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Towards Sustainable agriculture: Sugar beet production in Kenya as a potential viable solution to the current sugar deficit

An analysis of possibilities and challenges

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I dedicate the thesis paper to all the stakeholders in the Kenyan sugar sector to sustainably address the problems in the sector as well as the aspirations and needs of the poor farmers. The paper is dedicated too to academicians and researchers as a data base being the first step towards scientific analysis on sustainable sugar beet production in Kenya

Abstract

The research was carried out in the two Districts of Kakamega and Nyandarua in Kenya. The broad objective of the research was to analyze the potentials and challenges in sustainable sugar beet production in Kenya as a potential viable solution to the current sugar deficit. A specific objective was to identify and by use of GIS (Geographical Information System) map out potential sites within the study areas where sugar beets could be sustainably produced. Other objectives were to identify challenges and analyze the economic, social and environmental impact of sugar beet production in Kenya.

The potentials and challenges were categorized into social, biophysical (temperature, precipitation, soils and diseases) and economic. Results from both Kakamega and Nyandarua Districts indicate strong desire for sugar beets by the native farmers. The most desired characteristics in the new crop blend well with the farmer's aspirations and needs.

Precipitation and temperature are sufficient for both study areas regarding optimal sugar beet yield. The soil types for Nyandarua present a good potential for sugar beets since more than a half of the soil types are deep, well drained, fertile and with good water holding capacity. In Kakamega, the soil types can support sugar beets, however, large portions of the soils may respond well to liming. All the soils in the two regions would respond positively to fertilizers regarding yield. Clay soil textures constitute a substantial percentage area in both Districts. Soils especially with heavy clay texture may retain excessive water and hence provisions for good drainage systems will be advantageous. A number of potential sugar beet diseases do exist in both study areas. Therefore, the main challenges from the biophysical potential point of view would be to seek for mechanisms to minimize production cost and environmental impact from liming, fertilizer application, drainage and disease prevention/control.

Over ¾ of the total area in each District is in the sub-optimal zone 2 (good) for sugar beet production. This is estimated from a potential sugar beet map created by help of GIS by overlaying temperature, precipitation, soil type and soil texture. It is possible to obtain optimal sugar beet yield for the tropics under this zone if good agronomic practices are adopted and the farmers educated. The cost of producing sugar beets at the farm level would probably be higher than that for sugar cane therefore, a more comprehensive research is recommended to study the economic potential. Another challenge to the economic viability of the project is the current lack of sugar beet processors in Kenya.

Considering the social, biophysical and economic potentials and challenges from an integrated point of view, illustrates a potential for large-scale sugar beet production in both study areas. The sustainability issue would not be effectively estimated from the findings of this paper alone and hence a comprehensive research is recommended.

Scenarios were predicted to illustrate the likely trend in the sugar sector between the year 2001 and 2030 (30 year period). The results of the scenarios confirm that sugar beets can be one of the viable solutions to the current sugar deficit in Kenya.

Key words: Sustainable agriculture, Soils, Temperature, Precipitation Diseases, GIS,

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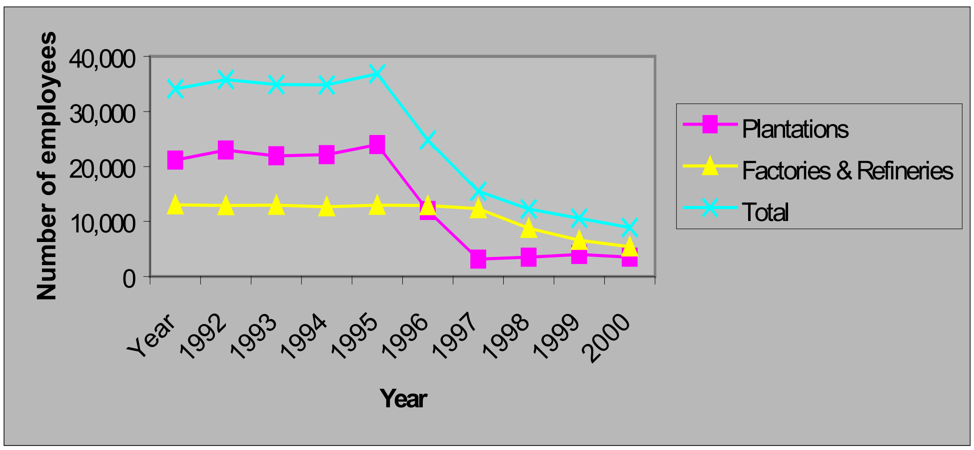
1.0 Introduction

1.1 Background of the study

Sugar beet is a fleshy root crop processed for sugar production. It is usually associated with the temperate climate. Sugar beets mature in five to six months (David, D. and A. Young 1981). They have an average sugar content of 15% and optimal yield between 40 and 60 tons beet/ha for the tropical climates (Doorenbos, J. and A.H. Kassam 1979). Currently, all the sugar processed in Kenya comes from sugar cane. Sugar cane is another crop that is processed for sugar production. It does well in tropical and sub-tropical climates. In Kenya the sugar cane matures in 18 to 24 months (Mumias Sugar Company Limited 1996). As per SUCAM, (Sugar Campaign for Change) (2002), the sugar sector contributes substantially to 34% to the Kenyan Gross Domestic Product (GDP) and provides employment (direct and indirect) to a substantial proportion of the Kenyan population. Figure 1 illustrates direct wage employment in the sugar industry.

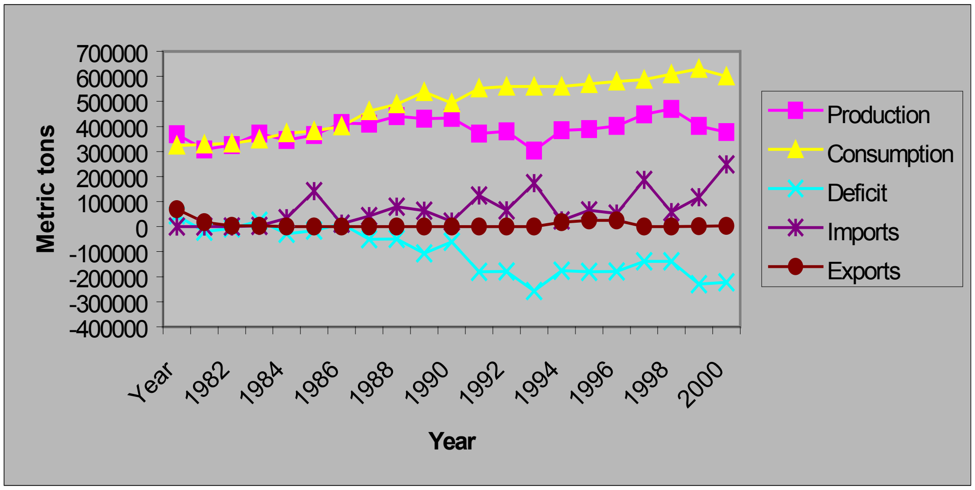
Figure 1: Number of people with direct wage employment in the sugar industry excluding casual workers



Data source: Kenya Sugar Board (2001)

Despite the fact that the sugar sector is very important to Kenya, the Kenya Sugar Board report (2001) illustrates a highly erratic but generally declining trend in the processed sugar yield in the last couple of years as illustrated in figure 2. The Kenya Sugar Board report (2001) attributes the declining sugar production trend mainly to harvesting and processing of premature cane coupled with a reduction in the total tonnage of cane supplied to the factories. Based on this observation, it is logical that the current sugar deficit in Kenya can only be met by sustainably increasing the supply of mature canes (raw materials) to the sugar processing factories. The issue of premature cane can be solved by investing in research and development aimed at varieties that can mature in a relatively shorter period than the current canes and/or, adopting a new crop that matures faster as a supplement to the sugar cane. Kenya Sugar Research Foundation (KESREF) has a number of ongoing research projects on early maturing cane varieties. However, to date they have not come up with a suitable variety for Kenya. " High altitude, low temperature, dry spells all retard sugar cane growth. Even early maturing varieties like D8484 and D8415 take 16 to 18 months to mature at Mumias whereas the same varieties take 9 months to mature in Guyana". (Personal communication with Mr. Titiya, Training Manager, Mumias Sugar Company)

Figure 2: Kenya sugar statistic for 18 years (1982 to 2000) in metric tonnes

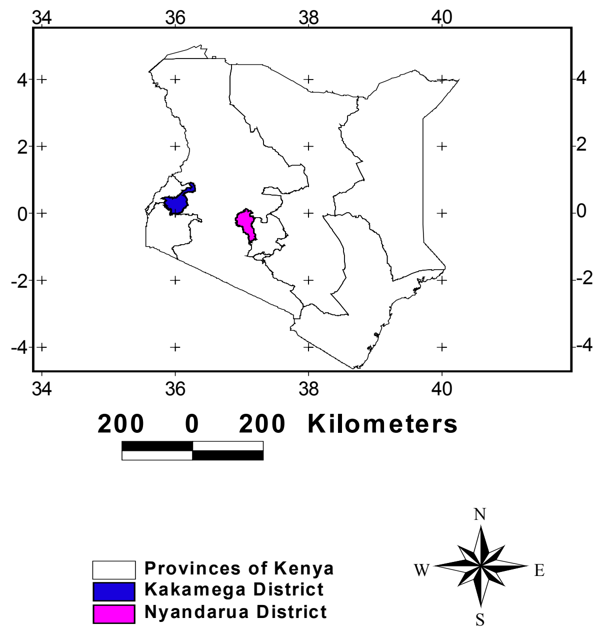


Data source: sugar board report (2001)

During the last three years there has been an ongoing sugar beet trial project by Kiriita Agricultural Self Help Group in the Nyandarua District. The project is purely a group project not based on any scientific research but out of ambition to have at least one cash crop in the area whose byproducts can also serve as animal feed. This is especially essential during the cold season when grass pasture is not available to the animals (personal communication with Mr. Wilfred Geita, Chairman Kiriita Agricultural Self Help Group). Inspired by the impressive performance of the sugar beets at the trial sites in Nyandarua, this research points to the possibilities and challenges of sustainably introducing sugar beets in Kenya. Beets are deemed to be one of the viable solutions to the current sugar deficit. This is based on the recognition that unlike sugar cane, sugar beets have a shorter maturity period, between five and six months, (David, D. and A. Young 1981) hence can address the harvesting of premature sugar cane. Additionally sugar beets have a potential of doing well on quite a wide variety of soils and climatic conditions (Loman G. 1986). This may imply that introduction of sugar beets probably may expand the sugar industry out of the traditional sugar cane-producing areas, and hence provide opportunity for more sugar production. Consequently, the introduction of sugar beets as a supplement to sugar cane may open up a window of opportunity for crop diversification, hence minimizing the risks associated with losses from diseases and pests or adverse weather conditions that may affect one crop in the case of monoculture.

This research shall be limited to Kakamega and Nyandarua Districts of Kenya. To be examined shall be the social, biophysical and economic potentials and challenges for sugar beets in Kenya as well as the implications of its introduction. Refer to figure 3 for geographical locations of the study areas.

Figure 3: Geographical locations of the study areas (i.e. Kakamega and Nyandarua Districts of Kenya)



Modified from Mud Spring Geographers, Inc. (2001)

1.2 Objectives

The objective of the study is to analyze the opportunities and challenges of sustainable sugar beet production in Kenya as a potential viable solution to the current sugar deficit.

Specifically, it is to:

- Identify and analyze the physical potential (Soils, precipitation, temperature, and diseases) for sugar beets and to map out potential sites within the study areas where sugar beets would be introduced with the aid of GIS (Geographical Information Systems). *(GIS is a "computer-based capability for the manipulation of geographical data". The system handles geographical information/data. GIS can process, analyze and store the geographical data. It can be used to make GIS maps to show spatial patterns of various themes. The system links the information on the GIS maps to attribute data and hence provide non-topographical information for the users of the maps. Through these, GIS is a tool that can be used to improve on environmental and resource management) (Bernnidsen, T. 1999)*
- Identify and discuss the possible challenges that would be encountered in the process of sugar beet production including social, environmental and economic impact/implications.

1.3 Significance of the study

The research is of interest since the information generated can help serve the following services:

- Provide information to government, investors and other interested groups on the possibility of sustainable sugar beet production in Kenya.
- Open a window of opportunity for the policy makers in Kenya to address the sugar deficit sustainably.

- Provide a basic database for further research on sustainable sugar beet production in Kenya
- Provide basic information to the farmers on the potentials, limitations and possibilities for sustainable investment in sugar beets.
- Provide opportunity for reliable income to the poor farmers.

1.4 Scope and limitations

Sugar beet is a new crop in Kenya that until now has not been grown for any commercial purposes. Therefore, this study will look at opportunities and challenges of sustainable sugar beet production in Kenya. The main focus shall be on soils, precipitation, temperature, and diseases, social and economic viability.

The study shall however be limited to Nyandarua and Kakamega Districts of Kenya (figure 3) The two Districts are deemed to be the potential areas for sugar beet production in the country. The main limitations of this study are:

- Information on tropical sugar beets was sufficiently accessed but from a few Journals and books since not much is documented on tropical sugar beets.
- The time provided both for thesis research and report compilation. This necessitated the exclusion of some important aspects of the study such as influence of global market, weeds, pests and infrastructure.

Despite of the limitations, this study is useful, unique and presents a first step towards scientific analysis on sustainable sugar beet production in Kenya.

2.0 Literature review

The research review section has adopted an integrated approach towards analysis of the possibilities and challenges in introduction of sugar beets in Kenya. The section has been divided into three main parts for analysis, i.e. social, biophysical and economic potentials and challenges.

2.1 Social challenges and potentials

This section of the research discusses the potential social opportunities and challenges that may arise from the introduction of sugar beets in Kenya.

"To be sustainable, development must flow from priorities of the society in which it is taking place" (UNDP –(United Nations Development Programme) 1996). This implies that any successful research and/or project must seek to meet objectives that reflect the needs of the local population. Therefore, the local people should be involved as much as possible in "problem and solution identification and prioritization through use of participatory approach"(UNDP 2003,)

The research therefore recognizes the need to seek for the local desires and aspiration on the sugar sector as well as the local performance of sugar beets. This would be achieved through the use of questionnaires to gather ideas and views from local farmers.

2.2 Biophysical potentials and challenges

This section reviews the potential biophysical opportunities and challenges that may impact sugar beet production in Kenya. The factors discussed are diseases, soils, rainfall and temperature. These are deemed to be the main factors that may present serious limitations/opportunities to sustainable sugar beet production. However, a comprehensive study is beyond the scope of the present thesis.

2.2.1 Diseases

Sugar beets are known to have quite a large number of diseases that have a potential of reducing the sugar beet yield drastically if precautionary/control measures are not taken in time (Gatineau, F., et al., 2001) Like any other crop, diseases can affect the economic viability of the sugar beets in two ways.

Firstly, diseases may reduce crop yield. This is by making the crop weak. Weak crops are less vigorous hence cannot develop a canopy large enough for sufficient carbon fixation for optimal yield. In extreme cases the diseases may wipe out the whole sugar beet crop. This is especially true when diseases hit in the early stages of sugar beet establishment and growth. (Duffus, E.J. and Ruppel, E.G. 1995)

Secondly, economic losses might arise from the cost incurred in spraying pesticides to prevent/control diseases, thereby increasing the cost of production and reducing income from agriculture. Further on, pesticides may pose a health risk to the user and increase the risk of environmental pollution through leaching/runoff into water and soil, which could contribute to further economic losses from costs of treatment/compliance to environmental legislations.

Consequently, Duffus, E.J. and Ruppel, E.G. (1995) found that diseases could influence spatial distribution of crops. This is because various diseases have definite thriving conditions and hence tend to be distributed where the conditions suit them most. Therefore, a profit oriented investor in quest for high profits would invest in areas where he can get maximum profit with minimum input. Thus, the disease free/little disease potential areas would be preferred and hence affecting the spatial distribution of crops.

It is crucial that an extensive study is carried out on the potential sugar beet diseases in Kenya and that their spatial distribution patterns are determined. Maria Nihlgård -Manager of Plant Pathology Department-Syngenta Seeds AB, Sweden, have Fusarium (Fusarium yellows), Cercospora (leaf spot), downy mildew, Pythium (Pythium root rot), Rhizoctonia (root and crown rot), Sclerotium (Sclerotium root rot) and Erwina (beet vascular necrosis and rot) as main potential diseases in the tropics (Kenya) (personal communication). Following is a brief discussion of these diseases. The discussion is meant to increase the understanding of the diseases as well as serve as a framework to precisely predict spatial distribution patterns of the diseases and the potential impact on yield and environment. (Nutter, F. W., et al., 2002).

Cercospora disease thrives well at 25° C to 32° C in humid weather with 60% relative humidity. The disease affects the leaves of the sugar beet plant. Cercospora disease develops brown necrotic leaf spots in most of the leaf surface, eventually making the affected leaves to fall off. Since leaves are important in plant photosynthesis, the result will be poor root yield in terms of tons root weight as well as low sugar content. How much of the yield in tons and sugar content that will be lost depends with the stage at which the beets are infected and the intensity of the infection. The disease has to be controlled if any substantial economic gains shall be expected from the sugar beet cultivation. However, there are commercial sugar beet varieties resistant to Cercospora disease. The disease can also be controlled effectively through use of disease free seeds, crop rotation (2-3 years) and application of a wide range of fungicides. (Duffus, E.J. and Ruppel, E.G. 1995)

Downy Mildew is a disease that thrives well in temperature range 4° C to 7° C and in wet weather. However, in areas with high relative humidity (80 to 90%) the disease can thrive at even higher temperature (Duffus, E.J. and Ruppel, E.G. 1995). The disease attacks young seedlings where it affects the leaves making them "wither, yellow and die" Duffus, E.J. and Ruppel, E.G. (1995). According to Kungu, J. N. and E.R. Boa (1997), the disease has a potential of destroying up to 90% of young crops. This is real a big loss that by any standards beats that logic of economical investment. But it is noteworthy that also in this case, there are commercial varieties resistant to the disease. The diseases can also be effectively controlled or reduced by early sowing, crop rotation and the use of a variety of fungicides. (Duffus, E.J. and Ruppel, E.G. 1995)

Fusarium disease thrives well at an optimal temperature 28 ^{o} C in soils with excess water (Duffus, E.J. and Ruppel, E.G. 1995). The disease causes wilting of the vascular system. The wilting of the vascular system will hamper the smooth transportation of water, minerals and other food substances within the crop resulting in stunted growth consequently death of the affected crops. Under suitable thriving conditions (warm soil temperature 28 ^{o} C, sandy soils), the disease can result in enormous losses to crops. The disease can remain viable in the soil for a long period of time and cannot be effectively controlled by a crop rotation programme. Seedbed sterilization is the most effective method of controlling the disease but the method is too expensive and can only be economically used in green houses. Therefore, the only economically viable way of controlling the disease is the use of healthy seeds. (Kungu, J. N. and E.R. Boa 1997)

Sclerotium is a disease that thrives well in warm climate with temperatures above 25 ^{o} C. The disease invades and adversely affects young seedlings causing death. The disease results in dampening off and rot of almost all parts of the plant including tubers (Duffus, E.J. and Ruppel, E.G. 1995). Therefore without proper control of the disease at the young ages of plant growth and development, large losses can be incurred including loss of whole stands. The disease can be controlled through effective crop rotation, deep ploughing and wide range of fungicides. No resistant varieties are available at present. (Kungu, J. N. and E.R. Boa 1997)

Erwina is a bacterial disease that affects sugar beets upon injury to the crop at favourable thriving conditions. The disease thrives well at a temperature range of 25^{o} C to 30 ^{o} C and wet soils. It causes "black streaks along the petioles, a white froth in the center of crowns, and wilt following severe root rot. Root symptoms vary from soft to dry rot, and vascular bundles become necrotic" (Duffus, E.J. and Ruppel, E.G. 1995). Erwina has a potential of leading to losses as high as 40% and hence need to be controlled to secure the crop. There are resistant varieties for the control of the disease. Avoiding physical injury to crops especially during cultivation can also control the disease. (Duffus, E.J. and Ruppel, E.G. 1995)

Rhizoctonia is a disease that thrives well at 25 ^{o} C to 33 ^{o} C. It is a disease of the seedlings that causes yellowing of leaves, wilting and death of the young seedling after emergence. The disease can be controlled through seed treatment, resistant varieties and through a wide range of fungicides. (Duffus, E.J. and Ruppel, E.G. 1995)

Sugar beets being a new crop in Kenya, the objective is to use the background on the potential diseases to predict the spatial distribution of the diseases in the study areas. The impact of the diseases to the sugar beets and the environment shall be analyzed. However, a comprehensive study on potential sugar beet diseases in Kenya is recommended since the current paper does not deal with the diseases exhaustively.

2.2.2 Soils

Soil is a fundamental resource in crop production since it supplies all crops with nutrients and water, thus influencing the crop vigour and yield. The level of soil nutrients will influence the distribution of crops. Sugar beets for instance require high levels of nutrients and a high but not excessive soil water level. Therefore, the sugar beets will preferentially be grown in soils with high natural fertility and moisture. (Young, A. 1976)

Agriculture increases potential for soil erosion (Pilesjö, P. 1992). In the cultivation of fleshy root crops such as sugar beets, the type of soil influences the amount of soil loss from the farms and hence determines the environmental impact from the activity (Tummarello, G., et al 2002). Depending on the agronomic practices employed, sugar beets may result in large amounts of soil loss from farms especially in soil types that are vulnerable to soil erosion. This is based on the fact that sugar beets are classified as one of the crops with high erosion hazard (Doorenbos, J.

and A.H. Kassam 1979). The loss in soil results in loss of soil nutrients from the field consequently reducing consequentive crop yield from the affected fields.

Soil conditions/attributes are important factors too to be taken into account during the soil mapping process. This is because they determine availability of soil nutrients to crops and at the same time influence distribution of diseases and pests. For instance soil texture can affect the soil moisture content (Robert, C.J., et al 2002). This is through the influence that it places upon the rate of water penetration into the soil hence water-holding capacity of the soil (Webster, C.C. and N.P. Wilson 1980). By affecting the water holding capacity, soil texture influences soil conditions such as water logging that in turn affects the distribution and intensity of water-borne diseases and pests. Pythium, for example, is a disease that thrives well in very wet soils meaning that its effects become pronounced with increased soil moisture while other crop diseases and pests may only thrive well in moderate soil moisture or dry soils, depending on their morphology and physiology (George, A.N. 1997). Sugar beets require "medium to slightly heavy-textured friable and well drained soils" (David, D. and A. Young 1981). This emphasizes the importance of including the soil attributes in the study of soils in assessing the potentials for this new crop in a given area/region.

Soil pH is another soil attribute that strongly influences the performance of a crop in a specific field. David, D. and A. Young (1981), Philip, A.D. and Donald, C.R. (2003) emphasize that sugar beets perform best at a pH of between 6 and 7 but are adversely affected at lower pH values. Low pH influences the mobility of toxic elements such as aluminum in the soil. These elements are then absorbed by the plant roots where they destroy the young thin roots impairing the capacity of the plant to absorb water and nutrients from the soil resulting in wilting and death of the plant in extreme cases (Olekysyn, J., et al 1995, Philip, A.D. and Donald, C.R. 2003). George, A.N. (1997) points out that soil pH influences the appearance and the extent of attack of specific plant diseases that are transmitted through the soil. Soil pH is a soil attribute that is related directly to the type of soil. Taking this into account, then the knowledge of soil types can be useful in prediction of the soil pH and its spatial distribution.

The dominant soil types in most potentially sugar beet growing areas in Kenya are; Cambisols, Luvisols, Ferralosols, Planosols, Arenosols, Leptosols, Andosols, Nitosols, Acrisols, Phaeozems and Alosols (Mud Springs Geographers, Inc. 2001). It is essential to study the characteristics of these soil types, their spatial distribution and percentage share in the study area. Doing this will provide sufficient background to predict the sugar beet potentials and challenges. Following is a short description of the above-mentioned soil types.

Cambisols: They are soils constituting substantial weatherable minerals with fine texture and reduced carbonates. Buringh, P. (1979), describes the soils as "good for agriculture". This being the case, then the type of soils can be good for the production of sugar beets since having reduced carbonates means that they are less acidic, and hence may present a pH within the optimal requirement for the sugar beets. Though its texture is fine it does not present a risk of water logging since Fitzpatrick E. A. (1991) describes it as "loamy very fine sand" meaning that it is within the optimal range slightly heavy textured friable and well-drained soils. Having sufficient weatherable minerals, the soil fertility is expected to be high and hence will respond well with relatively small additions of fertilizers regarding optimal/high yield.

Luvisols: The type of soil has "high base saturation" Buringh, P. (1979). This means that the soils are not acidic and therefore are good for sugar beet production. Buringh, P. (1979) continues to describe the soils as suitable for agriculture. Though this is the case, it is worth noting that for these soils, fertilizer application is advantageous for optimal yield (Buringh, P. 1979). This is true especially for the sugar beets that generally require high nutrient levels (Young, A. 1976). The soils, having some weatherable minerals, the quantities of fertilizer applied are normally expected to be minimal. However, permeability is not good enough (low), hence may present a risk of water logging. Water logging poses a risk to sugar beet from attack of diseases that thrive well in high moisture conditions e.g. Pythium. It also increases chances of environmental pollution through the leaching/runoff from fertilizers and other chemicals that may be used on the sugar beet farm. For optimal sugar beet yield a well drainage system is necessary to reduce the water logging to at least a medium level that can be tolerated by the sugar beets (McRae, S.G. and C.P. Burnham 1981).

Ferralosols: These are acidic soils that have a stable structure with good permeability and drainage (Buringh, P. 1979). Though the structure, permeability and drainage are sufficient for sugar beet production, the soils being acidic may respond well to liming in efforts to increase the pH to around neutral being the optimal for sugar beet production. The soils have very little fertility and no weatherable minerals meaning that fertilizer application is mandatory (Buringh, P. 1979). Taking into account the fact that the sugar beets require high levels of nutrients, it is logical to predict that quite a substantial amount of fertilizers will be advantageous regarding optimal yield. Large quantity of fertilizer use exerts high economic pressure on the farmer and increase risk of environmental pollution from leaching/runoff of the fertilizers to ground and surface water.

Planosols: These are soils with very high clay percentage and they are prone to "seasonal water logging and strong leaching" (Buringh, P. 1979). Given that sugar beets require medium clayey texture and that they can only tolerate medium water logging (while keeping in mind that the soil is prone to high leaching and that sugar beets require high nutrients), then this kind of soils may not be sustainably utilized for sugar beet production (McRae, S.G. and C.P. Burnham 1981).

Arenosols: They are " light coloured, coarse-textured sandy soils with a high proportion of almost pure quartz" (Buringh, P. 1979). These characteristics render the soil very high permeability hence low water retention capacity. This implies that the soils cannot store enough water for plant use. It is also worth noting that the soil is not suitable for sugar beet production since sugar beet require a medium to slightly heavy textured soils. (McRae, S.G. and C.P. Burnham 1981)

Leptosols: They are weakly developed shallow (30 cm deep) soils on a hard rock. They present "a new major soil group constituting former Ranker, Rendzinas and Lithosols" (FAO-UNESCO 1989). The soils have little agricultural value since they are too shallow to accumulate enough water for the crops and also accommodate root volume (Buringh, P. 1979). This is true for the sugar beets since they not only have a dense rooting pattern but also are deep rooted requiring a maximum rooting depth of 150 cm (Doorenbos, J. and A.H. Kassam 1979). The soils are further on characterized by "many stones and rock out crops" even more reducing their value for agriculture (Buringh, P. 1979).

Andosols: They are well drained, fertile with good water holding capacity and "high cation exchange capacity 35-54 mmol per 100g" (Buringh, P. 1979). They have sufficient organic matter content 5- 20% and are best for agriculture in the tropics (Buringh, P. 1979). This type of soil is suitable for sugar beet production due to its good drainage and water holding capacity. Although the soil has good natural fertility and appreciable organic matter, it may still need the application of fertilizers for the sake of optimizing yield.

Nitosols: They are deep, well-drained, stable soils with high water holding capacity (Buringh, P. 1979). They are suited to a variety of crop production but respond well to application of fertilizers in regard to high yield (Buringh, P. 1979). The soils are to some extent prone to soil erosion (Buringh, P. 1979). Due to their depth, structure, drainage and water holding capacity that corresponds well to the optimal for sugar beet production, it is possible to produce sugar beets in these soils. However, the main challenge shall be environmental degradation from soil erosion since sugar beets are classed as crops with "high erosion hazard" (Young, A. 1976). However the extent to which the soils shall be degraded from soil erosion depends on growing techniques/agronomic practices.

Acrisols: These are acidic soils with little natural fertility; they lack enough nitrogen and have toxic elements such as Aluminum (Buringh, P. 1979). The soils are prone to soil erosion

(Buringh, P. 1979). The pH of these soils needs to be adjusted through liming to the optimal level for the sugar beets. Liming not only increase the pH but also reduce the concentration of the toxic elements such as aluminum. Application of fertilizer is necessary too to improve on the soil fertility and enhance the nitrogen content of the soil.

Phaeozems: They are fertile soils with good water holding capacity (Buringh, P. 1979). "They are not massive or hard when dry and have organic matter content greater than 1%" (Fitzpatrick, A.E. 1991). The characteristics of the soil type match well the optimal sugar beet requirements. Therefore, it is possible to produce sugar beets on this soil with the application of fertilizers to boost the yield.

Alisols: They are acidic soils with "a base saturation less than 50%" (FAO-UNESCO 1989). Other characteristics are similar to that of Acrisols (FAO-UNESCO 1989), Refer to Acrisols section for details

A comprehensive study on the soil types and soil characteristics is beyond the focus of this paper. Therefore, there is need for a comprehensive future research(s) on soils to provide a detailed analysis on the soil types and characteristics and how the soils can be managed to optimize on the sugar beet yield.

2.2.3 Rainfall/moisture

Rainfall is an important factor determining the performance of any crop in a particular field. The amount of rainfall received in a particular area at a given time influences the level of soil moisture and air humidity, which are critical factors in the establishment and healthy development of a crop throughout the growing season. Therefore, for sustainable agriculture, it is vital that the amount of rainfall and its seasonal/temporal distribution is well understood to help make wise decisions. Rainfall/moisture affects a crop's performance in many ways, as discussed below.

Different types of crops do require different quantities of water for healthy growth and optimal yield. Going by this statement, it is true that the amount and temporal distribution of rainfall can affect not only the performance of crops in the field but also the spatial distribution. Sugar beets like any other crops do well within a specific range of rainfall amount during the growing season. David, D. and A. Young (1981) observe that sugar beets in the tropics perform best within 550 to 700 mm of rainfall in the optimal season. It will therefore, be wise to make an intensive study of the spatial and temporal distribution of rainfall patterns and compare it to the moisture/water requirement of the sugar beets before it is introduction in large scale to Kenya. Too much water in the soil causes water logging and oxygen deficiency while, too little water causes water stress, wilting and death of crop (David, B. and C. Frank 1991) The actual effect of water stress on the crop yield will be determined with the growth stage at which it occurs. Crops are most sensitive to water stress during germination, fertilization and bolting seasons. This underscores the importance of the temporal distribution in rainfall. Understanding the rainfall pattern will help to predict the potential field performance of the crop. It will also determine the optimal growing season of the crop and design in sustainable management practices to be applied in the management of the crop. Such management may include design for irrigation in case of lack of enough/well-distributed rainfall.

Moisture has a great influence on the occurrence, development and spatial distribution of crop diseases. For instance, in fungal diseases, moisture/water availability determines the time fungal spores are released and in this way influences their life cycles. Moving water influences the rate at which pathogens spread by moving them from one place to another. Therefore, it is worth noting that the amount of rainfall and its temporal/seasonal distribution has a strong influence on the spatial and temporal distribution of crop diseases. (George, A.N. 1997)

The intensity of rainfall received in an area is also an important factor. Webster, C.C. and N.P. Wilson (1980) and Pilesjö, P. (1992) observes that heavy rainfall influences the degree and type of soil erosion depending on frequency and soil characteristics such as texture. This means that understanding the rainfall pattern for the target area coupled with a good understanding of the types of soils and physical properties of the crop to be grown on the site, will help to reduce the rate of soil erosion. This is because the understanding will assist in the selection of the right type of crop and best agronomic practices for the area that will help curb down on soil erosion while ensuring high productivity from the farming activity.

Therefore, there is need to study the rainfall pattern in the study areas (Kakamega) and Nyandarua-Kenya). The present paper shall use GIS, to map out potential optimal and sub-optimal sites for sugar beet production in the study areas. The maps serve as a gauge for analyzing the potentials, challenges and impact of sugar beet production in the study areas.

2.2.4 Temperature

Temperature is a fundamental factor in crop production since it has a great influence on the establishment and development of the crops. Crops require some specific minimum temperature for germination and after establishment; they also require an optimum temperature for the best development and high yield. In case temperatures rise beyond the optimum, crops further have a specific maximum temperature beyond which they cannot survive (George A.N. 1997). Sugar beets do best in an optimal temperature range of 18 to 22 ^{o}c, however they can also reasonably well tolerate temperatures in the range of 10 ^{o}c to 17 ^{o}c and 23 ^{o}c to 30 ^{o}c (David, D. and A. Young 1981). Therefore, temperature can be an important factor to be studied since it influences the establishment and hence the spatial and seasonal distribution of any crop.

Temperature also affects the rate of evapotranspiration from a particular field/area. Through this, temperature affects the amount of soil moisture. Soil moisture determines the amount of water available to the crops at a given time; hence affecting the crop vigour and consequently yield (Oumarau, B., et al 1997). Kenya being a tropical country at the equator, mean day temperatures are usually higher than those in the temperate regions where sugar beets are native. Therefore there is need to analyze the impact of high temperatures on sugar beet yield and or sugar content as this is deemed to be one of the limiting factors in sugar beet production (Webster C.C. and N.P. Wilson 1980).

Temperature further affects on crop diseases. Specific crop diseases have varied but definite temperature ranges within which they thrive best. Therefore, temperature can influence the occurrence/spatial distribution of various crop diseases. Those requiring high temperatures increase in severity in hot seasons or are distributed in those regions with high temperatures throughout the year and the vice versa is true. (George A.N. 1997)

The present paper keenly analyses temperature data from the study areas and matches the temperature with the optimal and sub-optimal temperatures for sugar beet. GIS is then used to map out optimal and sub-optimal sugar beet temperature zones within the study areas.

2.3 Economic potentials and challenges

A project has to be economically viable for it to attract capital investment. Economic viability is a complex issue that is affected by social, environmental and economic factors in the locality. The global market for the product and free trade (liberalized global market) further affects the economic viability of the project. However, this paper shall only be concentrated in the analysis of the economic potentials and challenges for sugar beets within Kenya parse. Therefore, there is need for future comprehensive research(s) to analyze the economic potentials and challenges for sugar beets in Kenya taking into account the effects of free trade and globalization.

The factors discussed in this section are sustainability, diversification and income.

2.3.1 Sustainability

Economically viable development projects should be sustainable. "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development (WCED), 1987). Sustainable agriculture therefore, refers to the type of agriculture that will generate optimal benefits to the current generations while conserving the potential agricultural resources for the generations to come. Sustainable agriculture should generate enough food (food security) for the present generation. To conserve the land productivity for the generations to come, adequate strategies should be integrated into agricultural projects to promote sustainability. One of these strategies would be to reduce inputs to agriculture (adoption of low input agriculture) (Miller, G.T., JR. 2000). Low input agriculture would be achieved through adequate assessment of the land capability and matching it with the right kind of crop. By matching land use and land capability, it is possible to minimize on inputs such as fertilizers and pesticides. It is also possible to control land degradation from soil erosion. These are true since only the most suited crops and hence those that can be cultivated to give high yield at minimum sustainable inputs would be grown. The end result shall be optimal/high yield and minimized production cost as well as minimized potential environmental pollution from leaching, surface run off or poisoning through inhalation of fertilizers and other chemicals applied in farms.

The study areas have relatively high populations with small pieces of land. More so; large part of the areas are not supplied with pipe-borne water. The local population relies on water from wells, springs and boreholes. This being the case (while keeping in mind that agriculture can be a source of pollution through leaching of nutrients and chemicals to surface and ground water), there is every reason for adoption of sustainable agriculture so as to reduce negative impact of the farming activity on the population and the environment.

It is therefore, essential that before sugar beets are introduced in large scale, an integrated approach be taken to study the likely impact on the environment. This is vital in that it can serve as a guide to where sugar beets can be sustainably introduced within the study areas. However, the current paper does not cover the analysis of influence from, infrastructure, weeds and pests on sugar beet. Therefore there is need for a comprehensive future research(s) on these areas.

2.3.2 Diversification and income

Diversification as used in this paper refers to the incorporation of more than one crop in the farm at specified plots in a given period of time. Farmers at Kakamega District (Mumias Division) rely only on sugar cane as the sole cash crop, and hence the only source of income. The farmers at Nyandarua on the other hand rely on livestock as the main source of income. Therefore, there is a need for adoption of one or more cash crops in the study areas as a means of generating reliable income to the farmers. Sandra, M. (2002) stresses that diversification can help improve incomes. The author refers to diversification on farm by incorporating other beneficial activities rather than traditional farming. Diversification of crops can equally improve on income and make it more reliable to farmers.

Diversification serves as a security for the farmer's investment by optimizing the use of the limited land resources (Thapa, B.G. 1995). Furthermore, it increases safety making it possible for one crop to replace another incase of crop failure. In case the crops will be cultivated in a rotation programme, more yield are expected from each of the crops because of enhanced soil nutrients and the broken cycle of diseases and pests, resulting in increased cash flow from resultant sales. Jeremy, F., et al., (2002) who observe a reliable income as a result of diversification in the farming activities, further support the idea of reliable income from diversification.

However, whether the income from the farming can be sufficient and reliable depends on many factors. The most important ones are production cost, availability of market, prices and yield per unit area. Production cost includes the costs of all inputs such as land preparation, seeds, sowing, weeding, pesticides, fertilizer, harvesting and transporting. In Kenya, the prices for land preparation, sowing, weeding, transporting and harvesting are uniform within a specific region and hence are not crop dependent. Therefore, the unique costs that are crop dependent and hence need to be evaluated are cost of seeds, fertilizers and pesticide use. The lower the production cost the higher the profits to the farmers. Therefore, there is need to find ways of keeping the production cost at the lowest sustainable level possible. By assessing land capability and matching it with a suitable land use production cost can be considerably and sustainably reduced (Thapa, B.G. 1995).

The price offered to the sugar beet farmers is determined by the production cost at the processing plant level and the sugar price i.e. the income for the industry. Production cost is purely a function of management and processing procedures (Märländer, B., et al., 2003). Therefore, in case farmers have to be motivated by being paid attractive prices, the management of the processing plants and the sugar sector in general must be sufficiently good. Market price for sugar is affected by demand and supply forces. Demand can be created through adequate advertisement and high quality product while supply is influenced by quantity produced locally plus the imports.

Market availability for the sugar beets is determined by willingness to process sugar beets, the performance and capacity of sugar processing plants.

The sugar beet yield per a unit area is also important for determing the income to the farmers and the viability of the project. Doorenbos, J. and A.H. Kassam (1979) indicate that the optimal yield from sugar beets in the tropics is within the range of 40 to 60 tons/ha. The attainment of the optimal sugar beet yield is influenced by environmental, agronomic and genetic factors. Märländer, B., et al., (2003) underscores the importance of the environmental factors in determination of the sugar beet yield since it influences up to 90% of the yield output. Site-specific biophysical factors such as soils, temperature and rainfall are therefore important factors influencing yield and hence economic viability of the sugar beets at the farm level.

3.0 Possibilities and challenges of introducing sugar beets in Kenya. Two case studies from Kakamega and Nyandarua Districts

This section of the paper presents two case studies in which a field research was carried out. The aims of the field research were: (1) to establish an understanding of the current performance of the sugar sector in Kenya; Problems and challenges facing the sugar sector. (2) To assess the performance and the challenges facing the sugar beets at the trial sites as well as farmer's aspirations with the sugar beet production. The two study areas were Kakamega district and Nyandarua Districts in Kenya (figure 3).

3.1 Kakamega District case study

3.1.1 Study area

Kakamega District is in Western Province of Kenya. The District covers an area of 3606 km^2 (360,600 ha). Mumias Division in Kakamega District was chosen as the study area. The results of the study were then extrapolated to represent the whole of Kakamega District. Mumias Division is predominated with sugar cane farming as a cash crop with a few other food crops for subsistence such as maize and beans. (District Agricultural Office Kakamega 1993)

Mumias Division hosts the largest sugar processing company not only in Kenya but also in East and Central Africa. (Personal communication with Mr. J.J. Murabwa Laboratory Manager-Mumias sugar company). Mumias Sugar Company was founded in the year 1971 by the Government of Kenya with the main objectives of job creation, income to farmers and to improve on production of sugar, and hence lower sugar imports. The main stakeholder was the Government of Kenya with 71% shares. The factory has a capacity of 210,000 tons sugar in a year and produces over 50% of all the sugar produced domestically (Mumias Sugar Company Limited 1996).

This region was chosen as a case study because it has the largest sugar-processing factory in Kenya. Secondly, it has a large acreage under cane (44,640 ha) and quite a good number of individual OG farmers (42,520) (Mumias Sugar Company Limited 1996). By analyzing the performance of the sugar sector, problems at farmers level and farmer's desires and aspirations in this particular area of the country the results would make a good representative of the country's study.

The factory is supplied with cane from contracted farmers (out growers-OG) and factory farms (Nucleus estate-NE). The total cane land is 44,640 hectares, 41,245 ha of this land being utilized by out growers while the remaining 3,397 ha belong to the NE. (Mumias Sugar Company Limited 1996)

The objectives of the case study were to assess the performance of the sugar sector in the region through analysis of trend in production, problems and challenges. Included in the study also was a section to evaluate the farmers' willingness to adopt sugar beets as a new crop and their most desired characteristics in the crop.

The physical factors in the study area such as soil types and condition, rainfall, temperature and diseases were also collected and applied in identifying potential sugar beet production sites in the area. The availability of such sites is thought to be major limiting factor in the locality.

3.1.2 Methodology

The section of the paper presents a short description on how the work was carried out and the materials used for Kakamega case study. The section has been divided into two, i.e. data collection and GIS and zone mapping as described below.

3.1.2.1 Data collection

A total of 53 Questionnaires were handed to the farmers in an interview session aimed at understanding the current performance of the sugar sector, main problems facing them. The willingness to introduce sugar beets in their farming activities were also investigated. Desired characteristics/properties in the new crop. Refer to appendix I for a sample questionnaire. Through the answers to the questionnaires, it was possible to assess the social acceptability of the sugar beets and evaluate whether sugar beets could solve the farmers' problems by fulfilling the farmers' needs and aspirations.

The interviewed farmers were chosen in a planned way to ensure a balance between eleven villages in the area for the sake of uniform coverage and equal representation of the whole region. The villages that were visited are: (Elwasambi, Buchifi, Harambee, Matawa, Imanga, Ebubole, Emakombe, Ebwaliro, Ichinga, Nyapora and Musango. While in a specific village to interview farmers, care was taken to ensure that all groups of interest were represented such as large (with farm sizes equal/larger than 2 hectares) and small-scale (with farm sizes less than 2 hectares) farmers; those who have either increased or decreased their farm sizes under cane and those who shifted completely from sugar cane farming to other crops such as maize. By use of

GPS, the geographical locations for the villages were collected and by use of GIS the villages were mapped out.

The GPS (Geographical Positioning System) was used to collect geographical positions of interest in the field of study for mapping purposes. (GPS) is a system that is used in "providing accurate position, velocity and time (PVT) to users. The system has three main components satellites, receivers and control stations". (http://www.navcen.uscg.gov/pubs/gps/gpsuser/gpsuser.pdf

The GPS has a total of 24 satellites in orbit at about 20,200 km above the earth surface. The satellites generate and continuously send signals to the earth surface that can be received by a variety of GPS receivers such as the hand held GPS. (http://www.navcen.uscg.gov/pubs/gps/gpsuser/gpsuser.pdf

The receivers capture data from the satellites signal, and then use it to calculate the geographical location of the receiver (specific location being determined). The location is calculated as an intersection point between signals from at least three satellites on/near the surface of the earth. Four satellites are necessary for precision and elevation in position measurements; the four satellites should be able to transmit signals to the receiver simultaneously. (http://www.navcen.uscg.gov/pubs/gps/gpsuser/gpsuser.pdf

"The control segment consists of a network of monitoring and control facilities which are used to control satellite constellation and update the satellite navigation data messages". The control stations are located at selected places world over. (http://www.navcen.uscg.gov/pubs/gps/gpsuser/gpsuser.pdf

Physical conditions in the study such as soils, infrastructure, agricultural and other development activities were observed and recorded during the field study with the aim of getting real first hand information about study area.

More information and physical data on soil types, soil texture, precipitation, and temperature were obtained from maps, relevant literature and offices (Meteorological department and department of soil survey- Kenya Agricultural Research Institute (KARI)) and used in zone mapping as described in section 3.1.2.2.

A checklist of main potential sugar beet diseases (Fusarium, Cercospora, downy mildew, Pythium, Rhizoctonia, Sclerotium, and Erwina) was prepared. Each disease in the checklist was checked against the officially known crop diseases in Kenya (Kungu, J. N. and E.R. Boa 1997). In the process, all those diseases that were found to be native to Kenya were enlisted. From the list of the native diseases, with the help of suitable thriving conditions for each disease as discussed in section 2.2.1, the potential sugar beet diseases for Kakamega District were predicted.

3.1.2.2 GIS and zone mapping

The geographical positions of the villages visited in the study area were collected in degrees, minutes and seconds, and then converted into decimal degree. Decimal degree is the form that is accepted by the GIS software used in the analysis. Through GIS, the positions of the villages were converted into shapefiles and loaded into the map. *Shapefiles are a simple, non-topographical format for storing the geometric location and attribute information of geographic features.*

Data on physical conditions (soils, precipitation and temperature) from the field survey was compared with data from literature and official data. The data was converted into themes that were later used in mapping out potential sites for sugar beet production. From literature review, optimal and sub-optimal physical conditions for sugar beet production were obtained and applied in mapping out sugar beet production sites in the study area. The mapping was carried out as described below hereafter. Optimal zones in this study refers to areas where the sugar beets are expected to perform well, give optimal yield with minimum inputs of pesticides, fertilizer, liming and drainage provisions. Sub-optimal zones are those areas where sugar beets can be economically produced and give optimal yield but with a little more inputs compared to the optimal zone.

Precipitation: The optimal zone for sugar beet production was mapped out as precipitation class 1 (very good) at the range of 550 to 700 mm during the growing/optimal season. The sub-optimal zones were mapped out at the range of 701 to 1000 mm class 2 (good), 460 to 549 mm class 3 (fair) and class 4 (bad) at range below 460 and above 1000 mm. (David, D. and A. Young 1981)

Temperature: Optimal temperature range zone was mapped at 18 ^{o} C to 22^{o} C class 1 (very good) (David, D. and A. Young 1981). The sub-optimal temperature zone was mapped at a range of 10 ^{o} C to 17 ^{o} C class 2 (good), 23 ^{o} C to 30 ^{o} C class 3 (fair) and below 10^{o} C and above 30^{o} C class 4 (bad) (Doorenbos, J. and A.H. Kassam 1979).

Soils: Four potential soil sugar beet zones; optimal and sub-optimal were mapped out. The optimal zone class 1 (very good) constitutes soils that are deep, well-drained and good water holding capacity, class 2 (good) comprised soils that meet all the conditions of very good zone but either requires liming and or erosion control for optimal yield. Soil class 3 (Fair) deep well drained but require both liming and erosion control for high yield. Soil class 4 (Bad) comprises soils that do not meet characteristics of soil classes 1, 2 and 3.

Soil texture: Four soil texture sugar beet zones were mapped out. Soil texture class 1 (very good) constitutes loam texture, soil texture class 2 (good) with clay loam texture, soil texture class 3 (fair) with clay texture and soil texture class 4 (bad) constituting sandy and extremely sandy sandy texture. The texture class classification used was the FAO soil classification system.

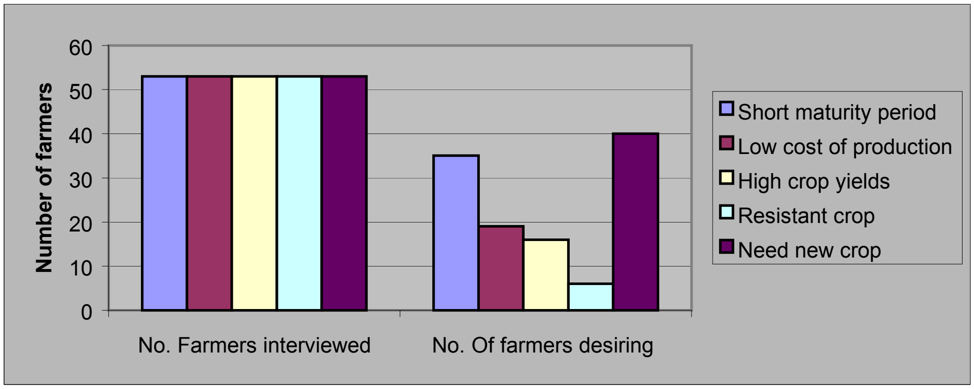
The optimal sugar beet growing zones were obtained by overlying the four-mentioned maps. First temperature and precipitation maps were overlaid. Then soil types and soil texture were overlaid. Finally the optimal map was obtained from the overlay of the product maps from the mentioned two overlays. All factors Temperature, precipitation, soil type and soil texture were treated equally (assigned weight of 1) since they are deemed to have equal influence on sugar beet growth and development. A product of the four classes of temperature, precipitation, soils and soil texture were obtained and used in mapping out four sugar beet potential sites. The four sugar beet potential sites were mapped out class 1=very good at the range 1-2 (calculated as 1x1x1x1x1 and 1x1x1x1x2), class 2=good at the range 4-24 (1x1x1x2x2 and 2x2x2x3), class 3=fair at the range 36-81 (2x2x3x3 and 3x3x3x3) and class 4=bad all parts that do not meet the criteria for class 1,2 and 3.

An integrated approach was utilized in the data analysis.

3.1.3 Results

This section presents results from both field research and GIS mapping for Kakamega District.

Figure 4: Farmer's willingness to adopt new crop and desired characteristics in new crop



Data source: Interview with farmers at Mumias

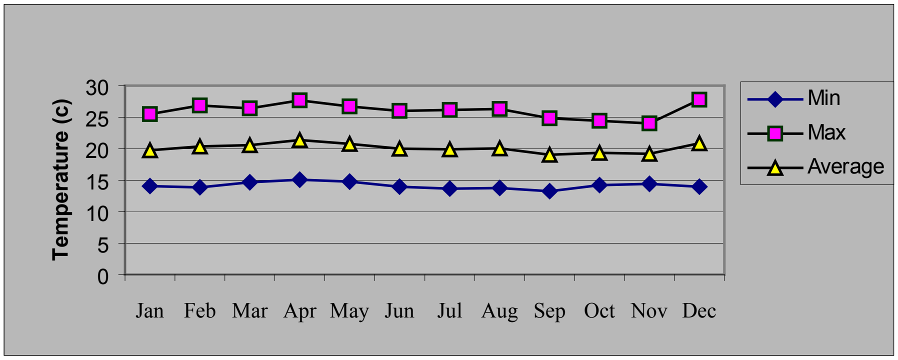
The main characteristics illustrated in figure 4 refer to those problems mentioned by 60% or more of the 53 interviewed farmers. Other minor desired characteristics mentioned are less workload, ability to with stand adverse weather conditions, market acceptance and cheap and readily available inputs. 40 of the 53 interviewed farmers expressed need for the new crop/sugar beets.

Figure 5: Main problems facing sugar cane farmers

Data source: Interview with farmers at Mumias

Main problems in figure 5 are those mentioned by 60% or more of the 53 interviewed farmers. However, it is worth keeping in mind that there are other minor problems mentioned by the sugar cane farmers such as late delivery of fertilizers, late harvesting of sugar canes upon maturity especially in remote areas with poor road network, cane spillage while on transit due to poor road network in some parts.

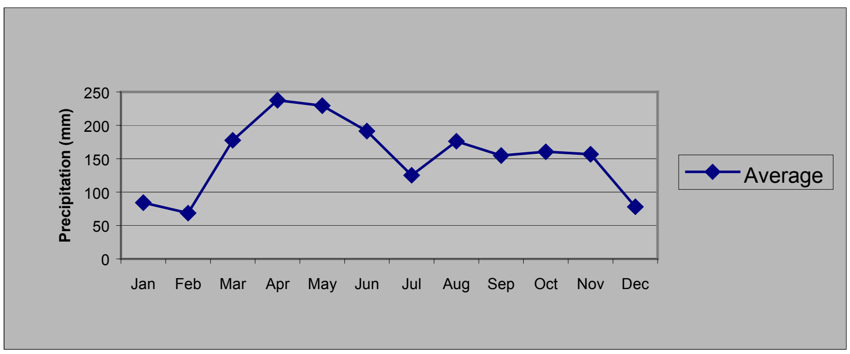
Figure 6: Average temperature for Kakamega District for the years 1993 to 2002.



Data source: Meteorological Department Nairobi

The average temperature for Kakamega District illustrated in figure 6 is approximately 20 ^{o} C. The average maximum temperature is 26 ^{o} C while the average minimum temperature is 14 ^{o} C.

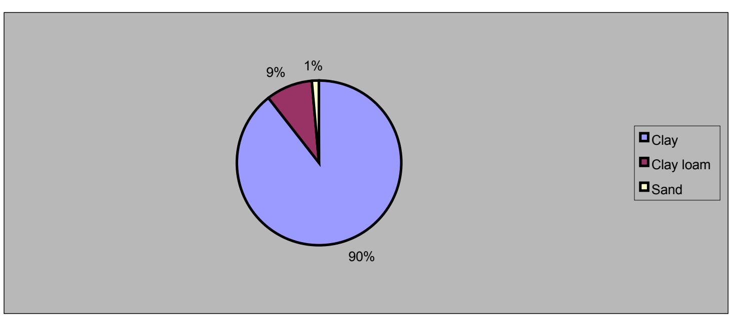
Figure 7: Average monthly precipitation for Kakamega for the years1993 to 2002



Data source: Meteorological Department Nairobi

The total average precipitation received in Kakamega during the optimal season (April to September) is 960 mm. The highest amount is recorded in May while the lowest is recorded in July (figure 17).

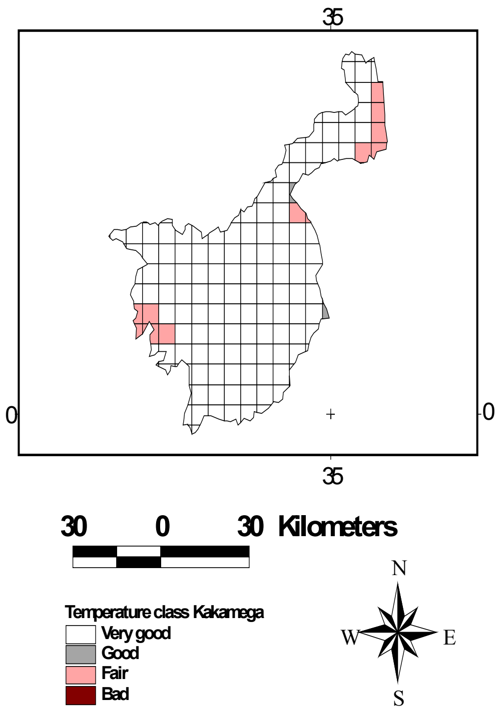
Figure 8: Dominant soil texture in Kakamega



Data source: Mud Spring Geographers, Inc. (2001)

Figure 8 illustrate that Kakamega District has three main soil texture classes i.e. clay, clay loam and sand. The clay soil texture constitutes the greatest percentage area followed by clay loam and sand textures respectively

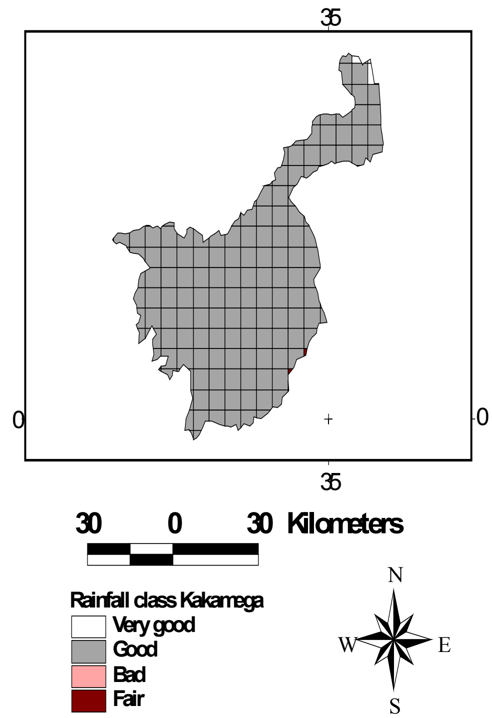
Figure 9: Potential sugar beet temperature sites in Kakamega District



Data source: Mud Spring Geographers Inc. (2001)

The potential sugar beet temperature sites in figure 9 illustrate three sugar beet temperature zones. The very good zone constitutes the largest proportion (over ¾ of the total area), followed in descending order by fair and good zones respectively

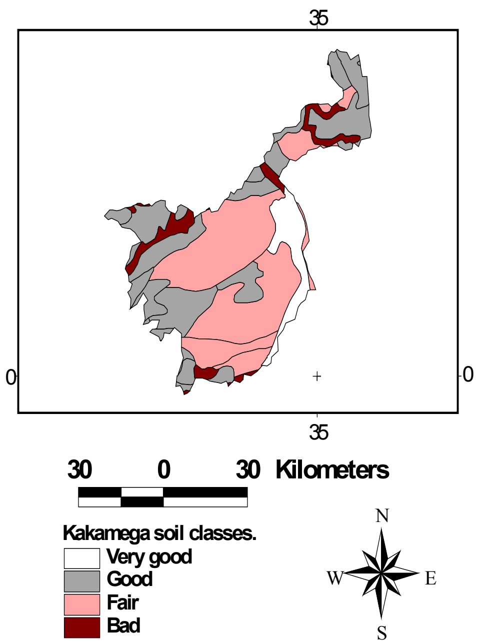
Figure 10: Potential sugar beet rainfall sites in Kakamega District



Data source: Mud Spring Geographers Inc. (2001)

The potential sugar beet rainfall sites in figure 10 are dominated by good zone that covers over ¾ of the total area. Other zones are very good and bad zones.

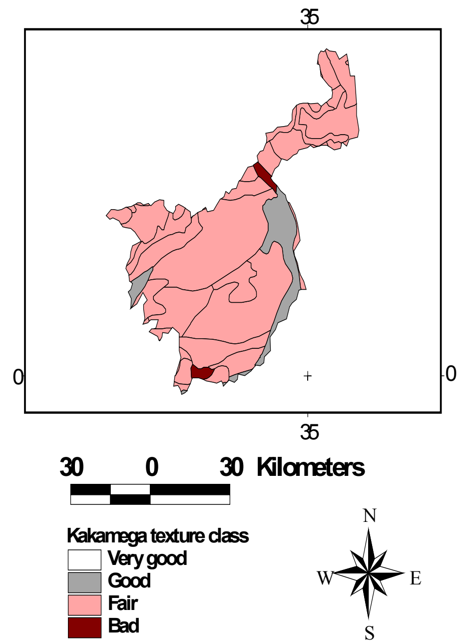
Figure 11: Potential sugar beet soil type sites in Kakamega District



Data source: Mud Spring Geographers Inc. (2001)

Four potential sugar beet soil type-sites are observed in figure 11. The most dominant soil type zone is the fair class that covers about ¾ of the total area. The good, very good and bad zone follows the fair zone respectively.

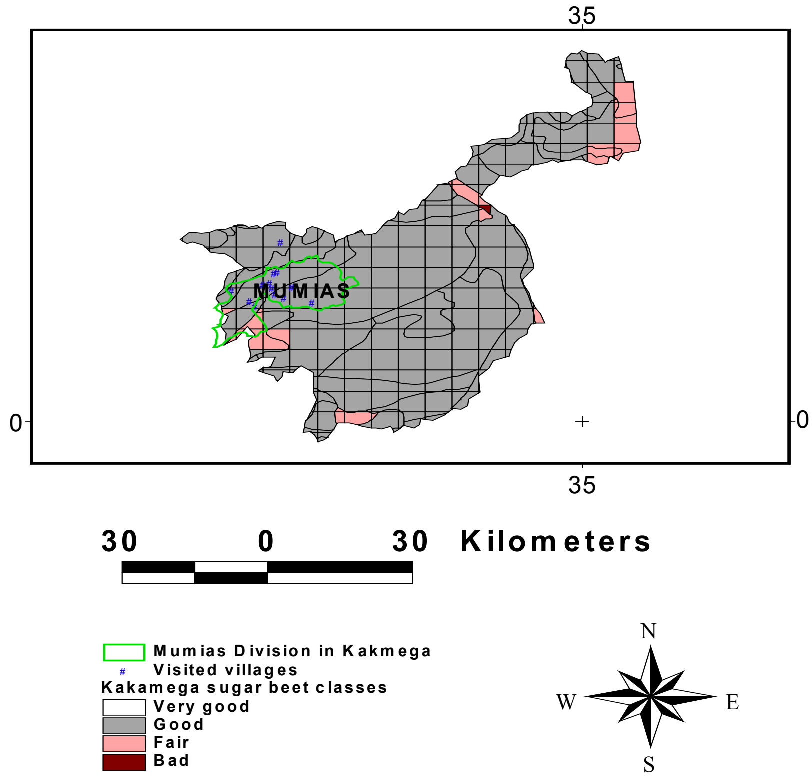
Figure 12: Potential sugar beet soil texture sites in Kakamega



Data source: Mud Spring Geographers Inc. (2001)

Three potential sugar beet soil texture sites are observed from figure 12. The fair soil texture zone dominates (constitutes over ¾ of the total area). The good and bad zones follow the zone respectively.

Figure 13: Potential optimal sugar beet sites in Kakamega District



Data source: Mud Springs Geographers, Inc. (2001)

The potential optimal sugar beet sites illustrated in figure 13 are a product of the overlay of figures 9,10,11 and 12. These zones present the actual sugar beet potential sites for Kakamega District when considering temperature, precipitation, and soil type and soil texture. Three potential sugar beet zones can be recognized. The largest potential zone is the good zone. The fair and the bad zone follow respectively.

Table 1: Potential sugar beet diseases in Kakamega District

Potential disease	Thriving conditions	Likelihood	Seriousness	Resistant/ tolerant varieties	Chemical treatment
Fusarium	Soil temperature (28 ^{o}C), excess soil water	high	high	no	no
Cercospora	Temperature (25-32 ^{o}C), 60% Humidity	high	high	yes	yes
Sclerotium	Temperature > 25 ^{o}C	Very high	high	no	yes
Erwina	Temperature 25-30 ^{o}C, wet soils	Very high	high	yes	yes
Rhizoctonia	Temperature (25–33 ^{o}C)	Very high	high	yes	yes

Data sources: (George, A N. 1997; Kung,u, J.N. and E.R. Boa 1997 and Duffus, E.J. and Ruppel, E.G. 1995)

In table 1 Fusarium, Cercospora, Sclerotium, Erwina and Rhizoctonia are the main potential sugar beet diseases in Kakamega District. The thriving conditions for all these diseases are within their optimal range therefore the likelihood/seriousness of these diseases is high/very high. Currently resistant sugar beet varieties are available for Cercospora, Erwina and Rhizoctonia diseases. No resistant varieties are currently available for Fusarium and Sclerotium diseases. Chemical treatment is currently available for all the diseases except Fusarium disease.

Table 2: Dominant soils Kakamega

Soil type	% Area	Suitability for sugar beets	Need of fertilizer	Liming	Drainage provision	Erosion risk
Acrisols	41	Fair	Yes	Yes	No	yes
Ferralsols	31	Good	Yes	Yes	No	No
Cambisols	8	Very good	Yes	No	No	No
Alisols	7	Fair	Yes	Yes	no	yes
Nitosols	6	Good	Yes	No	No	yes
Planosols	3	Bad	Yes	No	Yes	-
Leptosols	3	Bad	Yes	No	No	-
Arenosols	1	Bad	-	-	No	yes

Data source: Mud Spring Geographers, Inc. (2001)

Table 2 presents the dominant soil types for Kakamega District. The soil types have been allocated sugar beet suitability classes very good, good, fair and bad following the soil type classification scheme mentioned earlier in the methodology section. The largest proportion for the dominant soils constitutes the fair category (48%); this is followed by good (37%), very good (8%) and bad (7%). Acrisols, Ferralsols and Alisols may respond well to liming (79% area). Acrisols, Alisols, Nitosols and Arenosols are prone to soil erosion (55% area). Drainage provision may be essential for the Planosols soil (3% area)

3.1.4 Discussion

This section discusses the results from the study in Kakamega District. The section has been divided into social, biophysical and economic potentials and challenges as discussed below.

3.1.4.1 Social potentials and challenges

This section through the analysis of results in section 3.1.3 assess the possibility that the farmers at Kakamega may accept sugar beets in their farming activities and whether the beets meet the desired characteristics of the farmers. Analyzed also is the possibility for sugar beets to solve the problems mentioned by the farmers during interviews.

Out of the 53 farmers interviewed at Kakamega (Mumias), 40 (76%) of them express need for the new crop/sugar beets (figure 4). However, they do not only express the need for the new crop but also peg down the adoption of the new crop to some desired characteristics as illustrated in figure 4. Do sugar beets meet the desired characteristics and aspirations of farmers?

One of the most desired characteristics in the new crop is that it should mature faster than sugar cane (short maturity period). Sugar beets as per David, D. and A. Young (1981), mature within five to six months compared to sugar cane, which takes 18- 24 months to mature. This is further confirmed by results of the sugar beet trials in Nyandarua District in Central province of Kenya where sugar beets matured in six months (Personal communication with Kiriita Agricultural Self Help Group members).

Farmers at Kakamega need a crop that is disease resistant and/or easily available cheap pesticides. Are there resistant sugar beet varieties for the potential sugar beet diseases in Kakamega illustrated in table 1? There are resistant varieties for Erwina, Cercospora and Rhizoctonia. No resistant varieties exist for Sclerotium and Fusarium. Sclerotium diseases may be controlled through cultural practices such as crop rotation, deep ploughing and pesticides. Fusarium disease may be controlled through seed sterilization but the method is expensive. The use of healthy seeds is another option of reducing the incidence/severity of Fusarium disease (Duffus, E.J. and Ruppel, E.G. 1995, Kung'u, J. N. and E.R. Boa 1997).

Over ¾ of the total area in Kakamega belong to zone 2 (good) potential for sugar beet production (figure 13). In this zone it is possible to obtain optimal sugar beet yields. However, the adoption of good agronomic practices such as right and timely application of fertilizers, lime and provision for erosion control where appropriate, may be beneficial. Therefore, sugar beet yield may probably correspond to farmer's expectations.

Production cost is influenced by a number of factors such as the cost of inputs, existing climatic conditions, incidences of crop pests and diseases, cultural factors, level of mechanization and individual farmers capability. The cost of inputs is analyzed in section 3.1.4.3.

To conclude, farmers at Kakamega are willing and ready for sugar beets. The sugar beets have a potential to fulfilling main crop characteristics desired by the farmers. However, to create a sustainable sugar beet production (i.e. reliable supply of sugar beets to processing factories), the processors may need to motivate the farmers through prompt and sufficient/attractive price per ton/sugar content of the sugar beets supplied. It is through this that the sugar beets shall be socially acceptable and beneficial to farmers.

3.1.4.2 Biophysical potentials and challenges

The crop-growing season for Kakamega District begins in April and extends through a period of six months to September (Mud Spring Geographers, Inc. 2001). The average temperature for Kakamega District during this period is approximately 20 ^{o} C (figure 6). This temperature average is within the very good temperature range for the sugar beet production (18 ^{o} C to 22 ^{o} C) (David, D. and A. Young 1981). The zone under this temperature range covers over ¾ of the total area in the District (figure 9). Results of Brooms Barn experiments indicate that sugar beets germinate well and in a shorter time at 20.5 ^{o} C on non-salt soils relative to those grown at temperatures below or above this level (Gummerson, J.R. 1985). The temperature conditions after germination should remain at the optimal range throughout the growing season for high yield. However, towards harvesting time, the temperature below 10 ^{o} C is advantageous for high sugar yield (Doorenbos, J. and A.H. Kassam 1979). It is therefore; most likely that sugar beets in Kakamega would germinate well and relatively quicker since dominant soils are not salt (for details refer to section 2.2.2). The temperature 20 ^{o} C towards the expected harvesting time (August and September) may pose a challenge to sufficient sugar accumulation since it does not correspond to the optimal temperature for high sugar accumulation. As a result the sugar content would be expected to be lower than the optimal 15% sugar for the tropics (Doorenbos, J. and A.H. Kassam 1979). Staffan Nilsson, an expert in tropical sugar beets, confirms that sugar beets can germinate, establish and assimilate enough sugar at temperatures of up to 40 ^{o} C (personal communication). Hence, there would be no problem with sugar beet germination, establishment and sugar accumulation at temperature conditions such as those in Kakamega District. This works well when combined with Nitrogen deficiency two months before lifting of the sugar beets. Therefore, education to farmers would be essential if high sugar content has to be realized.

The average precipitation 960 mm received in the region during the optimal season (April to September) is within the good precipitation zone (range of 701 mm to 1000 mm). The precipitation to potential evapotranspiration ratio (P/PE) for the region is 1.5 (Mud Spring Geographers, Inc. 2001). Therefore, the region would have enough soil moisture hence agricultural potential. This is based on the rule of thumb that a place is deemed to be arable and agriculturally productive if the ratio of precipitation to potential evapotranspiration is higher than 0.5 (personal communication with Lennart Olsson- MICLU- (Centre for Environmental Studies at Lund University). The good precipitation zone covers over ¾ of the total area in the District (figure 10). To obtain high yield from this zone, soil drainage would be necessary especially in the heavy clay texture. 90% of the soil texture in Kakamega is clay texture (figure 8). Clay soils are usually associated with high water holding capacity implying that they risk accumulating excess water and cause oxygen deficiency. Drainage can be improved through drainage pipes, subsoiling and/or open terraces. However, the drainage must be well designed and executed to avoid over drainage that may result in a substantial reduction in yield. Nevertheless, sugar beet yield could be improved appreciably through adequate drainage and increased application of nitrogen fertilizers. (David, B. and C. Frank 1991)

Erwina, Sclerotium, Rhizoctonia, Cercospora and Fusarium are potential sugar beet diseases for Kakamega District (table 1). The common denominator with all these diseases is that they have capacity to cause substantial losses on sugar beets. (For more details about effects of the diseases refer to section 2.2.1. Therefore, preventing/controlling these diseases would be good for high yield. Sugar beet varieties resistant to the diseases Cercospora, Rhizoctonia and Erwina are currently available. Sclerotium disease, despite that currently has no resistant varieties, may be prevented/controlled through cultural practices such as crop rotation and deep ploughing. Fusarium on the other hand can be prevented/controlled through seedbed sterilization and the use of clean and healthy seeds. To maximize profit to the farmers, the resistant varieties, and chemical treatments should be easily accessible to farmers at affordable price in order to have an impact on sugar beet growing in the area. Sufficient education to farmers on good agronomic practices would be helpful in preventing the occurrence/incidence of the diseases. Doing these would minimize on production cost and risk for environmental pollution from leaching/runoff of pesticides into ground and surface water. Residual effects from some pesticides in the soil and the harmful effects to the user may also be minimized.

The dominant soils in Kakamega District such as the Acrisols, Ferralsols and Alisols are acidic. These three soil types constitute 79% of the total area in Kakamega (table 2). Therefore, liming shall be advantageous in sugar beet production to adjust the pH value to around neutral being the optimal for the sugar beets. Liming will increase the pH as well as reduce the concentration of toxic elements such as aluminum. Liming would also increase the availability of Calcium, Magnesium, Phosphorus, Potassium, Sulfur, Copper, Zinc and Boron in the soil (Philip, A.D. and Donald, C.R. 2003). Given the dominant soil types in Kakamega, fertilizer application is necessary for high/optimal sugar beet yield. The fertilizers would increase sugar beet yield however, the fertilizers may be a potential source of pollution since they leach/runoff to ground and surface water. In the ground water, the fertilizers may contaminate the drinking water through excess nitrate ion load. High concentration of nitrate ion makes the water unfit for human consumption. In the surface water, fertilizers may result in eutrophication, and hence potential loss of biodiversity (Miller, G.T., JR. 2000). Sugar beets are deep rooted thus may help in absorbing the leached nutrients from the subsoil that cannot be reached by other crops. Therefore, sugar beets would help minimize the risk of ground water pollution. Nitosols and Acrisols are soils vulnerable to soil erosion. These two soil types constitute 47% of the total area in Kakamega (table 2). Adequate mechanisms for soil erosion control would therefore be of benefit in sugar beet cultivation. Otherwise pronounced land degradation is possible since sugar beets are classified as a “high hazard” soil erosion crop (Young, A. 1976). Depending on the topography/gradient of the slope, soil erosion can be controlled cheaply through good agronomic practices such as mulching and proper tillage. But where the slope gradient is large then capital-intensive control measures such as gabions are needed. It is advisable that sugar beets be cultivated under good agronomic practices preferably on flat or very gently sloping landscapes.

It is important to point out that it is the interaction of the four elements temperature, precipitation, diseases and soils that determine the biophysical potentials and challenges for sugar beets in Kakamega. Therefore, it is worth noting that temperature, rainfall and soils present a good potential for sugar beet production in Kakamega. The main challenges shall be to seek for strategies to minimize the potential economic, environmental and social impact from soil drainage, fertilizer application, and erosion control and disease prevention/control. Sufficient education to the farmers coupled with affordable availability of the required inputs, may be advantageous in minimizing impact from the above-mentioned problems.

3.1.4.3 Economic potentials and challenges

Sugar cane farmers at Mumias (Kakamega District) use 6 tons of sugar cane cuttings per ha/18-24 months. The quantity of the sugar cane cuttings costed 12,000/= (Kenya shillings) =($151 U.S). One unit of high quality treated sugar beet seeds enough for one hectare in one growing season (5-6 months) sales at 7,900/= ($100 U.S). Thus cost of sugar beets for 18-24 months (two sugar beet seasons/one sugar cane growing season) is $200 U.S. Following these, then the cost for sugar cane cuttings is relatively cheaper compared to that for sugar beet seeds.

Sugarcane farmers at Mumias apply DAP (Di-ammonium phosphate) and Urea fertilizers in their sugar cane farms at the rate between 50-150 kg/ha/18-24 months for each type of fertiliser. Draycott, A.P. (1995) states that sugar beets require NPK (nitrogen, phosphorus and potassium) fertilizers in the ratio 150:40:100 kg/ha/5-6 months. The quantity of fertilizer applied translates to 100kg to 300 kg/ha/18-24 months and 580kg/ha/18-24 months for sugar cane and sugar beet respectively (one sugar cane growing season/ two sugar beet growing seasons). Going by the lower limit sugar cane utilizes 480kg/ha/18-24 less of fertilizer compared to sugar beet. In case of the higher limit for the fertilizers, sugar cane farming utilizes 280kg/ha/18-24 less fertilizer than sugar beets. Therefore, in both lower and upper limits for fertilizer, sugar cane utilizes less fertilizer compared to sugar beets. Further more, unlike sugar cane, sugar beets would respond well to liming on the acidic soils such as Acrisols, Ferralsols and Alsols that form 79% of the total area (table 2)

Sugar cane farming at Mumias (Kakamega District) currently does not utilize pesticides (interview with farmers). A number of potential sugar beet diseases are predicted for Kakamega District (table 1), as a result pesticide use will often be needed. This is true since some of the diseases predicted such as Sclerotium and Fusarium do not have resistant varieties at present. The use of pesticides adds to production cost through the price of the chemicals. Adoption of good agronomic practices and education to farmers on the diseases are beneficial in prevention/control of these diseases. The extent to which the production cost from pesticide use would increase above that of sugar cane depends on the agronomic practices, quantity and cost of chemicals applied and the farmer’s knowledge on sugar beet farming.

The average sugar cane yield for Mumias for the last 12 years is 76 tons cane/ha/18-24 months (Kenya Sugar Board report 2001). In case of good agronomic practices, sugar beets are expected to give an optimal yield between 40 and 60 tons beet/ha/5-6 months (one growing season) in Kakamega (Doorenbos, J. and A.H. Kassam 1979). Comparing the total yield for the two crops in 18- 24 months period (one growing season for sugar cane) is necessary to determine the relative economic returns from each of the two crops. Incase sugar beets are introduced; optimal yield range of 80- 120 tons/ha in 18 to 24 months (2 growing seasons) is expected. Both the minimum and maximum yield range for sugar beets in the two growing seasons are higher than those from sugar cane. In case sugar beet farmers shall be paid per tons of beet supplied to the factory in the same way the cane farmers are paid currently, then sugar beets will generate relatively higher income than the sugar canes per hectare in 18-24 months period. Incase the sugar beet yield are maintained at the minimum level the profit margin would probably be low when compared to the cost of inputs. Therefore, to maximize on profits, it would be advantageous to seek for strategies to keep sugar beet yield at/close to the maximum optimal level. The main advantage with sugar beets is that they mature 5 to 6 months and hence can generate quick income to farmers to meet the basic needs such as food, medication and fees. The quick maturity may also curb down on the harvest of premature sugar canes.

The possibility that sugar beet farmers can benefit from the sugar beet farming depends on availability of market for their production. Since there are no sugar beet factories in the region, the question arise is it possible to use the same sugar cane processing plant to process the sugar beets? In a personal communication with Mr. Titiya –Training Manager Mumias Sugar Company observed that it is possible to process sugar beets using the plant for sugar cane. However, he emphasized that this is only possible with the diffuser and not the milling system. There should be some modifications on the preparation compartments in which the sugar beets are received and fed to the machines for processing. Asked the same question Mr Staffan Nilsson of SwedeNile stressed that though it is possible to process the sugar beets with a modified plant for sugar canes, the economic feasibility may be minimal since the costs for modification may be substantially high. Therefore, a comprehensive and integrated research on the compatibility between sugar cane and sugar beet processing plants is recommended.

The current lack of sugar beet market accessibility in Kenya may be a barrier to large-scale sugar beet production. However, given that sugar beets are socially accepted, the large area under the good zone (figure 13), and the current sugar deficit in Kenya, probably it may be possible to attract investors. This is only possible if the sugar to be produced locally will effectively compete with sugar from the liberalized global market in price and quality. Therefore, a comprehensive research to study the economic viability of sugar beet in Kenya given the liberalized global market is necessary since it is not within the limits of this paper. It might be a good idea to explore the possibility of small community owned sugar beet processing projects. Incase of community owned projects the native farmers should be involved at all stages of planning, decision making and project implementation to nurture a sense of ownership. They should also be trained on management and maintenance of the facility. Farmers should be further trained on good agronomic practices to optimize on yield and minimize on the negative environmental impact from leachate of fertilizers and pesticide use. High efficiency at the processor level, prompt and attractive prices for the beets supplied are necessary in enhancing the benefits from sugar beets.

The actual economic potential from sugar beets in Kenya may need a more comprehensive study encompassing detailed analysis of the global market, market accessibility and production cost at both the farm and processing levels. However, there is a potential for farmers to benefit from quick/reliable income. Sugar beets also present a potential for processors to access regular, reliable and sufficient supply of raw materials for processing while the country would benefit from increased sugar production, less/no sugar deficit and hence domestic sugar security.

The introduction of the sugar beets though, should be gradual and after comprehensive feasibility and environmental impact assessment studies. It would be beneficial to introduce sugar beets as a supplement to sugar cane such that farmers benefit from crop diversification.

3.1.5 Conclusion for Kakamega

Sugar beets would be socially accepted at Kakamega District upon market creation. The biophysical potential provides a good opportunity for large-scale sugar beet production. Though the production cost and negative environmental impact may arise from poor drainage, risk for soil erosion, effect of diseases and disease control. Therefore, to ensure a sustainable introduction, a more comprehensive and integrated study would be necessary. Education, farmer involvement as well as access to reliable inputs would help maximize on profits and mitigate on the negative environmental impact.

3.2 Nyandarua case study

3.2.1 Study area

Nyandarua District is located in the Central province of Kenya. The District covers an area of 3260 km^2 (326,000 ha). Most residents in the area are farmer's raring daily cattle and horticultural crops especially vegetables (Spinach, kales, tomatoes cabbage, peas), maize and cattle feed crops such as Napier grass. (Author's observation from the field)

This region was chosen as a case study because there is already a self-help group (Kiriita Agricultural Self Help Group) that has been carrying out a sugar beet trial project in the area for the last three years. The trials are being carried out in a ten by ten metre plot per a farmer by at least ten members of the group (approximately 1000 m^2). The aim of the research in the study area was to gain some insight from the real ground on the performance of the sugar beets, challenges in the sugar beet production and the farmer's opinions pertaining the sugar beet production.

3.2.2 Methodology

3.2.2.1 Data collection

With the help of the Chairman of Kiriita Agricultural Self Help Group, Mr. Wilfred Geita, eight group members were mobilized into a single forum for an interview session. By use of a questionnaire, the members together as a group were probed on their experiences/observations from the sugar beet trial projects in their farms. The main questions centered on the observed root yield, sugar content and their general comments on challenges and economic viability of the sugar beet farming. Refer to appendix II for the sample questionnaire.

After the interview session, each and every farm of the present members was visited to make observations on the sugar beets that were already in the field. Observations on their vigour, diseases and pests were made and recorded. Photographs were taken (refer to appendix III). The field conditions in terms of soil types were also observed and recorded.

The Government demonstration fields in the District both at KARI (Oljororok) and Farmers Training Centers (FTC) at Miharati were visited and photographs were taken.

The rest of the procedure remained the same as discussed earlier in section 3.1.2.1

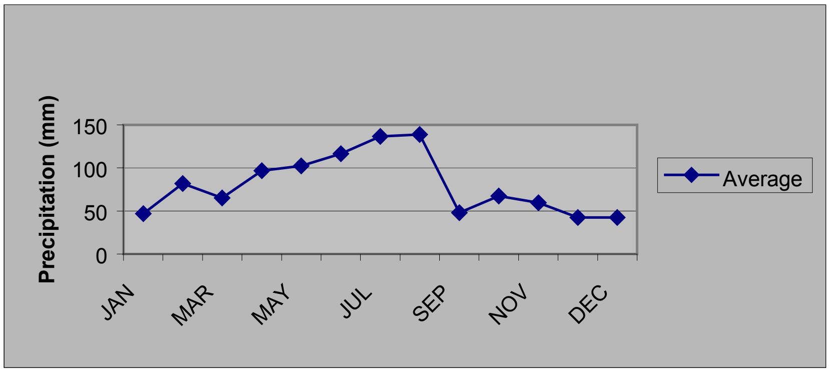
3.2.2.2 GIS and zone mapping

GIS and zone mapping were carried out as discussed earlier in section 3.1.2.2

3.2.3 Results

This section presents results from a field research and GIS data analysis for Nyandarua District.

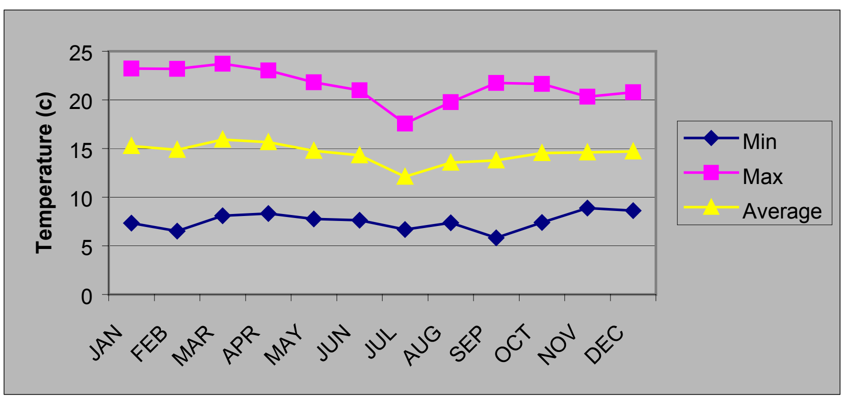
Figure 14: Average monthly precipitation in Nyandarua for the years 1993 to 2002



Data source: Meteorological Department Nairobi

The average precipitation received in Nyandarua during the optimal season April to September is 592 mm. The highest amount of rainfall is received in August and the lowest in September (figure 14).

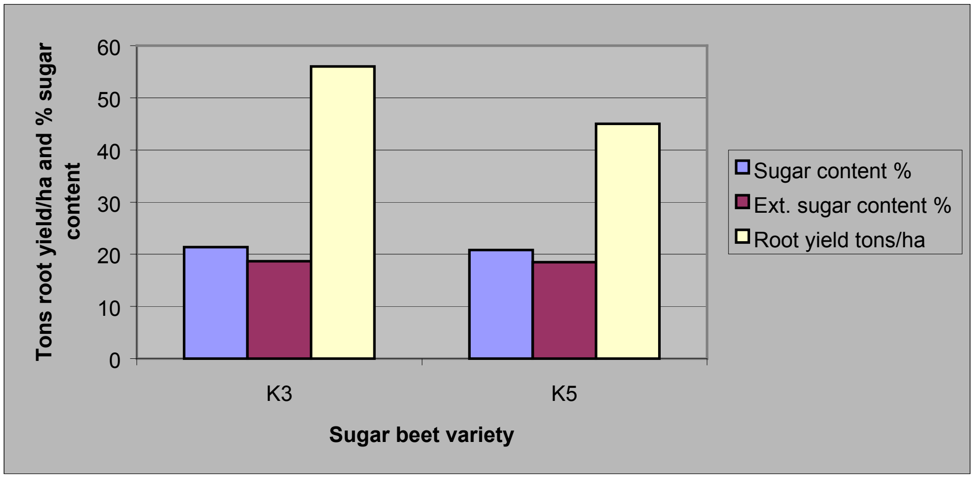
Figure 15: Annual temperature variations in Nyandarua for the years 1993 to 2002



Data source: Meteorological Department Nairobi

The average temperature in the District is approximately 15 ^{o}c. The mean maximum temperature is 21 ^{o}c while the minimum temperature is 8 ^{o}c (figure 15).

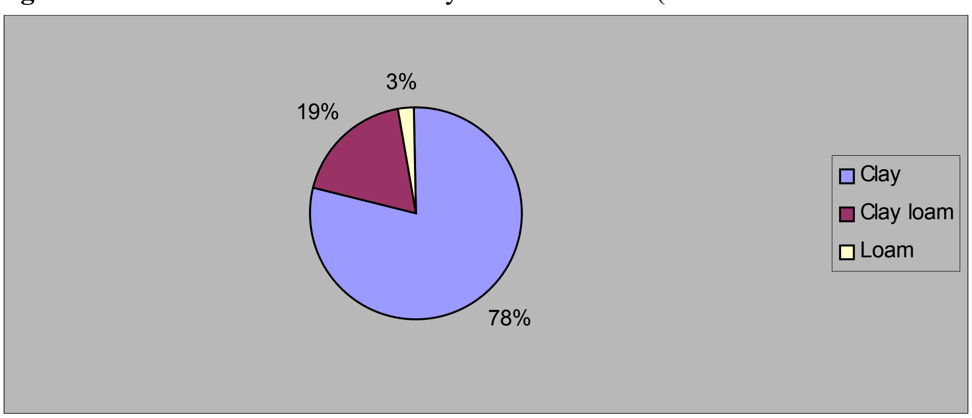
Figure 16: Sugar beet root and sugar content yield in Nyandarua trials for the year 2002



Data source: Interview with members of Kiriita Agricultural Self Help Group

The sugar content for K3 is 21.4%, extractable sugar content 18.67% and the root yield is 56 tons/ha. On the other hand the sugar content for K5 is 20.8%, extractable sugar content is 18.48% while the root yield is 46 tons/ha. The average sugar content therefore is 21.1%, extractable sugar content is 18.6% while the root yield is 50.2 tons/ha. The terms sugar content percentage in figure 16 refers to the total percentage of sugar in a raw sugar beet root. Extractable sugar content percentage refers to the amount of sugar in the sugar beet that is practically possible to extract in a sugar factory. It excludes all the sugar that is lost in pulp and molasses. Sugar beet sugar content for sugar beet varieties K3 and K5 was tested through the help of the Turkish Embassy.

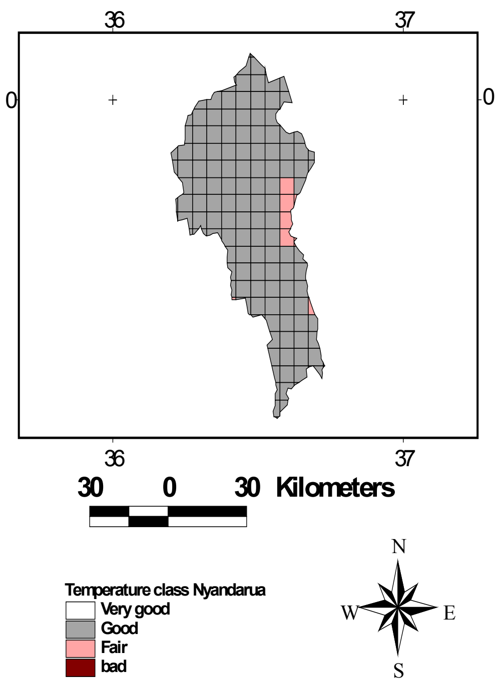
Figure 17: Dominant soil texture in Nyandarua District (FAO soil texture classification)



Data source: Mud Spring Geographers, Inc. (2001)

The dominant soil texture classes for Nyandarua are in their descending proportion percentage area cover are clay (78%), clay loam (36%) and loam (3%) (figure 17).

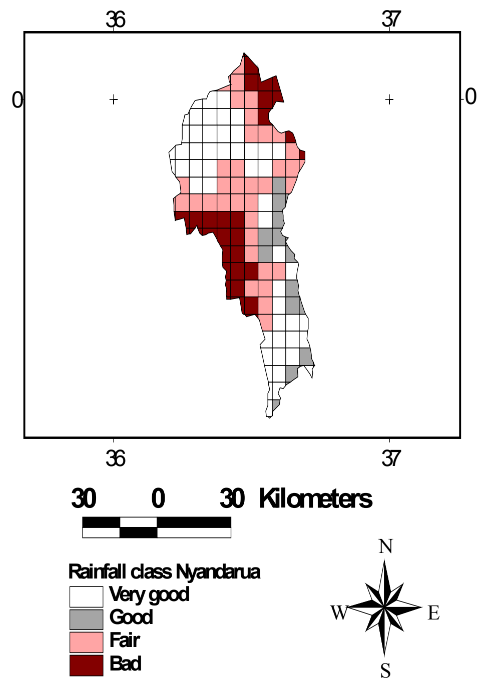
Figure 18: Potential sugar beet temperature sites in Nyandarua District



Data source: Mud Spring Geographers Inc. (2001)

The potential sugar beet temperature sites in figure 18 illustrate that Nyandarua District lies in the good and the fair zones. The good zone constitutes over ¾ of the total area and hence dominates the fair zone that only covers a small portion of the total area

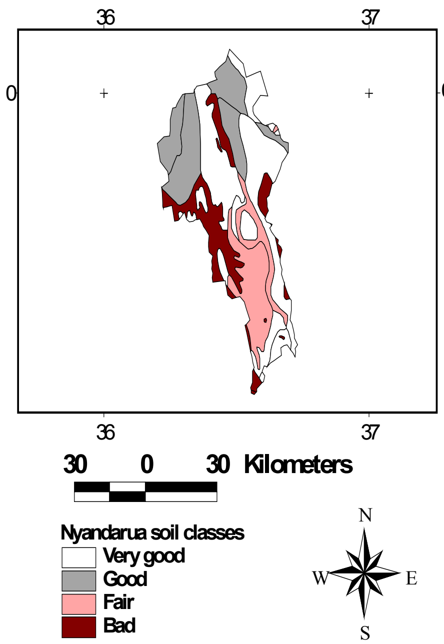
Figure 19: Potential sugar beet rainfall sites in Nyandarua District



Data source: Mud Spring Geographers Inc. (2001)

The potential sugar beet rainfall sites for Nyandarua are very good, good, fair and bad (figure 19). The good zone dominates and covers about ½ of the total area. It is then followed by fair, bad and good zones respectively

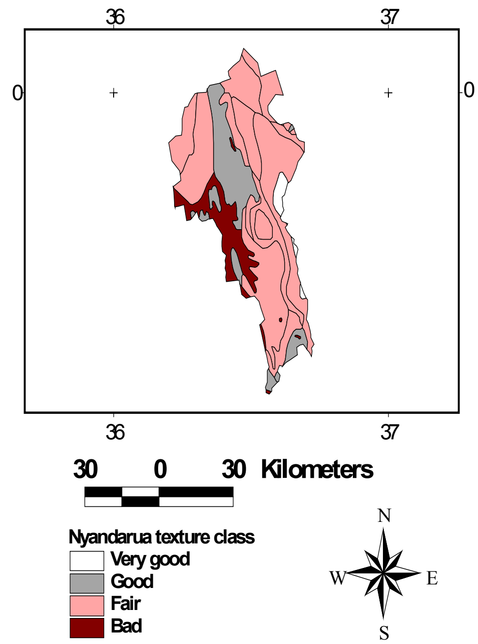
Figure 20: Potential sugar beet soil type sites in Nyandarua District



Data source: Mud Spring Geographers Inc. (2001)

Potential sugar beet soil type sites in Nyandarua are very good, good, fair and bad in their descending order of percentage cover of the total area (figure 20).

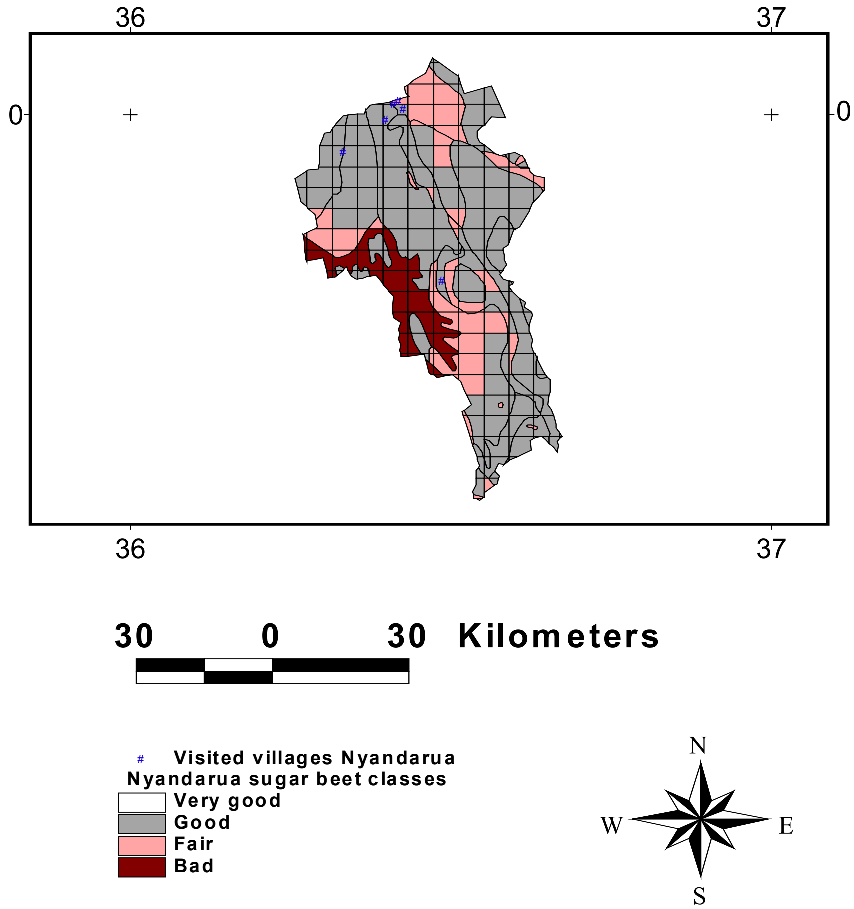
Figure 21: Potential sugar beet soil texture sites in Nyandarua District



Data source: Mud Spring Geographers Inc. (2001)

The potential sugar beet soil texture sites in Nyandarua District are very good, good, fair and bad (figure 21). The fair zone dominates and is followed by good, bad and very good zone respectively.

Figure 22: Potential optimal sugar beet sites in Nyandarua District



Data source: Mud Springs Geographers, Inc. (2001)

The potential optimal sugar beet sites in figure 22 present the actual potential sugar beet sites for Nyandarua District based on the analysis of temperature, precipitation, soil type and soil texture. The zones are a product of the overlay of figures 18, 19, 20 and 21. Three potential optimal sugar beet sites/zones are observed. The good zone cover about ¾ of the total area and hence dominates over the fair and bad zones.

Table 3: Potential sugar beet diseases in Nyandarua District

Potential disease	Thriving conditions	Likelihood	Seriousness	Resistant/ tolerant varieties	Chemical treatment
Cercospora	Temperature (25-32 ^{o}C), 6% humidity	high	high	yes	yes
Downy mildew	Temperature (4 –7 ^{o}C), wet weather, 80-90% relative humidity	Very high	Very high	Yes	yes

Data sources: (George, A.N. 1997; Kung,u, J.N. and E.R. Boa 1997 and Duffus, E.J. and Ruppel, E.G. 1995 and interview with Kiriita Agricultural Self Help Group)

The potential sugar beet diseases for Nyandarua in table 3 are Cercospora and Downey mildew. The chances of both diseases occurring and causing serious effect on the sugar beets are high/very high. Resistant sugar beet varieties and chemical treatments are currently available for the two diseases.

Table 4: Dominant soil types in Nyandarua District

Soil type	% Area	Suitability for sugar beets	Need of fertilizer	Liming	Drainage provision	Erosion risk
Phaeozems	23	Very good	yes	no	no	no
Andosols	18	Very good	yes	No	No	no
Nitosols	15	Good	Yes	No	No	yes
Planosols	13	Good	Yes	yes	Yes	-
Leptosols	12	Bad	Yes	-	No	yes
Luvisols	10	Good	Yes	No	Yes	-
Alisols	5	Fair	Yes	Yes	no	yes
Others	4	-	-	-	-	-

Data source: Mud Spring Geographers, Inc. (2001)

The table 4 above presents the dominant soil types for Nyandarua District. The soil types have been allocated sugar beet suitability classes very good, good, fair and bad following the soil type classification scheme mentioned earlier in the methodology section. The largest proportion for the dominant soils constitutes the very good category (41%); this is followed by good (25%), fair (18%) and bad (16 %). All the soil types would respond well to fertilizer application in regard to high yield. The Planosols and Alisols would respond positively to liming. Provision for adequate drainage system would be advantageous for the Planosols, and Luvisols. The Nitosols, Leptosols and Alisols are vulnerable to soil erosion. The soil names used in table 4 follows the FAO soil classification system except for the term others which has been use to refer to a group of soils with three or less percentage area. The soils under this group are Histosols (2%) and Solonchaks (2%).

3.2.4 Discussion

This section discusses the results from the study in Nyandarua District. The section has been divided into social, biophysical and economic potentials and challenges as discussed below.

3.2.4.1 Social potential and challenges

This section through the analysis of results in section 3.2.3 and other information from the field research, seeks to analyze the social acceptability of sugar beets by farmers at Nyandarua District. This will be achieved through assessment of farmer's satisfaction with sugar beet farming and willingness to produce sugar beets in large scale.

All the interviewed members of Kiriita Agricultural Self Help group, at Nyandarua expressed need for sugar beets. The farmers however, would wish to have accessibility to market for the sugar beets before they embark on large-scale sugar beet production. Another desire is that the pulp from the processed sugar beets should be available freely for their livestock in the very cold periods with not enough grass graze for the livestock. The farmers express a lot of hope in sugar beets. The main reasons being that they are convinced that sugar beets can be sustainably produced in Nyandarua District. Their argument is based on the findings from the sugar beet trials in their own farms that have shown impressive results. The main results of their sugar beet trials are briefly discussed below.

The average sugar beet root yield 50.2 tons/ha is within the optimal sugar beet yield range 40-60 tons/ha for the tropics (Doorenbos, J. and A.H. Kassam 1979). The average sugar content 21.1% and the extractable sugar content 18.6% are promising since they are higher than the optimal sugar content for the tropics (15% sugar content) (Doorenbos, J. and A.H. Kassam 1979). Refer to figure 16 for sugar beet yield and sugar content for Nyandarua sugar beet trials.

The members of Kiriita Agricultural Self Help Group in the interview session affirm that sugar beets present no much workload. They went further to say that the production cost is manageable and can be substantially minimized through good agronomic practices such as timely planting, early weeding and general crop hygiene. They observed that sugar beets planted with early rains during the growing season germinate well, show good plant vigour and are not affected by much diseases and pests especially at the early stages of development that are deemed to be critical stages. All these are important since they reduce the production cost through gapping and application of pesticides thus making the farming exercise affordable and may reduce the negative impact on the environment. However, it is noteworthy that production cost is influenced by a number of factors such as cost of inputs, existing climatic conditions, incidences of crop pests and diseases, cultural factors, level of mechanization and individual farmers capability. This emphasizes the need for further comprehensive research on the production cost from a holistic point of view.

The sugar beet trial farmers emphasize that the observed sugar beet diseases were of no much economic significance since they were sufficiently controlled at affordable cost. Though the observation is based on small-scale plots, it may be possible to economically control the diseases on the large-scale sugar beet farms. To achieve this, it will be advantageous to offer sufficient education to farmers on sugar beet diseases and agronomic practices that may prevent/reduce incidence of the diseases. Such education may touch on agronomic practices such as timely planting, early weeding and general crop hygiene and their influence on the occurrence and intensity of disease attack. Access to affordable high quality resistant sugar beet varieties will be advantageous too in minimizing the cost of disease control.

The sugar beet trial farmers when asked whether sugar beets/byproducts would serve as animal feed being one of their driving forces behind sugar beet trials, they confirm with confidence. They emphasized that the livestock like and feed well on the sugar beets and that the sugar beets survives the very cold seasons when the grass pasture dries up. (Personal communication with group members- Kiriita Agricultural Self Help Group)

The sugar beets therefore, meet the farmers expectations at Nyandarua, are capable of producing high yield in terms of root yield and sugar content. The sugar beets may be produced within affordable cost. The incidence, intensity of diseases as well as related treatment/control cost may be minimized through good agronomic practice. Sugar beets therefore, are socially acceptable to the farmers at Nyandarua District given that the two desires mentioned earlier are met.

3.2.4.2 Biophysical potentials and challenges

Crop-growing season for Nyandarua District begins in the month of April and extends through a period of six months to September (Mud Spring Geographers, Inc. 2001). The average temperature in the District during this period is approximately 15 ^{o}C (figure 15). This temperature average is within the sub-optimal temperature range for the sugar beet production (10 ^{o}c to 17 ^{o}C -good) (David, D. and A. Young 1981). Over ¾ of the total area in Nyandarua District lies in the good temperature zone (figure 18). At this temperature level the germination of the sugar beets is likely to take relatively longer compared to Kakamega. This probably explains the observations made by sugar beet trial farmers that sugar beets germinated in 18 to 27 days unlike other crops in the area that take 7 to 8 days to germinate. The sugar content is expected to be high because of lower temperature towards the expected harvesting time (August and September) that almost corresponds with the optimal temperature for high sugar accumulation (10 ^{o}c). As a result the sugar content would be expected to hit the optimal 15% sugar for the tropics (Doorenbos, J. and A.H. Kassam 1979). The main challenge shall be the relatively lower average temperature than the optimal for the tropical sugar beets 18 ^{o}c to 22 ^{o}c. However, given the results for the sugar beet root yield and sugar content as illustrated in figure 16, there may possibly be no cause for alarm since both root yield and sugar content is within the optimal ranges for the tropics.

The average precipitation 592 mm received in the region during the optimal season falls within the optimal precipitation range of 550 mm to 700 mm (very good) (David, D. and A. Young 1981). The precipitation to potential evapotranspiration ratio (P/PE) for the region is 1.2 (Mud Spring Geographers, Inc. 2001). Therefore, going by the rule of thumb the region may have enough soil moisture and hence agricultural potential. However, it is worth noting that though the average precipitation is within the optimal range, it is not uniformly distributed throughout the District (figure 19). Only about half of the District receives the optimal rainfall range while ¼ of the district receives the sub-optimal range 701 to 1000 (good). The rest of the district falls under sub-optimal range 460 to 549 (fair) and non-sugar beet zone (bad). Above this, the rainfall is well distributed throughout the growing season (figure 14). This implies that irrigation may not be necessary in the parts of the District under very good and good zones.

Downy mildew and Cercospora are the potential sugar beet diseases at Nyandarua (table 3). Downy mildew thrives well in cold conditions therefore it is likely to be a challenge during the cold months such as June, July and August (figure 15). This disease being a disease of the seedlings may have no significant effect on the sugar beet yield given that sugar beets would be sown in the month of April and by this time they will already be well established. The effects of Cercospora may be pronounced in the warm months April and May (figure 15). Given that this is the onset of the growing season for sugar beets, the disease is likely to cause substantial damage/losses associated with poor sugar beet establishment. Nevertheless, sugar beet varieties resistant to both Downy mildew and Cercospora diseases are currently available. Besides the resistant varieties, the diseases can also be sufficiently controlled through use of a wide range of fungicides and good agronomic practices such as crop rotation, early sowing and clean seeds. Sufficient education to farmers on good agronomic practices will be helpful in preventing the occurrence/incidence of the diseases. This kind of knowledge coupled with the availability of resistant varieties will present an effective prevention of the diseases. Doing this may reduce production cost and minimize on environmental pollution from leaching/runoff of pesticides into ground and surface water. Residual effects of some pesticides in the soil and the harmful effects to the user may also be minimized.

The dominant soils for Nyandarua District are illustrated in table 4. Phaeozems, Andosols and Nitosols are all deep, fertile, well-drained soils with good water holding capacity. Given that sugar beets require deep, well-drained friable soils, then these soils present a good potential for optimal sugar beet yield. This potential is enhanced further by their fertility (keep in mind that sugar beets require high nutrients) and the fact that the soils constitute 56% of the total area in Nyandarua (table 4). However, still it will be advantageous to add fertilizer and provide adequate mechanisms for erosion control for 15% area constituting the Nitosols since they are vulnerable to soil erosion. It is possible also to produce sugar beets on Luvisols and Alisols soils. But good drainage is necessary on the 10% area for the luvisols since they are prone to water logging. The Alisols being acidic would respond well to liming to adjust the pH to around neutral being the optimal for sugar beets. The two soil types will also respond well to fertilizer application regarding optimal sugar beet yield. Through the above discussion, it is noted that fertilizer application is necessary for all the soil types in this region. Erosion control, drainage and liming have also to be provided but on relatively small percentage areas. Refer to section 3.1.4.2 for more details about effects of liming and fertilizer application.

The interaction between temperature, precipitation, diseases and soils determines the biophysical opportunities and challenges for sugar beets in Nyandarua District. Temperature, rainfall and soils all present a good potential for optimal sugar beet yield in Nyandarua District. This is especially true if the sugar beets are introduced on the ¾ area under zone 2 (good zone). The two potential sugar beet diseases in the District may not pose a significant threat to the sugar beet yield nor environment since they have commercially available resistant varieties. Therefore, the main challenge is cost and environmental impact of providing for drainage where possible for the soil texture class 3 (clay) that forms about ¾ (figure 17) of the total area. Provisions for erosion control for the 15% area constituting the Nitosols (table 4) shall also be a challenge. However, depending on the method employed the cost and effects may be substantially minimized. Based on the biophysical potential, it is possible to produce large-scale sugar beets in Nyandarua District.

3.2.4.3 Economic potential and challenges

The results of the sugar beet trials at Nyandarua District are encouraging in terms of the economic potential. The average root yield of 50.2 tons/ha is within the optimal range for the tropics. The extractable sugar content 18.6 % is slightly above the optimal 15% for the tropics. About ¾ of the total area in Nyandarua fall under the sub-optimal zone 2 (good) and hence optimal sugar beet yield may be expected (figure 22). The observed root yield, sugar content and proportion of area under zone 2 (good), underscores the economic feasibility for the sugar beet project. This potential gives opportunity for profits in the investment for both processors and the individual farmers.

The economic potential is further enhanced by the fact that all the potential sugar beet diseases predicted for the area have got resistant sugar beet varieties. This means that losses of sugar beets from the effect of the diseases can be avoided and hence high yield. Resistant varieties further provide an opportunity for environmental conservation by minimizing/eliminating the use of pesticides together with the associated negative environmental impact. However, these are only possible if the resistant sugar beets varieties can be available to the farmers at affordable price.

In the trial farms at Nyandarua, NPK fertilizers were added at the rate 4.3 kg/0.1ha (43.3 kg/ha). Though the rate is less than the expected for the tropical sugar beet production (NPK

150:40:100), it gave optimal yield as discussed earlier. Incase this rate remains viable over time, it presents an opportunity for minimizing on production cost and negative impact on the environment. This is true since relatively little fertilizers are expected to be applied compared to the amount expected for the tropics. With minimized application of fertilizer, probably less fertilizers would leach out to ground/surface water. Leaching of fertilizers from a sugar beet farm is not a big challenge. This is because sugar beets are deep rooted (150 cm) thus absorb nutrients from deep soil horizons curbing down on the leachate to ground water.

The sugar beet farmers at Nyandarua expressed that both workload and production cost were manageable. However, it is worthy noting that the sugar beets were only grown in ten by ten metre plots and that seeds were provided free by donors. Therefore, the expressions on satisfaction with workload and production cost may not reflect the true picture when it comes to large-scale production. Thus, a comprehensive research(s) is necessary to explicitly analyze the workload and production cost for sugar beets.

The other challenge to jump-start the project is the lack of sugar beet processors in the locality. To establish a sugar beet processing plant, independent willing investors have to be seeked for. Alternatively, a possibility for small-scale community/group owned sugar beet processing plants/factory(s) should be explored. To achieve this, appropriate campaign and sugar beet demonstration projects are necessary to woo investors and donors. Given the large sugar beet potential under zone 2 (good) and the large sugar deficit in Kenya, perhaps it may be possible to attract investors/donors. The greatest challenge shall be to seek for modalities of wooing investors into the area and/or seeking for donor funds for the community owned projects. This can be done through the close co-operation between local community, government, donor agencies and potential investors.

Another challenge shall be on how to ensure sustainability of the project. The sustainability issue is complex and needs a more detailed research. Nevertheless, sustainability may be enhanced if processors strive for high efficiency to reduce the production cost. They should further strive to pay attractive prices for the beets supplied by farmers and promptly. Farmers on the other hand should be trained on good agronomic practices. These shall be aimed at maximizing on profits while minimizing on production cost and potential negative environmental impact. Incase of community owned processing plants, the community members should be involved in all stages of design, planning and implementation. Furthermore, they should be sufficiently trained on how to manage/maintain the facilities. This shall nurture a sense of ownership and hence promote good management and efficiency.

The cultivation of sugar beets should be well planned and be carried out along with the current livestock production. A modality should be explored to enable the sugar beet farmers get back the sugar beet pulp for their livestock especially in the cold season with little grass graze for their livestock. This will open an opportunity for farmers to benefit from the diversification.

3.2.5 Conclusion for Nyandarua

Socially sugar beets may be acceptable in Nyandarua District. The biophysical potential for sugar beets in terms of temperature, rainfall and soils is sufficiently good regarding high sugar beet yield. The problems that are likely to be encountered are the effect and cost of preventing/controlling diseases, soil erosion, soil drainage and the quantity of fertilizer use. Therefore, to minimize on the production cost and environmental impact proper/adequate modalities for addressing these problems are necessary. The current lack of sugar beet processors may be a challenge for large-scale sugar beet production. Thus strategies to attract large-scale/small-scale community owned processors would help create the market.

4.0 Comparison between the two case studies (Kakamega and Nyandarua Districts)

The mapping of optimal crop growing zones in both Districts was made by GIS technology. Results need to be interpreted with due attention to possible limitations in the technique and inaccuracy of the input data. Nevertheless, sugar beet production appears to be possible at large-scale in both Districts. This is because of the existence of sufficient, social, biophysical and economic potentials in both Districts. The social potential for sugar beets for both Districts is sufficient and promising given that over 75% of the interviewed farmers from both Districts expressed need for sugar beets. This potential is further enhanced due to the fact that sugar beets possess potential characteristics that are compatible (correspond) to the farmers desired characteristics in both Districts. Though both Districts have sufficient biophysical potential, the potential for Kakamega District seems a bit weaker compared to that for Nyandarua District. This is because a greater percentage of soils in Kakamega may respond well to liming, drainage and erosion control compared to that found in Nyandarua. Most of the soils too have little natural fertility meaning that relatively larger quantity of fertilizers may be advantageous for high/optimal yield. Above these, the number of potential sugar beet diseases at Kakamega is higher than that in Nyandarua. Some of these diseases currently have no resistant varieties necessitating the use of pesticides incase good agronomic practices are not sufficiently adopted.

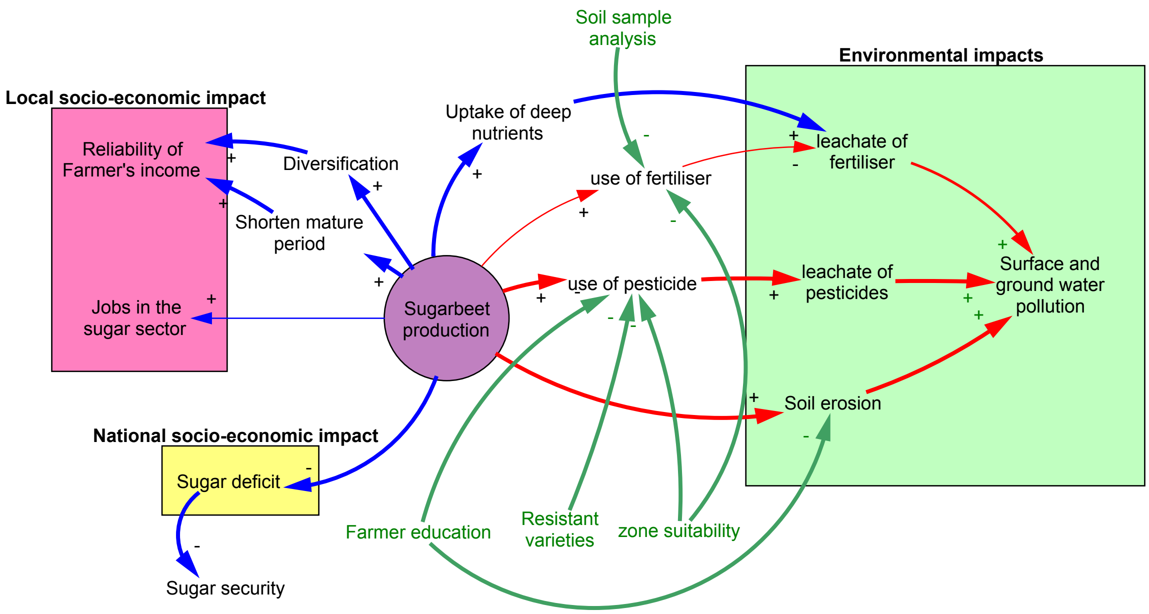
Following the above discussion, then, though it is possible to produce sugar beets at Kakamega District, the production cost would most probably be relatively higher than that incurred in Nyandarua. The negative environmental impact would be more due to the use of pesticides and relatively larger quantities of fertilizer. This is possible since ¾ of the soils have texture class 3(clay) implying a possibility of poor drainage in some of the soils. Poor drainage encourages leachate to ground and surface water where they cause water pollution. Nevertheless, it is worth noting that the deep roots of sugar beets may minimize the effect of leachate to ground water.

Nyandarua District presents a relatively good potential for sugar beets compared to Kakamega District. Further on, due to the on going sugar beet trials in the area, coupled with the impressive results from the trials, farmers at Nyandarua would non-reluctantly accept sugar beets. Hence, incase sugar beets would be introduced in large-scale in Kenya; Nyandarua District would probably be preferred.

Since the potential impacts from sugar beets cannot be underestimated, farmers in both Districts should be sufficiently educated on the good sugar beet production agronomic practices and be made to understand the likely environmental impact. Through these, it is possible to optimize on sugar beet yield at the same time curb down on the negative environmental impact and the production cost.

It would be important to have scientifically designed, managed and controlled sugar beet experimental and demonstration projects in both Districts to confirm/analyze the potentials and challenges in sugar beet cultivation. This should be carried out in close collaboration with all main stakeholders. Figure 23 summarizes the potential impacts of sugar beet production in Kenya.

Figure 23: Summary of the potential impacts from sugar beet production in Kenya



The figure 23 presents a summary of the possible impacts from large-scale sugar beet production in Kenya as discussed in this paper. The blue loops represent the potential positive impacts from sugar beet production. The red loops represent the potential negative impacts while the green loops represent the possible ways of addressing the negative impacts. The thick loops represent the impacts/solutions that are deemed more important while the thin loops represent those with minor impacts. The + sign shows that the two variables being compared increase/decrease in the same direction (directly proportional). The – sign shows that the two variables being compared increase/decrease in the opposite direction (inversely proportional).

5.0 General conclusion

There is a potential for large-scale sugar beets production in Kakamega and Nyandarua Districts in Kenya. However, much comprehensive analysis would be necessary to adequately determine the real impacts from sugar beets and hence possibility for sustainable sugar beet production. Education to farmers, resistant varieties and utilizing the most suitable zones for sugar beet production may be advantageous in sustainable sugar beet production. Sugar beet processors should be seeked for to create market for sugar beets.

6.0 Sugar sector scenarios in Kenya for the period 2001 and 2030.

This section has a description of two sugar production scenarios based on the discussions in this paper. The two scenarios are Business as Usual Scenario (BAU) that describes the likely trend in the sugar sector in a period of 30 years (2001 to 2030). In the BAU scenario it is assumed that no action is taken to address the current problems in the sugar sector. The other scenario is sugar sector with sugar beets; this describes a scenario where sugar beets are sustainably introduced as one of the viable solutions to the current sugar deficit.

6.1 BAU scenario

Facts on sugar sector dynamics in Kenya between the years 1992 to 2001
Data source: Sugar board report 2001 (refer to figures 1 and 2)

The difference sugar production dynamics 1992 to 2001 is (377,438-371,225) =6,213 metric tons white sugar. This is a growth rate of 1.7% increase in the ten years (0.17% per year)

The difference sugar consumption dynamics in the same period of time is (600,000-552,000) = 48,000 metric tons white sugar. This translates to a growth rate of 8% in the ten years consequently 0.8%/year.

The difference sugar deficit dynamics 1992 to 2001 is (222,562-180,775) = -41,787 metric tons of white sugar. This translates to a growth rate of 18.8% in the ten years and hence 1.9% per year.

The difference in sugar import between the years 1992 and 2001 is (249,336-124,463) =124,873 metric tons of white sugar. This is equal to a growth rate of 50% in the ten years and hence 5% per year.

The difference in total employment dynamics between 1992 and 2001 is (8,876-34,140) =-25,264 employees. The result is a growth rate of -74% in the ten years. This translates to a growth rate of -7.4% total employments in sugar sector per a year

In the BAU it is assumed that nothing is taken to curb down on the current sugar sector problems and every thing continues to grow at the same rate. In such kind of scenario, during the next 30 years (2001 to 2030), production is expected to increase at the current rate of 0.17% metric tons per year to stand at 396,495 metric tons by the year 2030.

Consumption rate shall continue to increase at 0.8% per year and hence 755,973 metric tons by the year 2030.

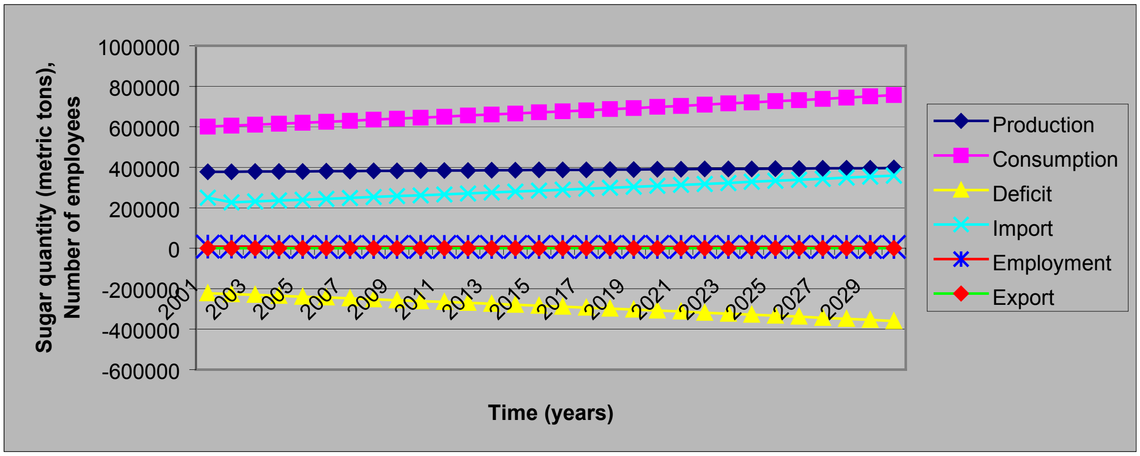
The sugar deficit is expected to rise at the rate of 1.9% per year. However, in the BAU as usual scenario, sugar deficit is calculated as a difference between quantity of sugar produced and the quantity sugar consumed. This being the case the sugar deficit by the year 2030 stands at –359,478 metric tons.

Further on, the imported sugar is expected to grow at the rate of 5% per year. But in the BAU, the imported sugar is calculated as a difference between quantity of sugar consumed and that produced. Therefore, the quantity of the imported sugar shall stand at 359,478 metric tons by the year 2030.

The total employment in the sugar sector is expected to decline at the rate 7.4% per year from 8,876 employees. However, in the BAU it has been assumed that the number of employees cannot go down beyond 7000 employees if the sugar sector has to be adequately functional. Therefore, by the year 2030 the number of employees shall be 7048 people.

The expected dynamics in the sugar sector based on the above-described scenario has been summarized and illustrated in figure 24.

Figure 24: Business as usual scenario for the year 2001 to 2030 (a Microsoft excel model)



The data source is Kenya sugar board report (2001)
The scale is the same for both sugar quantity and number of employees

6.2 Sugar scenario with sugar beets

This section describes a scenario where sugar beets are introduced as one of the solutions to the current sugar deficit. In this scenario, sugar beets are sustainably introduced to Nyandarua District in the year 2008 and at Kakamega District in the year 2010. This is because in Nyandarua District already exists sugar beet trial projects and farmers are already confident that sugar beets can be economically and sustainably produced. Nyandarua District also has little challenges from the biophysical potential. In Kakamega, time is needed to start up experimental/demonstration projects from scratch so as to confirm the existence for the sugar beet potential as well as convince farmers, investors and the policy makers on the possibilities for sustainable sugar beet production in the District.

Facts and assumptions made

Average extraction rates of white sugar from:

- Sugar cane =12%
- Sugar beets =14%

(Personal communication with Staffan Nilsson of SwedeNile)

Between the years 2004 and 2006, large-scale and well-controlled sugar beet experiments and demonstration projects take place in Nyandarua District to confirm and improve on the findings by Kiriita Agricultural Self Help Group. Consultation and negotiations with potential investors, donor agencies, policy makers, farmers and other interest groups take place simultaneously. Between the second half of the year 2006 and end of year 2008 a sugar beet processing plant is constructed and ready to process sugar beets.

In the year 2008, first large-scale sugar beets are grown by individual farmers on approximately 15,000 ha of land in Nyandarua District. The sugar beets give an average sugar beet root yield of 100 tons beet/ha in 18 to 24 months (two growing seasons). The total sugar beet root yield in Nyandarua for the year is (100 ton/ha x 15,000 ha)/2 = 750,000 tons beet/ha. The total white sugar from the sugar beets is; 14% x 750,000= 105,000 metric tons white sugar per year.

It is further assumed that by the year 2008 all other sugar factories in Kenya have not introduced sugar beets. Thus the total sugar produced by these factories continues to grow at the rate 0.17% per year. The total white sugar produced in the year 2008 in the country shall be equal to sugar from sugar beet in Nyandarua + total sugar from the other sugar factories in Kenya= 105,000 metric tons + 381,952 metric tons = 486,952 metric tons. This constitutes an increase in white sugar yield by 105,000 (27%) and hence a reduction in sugar deficit from –252,465 to –147,465 metric tons (58%). Thereafter, at the year 2009 the sugar production grows at the rate of 2% per year to stand at 2% x 486,952 +486,952 = 496,691 metric tons white sugar.

The new sugar beet processing plant at Nyandarua increases employment in the sugar sector by 27 % in the year 2008 from 7048 to 8951 employees (assumed proportional growth rate as the sugar production rate). In the year 2009 the number of employees in the sugar sector remain the same as in the year 2008.

In the year 2010, an expansion/modification is completed at Mumias Sugar Company for sugar beet processing. Sugar beets are introduced in a half of the total cane land at Mumias (22320 ha). Expected average tons sugar beets/ha at Mumias (Kakamega) in (18 to 24 months) =100 tons beets/ha. Average tons sugar cane tons/ha at Mumias (Kakamega) in one growing season (18 to 24 months) =76 tons cane/ha.

Sugar cane yield remaining constant, at 18 to 24 months total yield =76 tons/ha x 22320 ha =1,696,320 tons cane. The white sugar extracted = 12% x 1,696,320 = 203,558 tons white sugar in 18 to 24 months. This is equivalent to 101,779 metric tons of white sugar per year.

Total sugar beet yield in 18 to 24 months = 100 tons/ha x 22320 ha = 2,232,000 tons sugar beet. The white sugar extracted = 14% x 2,232,000 = 312,480 tons white sugar in 18-24 months (156,240 metric tons per year). Therefore, the total white sugar yield from Mumias per year shall be sum of sugar from sugar cane + sugar from sugar beet = 101,779 + 156,240 =258,019 metric tons white sugar per year. This is 35% increase a t Mumias from 191,626 metric tons that would be obtained from the BAU by the year 2010.

At this point in time it is assumed that sugar beets have not been introduced in other factories except Mumias Sugar Company and Nyandarua. Therefore, the rate of sugar production continues to increase at 0.17% per year (in non-sugar beet processing factories), thus in the year 2010, they shall produce 191,626 metric tons white sugar per year as in BAU. The total sugar produced in the country for the year 2010 shall = sugar from sugar beet in Nyandarua + sugar from Mumias + sugar from other sugar cane processing plants = 107,100 + 258,019 + 191,626= 556,745 metric tons white sugar per year. This is an increment of 60,054 metric tons white sugar per year (i.e. 12% increment) compared to the year 2009. Given that the sugar consumption in the year 2010 is at 644,609 metric tons per year, then the sugar deficit shall be = -87,864 metric tons white sugar down from -147,465 metric tons (60% reduction) in the year 2009.

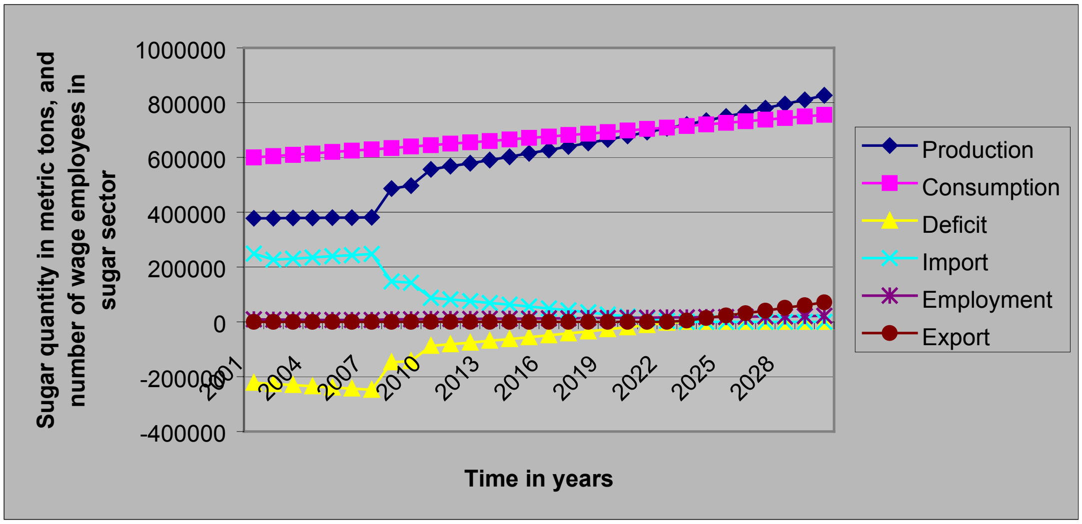
It is further on assumed that after the year 2010, sugar production shall keep on growing at the rate 2% each year up to the year 2030. By the year 2030, the amount of sugar produced shall hit 827,294 metric tons.

Consumption rate remains the same as in BAU thereby standing at 755,974 metric tons per year in the year 2030. The sugar imports, exports and deficit are calculated in the same way as the BAU. In the year 2030 imported sugar shall remain at a negligible percentage around zero, 7,140 tons of white sugar shall be exported while the sugar deficit shall be at zero.

It is assumed that in the year 2010, employment in the sugar sector shall increase by 12 % to stand at 10,025 employees. This is associated with the expansion of Mumias Sugar Company factory. Thereafter the employment shall grow at the rate 4 % per year and hence hit 21,966 wage employees by the year 2030.

The sugar sector dynamics in the sugar beet scenario (for years 2001 to 2030) is summarized and illustrated in figure 25.

Figure 25: Sugar sector scenario with sugar beets (a Microsoft excel model)



Data source Kenya Sugar Board report (2001)
The scale is the same for both sugar quantity and number of employees.

From the results of the scenarios, sugar beets can be one of the viable solutions to the current sugar deficit in Kenya (refer to figure 25).

7.0 Recommendations

This section presents recommendations that can promote sustainable production of sugar beets in Kenya as well as improve on the performance of the sugar sector in general. These recommendations are:

- Farmers should be well trained on the good agronomic practices necessary for sugar beets cultivation prior to large-scale sugar beet introduction in the study areas
- To sustain the sugar sector processors should give prompt and attractive payment to farmers for sugar beets/sugar cane supplied.
- For high/optimal sugar beet sugar content accumulation, the sugar beets at Kakamega should be exposed to nitrogen deficiency two months before lifting.
- Adequate but affordable soil drainage coupled with sufficient application of nitrogen fertilizers is necessary regarding high/optimal sugar beet yield in some soil types.
- The diseases should be controlled as much as possible through good agronomic practices and use of resistant varieties. However, where these two cannot work, then seed treatment is recommended. Pesticides should only be used carefully and as a last resort.
- Soil sample analysis should be carried out to determine the types and quantity of fertilizers to be applied. This will also determine the design on where liming should be done and the application rate. This will curb down on production cost and environmental impact.
- Sugar beet demonstration projects in the localities are advisable prior to commercial sugar beet cultivation. Such demonstration projects should be carried out in close collaboration with all main stakeholders (i.e. farmers, local leaders, government officials, sugar processors and other interest groups).

- Large-scale sugar beet introduction should be gradual and only after comprehensive feasibility and environmental impact assessment studies. The sugar beets should only serve as supplements to sugar cane/other activities on farm and not as substitutes for farmers benefit from the diversification.
- Improve on management of the sugar sector at all levels to encourage efficiency and innovativeness for quality product, environmental conservation and cost reduction.

8.0 Future research areas

The following are areas recommended for future study to enhance sustainable large-scale sugar beet production in Kenya

- A comprehensive research to study the economic viability of sugar beets in Kenya from a holistic point of view. The study should involve the analysis of liberalized market and effects of globalization on sustainable sugar beets production in Kenya.
- A comprehensive study to analyze the influence from infrastructure, weeds and pests on sustainable sugar beet production in Kenya.
- A sugar beet yield prediction model for Kenya. This should involve actual experimental sugar beet projects in selected sites within the study areas. The results from these experiments should be used to develop a homegrown sugar beet yield prediction model based on a number of experiments and sensitivity analysis.
- A comprehensive study to analyze the compatibility between sugar cane processing technologies compared to that for sugar beets. The study should involve the analysis of social, environmental and economic viability incase sugar beets are processed with sugar cane plant modified/unmodified.
- A comprehensive study to predict and compare the workload involved in sugar beets cultivation compared to that involved in sugar cane production.
- Comprehensive study to analyze the potential affects on sugar beet yield and the environment as a result of influence from the existing soil types. The study should include an analysis on how the soil structure and soil water infiltration can be improved especially on the heavy textured soils.
- A GIS study to determine other potential sites for sugar beet production a part from the two study areas (i.e. Kakamega and Nyandarua District). The study should involve a comparison of potentials, challenges and yield to that in Kakamega and Nyandarua.

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10.0 Appendix

10.1 Appendix I: Sample questionnaire for sugar cane farmers at Mumias (Kakamega District)

QUESTIONNAIRE FOR LUMES THESIS 2003
By Mr. Nicodemus Mandere Mandere

SUGARCANE FARMERS
The objective is to assess the farmers' condition and farm structure, to evaluate performance of sugar cane and potential for establishing sugar beets.

Introduction

Questionnaire No.		Date	
Name of Farmer		Name of Interviewer	
Age		Name of Village/area	
Education status		Family size	
Income			
Sources of income			
No. Of years in sugar cane production			

2.0 Farm condition
What is the average size of your farm (ha)--
(*Check soil condition, type of soil, drainage, rainfall pattern, etc*)

What proportion of your land is devoted to?
a). Sugar cane production---
b). Other crops (specify)--
What is the trend of your farm size under sugarcane over the last few years?
Has it remained the same? [] yes [] no
Reasons--
Has it increased [] yes [] no
Reasons--
Has it reduced [] yes [] no
Reasons--
Production
When do you plant your sugarcanes---
How long does it take to reach maturity and harvesting--
What types of inputs do you use in your farm on the production process?

Inputs	Types	Amount/ha	Cost	Comments
Seed canes				
Fertilisers				
Pesticides				
Labour				
Transport				
Harvesting				
Others				

How do you acquire the above-mentioned inputs?
Are they provided by the company [] yes [] no
If yes briefly comment on the procedure and payment process-----------------------------Do you purchase on your own? [] yes [] no
If yes comment on the sources of money (earnings from agriculture, loans etc) --------
Do you use locally available resources and by products such as manure from the farm---
Do you have access to credit facilities (e.g. loans (inputs), grants, etc)?
[] Yes [] No
If yes state the sources and types--What other comments can you make about the credit facilities---------------------------------
Sugar cane yields (Harvesting)

Year	No. Acres	Total yields (tons)	Total production cost	Total sales Kshs.	Comments
2002					
2001					
2000					

What can you comment on the trend of sugar cane yields over time---------------------------How to get payment for the sugar cane delivered to the factory? ------------------------------
Is the payment prompt [] yes [] no?
If no on average how long does it take for you to receive your payments? -------------------Why do you think it takes such long to receive your payments--------------------------------What can you comment about the amount of money you receive per ton of sugar cane supplied to the factory? ---
Are you satisfied with the mode of payment?
[] Yes [] No
Give reasons for yes or no? ---Give comments/suggestions necessary for improvement ---------------------------------------
Willingness to switch to other crops
Are you satisfied with current status of sugarcane growing? *(Tick where appropriate)*
Yes [] No []
If yes, (*give reasons why you think so*)-- If no (*give reasons why you think so*)
Do you know of any other crop that can also be used to produce sugar other than sugar cane? If yes, give examples
If you are given an alternative sugar-producing crop what qualities could you prefer in the crop---
If the crop meets the above-mentioned qualities, would you prefer to:
(*Tick where appropriate*)

[] Switch from sugarcane growing
[] Cultivate both crop and sugarcane
[] None of the above
Others (*specify*)---
Why do you choose the above options---
Have you heard about sugar beets?
Yes [] No []
If yes, give a brief comment about them---
Constraints
What problems/challenges do you experience as a sugarcane farmer?
As an individual farmer what plans or strategies have you put in place to address the above-mentioned problems/challenges---
In what ways do you think the above-mentioned problems/challenges can be addressed?
What are some of the benefits that the community has gained from either sugar cane farming or the sugar company? --

10.2 Appendix II: Sample questionnaire for sugar beet farmers at Nyandarua

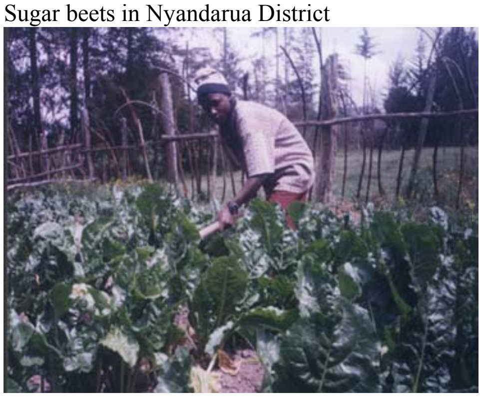
The objective is to establish the farmers' opinion about the sugar beet farming, performance (root and sugar yields) and the aspirations on commercial sugar beet production.
For how long have you been trying sugar beets in your farms?
What are the main objectives behind your sugar beet trial project?
Do you think the sugar beets are capable of meeting the above-mentioned objectives?
Averagely what amount of kilograms have you been able to realize from your 10 by 10 metre plots?
Incase you were to carryout the sugar beet project on large scale for commercial purposes do think given the observed yields you can make profit?
What can you comment on the work load involved in the sugar beet cultivation?
What are the main inputs into the sugar beet trials?

Inputs	Types	Amount/ha	Cost	Comments
Seeds				
Fertilisers				
Pesticides				
Labour				
Others				

Have you ever carried out tests on the sugar content on the sugar beets?
If yes, what were the results of the sugar test?
What are your future aspirations in the sugar beet farming?

10.3 Appendix III: Sugar beet pictures in Nyandarua District.

Sugar beets in Nyandarua District



Source: Field survey

Sugar beets in Nyandarua District

Source: Field survey