2013). Farmers can improve their seeds from informal sources through positive selection. To assure high quality seed, the process of producing basic seeds should be rapid and should minimize the number of times the pre-basic seeds are multiplied in the field; frequent exposure of seeds to the soil leads to rapid build-up of soil-borne pathogens such as bacteria as well as viruses. Production of large number of minitubers through rapid multiplication techniques (RMT) such as aeroponics and hydroponics allows for rapid bulking of basic seeds in only two field generations rather than the conventional four to six. This not only reduces the cost of producing basic seeds but also prevents the build-up of diseases in the field. Potatoes are largely propagated through tubers; there is a great risk of introducing alien pathogens or pests into the region through seed tubers movement. Measures to prevent/avoid introduction of pests and diseases include zoning or quarantining seed production areas as well as strict observation and enforcement of importation regulations.

6.3 Postharvest

Unlike many vegetables and fruits, potatoes can be stored for several months without serious loss of quality. Improved crop storage can help reduce market supply and price volatility by allowing the harvest to be more evenly distributed throughout the year. Ware potato should be stored in a suitable environment to prevent weight loss, rot, shrinkage, sweetening, dis-colouring and sprouting (Gottschalk and Christenbury, 1998). Additionally, seed potatoes need to be stored to maintain their dormancy pending planting in the next season. An ideal method for seed storage particularly among small scale farmers is use of the diffuse light store (DLS). In Kenya, KARI-Tigoni in collaboration with other development agencies such as USAID and the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) have been promoting use of DLS, which allow for better potato seed storage and uniform sprouting.

6.4 Agronomic interventions

Agronomic practices such as planting time, irrigation, minimum tillage, mulching and intercropping are recommended to increase water percolation into the soil, reduce surface runoff, reduce evaporative loss and increase water use efficiency.

*Planting date:* Planting date results in the greatest differences in growth and yield of potato crop; the situation is compounded by the low and erratic rainfall occasioned by climate change. Although potato has a narrow planting window, planting early in the season helps the crop to grow and mature before drought times set in (Mendoza and Estranda, 1979; Robert, 2003; David, 2007). One strategy that farmers can use to maintain or increase crop yields in the face of a changing climate is to adjust planting dates (Lauer et al., 1999). According to Kucharik (2006) planting dates can change over time due to changes in climate as well as changes in technological and socio-economic factors. Effective use of planting date as an intervention strategy depends on reliable weather forecasts.

*Irrigation:* Climate change will most likely lead to increased need of water harvesting and improved water use efficiency. Rainwater harvesting will primarily involve the collection, storage and subsequent use of captured rainwater as either the principal or as a supplementary source of water. Over eighty percent of Kenya’s landmass is hot and dry and therefore unsuitable for arable farming. However, Kenya has two major fresh-water rivers, Tana and Athi River, which have traditionally been used mainly for production of paddy rice in irrigation schemes. The Kenyan government having realized the huge potential the country has in improving food sufficiency through prudent use of irrigation water is putting a lot of emphasis into expanding the irrigation schemes in the country (GoK, 2007). In addition, there is need to increase productivity of these irrigation schemes through crop diversification. In most of these irrigation schemes, paddy rice is the main food crop; it is rotated with maize. The irrigation board has been seeking alternative crop with which to rotate with rice because maize takes a long time to mature; a short-duration crop such as potatoes could fill in the gap. Introduction of potatoes as one of the rotational crops to replace maize may play an important role in increasing productivity of
the irrigation schemes since potato matures early and has many uses (Muthoni et al., 2016). One of the irrigation methods that can be employed to improve water use efficiency is drip irrigation. Drip irrigation has the potential to use scarce water resources most efficiently. The major benefits of drip irrigation are the ability to apply low volumes of water to plant lots, reduce evaporation losses and improve irrigation uniformity (Schwankl et al., 1996). High-frequency water management by drip irrigation minimizes soil as a storage reservoir for water, provides at least daily requirements of water to a portion of the root zone of each plant, and maintains a high soil matric potential in the rhizosphere to reduce plant water stress (Phene and Sanders, 1976). Many studies have shown drip irrigation to be well suited for row crop and potato production (Sammis 1980; Shalhevet et al., 1983).

Minimum tillage and mulching: Minimum tillage increases soil moisture retention in case of potato, this reduces the number of weedicings and hilling, thus reducing loss of moisture by exposure of the soil and reducing labour. Mulching can be used to conserve soil moisture as well as raise the soil organic matter content. This, in turn, increases the soil’s water holding capacity, thus reducing runoff and erosion and making more water available to plants (Midmore, 1991).

Intercropping: Intercropping (growing multiple crops on one plot) leads to more biodiversity within a plot and more efficient utilization of soil nutrients, moisture and solar radiation. Intercropping protects the plants from being lodged during floods and reduces moisture loss through evaporation of the soil surface (Midmore, 1985).

7 Conclusion and Future Perspective
Adapting potato to climate change to ensure optimum production is critical in enhancing food security in Kenya. Consequently, potato production in traditional areas need to be enhanced while new potato production areas particularly in the arid and semi-arid areas need to be explored. Potato breeders may have to explore more germplasm and employ modern breeding techniques including molecular approaches to develop suitable varieties; development of early maturing, heat and drought tolerant and well as pest and diseases resistant varieties is crucial. Participatory variety selection will need to be employed so as to ensure varieties developed meet consumer expectations. Climate change adaptation strategies in potato will need to be promoted vigorously if crops yields are to be sustained and the contribution of potato to national objectives of food security and income generation is to be maintained.

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