CHAPTER 4

BIOMASS POTENTIAL

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4. INTRODUCTION

The impacts of bioenergy on food security are uncertain. There may be positive or negative effects which depend on how the sector is managed. In order to ensure that food security is not negatively affected with the advent of bioenergy feedstock production it is crucial that staple food crops and their primary growing regions are well understood. At a minimum, this will ensure the potential impacts are clearly understood. Tanzania is a land-rich country and therefore is in a unique position to be able to protect existing and future agricultural production areas, keep tropical forests, conservation areas and biodiversity hotspots intact, all while expanding agriculture to meet new bioenergy demands. Accurate and efficient land planning is the route to achieving this.

Agriculture is a key sector for the Tanzanian economy and for food production. Improving agriculture performance and planning is thus key to ensuring continuing economic growth first and secondly targeting poverty reduction. As part of planning activities, it is essential to optimally plan land use and land allocation. In this context and within the scope of bioenergy developments, this chapter illustrates how land planning and zoning can be carried out. The chapter will focus on bioenergy crops, which is the scope of this analysis, but it is important to note that the analysis presented can be applied to any agriculture crop. Sustainable production would mean production that does not contrast with protected areas, including game reserves, protected forests, biodiversity areas, and key food production or agriculture areas.

To assist in sound decision-making regarding land assessment and planning for the agricultural and biofuel sectors, this module, Module 1 of the BEFS Analytical Framework (AF), provides policy-makers with both the area of suitable land available for bioenergy crops as well as the potential agricultural production from that land. Further, before deciding whether the suitable area identified can be exploited for bioenergy crop production potential environmental or food production conflict areas need to be identified. Thus, both the environmental and social effects need to be factored in the decision to use that land and how changing land use may affect food security and livelihoods.

The methodology framework of Module 1 is based on FAO's Agro-ecological Zoning (AEZ) approach (FAO, 1978) and allows to pinpoint where bioenergy crops can be cultivated under

1 Special appreciation goes to Rommert Schram for his feedback and comments on the chapter.

varying degrees of suitability from an agro-ecological perspective. The assessment is carried out over four combinations of agricultural production systems and input levels. Special attention is paid to conservation agriculture which will enhance sustained agricultural production while promoting long-term sustainability, food security, or environmental protection. An important consideration in the analysis relates to whether Tanzania should consider expansion into new lands for bioenergy developments, the intensification of current lands under agricultural production or a combination of both.

This chapter of the analysis proceeds as follows. Section 4.1 provides an overview of the methodology. Section 4.2 illustrates the set-up of the analysis in the Tanzanian context. Section 4.3 discusses the main features of agriculture production in Tanzania. Section 4.4 discusses the results. Section 4.5 shows how the results should be balanced against other location specific information available. Section 4.6 concludes.

4.1 ASSESSMENT OF BIOENERGY CROP POTENTIAL: THE METHODOLOGY

The methodology framework of Module 1 is based on FAO's Agro-ecological Zoning (AEZ) approach (FAO, 1978). This part of the analysis is used to assess the actual *availability of suitable land* that can be used to grow bioenergy crops.

The methodology presented here has two core elements to it (see Figure 4.1):

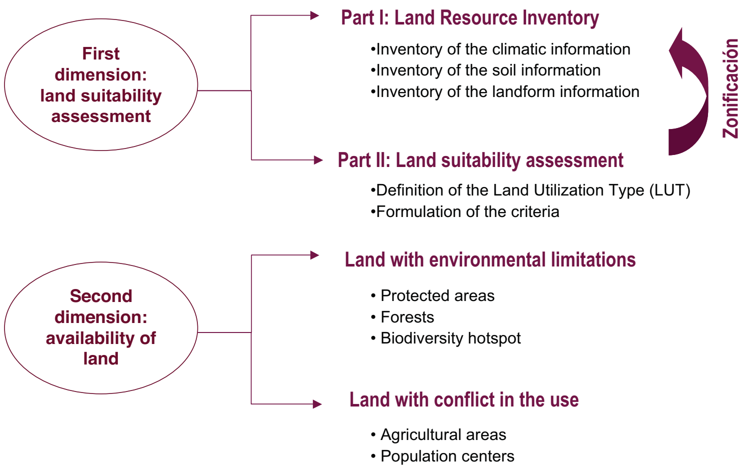
1. **suitable land area** is assessed;
2. **suitable land available** is calculated by excluding all environmental and agriculture land.

In the analysis, suitability is classified based on a suitability index. The suitability index categorizes, in percentage terms, the capability of a specific location. Capability to produce is defined in terms of the maximum attainable yield. The maximum attainable yield is defined as the full potential yield achievable in the specific location being studied under a specific agriculture system and input level. This is based on expert agronomic knowledge. Note that the maximum attainable yield is generally only achievable under laboratory conditions.

In general, the suitability index has six classes: not suitable (0 percent), very marginally suitable (0-20 percent), marginally suitable (20-40 percent), moderately suitable (40-60 percent), suitable (60-80 percent) and very suitable (80-100 percent). However, in the analysis presented here, these six classes have been collapsed into four classes for analytical ease (see Section 4.4).

Within the first dimension, the AEZ methodology is used to assess the suitability of land. Suitability is defined as the capability of a specific location to produce a specific crop based on the agroclimatic and soil conditions of the specific location. The first part of the analysis has two steps to it: the set-up of the Land Resource Inventory (LRI) and the Land Suitability Assessment (LSA). The LRI is a set of geo-referenced data of climatic, soil and landform resources. The LRI includes the climatic resource inventory (thermal zones, length of growing period zones, rainfall patterns and dry spell areas) and soil and land resource inventory. In the second part, the LSA, the Land Utilization Types (LUTs) are specified. The LUTs are defined as combinations of crop types, production systems, and input levels. For each LUT specific criteria are formulated[2] and applied to the LRI database. This combination will result in the identification of the suitability index in each locations (*zoning*).

Figure 4.1
Methodological Framework



Following the suitability assessment, the second dimension of Module 1 focuses on determining whether the suitable areas are **actually** available for use and therefore for bioenergy crop production. In fact, not all land that is found to be suitable for bioenergy crop production may actually be available for use. Some of the suitable land might be currently used for human settlement, or be covered by protected forests or for food production[3]. Through this second stage of the analysis, the areas that pose potential environmental, food production or other conflicts are identified. Note that additional no-go zones could be added based on the policy goals of the policy-makers. A dedicated set is presented here but in further analysis more specific considerations could be incorporated, for example the inclusion of pastoral areas as an exclusion area. The policy-maker needs to examine which policy goals to prioritize.

Finally, the results obtained from the assessment should be used in conjunction with other location specific information sets and analyses, an important step in concerted policy analyses. Through the integrated approach policy-makers will be in a position to narrow down the total suitable land based on existing land use, infrastructure and government priorities. An example of this is provided and discussed in Section 4.5. In addition, while the focus of this analysis is on the potential to grow bioenergy feedstocks, the same framework can be utilized to assess all

2 Note this step of the analysis requires expert information provided by agronomists and soil scientists.
3 Note that food production considerations include both current and future food needs.

forms of agriculture in Tanzania, be it crops for food, animal feed, fibre or fuel. This is essential in the context of optimal land planning, whereby every specific location is used to its full potential. The methodology for Module 1 can be utilized broadly for energy and environment to agriculture and food security policy in the context of land use planning across Tanzania.

4.2 SETTING THE SCENE FOR TANZANIA

The first step required to implement the analysis is the set up of the LRI, i.e. of the climatic resource inventory and the soil and land resource inventory (see methodology section above). Details of the creation, data source and results of the LRI for Tanzania are presented in Appendix 4A.

In Tanzania the LSA analysis is run under rainfed condition as this best describes the current agriculture management practice in the country[4]. The same methodology can be applied to assess suitability under irrigated conditions. In this case, geo-referenced data on currently irrigated areas and water availability are required. Irrigation schemes could help unleash the potential of some crops that are currently limitedly suitable under rainfed conditions.

Secondly, the LUTs are defined as combinations of crop types, input levels and production systems. In Tanzania, the analysis focuses on five crops. The crops were selected following consultation with government officials and key stakeholders. The crops analysed are cassava, sugar cane, sweet sorghum (two varieties), palm oil (two varieties) and sunflower. Cassava, sugar cane, sweet sorghum are ethanol crops while oil palm and sunflowers can be used for biodiesel production. Input use is considered in terms of low and high levels in order to represent the two extremes of the inputs' spectrum. However, the analysis can be modified to consider a range of intermediate input levels. Inputs include fertilizer, pesticides, mechanization and capital.

For each crop, the assessment is carried out under two production systems:

1. **Tillage-based** systems (TA).
2. **Conservation agriculture** systems (CA).

Particular emphasis is placed on CA. This agricultural practice is not new to Tanzania as there are a number of farmers currently practising CA (Shetto *et al*., 2007). However, it has yet to be adopted on a wide-scale level and doing so would require a concerted effort by the government to train and support farmers. Box 4.1 describes the principles and the benefits of CA and more details explaining the practice can be found in Appendix 4B. These two agriculture systems represent the two extremes of the agricultural management spectrum. Tillage-based agriculture, and in particular under low inputs and rainfed conditions, largely

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4 Note that even if rainfall can be very erratic and water supply in some areas is scarce, current access to irrigation is very limited, whereby both irrigation infrastructure and water supply to the irrigation scheme is restricted. Note that, smallholder farmers have less than 3 percent of the planted area for annual crops under irrigation, whereby irrigation is mainly for cereals, fruits and vegetable crops. The majority of irrigated lands are held by large commercial estates, mainly dedicated to sugar-cane production (NBS, 2006).

represents the current status quo in terms of agricultural practice in Tanzania. The alternatives to the current production systems are meant to represent possible development paths for the Government of Tanzania. Further analysis might consider more production system options that lie between tillage and conservation agriculture.

In the case of Tanzania, this results in four agricultural configurations and the primary features are described in Table 4.1.

1. Tillage-based at low inputs (**TA-L**).
2. Tillage-based at high inputs (**TA-H**).
3. Conservation agriculture at low inputs (**CA-L**).
4. Conservation agriculture at high inputs (**CA-H**).

The following example helps to illustrate some of the points discussed. A specific location might have a suitability of 70 percent for sweet sorghum under TA-L. This means that under TA-L the location is classified as suitable and can achieve 70 percent of the maximum attainable yield (i.e. 70 percent of 4.1 tons/ha resulting in an area with 2.8 tons/ha). Under CA-H, that location might have a suitability of 90 percent, meaning it is classified as very suitable (i.e. 90 percent of 20 tons/ha resulting in an area with a yield of 18 tons/ha).

Table 4.1

Primary features of the agriculture configurations

	Conventional Tillage	Conservation Agriculture
Low Input Level	**Tillage-based system, low input (TA-L)** ■ Subsistence-type production system with low capital input ■ Use of traditional or modern cultivars of crops ■ Tilling uses hand labour and traditional tools only ■ Tillage-based cultivation in rotation with bush, often referred to as 'slash and burn' ■ Excludes the use of: □ Synthetic mineral fertilizer or other agrochemicals □ Large-scale conservation measures	**Conservation agriculture, low input CA-L** ■ Subsistence-type production system with low capital input ■ Use of traditional or modern cultivars of crops ■ Hand labour only, traditional or improved tools for seeding or planting with minimum soil disturbance ■ Crops are planted in rotation with other crops (including legumes) to maintain pest control, soil fertility and productive capacity ■ Residues are retained as much as possible for "in situ" composting ■ *Excludes the use of:* □ *Synthetic mineral fertilizer or other agrochemicals* □ *Large-scale conservation measures* □ *Bush fallows in the rotations and 'slash and burn'*
High Input Level	**Tillage-based system, high input TA-H** ■ Capital-intensive management practices with high-level of input ■ Full use of the most productive and adapted modern cultivars of crops ■ Complete mechanization with plough-based intensive tillage ■ Application of high levels of agrochemicals ■ Full soil conservation measures ■ *Excludes the use of:* □ *Attention to protect or enhance ecosystem services such as increasing carbon sequestration and soil organic matter build-up, or improving water resource quantity and quality*	Conservation agriculture, high input CA-H ■ Capital-intensive management practices with high-level input ■ Full use of the most productive and adapted modern cultivars of crops ■ Complete mechanization with no tillage ■ Use of optimum levels of agro-chemicals ■ 'Permanent' organic-matter soil cover from crop residues and cover crops ■ Cover crops with legumes in the rotations ■ Full attention to ecosystem services to keep production, environmental costs and product price competitively low and productivity and returns high. ■ *Excludes the use of:* □ *Tillage or soil disturbance*

BOX 4.1

THE PRINCIPLES AND BENEFITS OF CONSERVATION AGRICULTURE

Conservation agriculture (CA) is a resource-saving agricultural cropping system that strives to achieve high and sustained production levels while conserving the environment and improving the livelihoods of farmers.

CA is based on enhancing natural biological processes above and below the ground. It utilizes soils for the production of crops with the aim to reduce excessive mixing of the soil and maintaining crop residues on the soil surface in order to minimize damage to the environment. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and mineral and organic-based nutrients are applied at optimum levels so as not to interfere with, or disrupt, biological processes. CA is characterized by three principles which are linked to each other, namely:

- Continuous minimum mechanical soil disturbance
- Permanent organic soil cover
- Diversified crop rotations for annual crops or plant associations for perennial crops.

Conservation agriculture practices can yield many benefits, including:

Economic: CA can improve production efficiency through time savings, reduced labour requirements, and reduced capital costs (e.g. fuel, machinery operating costs and maintenance).

Agronomic: Adopting CA leads to improvement of soil productivity (organic matter increase, in-soil water conservation as well as improvement of soil structure, and thus rooting zone).

Environmental and social: CA will reduce soil erosion (and thus of road, dam and hydroelectric power plant maintenance costs), improve water quality, improve air quality, and increase biodiversity carbon sequestration, all of which will offer sustained levels of high productivity agriculture for Tanzania.

Source: FAO Conservation Agriculture Web site (www.fao.org/ag/ca)

Moving from TA-L to TA-H requires increased input use, while shifting from TA-L to CA-L implies changes in agriculture management practices. The CA-H configuration represents a mixture of increased input use and changes in agriculture management practices. The results for CA-H will be illustrative of the full potential of the agriculture sector in the country and of where combined agriculture policies focusing on input access and improved agriculture management practices can drive agriculture planning and production.

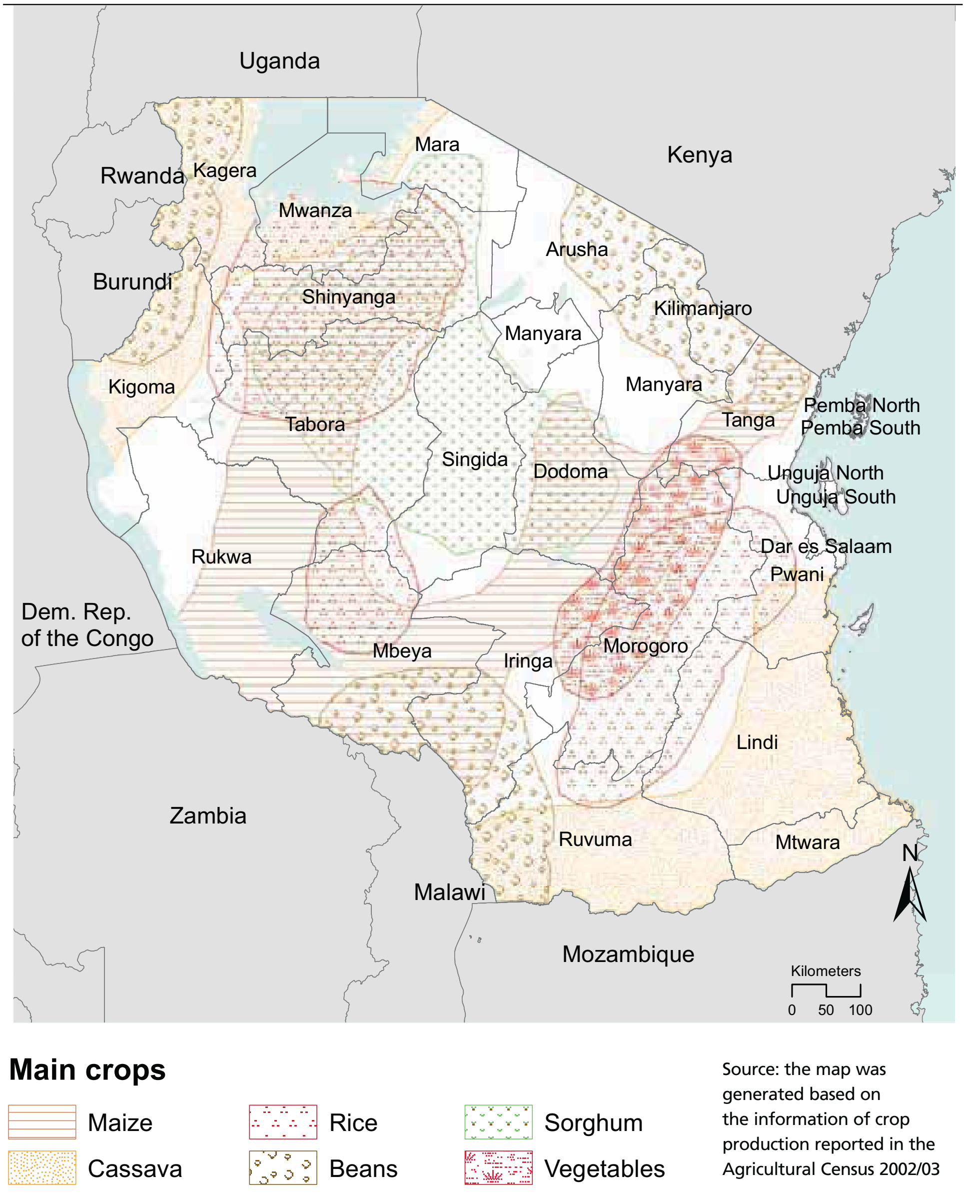
In the second dimension of the analysis a set of filters needs to be identified against which to screen the suitable land so as to define the amount of land available for use. Details of the filters used here are contained in Appendix 4C. This analysis removes all forms of *protected* and *agricultural lands*. Further investigation could apply different land filters based on the government's current priorities and policy options.

4.3 AGRICULTURE AND MALNUTRITION IN TANZANIA

Agriculture production is important to all regions in Tanzania. In terms of area under crops and production volumes, maize, cassava, rice, bean, sorghum and vegetables are the main crops for Tanzania. Furthermore, existing agriculture is mostly smallholder based. The regional coverage for the main crops is presented in Figure 4.2.

Figure 4.2

Primary crop production areas in Tanzania



Source: the map was generated based on the information of crop production reported in the Agricultural Census 2002/03

Source: Agricultural Census 2002/03 (NSB, 2006)

The most important food crops in terms of calorie contribution in Tanzania are maize, cassava and rice. Maize, the primary food crop, is an annual crop and is also the most important in terms of planted area and production. Maize is mainly produced in Shinyanga, Dodoma, Tanga, Iringa, Tabora and Mbeya.

Cassava, the next most important crop in terms of food security, is a subsistence food crop in Tanzania. A large share, 84 percent, of Tanzania's total cassava production is used for food. The rest of production is used to produce starch and feed. However, even though cassava is one of the most important food crops, production could be enhanced significantly by better agriculture practices. Cassava is cultivated and produced in all regions of Tanzania. However, the main producing areas are Mtwara, Ruvuma, Lindi and Pwani in the coastal and southern regions, and Kagera, Kigoma, Mwanza and Mara in the northwest.

Rice production is primarily centered around Shinyanga and Mwanza in the north and in Morogoro. Rice is also grown in other regions such as Tabora, Mbeya, Ruvuma and Pwani, but production is not as concentrated. Beans are produced in the northwest (Kagera and Kigoma) and northeast regions (Tanga, Arusha, Manyara and Kilimanjaro). The central plateau is the primary growing region for sorghum. Vegetable production is in Morogoro, Tanga and Iringa regions and groundnut production is in Dodoma, Tabora and Shinyanga.

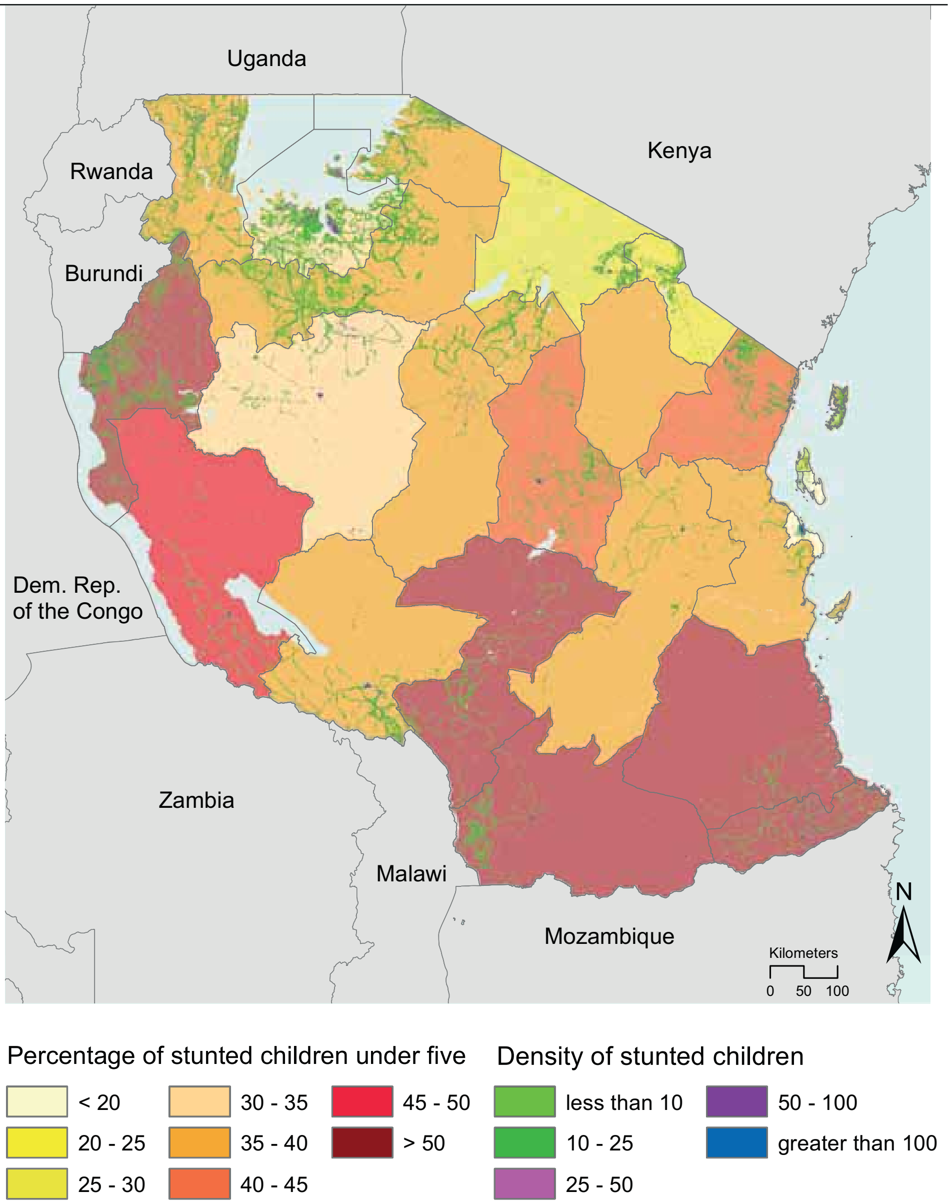
There are high levels of food insecurity in nearly all regions of Tanzania. To illustrate this, Figure 4.3 shows regional stunting[5] rates and densities of stunted children under five years of age across Tanzania[6]. Figure 4.3 shows that, with the exception of the Dar es Salaam region and Zanzibar, even the least affected areas still exceed 20 percent childhood stunting, with many regions being much worse off. Kigoma and Ruvuma are the most affected having both high rates and high densities of stunted children. In fact, Kigoma, Ruvuma, Iringa, Mtwara and Lindi all exceed 50 percent stunting rates, with regions such as Rukwa, Dodoma and Tanga not far behind at between 40 percent and 50 percent stunting.

5 Stunting refers to the reduced growth rate of human development, typically brought on by malnutrition in early childhood. The resulting diminutive stature (up to 20cm shorter than expected in moderate stunting of a five-year old) has a negative impact on cognition, susceptibility to disease and labour capacity for the individual. This in turn has a significant impact on household and community productivity, which will further exacerbate regional food security problems in the future.

6 The information presented includes percentage of stunting children under five (DHS, 2005); population under five by district (NBS, 2003), and LandScan Global Population Database (ORNL, 2005).

Figure 4.3

Distribution of stunted children under five



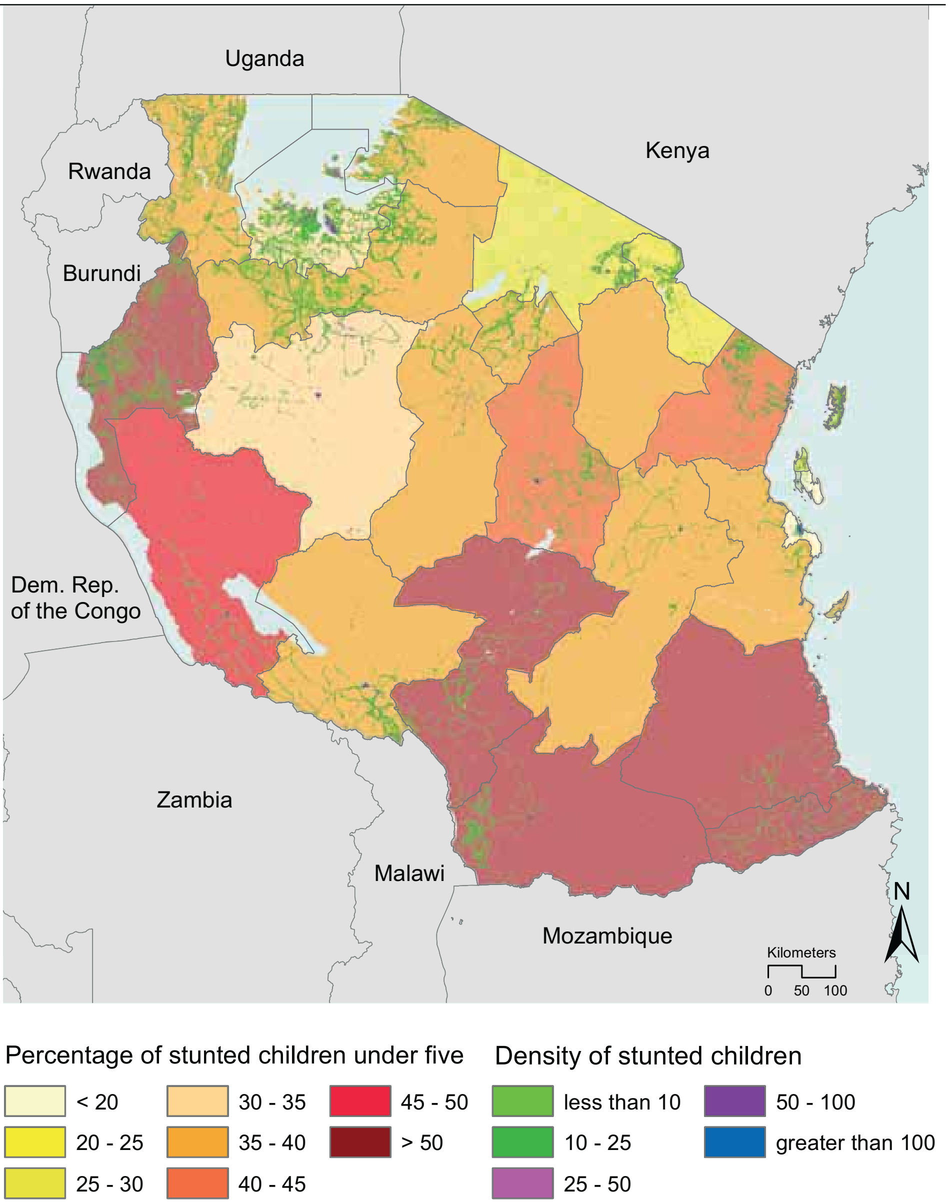
Source: DHS, 2004/05; NBS, 2003; ORNL, 2005.

4.4 RESULTS

This section presents the results for the crop list discussed both in terms of suitable and available areas. Once the actual areas that are available for potential bioenergy development are identified then the production (tons) is calculated based on the suitability of the specific location both on new lands and on lands under crop production. To make the results easier

Figure 4.3

Distribution of stunted children under five



Source: DHS, 2004/05; NBS, 2003; ORNL, 2005.

4.4 RESULTS

This section presents the results for the crop list discussed both in terms of suitable and available areas. Once the actual areas that are available for potential bioenergy development are identified then the production (tons) is calculated based on the suitability of the specific location both on new lands and on lands under crop production. To make the results easier to understand the suitability index is aggregated into four classes:

- Highly Suitable (HS): >60-100 percent of maximum attainable yield.
- Moderately Suitable (MS): >40-60 percent of maximum attainable yield.
- Marginally Suitable (mS): >0-40 percent of maximum attainable yield.
- Not Suitable (NS): 0.

As described, TA-L characterizes the current average agriculture practice in Tanzania. Consequently this represents the baseline against which results have to be compared and discussed. TA-H and CA-L, as medium term options, will be directly compared to the baseline, TA-L. CA-H, the longer term and full potential option, will also be compared to baseline to give a feel for the targets that the agriculture sector can achieve in terms of overall production.

Results are presented based on the following structure:

1. **Total suitable land area**
   The highly suitable and moderately suitable land area is calculated (see part 1 in Figure 4.4). This result is included to give an idea of the magnitude of suitable land (ha) for each crop, nevertheless this area cannot be directly considered for bioenergy development. Land for development will have to be either through expansion or through intensification (see points 2 and 3 below).

2. **Suitable area available for *expansion*[7] and potential production**
   Once the total suitable area that is highly and moderately suitable is identified, the environmental areas, the areas under crop production, and the urban areas are excluded. This yields the total available area for bioenergy crop (agriculture) expansion. As a result of the net area identified, the total production achievable is calculated. Here, the assessment looks only at land that has been found to be suitable and available, and that is not already under existing cultivation of any crops. These results focus on new areas suitable for expansion of bioenergy crops while avoiding competition with existing food crops (see part 2 in Figure 4.4).

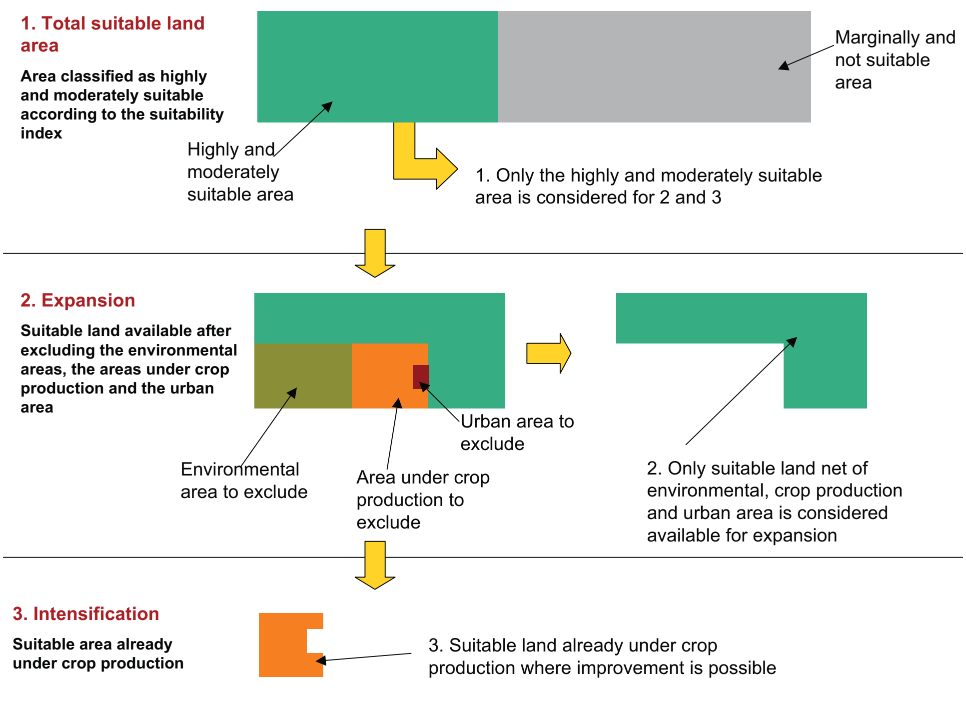
3. **Suitable area available for *intensification*[8] and potential production**
   Part of the total suitable area identified under 1 might already be under crop production. This has the potential to identify areas where better agricultural management practices can increase production. Note though that land already under crop production may not already be growing the bioenergy crop in question. In those cases, bioenergy crops may be displacing food crops. In these areas further analysis, including disaggregate crop production information and social implications of changes in crop production, would be required in conjunction with detailed land planning (see part 3 in Figure 4.4).

7 Expansion refers to agriculture production in new areas based on the criteria selected so far in this analysis. Note that additional criteria, for example exclusion of pastoral areas, might reduce the availability of new land for expansion.

8 Intensification refers to improvement of agriculture production in areas already under crop production. The analysis can show if better agriculture practices can lead to higher target production based on the configuration being considered.

Figure 4.4

Total suitable area, area for expansion and intensification



Note: This is a stylized diagram to explain the steps but no conclusions should be drawn on dimensions of the land components as drawn in the diagram.

The individual crop results are ordered based on the fuel they can produce. First ethanol crops are discussed (cassava, sugar cane, sweet sorghum), then biodiesel crops (oil palm, sunflower).

The results are presented in both map format and summary tables. The maps provide an initial visual screening of the location of suitable land. The summary tables present total area and potential production for the whole country. More detailed tables containing suitable area and attainable production by region are included in Appendix 4D. During the planning stage it will be important to allocate production optimally across regions so as to use each region's potential as fully as possible.

4.4.1 CASSAVA

4.4.1.1 CASSAVA TOTAL SUITABLE LAND AREA

The results show great potential for cassava in Tanzania (see Table 4.2 and Figure 4.5). Table 4.2 contains summary results of suitable land area for the country as a whole. Figure 4.5 offers a visual illustration of the location of suitable areas under all four configurations.

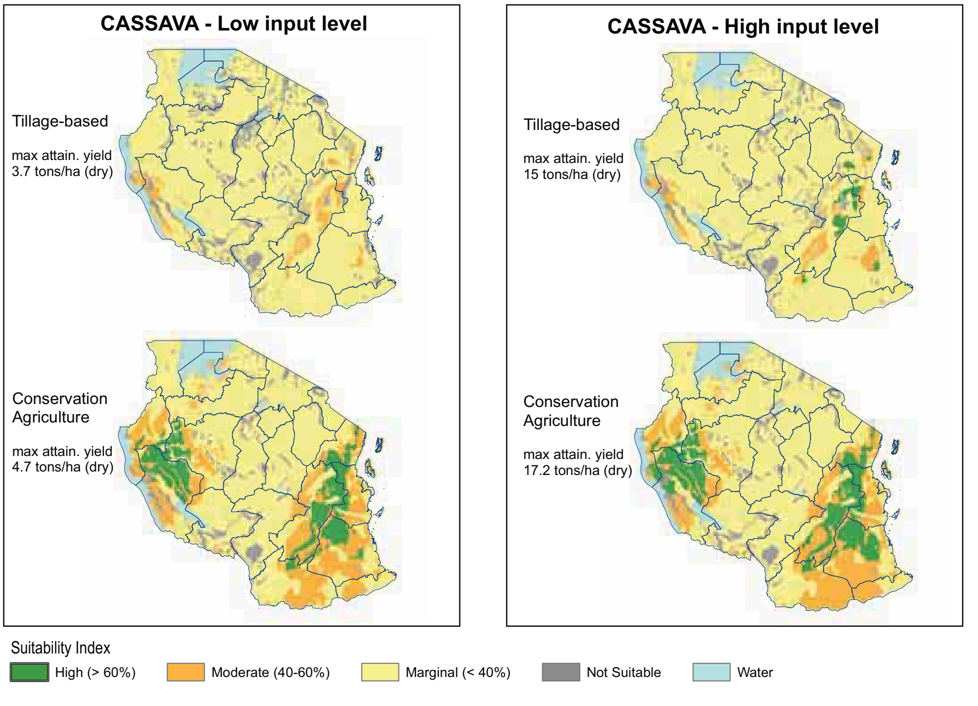
Table 4.2

Suitable land area for cassava

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total suitable area (HS+MS)
	(ha)	(ha)	(ha)
TA-L	2,943,441	6,686,114	9,629,555
TA-H	4,240,709	7,240,429	11,481,138
CA-L	11,630,941	17,023,238	28,654,179
CA-H	12,564,218	17,156,867	29,721,085

Figure 4.5

Land suitability assessment for cassava



Under TA-L, the results show that Tanzania has almost three million hectares of land classified as highly suitable, and another 6.7 million hectares of moderately suitable land for cassava production. The maximum attainable yield in this case is 3.7 tons/ha for dry cassava.

Under TA-H, 4.2 million hectares of land classified as highly suitable, and another 7.2 million hectares of moderately suitable land for cassava production. This represents an approximate increase of 44 and eight percent respectively for HS and MS when compared to TA-L. The maximum attainable yield in this case is 15 tons/ha for dry cassava.

An even larger increase, however, can be realized by switching from a TA-L system to a low-input conservation agriculture system, CA-L. Cultivable hectares will rise to 11.6 million (HS) and 17 million (MS) hectares, an increase of almost 300 percent and 150 percent respectively. The maximum attainable yield in this case is 4.7 tons/ha for dry cassava.

When moving to CA-H, the full potential condition, the total suitable area reaches 29.7 million hectares and a maximum attainable yield of 17.2 tons/ha.

At a regional level, the regions that offer the larger areas of suitable land are Morogoro, Rukwa and Lindi under TA-L. When the agriculture management system changes, Pwani also becomes an important potential contributor to cassava production. The results presented here are kept at an aggregate level to give an overall indication for location and of the potential production that could be achieved. In further stages of the analysis though it will be necessary to go the regional level and given the crops of interest, optimally allocate crops within the region, be it bioenergy, food, feed or other agriculture crops. Further details on area and production are in Appendix 4D.

4.4.1.2 CASSAVA SUITABLE AREAS AVAILABLE FOR EXPANSION AND POTENTIAL PRODUCTION

The results show there is also much room to expand production through increasing the area under cassava cultivation for bioenergy production. It is important to note that the initial results described above do not factor in existing uses of land such as urban development, conservation areas, and existing agricultural areas. It is necessary therefore to filter out lands that cannot be used, as described in Section 4.3. Once protected and other land uses are removed, as seen in Figure 4.6, the overall suitable number of hectares for each configuration decrease by two-thirds on average. The resulting figures are listed in the Table 4.3.

Table 4.3

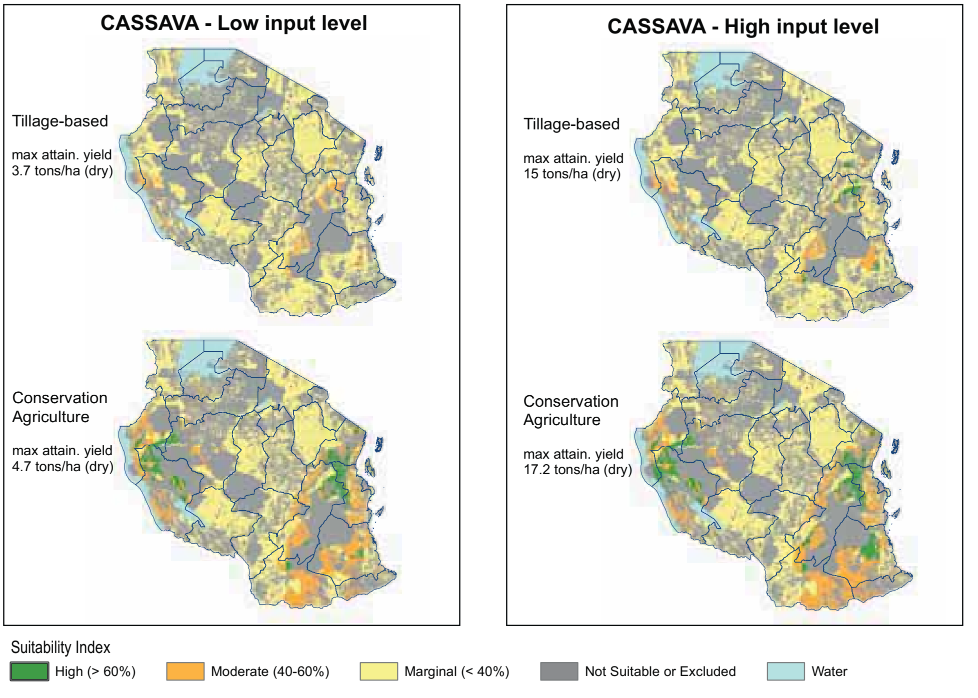
Suitable land area available for expansion and potential production for cassava

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total available suitable area (HS+MS)	Total dry production *
	(ha)	(ha)	(ha)	(ton)
TA-L	1,153,431	2,274,811	3,428,242	7,194,296
TA-H	1,744,818	2,343,195	4,088,013	35,888,320
CA-L	3,965,195	5,584,261	9,549,456	26,634,709
CA-H	4,324,562	5,680,992	10,005,554	102,805,158

** Note that this is an aggregate of areas diversely suitable*

Figure 4.6

Land suitability assessment for cassava excluding environmental and land use constraints



The most striking result from the analysis is that conservation agricultural production systems, even under low input levels, can increase the suitable area for cassava production by more than 9.5 million hectares (HS+MS) providing 26.6 million dry-tons of cassava - an almost threefold increase compared to the baseline. An important distinction to make is that conservation agriculture, while it can modestly increase attainable yields, will not increase yields to the same extent as is possible with the additional of high levels of agrochemical inputs.

However, conservation agriculture at low level of input is still a very attractive production system as number of hectares suitable for cassava production increases immensely while at the same time the overall capital requirements are significantly lower than high-input-based systems. The results for TA-H can also achieve similar levels of dry cassava production using less land, but capital costs are much higher. For details of regional distribution of area and production see Appendix 4.D.

4.4.1.3 SUITABLE AGRICULTURE AREAS AVAILABLE FOR INTENSIFICATION AND POTENTIAL PRODUCTION

The results seem to indicate that the majority of existing cassava agricultural lands can improve their yields simply through better management, given the fact that the average cassava yield in Tanzania is only two tons/hectare.

The area that is currently being used for agriculture[9] and that is suitable for cultivation of cassava is listed in the Table 4.4.

Table 4.4
Suitable land area available for intensification and potential production for cassava

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total available suitable area (HS+MS)	Total dry production*
	(ha)	(ha)	(ha)	(ton)
TA-L	453 476	1 060 760	1 514 236	3 108 850
TA-H	706 232	1 204 563	1 910 795	16 303 090
CA-L	2 067 258	5 195 371	7 262 629	19 213 044
CA-H	2 234 050	5 323 843	7 557 893	73 444 106

** Note that this is an aggregate of areas diversely suitable*

Based on the assumption that the highly and moderately suitable areas that are already under agriculture can be used, under TA-L the total production can reach 3.1 million tons. When moving to TA-H and CA-L, production can go up to 16 and 19 million tons respectively. Target production under CA-H could be as high as 73 million tons.

In the case of cassava, we find that the amount of suitable land that would come through expansion is double the amount from intensification, i.e. land already under agriculture.

Knowing where and at what intensities different crops are grown is critical for understanding what trade-offs will be necessary to encourage bioenergy crop production. Morogoro, for example, has great potential for growing cassava as a bioenergy feedstock, see detailed tables in Appendix 4D. However, land there is already intensively cultivated with high-value vegetable crops. Introducing bioenergy production in this region through government land grants could negatively affect vegetable farmer's livelihoods by displacing high value crop production or by decreasing land values. Accurate land planning will highlight the potential tensions and decisions to be made.

4.4.2 SUGAR CANE

4.4.2.1 SUGAR CANE TOTAL SUITABLE LAND AREA

The results show limited potential for sugar cane in Tanzania under rainfed conditions (see Table 4.5 and Figure 4.7). Table 4.5 contains summary results of suitable land area for the country as a whole. Figure 4.7 offers a visual illustration of the location of suitable areas under all four configurations.

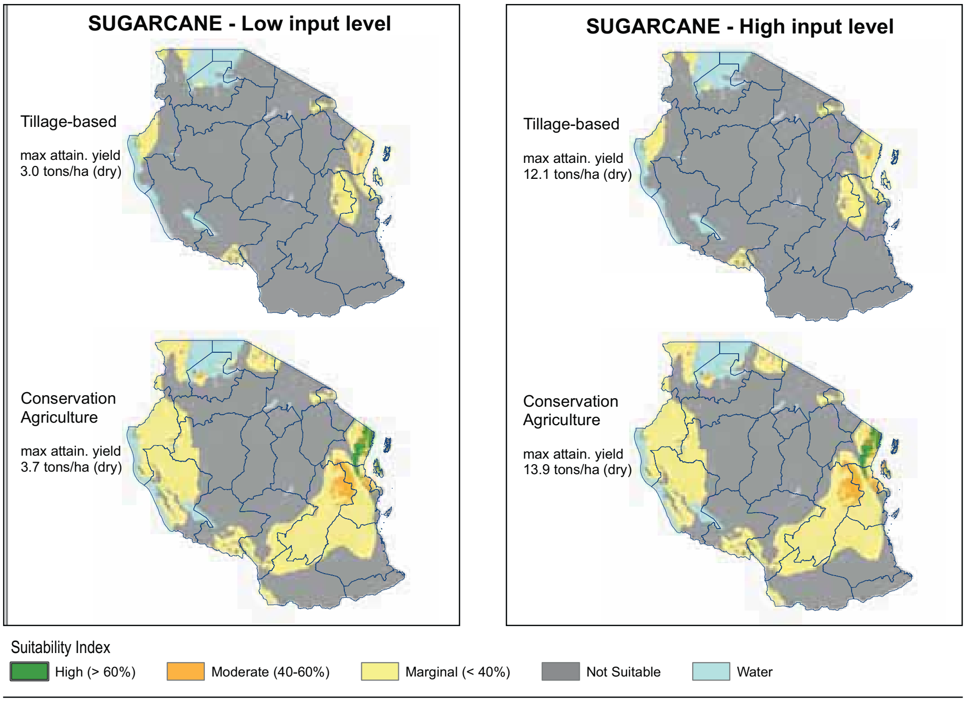
9 Note that, as discussed, the agriculture area being considered for intensification includes all crops, not just cassava.

There are clearly not many areas suitable for sugar-cane production under rainfed conditions. Under TA-L, only about 200 000 ha are assumed to be suitable. Moving to TA-H increases the number of hectares slightly to 220 000 ha. However, if a CA-L were implemented, the number of suitable hectares grows more than ten-fold to nearly 2.5 million ha, mainly concentrated in Tanga, Pwani, and Morogoro, see Appendix 4.D for more detail. The maximum attainable yield ranges from three tons/ha under TA-L to 13.9 under CA-H.

Table 4.5
Suitable land area for sugar cane

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total suitable area (HS+MS)
	(ha)	(ha)	(ha)
TA-L	38,643	164,030	202,673
TA-H	98,620	125,228	223,848
CA-L	935,291	1,533,586	2,468,877
CA-H	947,431	1,540,526	2,487,957

Figure 4.7
Land suitability assessment for sugar cane



4.4.2.2 SUGAR CANE SUITABLE AREAS AVAILABLE FOR EXPANSION AND POTENTIAL PRODUCTION

When looking at the potential for expanding sugar-cane production onto new lands, conservation agriculture holds much more overall potential. Thus, when moving to CA-L total suitable land is 876 578 ha, equivalent to 1.8 million tons of sugar production, as shown in Table 4.6.

In this case due to the limited initial area under TA-L, the real improvement is found by transiting first to a CA-L system and then to CA-H where the full potential would result in a total production of almost 7 million tons of sugar.

Figure 4.8 shows that most of the suitable areas lie along the northern costal areas. Again, it will be up to the policy-makers to optimally allocate specific locations across crops.

Table 4.6

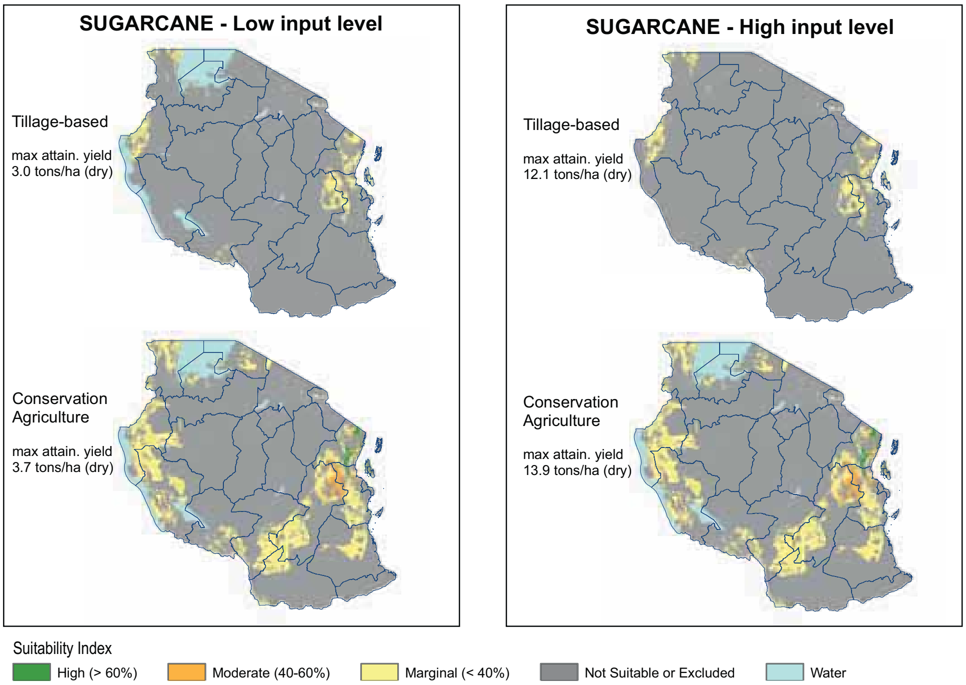
Suitable area available for expansion and potential production for sugar cane

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total available suitable area (HS+MS)	Total sugar production*
	(ha)	(ha)	(ha)	(ton)
TA-L	2,816	19,847	22,663	25,757
TA-H	5,011	12,331	17,342	117,038
CA-L	250,257	626,321	876,578	1,814,696
CA-H	254,364	628,557	882,921	6,873,068

** Note that this is an aggregate of areas diversely suitable*

Figure 4.8

Land suitability assessment for sugar cane excluding environmental and land use constraints



4.4.2.3 SUGAR CANE SUITABLE AREAS AVAILABLE FOR INTENSIFICATION AND POTENTIAL PRODUCTION

When limiting the focus to existing agricultural lands, the results under TA-L show that the majority of the suitable area for sugar-cane production is already used for some form of agriculture production. In fact, some of the land already under agriculture production could already be used for sugar-cane production. Improvements for smallholder sugar-cane production under rainfed conditions through improved management practices could be an important policy direction in this case. These should be integrated with large scale production, although in this case the inclusion of irrigation schemes in the analysis would be an important additional factor.

Table 4.7

Suitable area available for intensification and potential production for sugar cane

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total available suitable area (HS+MS)	Total sugar production*
	(ha)	(ha)	(ha)	(ton)
TA-L	29 950	113 221	143 171	242 587
TA-H	77 346	78 681	156 027	1 130 872
CA-L	539 416	509 019	1 048 435	2 442 030
CA-H	544 386	506 805	1 051 191	9 203 518

** Note that this is an aggregate of areas diversely suitable*

4.4.3 SWEET SORGHUM

4.4.3.1 SWEET SORGHUM TOTAL SUITABLE LAND AREA

Tanzania does not currently produce sweet sorghum, but has long-term experience in the production of sorghum. Two crop types, lowland and highland sweet sorghum, are considered in the analysis. The results show very strong potential for sweet sorghum in Tanzania (see Table 4.8 and Figure 4.9). Table 4.8 contains summary results of suitable land area for the country as a whole. Figure 4.9 offers a visual illustration of the location of suitable areas under all four configurations.

Figure 4.9shows that the most suitable areas for growing sweet sorghum under the TA-L system are almost everywhere *except* the central plateau. Interestingly, once the system steps up to CA-H almost all regions in the country are moderately to highly suitable. Thus, although not currently produced in Tanzania, sweet sorghum could be a very interesting crop for ethanol production, especially since sweet sorghum is a multipurpose crop and therefore can simultaneously be used for food production.

Together, there is approximately 47.5 million ha of suitable land (32.7 million ha of highly suitable and another 14.7 million ha of moderately suitable) under the TA-L system. Moving to a TA-H system would increase the suitable area by approximately 20 percent while a CA-L system would increase the total by 45 percent. It should be noted that production under a CA system is much more distributed across the country and less concentrated in the south (see Appendix 4D for more detail). The maximum attainable yield ranges from 8.1 tons/ha under TA-L to 40.6 under CA-H.

Most regions in the country are found to have large areas of suitable land for the production of sweet sorghum. Under TA-L, the regions that offer the larger areas of suitable land in terms of hectares are Lindi, Ruvuma, Morogoro, Rukwa, Tabora, all exceeding three million hectares of suitable land. Kigoma, Mbeya, Mtwara, Pwani, Shinyanga and Tanga have the potential to offer more than one million hectares of suitable land in each region. Further details on area and production are in Appendix 4D.

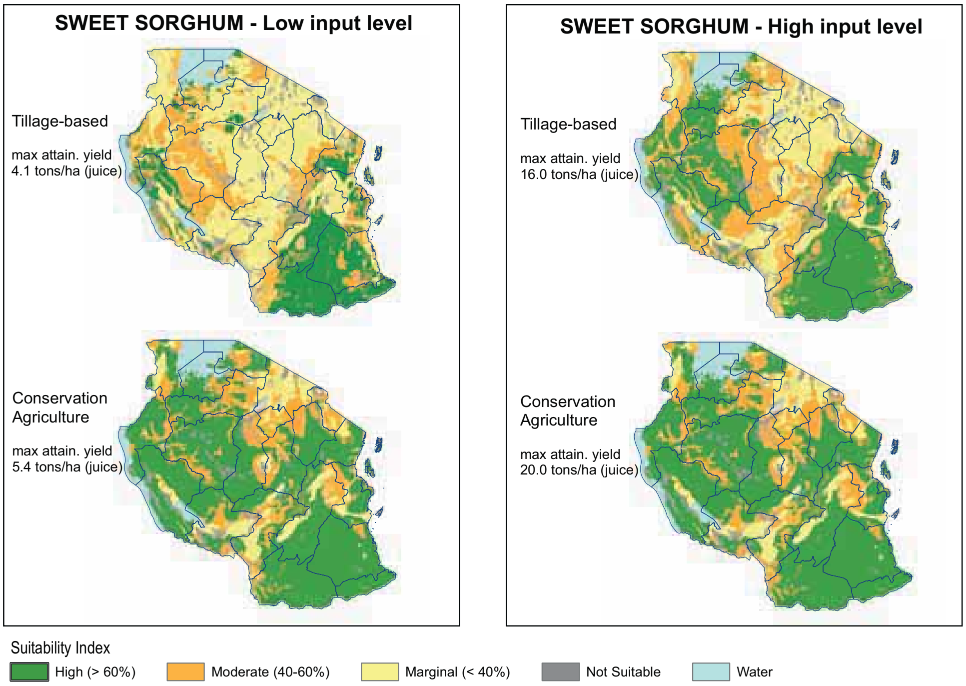
Table 4.8

Suitable land area for sweet sorghum

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total suitable area (HS+MS)
	(ha)	(ha)	(ha)
TA-L	32 797 044	14 793 760	47 590 804
TA-H	44 029 217	12 406 658	56 435 875
CA-L	59 585 708	9 367 269	68 952 977
CA-H	60 127 929	9 369 763	69 497 692

Figure 4.9

Land suitability assessment for sweet sorghum



4.4.3.2 SWEET SORGHUM SUITABLE AREAS AVAILABLE FOR EXPANSION AND POTENTIAL PRODUCTION

After removing excluded lands, as shown in Table 4.9, the total suitable area decreases by approximately 30 percent for each configuration. However, that still leaves a great deal of suitable area that might be used for bioenergy production. Under TA-L total suitable area is 17 million ha, while production is 72 million tons. The results for sweet sorghum show that moving to high inputs under tillage increase production significantly up to 194 million tons, potentially the most relevant medium term strategy in the context of sweet sorghum. The target potential for sweet sorghum is 26 million ha and close to 346 million tons of juice production.

Table 4.9

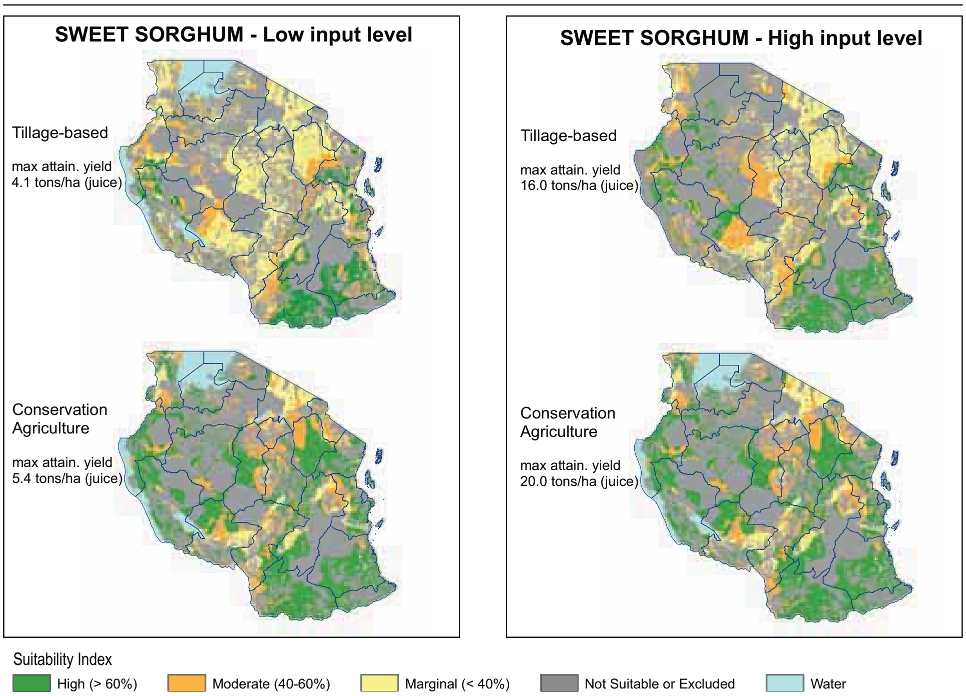
Suitable areas available for expansion and potential production for sweet sorghum

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total available suitable area (HS+MS)	Total juice production*
	(ha)	(ha)	(ha)	(ton)
TA-L	11 052 901	6 027 902	17 080 803	36 315 722
TA-H	15 296 148	5 358 004	20 654 152	193 791 344
CA-L	21 754 588	4 394 268	26 148 856	92 366 959
CA-H	21 951 281	4 442 658	26 393 939	346 149 492

** Note that this is an aggregate of areas diversely suitable*

Figure 4.10

Land suitability assessment for sweet sorghum excluding environmental and land use constraints



4.4.3.3 SWEET SORGHUM SUITABLE AREAS AVAILABLE FOR INTENSIFICATION AND POTENTIAL PRODUCTION

In a TA-L system, the suitable area obtained after removing environmental constraints is divided fairly evenly between new lands (17 million ha) and land already under agriculture (14.5 million ha).

Potential production under TA-H and CA-L systems are also split relatively evenly between existing agricultural lands and new lands. However, as mentioned above, new lands should be prioritized for sweet sorghum if the goal is not to impact existing food production. Overall, sweet sorghum holds massive production potential.

Table 4.10

Suitable areas available for intensification and potential production for sweet sorghum

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total available suitable area (HS+MS)	Total juice production*
	(ha)	(ha)	(ha)	(ton)
TA-L	9 539 463	5 042 315	14 581 778	31 160 854
TA-H	13 289 425	4 685 577	17 975 002	168 399 592
CA-L	18 968 432	3 134 827	22 103 259	79 673 773
CA-H	19 240 855	2 947 058	22 187 913	298 364 388

** Note that this is an aggregate of areas diversely suitable*

4.4.4 OIL PALM

4.4.4.1 OIL PALM TOTAL SUITABLE LAND AREA

Two crop types were analysed for oil palm, the tall and compact. The tall crop type is the most widely used. The compact crop type is a new crop type that is being experimented on that is tolerant to low temperatures and can be used at higher altitudes. The results show limited potential for oil palm in Tanzania under rainfed conditions. Much like sugar cane, the analysis shows that oil palm production is not suitable in most areas of the country. Under a TA-L system there is only 170 000 ha of suitable land. This number grows slightly to 220 000 ha under TA-H, but the overall number of hectares is still quite low. Conservation agriculture can increase the suitable hectares by a factor of 10, to approximately 1.6 and 1.8 million ha respectively under low and high input. Most of the suitable area is concentrated in the same northeastern coastal area as sugar cane.

The little suitable area that is found is mostly located in the Tanga region under TA-L. When the agriculture management system is improved larger suitable areas become available and are also found in Pwani, Mwanza and Dar Es Salaam, nevertheless still small compared to other more suitable crops outlined in this analysis under rainfed condition.

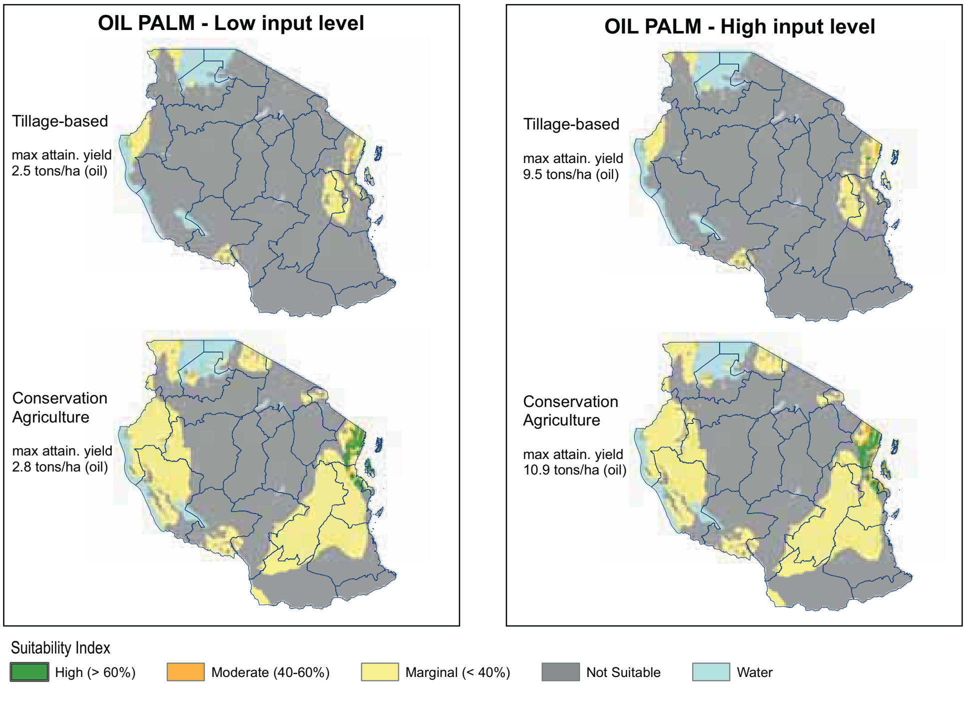
Table 4.11

Suitable land area for oil palm

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total suitable area (HS+MS)
	(ha)	(ha)	(ha)
TA-L	45,756	124,112	169,868
TA-H	88,091	132,659	220,750
CA-L	1,354,625	225,760	1,580,385
CA-H	1,502,780	264,654	1,767,434

Figure 4.11

Land suitability assessment for oil palm



4.4.4.2 OIL PALM SUITABLE AREAS AVAILABLE FOR EXPANSION AND POTENTIAL PRODUCTION

After removing environmental and land use constraints, Table 4.12 shows an approximate 20 percent decrease in the amount of suitable land in each configuration.

Given the overall limitations in area suitable for oil palm production, the CA configurations likely hold the most promise if expansion is the goal. Under CA-L the oil production will yield approximately 800 000 tons on almost 440 000 ha of land. However, under CA-H the overall production would increase up to 2.8 million tons but with a considerable increase of the production cost.

Table 4.12

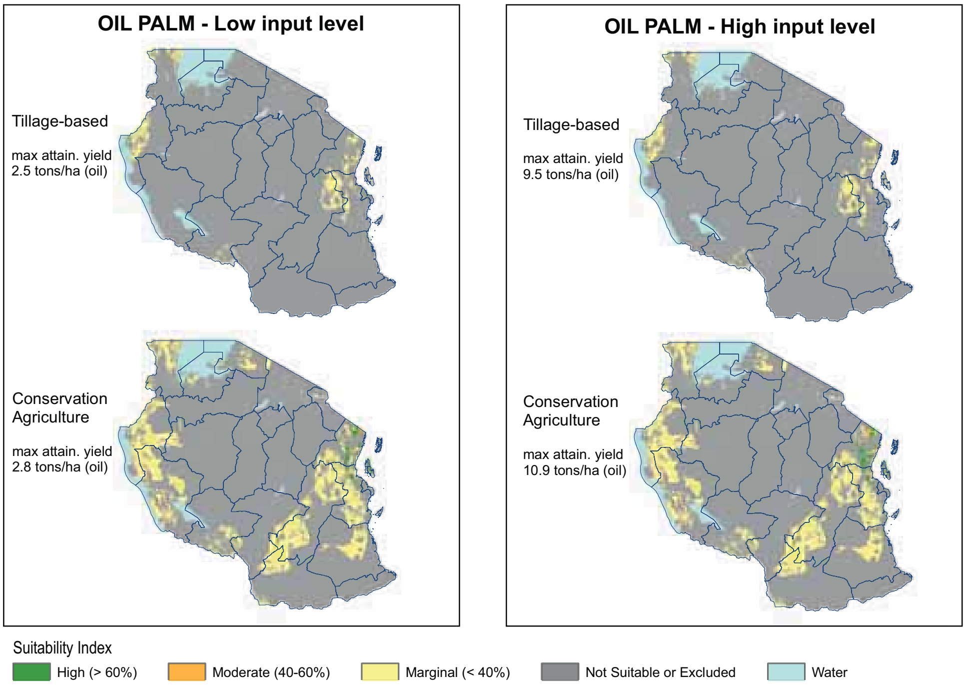
Suitable areas available for expansion and potential production for oil palm

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total available suitable area (HS+MS)	Total oil production*
	(ha)	(ha)	(ha)	(ton)
TA-L	1,926	13,099	15,025	13,594
TA-H	6,836	10,137	16,973	68,313
CA-L	376,644	59,534	436,178	818,538
CA-H	424,940	75,886	500,826	2,712,074

** Note that this is an aggregate of areas diversely suitable*

Figure 4.12

Land suitability assessment for oil palm excluding environmental and land use constraints



4.4.4.3 OIL PALM SUITABLE AREAS AVAILABLE FOR INTENSIFICATION AND POTENTIAL PRODUCTION

Oil palm is not a widespread crop in Tanzania. The potential area on existing agricultural lands is much higher than in the new lands.

Table 4.13 shows that under TA-L the suitable area is 126 000 ha with a potential production of 120 000 tons of oil. Simply increasing the input the suitable area increases slightly but the oil production rises up to 650 000 tons. Moving towards CA, the suitable area increases by eight times with a resulting production of 1.5 and five million tons respectively under low and high level of input.

Table 4.13

Suitable areas available for intensification and potential production for oil palm

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total available suitable area (HS+MS)	Total oil production*
	(ha)	(ha)	(ha)	(ton)
TA-L	37 616	88 416	126 032	121 522
TA-H	70 428	90 331	160 759	654 916
CA-L	709 247	102 208	811 455	1 476 406
CA-H	772 766	115 184	887 950	5 094 252

** Note that this is an aggregate of areas diversely suitable*

4.4.5 SUNFLOWER

4.4.5.1 SUNFLOWER TOTAL SUITABLE LAND AREA

The results show great potential for sunflower in Tanzania. Table 4.14 contains summary results of suitable land area for the country as a whole. Figure 4.13 offers a visual illustration of the location of suitable areas under all four configurations.

Under TA-L the suitable area is almost 38 million ha. The addition of inputs in the TA-H system increases this figure up to 51 million ha. Conservation agriculture can further expand the total number of suitable hectares up to 66.6 million ha, mainly in the central and east regions of Tanzania. Under TA-L, the larger suitable areas are found in Ruvuma, Lindi, Tabora, Morogoro, Shinyanga and Kigoma. A larger area becomes suitable under CA-L and CA-H (see Appendix 4D for more details).

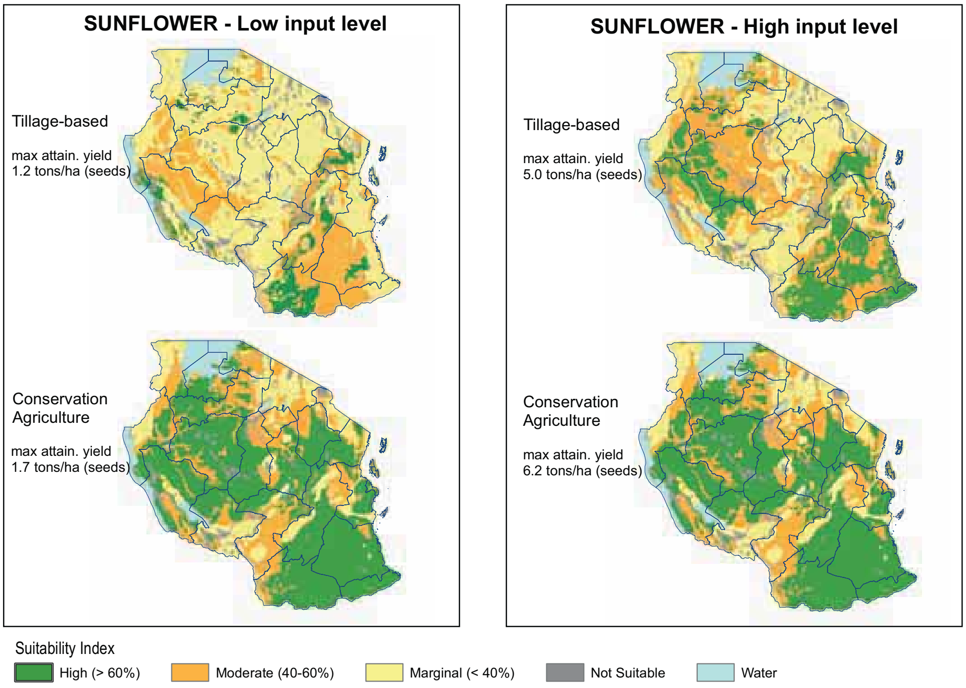
Table 4.14

Suitable land area for sunflower

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total suitable area (HS+MS)
	(ha)	(ha)	(ha)
TA-L	25 657 914	12 338 477	37 996 391
TA-H	35 991 148	14 792 122	50 783 270
CA-L	55 046 419	11 466 714	66 513 133
CA-H	55 249 942	11 365 987	66 615 929

Figure 4.13

Land suitability assessment for sunflower



4.4.5.2 SUNFLOWER SUITABLE AREAS AVAILABLE FOR EXPANSION AND POTENTIAL PRODUCTION

Figure 4.14 shows the land suitability results after excluded areas have been removed. Overall, Table 4.15 shows that the total suitable land decreases by about 30 percent under each configuration once excluded areas have been deducted. This is consistent with most of the other crops.

When limiting the potential identified to new lands, under TA-L it is possible to achieve a production of 11 million tons of seed on almost 14 million ha whereas a more intensive

TA-H system would produce approximately 62 million tons of sunflower seeds on 18.3 million ha. Similarly, a CA-L system would result in 32.8 million tons on 25.3 million ha that could rise to 120 million tons on the same amount of land under the more intensive CA-H.

Table 4.15

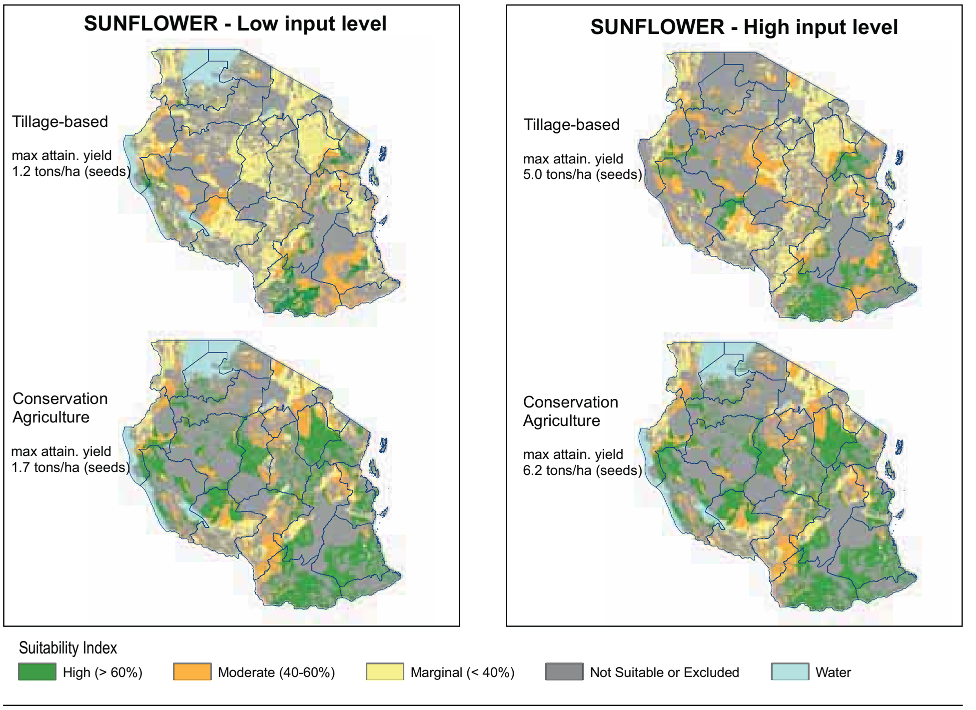
Suitable areas available for expansion and potential production for sunflower

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total available suitable area (HS+MS)	Total seeds production*
	(ha)	(ha)	(ha)	(ton)
TA-L	8 981 461	4 988 594	13 970 055	11 129 085
TA-H	12 293 909	6 040 167	18 334 076	62 265 452
CA-L	19 831 310	5 448 037	25 279 347	32 872 330
CA-H	19 920 690	5 439 300	25 359 990	120 053 596

** Note that this is an aggregate of areas diversely suitable*

Figure 4.14

Land suitability assessment for sunflower excluding environmental and land use constraints



4.4.5.3 SUNFLOWER SUITABLE AREAS AVAILABLE FOR INTENSIFICATION AND POTENTIAL PRODUCTION

Under TA-L, approximately 12 million ha of land already under crop production could be used for sunflower production resulting in 9 million tons of seed. However, under a tillage-based production system sunflower is not a widespread crop so cultivating it on a large scale on existing agricultural lands could come at the expense of current food crops.

Comparing CA-L to TA-L the suitable area is twofold, however seed production is tripled. At high level of inputs the tillage-based system could achieve 53 million tons of seed production on 15 million ha. Under CA-H the suitable area expands to 21 millions and the production is twice the TA-H production.

Table 4.16

Suitable areas available for intensification and potential production for sunflower

Configuration	Highly suitable area (HS)	Moderately suitable area (MS)	Total available suitable area (HS+MS)	Total seed production*
	(ha)	(ha)	(ha)	(ton)
TA-L	7 495 432	4 396 892	11 892 324	9 348 165
TA-H	10 423 559	5 406 453	15 830 012	53 106 527
CA-L	17 090 625	3 948 557	21 039 182	27 668 763
CA-H	17 232 891	3 817 338	21 050 229	101 056 266

** Note that this is an aggregate of areas diversely suitable*

In the case of sunflower, suitable land is evenly distributed across new lands and lands already under crop production.

4.5 USING THE RESULTS IN THE TANZANIA CONTEXT: AN EXAMPLE

The results discussed so far have shown how some crops hold great potential as an ethanol feedstock crop in Tanzania through both expansion and intensification. However, the results obtained need to be screened against the reality in the country. An example of this process is provided below, relating to the infrastructure limitation problem in the regions of the country. Depending on data availability and government priorities, policy-makers might want to screen the results against other important parameters. The BEFS analysis is only a starting point in this regard, but as better datasets and more specific scenarios are developed, the methodology presented in Module 1 can continue to be used by the government as a key land use planning tool.

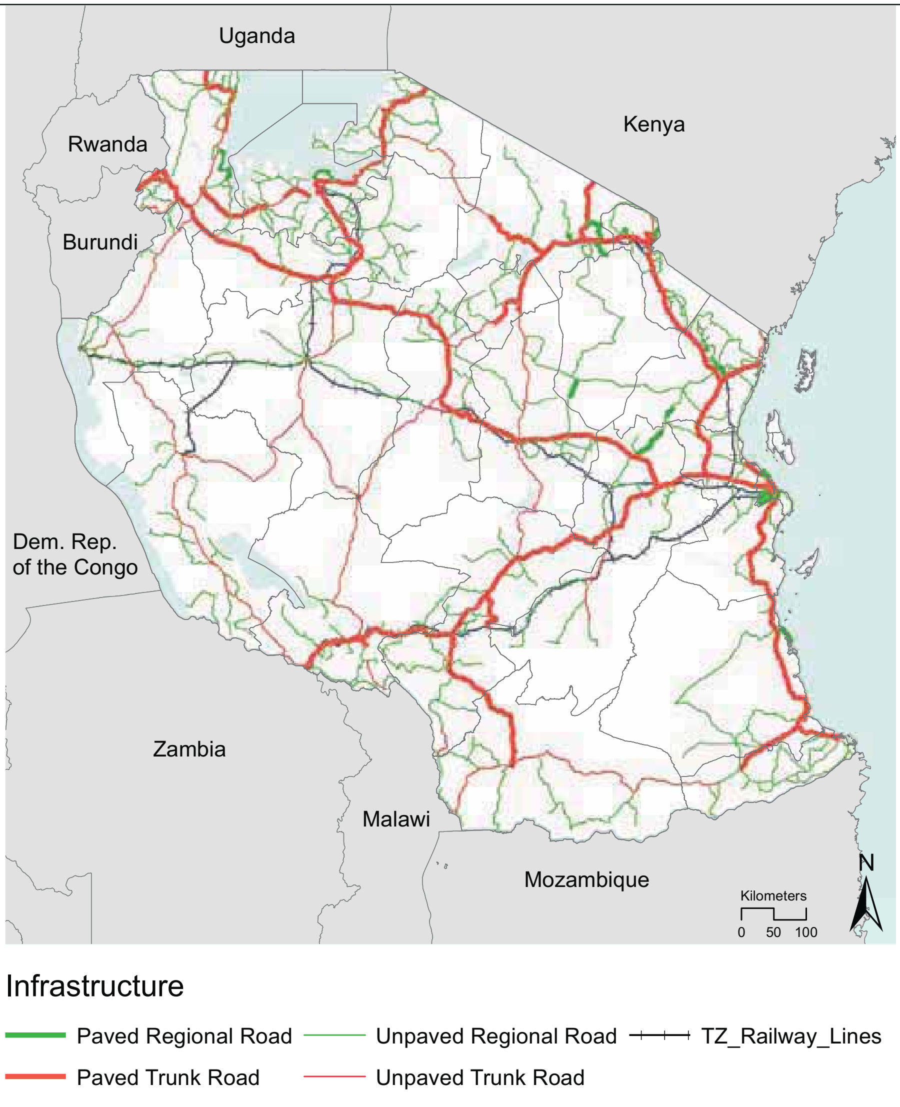
Agriculture in Tanzania continues to be adversely affected by lack of access to competitive markets due to high transport and transaction costs. This can lead to lower producer prices, post-harvest losses of cereals, and an overall lack of regional-specific expert advice and technologies making their way to different parts of the country. There is also a shortage of credit available to farmers. All of these factors exacerbate problems of low productivity and low rural incomes.

Transportation is a particularly acute problem in Tanzania. Figure 4.15 is a map of Tanzania's primary road and rail infrastructure. This map consists of almost 29 000 km of trunk and regional roads (out of 56 000 km of total roads in the country). However, only 16 percent of primary roads are paved (eight percent overall), making market accessibility rather limited (TANROADS, 2006). Simply put, the lack of transportation is the most frequently mentioned obstacle to increasing the livelihoods of rural farmers.

In general, rail, marine, air and road transport networks need to be expanded and maintained to international standards before widespread development can happen.

Figure 4.15

Infrastructures in Tanzania



Source: Database managed by Prime Ministers Office Regional Administration and Local Government (PMO-RALG); financed and provided by World Bank.

4.6 CONCLUSION

Food security is a major concern for Tanzania and it is important to ensure that a future biofuels industry will not adversely impact on the availability of food crops. The analysis here allows policy-makers to be in a position to support the development of biofuels without harming food security, and indeed attempting to improve food production levels.

Tanzania has great potential for bioenergy crop production. The results of this analysis demonstrate that Tanzania has potential for increasing agricultural production, both through the intensification of existing areas under crop production and through the cultivation of new lands dedicated to bioenergy crops.

The analysis presented shows, under rainfed conditions, which bioenergy crops are most suitable for producing in Tanzania and generally in which locations. The analysis presented focuses on cassava, sugar cane, sweet sorghum, oil palm and sunflower. The results for cassava show that Tanzania has significant capacity to produce high volumes of cassava. Nevertheless, as cassava is a very important food crop, careful land planning will be necessary to ensure that production targeted towards the bioenergy industry does not preclude food availability. Other crops of interest might be sunflower, sweet sorghum both of which can be grown on new lands without impacting existing food production. Sweet sorghum and sunflower both have great potential across all of Tanzania. Sweet sorghum would be a new crop, while sunflower might be particularly interesting as it can be used to produce biodiesel to substitute for national diesel consumption. The suitability of sugar cane and oil palm is extremely limited under rainfed conditions. The total amount of land suitable for both crops is relatively small and concentrated along the northwest coast. Adding the irrigation dimension would be essential for the cases of sugar cane and oil palm. The analysis demonstrates the importance of conservation agriculture to the future of Tanzania's agriculture as a long-term sustainable agricultural practice. The specific analysis presented here is meant to represent some of the most likely outcomes of introducing a bioenergy economy to Tanzania. However, the inherent flexibility built into Module 1 makes it easy to rapidly adapt the analysis to address the ever evolving priorities and challenges faced by the Government of Tanzania.

In this, the analysis provides a stepping stone in identifying broad areas of suitability. A much deeper analysis is needed, and at a significantly more disaggregated level, in order to identify how much land can be used. This is necessary to ensure that each region can optimally plan which crops to produce, including food, feed and export crops, so that at the regional level policy-makers can allocate the most effective crop to its most suitable location.

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APPENDIX 4 A

THE LAND RESOURCE INVENTORY FOR TANZANIA

The Land Resources Inventory is comprised of numerous climate, soil and landform data layers that are integrated to assess the overall suitability for agriculture.

The datasets for Tanzania were compiled mainly by FAO GIS experts and then refined based on input from local experts on meteorology and agriculture.

The climate resources inventory, shown in Figure 4A.1, was created from information gathered at nearly 600 meteorological stations across Tanzania (Figure 4A.1a). Historical data from these research stations on temperature, precipitation and evapotranspiration[1] (dating back to 1971) were used in combination with altitude and rainfall patterns to generate the primary climate datasets, thermal zones (Figure 4A.1b) and length of growing period (LPG) zones (Figure 4A.1c).

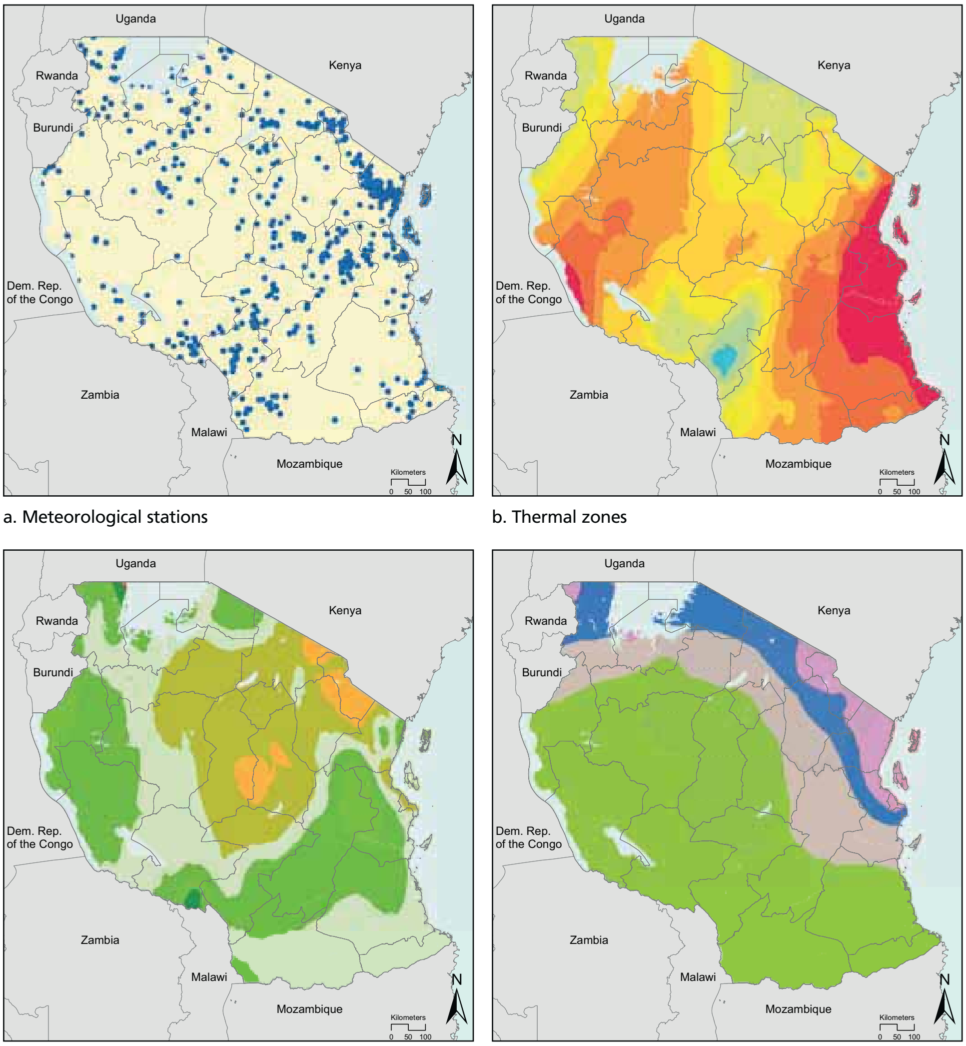
The thermal zones refer to the amount of heat available for plant growth and development during the growing period. In Tanzania the annual mean temperature varies from 10 °C in the southern highlands zone to more than 25 °C in the coastal area (from blue to red in the map). The LGP zones refer to soil moisture conditions, corresponding to the number of days when moisture conditions are considered adequate for crop growth. In Tanzania the LGP varies from 90 days in the central part to 330 days in the lake area.

The resulting information was evaluated by local experts in the Tanzania Meteorological Agency (TMA) to ensure validity and robustness. The contribution of local experts was invaluable to help identify unique climatic variations which are difficult to recognize at the national level. For example, the central region of Tanzania often has short, but numerous dry spells that occur throughout what would otherwise simply be classified as the rainy season (Figure 4A.1d). In this case, local knowledge was critical to properly estimating the overall number of days with moisture in the soil.

1 Potential evapotranspiration is the amount of water that could be evaporated and transpired if sufficient water were available.

Figure 4A.1

Climatic resource inventory



a. Meteorological stations

b. Thermal zones

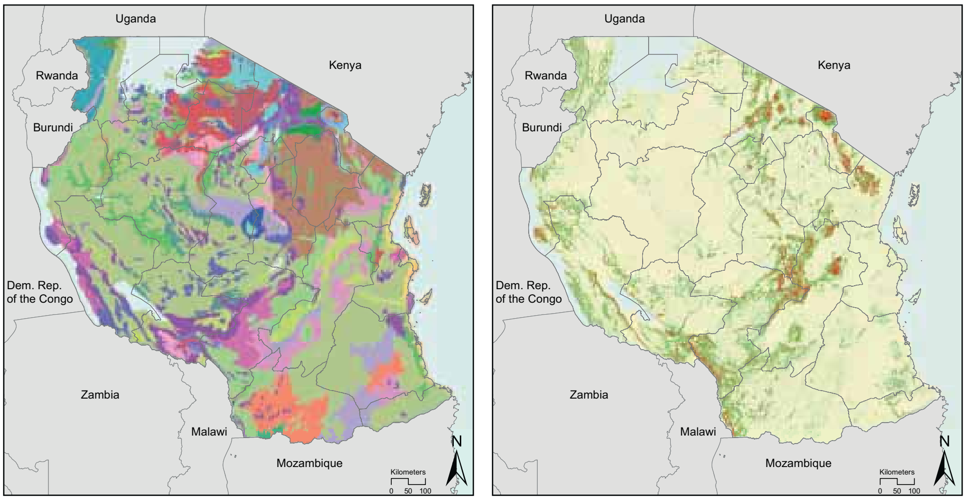
c. Length of growing period zones

d. Rainfall pattern and dry spell area

Similarly, the soil resource inventory (Figure 4A.2) was created using attributes such as soil type and soil texture taken from the Soil and Terrain (SOTER) digital database for Southern Africa. The landform resource inventory uses slope as a proxy for suitability. Land that has a steep slope, such as mountain sides or precipitous hills, is a limiting factor for certain types of production systems and, if not managed carefully, can lead to erosion problems. The slope information is derived from the elevation database and is expressed in percentage. The brown areas of the map are mainly concentrated on the borders of Iringa and Dodoma with Morogoro and in the northeast – Kilimanjaro and Arusha – with more than 15 percent of slope.

Figure 4A.2

Soil and landform resource inventory



a. Dominant soil

b. Slope

APPENDIX 4 B

PRINCIPLES AND PRACTICES OF CONSERVATION AGRICULTURE

CA is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. CA is based on enhancing natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way that quantity does not interfere with, or disrupt, the biological processes. CA is characterized by three principles which are linked to each other, namely:

1. **Direct seeding or planting**
   Direct seeding involves growing crops without mechanical seedbed preparation and with minimal soil disturbance since the harvest of the previous crop. The term direct seeding is understood in CA systems as synonymous with no-till farming, zero tillage, no-tillage, direct drilling, etc. The equipment penetrates the soil cover, opens a seeding slot and places the seed into that slot. The size of the seed slot and the associated movement of soil are to be kept at the absolute minimum possible. Land preparation for seeding or planting under no-tillage involves slashing or rolling the weeds, previous crop residues or cover crops; or spraying herbicides for weed control, and seeding directly through the mulch.

2. **Permanent soil cover**
   A permanent soil cover is important to: protect the soil against the deleterious effects of exposure to rain and sun, to provide the micro- and macro-organisms in the soil with a constant supply of "food", and to alter the microclimate in the soil for optimal growth and development of soil organisms, including plant roots. Cover crops need to be managed before planting the main crop. This can be done manually or with animal or tractor power. The important point is that the soil is always kept covered.

3. **Crop rotations**
   The rotation of crops is not only necessary to offer a diverse "diet" to the soil micro-organisms, but as they root at different soil depths, they are capable of exploring different soil layers for nutrients. Nutrients that have been leached to deeper layers and that are no longer available for the commercial crop can be "recycled" by the crops in rotation. This way the rotation crops function as biological pumps. Furthermore, a diversity of

crops in rotation leads to a diverse soil flora and fauna, as the roots excrete different organic substances that attract different types of bacteria and fungi, which in turn, play an important role in the transformation of these substances into plant available nutrients. Crop rotation also has an important phytosanitary function as it prevents the carryover of crop-specific pests and diseases from one crop to the next via crop residues.

Conservation agriculture, understood in this way, provides a number of advantages on global, regional, local and farm level:

- It provides a truly sustainable production system, not only conserving but also enhancing the natural resources and increasing the variety of soil biota, fauna and flora (including wild life) in agricultural production systems without sacrificing yields on high production levels. As CA depends on biological processes to work, it enhances the biodiversity in an agricultural production system on a micro- as well as macro-level.
- No-till fields act as a sink for CO2 and conservation farming applied on a global scale could provide a major contribution to control air pollution in general and global warming in particular. Farmers applying this practice could eventually be rewarded with carbon credits.
- Soil tillage is among all farming operations the single most energy consuming and thus, in mechanized agriculture, air-polluting, operation. By not tilling the soil, farmers can save between 30 and 40 percent of time, labour and, in mechanized agriculture, fossil fuels as compared to conventional cropping.
- Soils under CA have very high water infiltration capacities reducing surface runoff and thus soil erosion significantly. This improves the quality of surface water reducing pollution from soil erosion, and enhances groundwater resources. In many areas it has been observed after some years of conservation farming that natural springs that had dried up many years ago, started to flow again. The potential effect of a massive adoption of conservation farming on global water balances is not yet fully recognized.
- Conservation agriculture is by no means a low output agriculture and allows yields comparable with modern intensive agriculture but in a sustainable way. Yields tend to increase over the years with yield variations decreasing.
- For the farmer, conservation farming is mostly attractive because it allows a reduction of the production costs, reduction of time and labour, particularly at times of peak demand such as land preparation and planting and in mechanized systems it reduces the costs of investment and maintenance of machinery in the long term.

Disadvantages in the short term might be the high initial costs of specialized planting equipment and the completely new dynamics of a conservation farming system, requiring high management skills and a learning process by the farmer. Long-term experience with conservation farming all over the world has shown that conservation farming does not present more or less but different problems to a farmer, all of them capable of being resolved. Particularly in Brazil the area under conservation farming is now growing exponentially having already reached the 10 million hectare mark. Also in North America the concept is widely adopted.

APPENDIX 4

C AVAILABILITY OF LAND

The second step in the Module 1 framework is to filter out lands already in use or that have protected status (Figure 4.2). The LSA assigns the degree of suitability in growing a specific crop based on biophysical and management characteristics (climate, soil, mechanization, inputs, etc.) to all the land. To get a true understanding of which lands are available for bioenergy production, the LSA results are refined by excluding environmental, agriculture and urban areas. Equation E1 is applied to exclude environmental areas. Equation E2 is used to exclude agriculture and urban areas, see below.

E1: No_Enviroment = Tot land – Conservation/Protected
E2: No_Ag_Conflict = No_Enviroment – Agriculture – Urban

Before the LSA results can be interpreted, existing and protected land uses must be removed from consideration. To start, the World Database on Protected Areas (WCMC) was used to designate conservation and protected areas for Tanzania. The International Union for Conservation of Nature (IUCN) has defined a series of six protected area management categories. In Tanzania, three of these classes are present, the specifics of which are described in Table 4C.1.

Table 4C.1
Description of Protected Area Classes present in Tanzania

Category	Description
Category II National park	National Park: protected area managed mainly for ecosystem protection and recreation Category II protected areas are large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities.
Category IV Game reserve	Habitat/Species Management Area: protected area managed mainly for conservation through management intervention Category IV protected areas aim to protect particular species or habitats and management reflects this priority. Many category IV protected areas will need regular, active interventions to address the requirements of particular species or to maintain habitats, but this is not a requirement of the category.
Category VI Conservation area	Managed Resource Protected Area: protected area managed mainly for the sustainable use of natural ecosystems Category VI protected areas conserve ecosystems and habitats, together with associated cultural values and traditional natural resource management systems. They are generally large, with most of the area in a natural condition, where a proportion is under sustainable natural resource management and where low-level non-industrial use of natural resources compatible with nature conservation is seen as one of the main aims of the area.

Source: IUCN, 2008

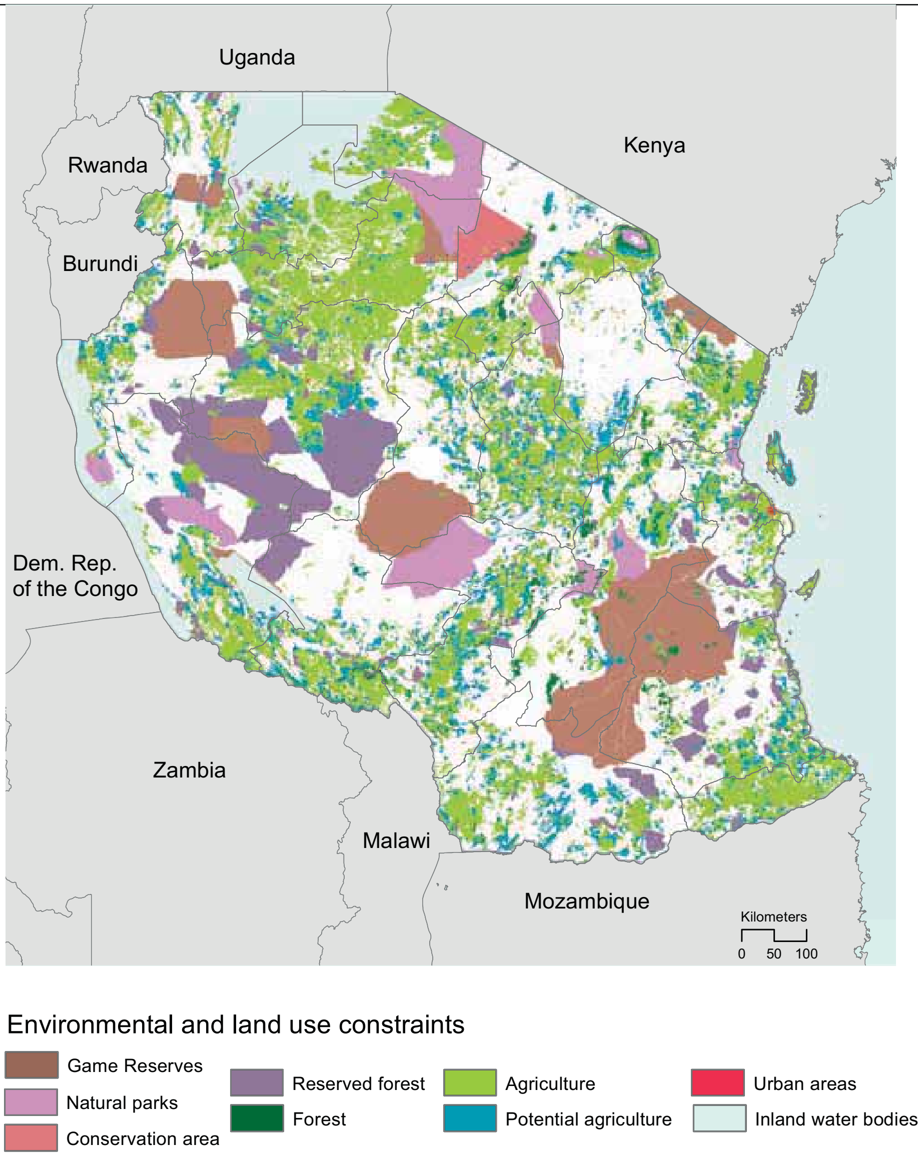
The information on urban settlements and existing agricultural lands were extracted from the Africover Eastern Africa Digital Land Cover database. This database was produced by FAO under the Africover project operational in the period 1995-2002 (FAO, 1995) at 1:200 000 scale and covers ten countries of Eastern Africa. Africover has been produced from visual interpretation of digitally enhanced LANDSAT TM images (Bands 4,3,2) acquired mainly in the year 1997. The land cover classes have been developed using the FAO/UNEP international standard LCCS classification system. For agriculture lands these are considered lands containing more than 60 percent of agriculture, taking into account that the database requires an update since it is symptomatic of a picture of 1997; the potential agriculture are lands containing in 1997 from 20 to 40 percent of agriculture, considering the expansion of the agriculture in the next 20-30 years simply due to the increase of the population.

Figure 4C.1 shows the map of land use constraints for Tanzania. These areas were used as a filter to contextualize the land suitability results.

Once the lands described above are identified and removed from the assessment, the remaining land available for bioenergy production becomes clear. To insure food security is not jeopardized, it is paramount that existing agricultural lands are also considered and protected. However, these lands are not removed in the same way as other existing uses of land as the suitability assessment can estimate the potential for intensification of existing lands as well as agricultural expansion on to new lands.

Figure 4C.1

Protected areas and specific land use



APPENDIX 4

D TABULAR RESULTS

4D.1 CASSAVA

TABLE 4D.1a

Highly and moderately suitable land for cassava by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	4 275	-	6 453	12 741	93 843	13 210	88 707
Dodoma	-	-	-	-	-	30 055	-	30 055
Iringa	35 162	65 400	35 205	65 443	125 503	188 283	125 548	190 363
Kagera	-	6 346	-	38 357	-	189 534	-	195 742
Kigoma	109 011	321 803	157 874	427 992	594 294	1 339 688	625 447	1 366 635
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	589 589	989 160	730 029	971 533	1 555 758	3 305 362	1 790 380	3 368 327
Manyara	-	-	-	-	-	-	-	-
Mara	12 493	31 274	17 602	55 139	59 350	167 101	61 686	162 984
Mbeya	-	16 314	-	19 772	-	265 791	-	279 020
Morogoro	963 279	1 876 113	1 662 562	1 523 673	3 334 311	1 483 530	3 543 266	1 354 210
Mtwara	-	-	-	-	-	1 004 303	-	1 067 429
Mwanza	292	58 225	292	76 539	29 948	668 190	30 000	683 275
Pwani	290 450	734 777	408 189	860 741	1 511 327	833 535	1 599 219	748 581
Rukwa	658 532	1 501 239	799 252	1 628 023	2 506 520	1 822 710	2 747 292	1 736 460
Ruvuma	89 888	291 287	121 003	336 529	246 212	2 219 703	267 315	2 525 451
Shinyanga	2 476	12 967	2 476	43 381	44 787	693 778	45 733	700 200
Singida	-	-	-	-	-	-	-	-
Tabora	84 354	351 750	84 354	747 826	765 960	1 978 847	834 570	1 920 113
Tanga	107 885	425 184	221 871	439 028	844 230	738 985	880 552	739 315
Total	**2 943 411**	**6 686 114**	**4 240 709**	**7 240 429**	**11 630 941**	**17 023 238**	**12 564 218**	**17 156 867**

TABLE 4D.1b

Expansion: highly and moderately suitable new area available for cassava by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	98	-	149	231	24 874	252	20 647
Dodoma	-	-	-	-	-	13 677	-	13 677
Iringa	6 704	14 350	6 746	14 392	23 008	96 978	23 053	98 154
Kagera	-	1 334	-	17 266	-	78 094	-	80 172
Kigoma	73 212	185 630	104 317	227 262	342 160	561 782	359 216	559 193
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	212 249	219 179	299 660	182 305	372 632	1 135 383	500 608	1 149 668
Manyara	-	-	-	-	-	-	-	-
Mara	1 144	7 331	1 724	9 292	5 290	31 136	5 496	30 303
Mbeya	-	1 514	-	1 671	-	23 852	-	26 064
Morogoro	351 271	577 323	627 529	495 152	1 073 182	485 495	1 141 748	457 505
Mtwara	-	-	-	-	-	201 595	-	224 390
Mwanza	-	6 007	-	7 305	675	101 102	675	102 242
Pwani	134 663	312 850	196 758	327 842	619 943	300 948	651 271	268 116
Rukwa	287 256	595 867	362 073	580 408	1 014 328	606 173	1 092 256	574 010
Ruvuma	41 023	135 987	69 020	175 275	73 035	1 107 302	81 232	1 265 399
Shinyanga	-	180	-	258	258	136 149	258	137 005
Singida	-	-	-	-	-	-	-	-
Tabora	18 442	80 825	18 442	166 936	169 344	422 801	185 379	416 882
Tanga	27 467	136 336	58 549	137 682	271 109	256 920	283 118	257 565
Total	**1 153 431**	**2 274 811**	**1 744 818**	**2 343 195**	**3 965 195**	**5 584 261**	**4 324 562**	**5 680 992**

TABLE 4D.1c

Intensification: highly and moderately suitable area available for cassava already under crop production by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	3 784	-	5 707	11 449	54 075	11 801	55 138
Dodoma	-	-	-	-	-	9 382	-	9 382
Iringa	120	1 120	120	1 121	612	27 297	611	28 035
Kagera	-	3 059	-	15 750	-	96 910	-	98 927
Kigoma	12 984	45 262	19 051	52 338	97 869	349 393	103 071	349 888
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	54 163	44 005	76 816	52 657	116 608	736 211	131 471	774 843
Manyara	-	-	-	-	-	-	-	-
Mara	11 349	19 152	15 878	41 043	53 725	124 975	55 854	121 736
Mbeya	-	14 321	-	17 530	-	105 438	-	112 276
Morogoro	143 596	222 108	233 639	206 500	543 809	190 739	558 992	180 559
Mtwara	-	-	-	-	-	716 663	-	748 460
Mwanza	292	35 243	292	43 024	27 703	507 458	27 755	518 237
Pwani	70 621	180 130	114 738	233 316	384 780	260 640	397 801	247 639
Rukwa	95 104	235 879	123 281	221 238	331 622	296 232	419 769	272 283
Ruvuma	2 845	24 375	4 268	29 863	3 793	564 916	4 268	653 340
Shinyanga	-	1 263	-	1 803	1 803	372 342	1 803	378 835
Singida	-	-	-	-	-	-	-	-
Tabora	6 795	31 917	6 795	58 680	59 090	436 020	65 473	426 624
Tanga	51 187	190 573	103 997	215 154	416 528	317 735	436 756	316 763
Total	**449 056**	**1 052 191**	**698 875**	**1 195 724**	**2 049 391**	**5 166 426**	**2 215 425**	**5 292 965**

TABLE 4D.1d

Expansion: potential production of cassava into new highly and moderately suitable land by region (tons))

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	181	-	1 121	759	58 441	3 034	177 552
Dodoma	-	-	-	-	-	32 139	-	117 614
Iringa	17 362	26 543	70 832	107 926	75 692	227 876	277 539	844 054
Kagera	-	2 467	-	129 462	-	183 508	-	689 427
Kigoma	189 583	343 355	1 095 189	1 704 179	1 125 617	1 320 032	4 324 611	4 808 481
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	549 614	405 368	3 146 027	1 366 830	1 225 813	2 667 788	6 026 825	9 886 112
Manyara	-	-	-	-	-	-	-	-
Mara	2 962	13 562	18 105	69 684	17 400	73 160	66 164	260 574
Mbeya	-	2 800	-	12 531	-	56 043	-	224 118
Morogoro	909 572	1 067 903	6 588 156	3 712 955	3 843 519	1 140 694	14 938 174	3 933 881
Mtwara	-	-	-	-	-	473 694	-	1 929 576
Mwanza	-	11 112	-	54 783	2 221	237 571	8 126	879 204
Pwani	348 652	578 641	2 065 461	2 458 275	2 209 691	707 081	8 523 451	2 305 428
Rukwa	743 800	1 102 151	3 801 058	4 352 166	3 336 817	1 424 183	13 149 765	4 935 586
Ruvuma	106 238	251 544	724 656	1 314 454	240 270	2 601 931	977 967	10 881 591
Shinyanga	-	334	-	1 932	848	319 929	3 102	1 178 164
Singida	-	-	-	-	-	-	-	-
Tabora	47 722	149 506	193 466	1 251 909	557 088	993 474	2 231 785	3 584 804
Tanga	71 131	252 193	614 688	1 032 475	895 750	603 680	3 423 633	2 214 816
Total	**2 986 636**	**4 207 660**	**18 317 638**	**17 570 682**	**13 531 485**	**13 121 224**	**53 954 176**	**48 850 982**

TABLE 4D.1e

Intensification: potential production of dry cassava into highly and moderately suitable land already under crop production by region (tons)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	6 999	-	42 791	37 666	127 062	142 065	474 150
Dodoma	-	-	-	-	-	22 045	-	80 676
Iringa	309	2 071	1 253	8 402	2 012	64 143	7 364	241 062
Kagera	-	5 659	-	118 080	-	227 722	-	850 701
Kigoma	33 624	83 719	200 013	392 461	321 965	821 000	1 240 873	3 008 756
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	140 251	81 385	806 441	394 869	383 594	1 729 915	1 582 737	6 663 079
Manyara	-	-	-	-	-	-	-	-
Mara	29 391	35 427	166 694	307 811	176 749	293 671	672 453	1 046 873
Mbeya	-	26 489	-	131 465	-	247 758	-	965 507
Morogoro	371 827	410 845	2 452 874	1 548 451	2 018 678	448 171	7 597 957	1 552 568
Mtwara	-	-	-	-	-	1 683 989	-	6 436 146
Mwanza	757	65 189	3 070	322 649	94 052	1 192 412	344 814	4 456 488
Pwani	182 852	333 182	1 204 545	1 749 607	1 360 635	612 399	5 152 999	2 129 364
Rukwa	246 219	436 244	1 294 046	1 658 766	1 090 893	695 980	5 053 636	2 341 251
Ruvuma	7 368	45 086	44 806	223 949	12 479	1 327 449	51 377	5 618 309
Shinyanga	-	2 335	-	13 526	5 933	874 956	21 714	3 257 801
Singida	-	-	-	-	-	-	-	-
Tabora	17 576	59 037	71 256	440 051	194 388	1 024 549	788 251	3 668 691
Tanga	132 538	352 471	1 091 851	1 613 363	1 374 224	746 555	5 272 689	2 723 755
Total	**1 162 712**	**1 946 138**	**7 336 849**	**8 966 241**	**7 073 268**	**12 139 776**	**27 928 929**	**45 515 177**

4D.2 SUGAR CANE

TABLE 4D.2a

Highly and moderately suitable land for sugar cane by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	-	-	-	12 741	6 790	12 672	6 859
Dodoma	-	-	-	-	-	-	-	-
Iringa	-	-	-	-	-	-	-	-
Kagera	-	-	-	-	-	29 049	-	30 021
Kigoma	-	-	-	-	-	-	-	-
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	-	-	-	-	-	-	-	-
Manyara	-	-	-	-	-	-	-	-
Mara	-	-	-	-	-	-	-	-
Mbeya	-	-	-	-	-	-	-	-
Morogoro	-	-	-	-	-	788 284	-	786 951
Mtwara	-	-	-	-	-	-	-	-
Mwanza	-	17 665	-	41 906	54 297	25 247	56 745	22 819
Pwani	2 544	17 111	8 898	6 049	169 273	476 936	172 393	486 777
Rukwa	-	-	-	-	-	-	-	-
Ruvuma	-	-	-	-	-	-	-	-
Shinyanga	-	-	-	-	-	-	-	-
Singida	-	-	-	-	-	-	-	-
Tabora	-	-	-	-	-	-	-	-
Tanga	36 099	129 254	89 722	77 273	698 980	207 280	705 621	207 099
Total	**38 643**	**164 030**	**98 620**	**125 228**	**935 291**	**1 533 586**	**947 431**	**1 540 526**

TABLE 4D.2b

Expansion: highly and moderately suitable new area available for sugar cane by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	-	-	-	231	146	252	124
Dodoma	-	-	-	-	-	-	-	-
Iringa	-	-	-	-	-	-	-	-
Kagera	-	-	-	-	-	14 454	-	14 815
Kigoma	-	-	-	-	-	-	-	-
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	-	-	-	-	-	-	-	-
Manyara	-	-	-	-	-	-	-	-
Mara	-	-	-	-	-	-	-	-
Mbeya	-	-	-	-	-	-	-	-
Morogoro	-	-	-	-	-	333 247	-	331 955
Mtwara	-	-	-	-	-	-	-	-
Mwanza	-	4 332	-	5 640	6 755	2 856	7 362	2 250
Pwani	1 351	8 647	1 732	2 858	46 147	198 682	44 682	205 187
Rukwa	-	-	-	-	-	-	-	-
Ruvuma	-	-	-	-	-	-	-	-
Shinyanga	-	-	-	-	-	-	-	-
Singida	-	-	-	-	-	-	-	-
Tabora	-	-	-	-	-	-	-	-
Tanga	1 465	6 868	3 279	3 833	197 124	76 936	202 068	74 226
Total	**2 816**	**19 847**	**5 011**	**12 331**	**250 257**	**626 321**	**254 364**	**628 557**

TABLE 4D.2c

Intensification: highly and moderately suitable area available for sugar cane already under crop production by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	-	-	-	11 449	5 975	11 263	6 162
Dodoma	-	-	-	-	-	-	-	-
Iringa	-	-	-	-	-	-	-	-
Kagera	-	-	-	-	-	14 726	-	15 328
Kigoma	-	-	-	-	-	-	-	-
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	-	-	-	-	-	-	-	-
Manyara	-	-	-	-	-	-	-	-
Mara	-	-	-	-	-	-	-	-
Mbeya	-	-	-	-	-	-	-	-
Morogoro	-	-	-	-	-	244 952	-	244 610
Mtwara	-	-	-	-	-	-	-	-
Mwanza	-	6 223	-	18 600	23 578	14 009	25 198	12 388
Pwani	1 057	5 838	5 127	2 703	83 778	135 077	86 619	131 389
Rukwa	-	-	-	-	-	-	-	-
Ruvuma	-	-	-	-	-	-	-	-
Shinyanga	-	-	-	-	-	-	-	-
Singida	-	-	-	-	-	-	-	-
Tabora	-	-	-	-	-	-	-	-
Tanga	28 893	101 160	72 219	57 378	420 611	94 280	421 306	96 928
Total	**29 950**	**113 221**	**77 346**	**78 681**	**539 416**	**509 019**	**544 386**	**506 805**

TABLE 4D.2d

Expansion: potential production of sugar into new highly and moderately suitable land by region (tons)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	-	-	-	598	269	2 451	860
Dodoma	-	-	-	-	-	-	-	-
Iringa	-	-	-	-	-	-	-	-
Kagera	-	-	-	-	-	26 737	-	102 956
Kigoma	-	-	-	-	-	-	-	-
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	-	-	-	-	-	-	-	-
Manyara	-	-	-	-	-	-	-	-
Mara	-	-	-	-	-	-	-	-
Mbeya	-	-	-	-	-	-	-	-
Morogoro	-	-	-	-	-	616 444	-	2 306 849
Mtwara	-	-	-	-	-	-	-	-
Mwanza	-	4 332	-	34 118	17 494	5 284	71 622	15 637
Pwani	2 835	8 647	14 662	17 291	122 943	367 515	447 641	1 425 893
Rukwa	-	-	-	-	-	-	-	-
Ruvuma	-	-	-	-	-	-	-	-
Shinyanga	-	-	-	-	-	-	-	-
Singida	-	-	-	-	-	-	-	-
Tabora	-	-	-	-	-	-	-	-
Tanga	3 075	6 868	27 775	23 192	515 113	142 299	1 983 372	515 787
Total	**5 910**	**19 847**	**42 437**	**74 601**	**656 148**	**1 158 548**	**2 505 086**	**4 367 982**

TABLE 4D.2e

Intensification: potential production of sugar into highly and moderately suitable land already under crop production by region (tons)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	-	-	-	29 651	11 052	109 573	42 824
Dodoma	-	-	-	-	-	-	-	-
Iringa	-	-	-	-	-	-	-	-
Kagera	-	-	-	-	-	27 240	-	106 523
Kigoma	-	-	-	-	-	-	-	-
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	-	-	-	-	-	-	-	-
Manyara	-	-	-	-	-	-	-	-
Mara	-	-	-	-	-	-	-	-
Mbeya	-	-	-	-	-	-	-	-
Morogoro	-	-	-	-	-	453 122	-	1 699 884
Mtwara	-	-	-	-	-	-	-	-
Mwanza	-	11 497	-	112 515	61 061	25 914	245 163	86 086
Pwani	2 219	13 078	43 430	16 348	222 577	249 866	863 793	913 064
Rukwa	-	-	-	-	-	-	-	-
Ruvuma	-	-	-	-	-	-	-	-
Shinyanga	-	-	-	-	-	-	-	-
Singida	-	-	-	-	-	-	-	-
Tabora	-	-	-	-	-	-	-	-
Tanga	60 653	155 140	611 563	347 016	1 187 181	174 366	4 463 090	673 518
Total	**62 872**	**179 715**	**654 993**	**475 879**	**1 500 470**	**941 560**	**5 681 619**	**3 521 899**

4D.3 SWEET SORGHUM

TABLE 4D.3a

Highly and moderately suitable land for sweet sorghum by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	38 198	241 829	52 593	312 461	80 618	1 534 827	80 690	1 749 355
Dar es Salaam	44 751	69 626	78 386	42 578	134 628	3 403	127 836	10 194
Dodoma	280 234	1 097 916	755 355	1 346 127	2 538 488	762 171	2 594 611	748 606
Iringa	526 777	1 600 795	1 342 330	1 564 821	3 490 695	740 845	3 515 331	726 548
Kagera	342 751	903 601	1 067 621	634 290	1 652 534	406 872	1 652 675	399 196
Kigoma	1 834 490	772 808	2 634 989	256 638	3 130 321	55 870	3 132 373	54 256
Kilimanjaro	-	71 415	-	96 850	52 930	726 626	57 314	748 739
Lindi	5 344 305	462 194	5 828 557	195 797	6 185 911	30 347	6 216 260	-
Manyara	280 565	726 545	467 265	1 068 460	1 864 628	1 784 265	1 965 160	1 785 114
Mara	710 672	272 229	1 160 928	195 027	1 363 306	87 746	1 388 462	77 169
Mbeya	1 379 915	1 160 731	2 189 181	928 709	3 156 360	594 687	3 162 754	594 388
Morogoro	3 138 891	845 416	3 648 663	945 507	4 303 747	992 260	4 309 264	997 204
Mtwara	1 427 386	112 564	1 508 393	46 938	1 636 639	6 840	1 643 478	-
Mwanza	857 605	188 707	1 307 505	122 140	1 510 877	25 983	1 531 446	5 415
Pwani	1 436 982	276 687	1 642 504	491 964	1 857 294	514 728	1 854 058	561 139
Rukwa	3 675 551	650 912	4 176 906	352 326	5 199 091	80 765	5 275 630	5 215
Ruvuma	4 653 447	915 634	5 258 084	502 602	5 946 760	108 984	5 966 122	99 137
Shinyanga	1 569 359	848 884	2 465 917	873 081	3 514 905	330 469	3 658 186	241 894
Singida	361 611	1 640 555	1 545 912	1 449 873	3 423 283	394 211	3 429 565	400 802
Tabora	3 384 271	1 517 460	5 052 524	751 013	6 346 209	17 027	6 363 237	-
Tanga	1 509 283	417 252	1 845 604	229 456	2 196 484	168 343	2 203 477	165 392
Total	**32 797 044**	**14 793 760**	**44 029 217**	**12 406 658**	**59 585 708**	**9 367 269**	**60 127 929**	**9 369 763**

TABLE 4D.3b

Expansion: highly and moderately suitable new area available for sweet sorghum by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	35 033	162 989	47 859	208 147	72 614	802 166	72 665	911 696
Dar es Salaam	11 589	13 099	16 993	10 544	33 252	83	31 700	1 633
Dodoma	52 231	275 104	156 703	382 075	713 725	231 390	733 175	223 020
Iringa	211 707	509 232	430 272	625 289	1 371 216	299 173	1 386 052	292 161
Kagera	150 643	413 520	487 626	277 879	707 588	223 206	707 699	217 631
Kigoma	847 325	320 170	1 159 187	111 184	1 368 067	27 010	1 369 736	25 636
Kilimanjaro	-	10 825	-	19 675	10 686	247 783	11 805	258 875
Lindi	1 775 315	164 844	1 945 720	68 462	2 073 778	12 720	2 086 503	-
Manyara	178 870	538 731	311 995	810 648	1 355 203	1 087 745	1 432 083	1 077 542
Mara	99 670	54 675	173 923	50 892	224 931	21 823	230 787	17 845
Mbeya	707 293	817 479	1 316 252	639 896	1 903 675	424 958	1 897 416	434 686
Morogoro	911 894	388 028	1 154 953	439 546	1 464 331	415 498	1 467 583	413 799
Mtwara	286 382	29 012	307 158	12 949	339 995	1 581	341 575	-
Mwanza	100 716	61 001	228 357	23 162	260 817	3 481	264 297	-
Pwani	550 300	98 358	612 494	204 626	686 898	225 394	685 837	242 480
Rukwa	1 247 326	293 211	1 424 707	135 928	1 821 760	26 695	1 845 907	3 297
Ruvuma	2 190 710	388 526	2 440 584	233 758	2 745 039	60 964	2 757 167	57 328
Shinyanga	304 025	159 879	515 805	153 731	718 502	30 484	733 177	18 546
Singida	57 494	737 980	582 920	646 117	1 418 322	204 654	1 422 108	207 868
Tabora	746 110	430 163	1 250 524	220 619	1 604 164	6 616	1 610 780	-
Tanga	588 268	161 076	732 116	82 877	860 025	40 844	863 229	38 615
Total	**11 052 901**	**6 027 902**	**15 296 148**	**5 358 004**	**21 754 588**	**4 394 268**	**21 951 281**	**4 442 658**

TABLE 4D.3c

Intensification: highly and moderately suitable area available for sweet sorghum already under crop production by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	198	66 900	283	91 581	1 360	356 542	1 381	370 172
Dar es Salaam	29 827	45 213	54 113	23 436	82 976	3 108	79 811	6 274
Dodoma	223 356	781 347	578 512	889 742	1 669 566	403 743	1 699 829	399 501
Iringa	164 290	373 796	274 774	544 708	849 363	370 205	854 710	367 066
Kagera	165 425	313 504	412 809	231 577	676 804	103 317	676 827	101 150
Kigoma	397 666	240 991	598 283	73 507	732 463	24 121	732 847	23 881
Kilimanjaro	-	57 340	-	72 277	36 722	318 452	39 791	321 316
Lindi	888 054	106 116	1 051 731	32 826	1 142 845	11 496	1 154 335	-
Manyara	99 837	174 978	152 540	234 450	462 496	515 075	483 008	519 598
Mara	367 014	106 341	589 457	86 780	725 340	18 034	742 649	794
Mbeya	366 688	267 214	497 351	228 117	720 266	148 516	735 939	135 288
Morogoro	354 308	119 274	430 186	209 547	529 891	297 335	530 455	297 210
Mtwara	1 020 615	68 458	1 072 069	26 699	1 151 048	4 694	1 155 743	-
Mwanza	647 776	109 539	943 878	94 040	1 100 757	22 015	1 117 709	5 063
Pwani	456 148	55 388	521 536	132 523	570 743	122 629	574 886	119 468
Rukwa	654 469	241 688	759 080	145 504	1 068 233	47 355	1 115 065	699
Ruvuma	1 391 052	351 595	1 634 471	183 564	1 900 182	32 801	1 904 138	29 838
Shinyanga	883 646	495 450	1 402 840	523 418	2 038 249	91 512	2 118 047	14 350
Singida	5 132	194 961	155 378	456 531	729 798	182 791	732 293	186 148
Tabora	743 204	726 972	1 350 476	340 687	1 835 155	10 372	1 845 526	-
Tanga	680 758	145 250	809 658	64 063	944 175	50 714	945 866	49 242
Total	**9 539 463**	**5 042 315**	**13 289 425**	**4 685 577**	**18 968 432**	**3 134 827**	**19 240 855**	**2 947 058**

TABLE 4D.3d

Expansion: potential production of sweet sorghum's juice into new highly and moderately suitable land by region (tons)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	122 277	274 881	667 611	1 379 621	413 480	1 704 484	1 590 537	7 122 182
Dar es Salaam	25 394	20 462	156 202	65 894	118 023	177	404 009	12 760
Dodoma	115 214	429 783	1 381 176	2 387 592	2 408 600	491 621	9 129 198	1 742 099
Iringa	557 985	988 854	4 561 902	5 239 102	6 019 878	699 781	23 011 498	2 546 844
Kagera	411 729	815 301	5 626 726	2 043 185	3 297 152	481 476	12 534 604	1 703 509
Kigoma	2 300 050	610 271	14 140 652	883 262	6 096 419	72 313	22 990 036	260 378
Kilimanjaro	-	16 911	-	122 951	31 788	526 509	129 111	2 022 356
Lindi	4 112 091	257 485	20 102 367	427 513	7 765 672	26 936	29 117 877	-
Manyara	407 002	841 591	2 843 335	5 065 801	4 225 630	2 311 162	16 421 490	8 417 218
Mara	228 756	86 102	1 657 720	320 234	1 068 352	50 127	4 128 252	141 679
Mbeya	1 645 038	1 312 120	13 005 852	4 140 581	6 645 713	908 549	24 553 391	3 411 558
Morogoro	2 182 177	652 720	12 101 009	2 900 236	5 770 260	883 517	21 563 432	3 233 728
Mtwara	655 664	45 321	3 132 282	80 887	1 271 452	3 342	4 742 674	-
Mwanza	227 505	95 295	2 259 751	144 720	973 392	7 384	3 618 286	-
Pwani	1 273 533	153 643	6 205 986	1 278 703	2 552 276	478 930	9 437 924	1 894 243
Rukwa	2 915 838	460 153	14 472 421	854 804	6 730 085	57 529	25 247 133	28 396
Ruvuma	5 256 828	655 548	25 552 765	1 624 075	10 793 241	130 169	40 381 410	449 314
Shinyanga	669 567	249 755	5 040 258	960 657	2 593 785	64 746	9 729 172	144 867
Singida	125 935	1 152 990	5 164 447	4 037 541	5 055 253	434 821	18 712 078	1 623 711
Tabora	1 648 308	672 052	12 407 933	1 378 598	5 969 661	14 047	22 030 639	-
Tanga	1 391 964	251 632	7 457 197	517 799	3 132 450	86 781	11 620 260	301 644
Total	**26 272 854**	**10 042 868**	**157 937 590**	**35 853 754**	**82 932 560**	**9 434 399**	**311 093 009**	**35 056 483**

TABLE 4D.3e

Intensification: potential production of sweet sorghum's juice into highly and moderately suitable land already under crop production by region (tons)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	589	105 044	3 244	574 834	6 245	757 630	24 115	2 891 900
Dar es Salaam	67 476	70 639	503 722	146 444	269 369	6 597	950 301	48 976
Dodoma	489 132	1 220 653	5 070 269	5 559 783	5 820 768	857 803	21 968 930	3 120 607
Iringa	438 575	691 672	2 888 708	4 213 351	3 472 528	827 042	13 183 484	3 035 475
Kagera	439 150	630 460	4 841 582	1 808 190	3 279 176	222 845	12 484 235	793 792
Kigoma	1 309 723	503 985	8 718 296	604 727	3 833 196	61 062	14 668 091	226 501
Kilimanjaro	-	89 589	-	451 710	109 239	676 687	435 174	2 510 212
Lindi	2 046 146	165 769	10 988 012	204 993	4 283 054	24 378	16 016 669	-
Manyara	233 335	273 346	1 447 772	1 465 068	1 465 182	1 094 434	5 632 205	4 059 008
Mara	831 166	166 138	5 870 071	542 202	3 014 837	44 535	11 477 491	9 010
Mbeya	1 132 598	526 628	6 148 063	1 771 743	3 443 898	339 256	13 485 676	1 124 452
Morogoro	857 744	186 454	4 468 689	1 311 436	1 981 623	631 798	7 340 287	2 321 854
Mtwara	2 341 381	106 942	10 975 999	166 758	4 338 456	9 956	16 082 469	-
Mwanza	1 471 757	173 411	9 653 722	592 254	4 070 913	47 013	15 151 944	40 796
Pwani	1 055 009	86 526	5 341 041	828 149	2 124 813	260 574	7 858 704	933 309
Rukwa	1 518 524	378 502	7 612 898	911 192	3 817 941	100 945	15 079 321	6 696
Ruvuma	3 339 780	585 748	16 898 402	1 210 997	7 514 114	71 116	28 089 560	239 140
Shinyanga	1 947 701	773 915	13 432 482	3 270 459	7 382 740	194 300	28 244 479	112 095
Singida	11 222	304 592	1 362 436	2 852 943	2 380 418	388 346	8 802 217	1 453 972
Tabora	1 639 317	1 135 779	12 823 403	2 128 831	6 868 994	22 028	25 326 242	-
Tanga	1 587 829	226 911	8 334 451	400 266	3 450 163	107 761	12 750 313	384 685
Total	**22 758 152**	**8 402 702**	**137 383 264**	**31 016 328**	**72 927 666**	**6 746 107**	**275 051 907**	**23 312 481**

4D.4 OIL PALM

TABLE 4D.4a

Highly and moderately suitable land for oil palm by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	-	-	-	73 414	22 672	81 799	21 539
Dodoma	-	-	-	-	-	-	-	-
Iringa	-	-	-	-	-	-	-	-
Kagera	-	-	-	-	-	38 252	-	35 172
Kigoma	-	-	-	-	-	-	-	-
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	-	-	-	-	-	-	-	-
Manyara	-	-	-	-	-	-	-	-
Mara	-	-	-	-	-	-	-	-
Mbeya	-	-	-	-	-	-	-	-
Morogoro	-	-	-	-	-	-	-	-
Mtwara	-	-	-	-	-	-	-	-
Mwanza	-	19 845	-	25 919	41 992	19 771	48 473	27 026
Pwani	845	13 207	7 950	6 321	290 183	16 814	336 131	21 864
Rukwa	-	-	-	-	-	-	-	-
Ruvuma	-	-	-	-	-	-	-	-
Shinyanga	-	-	-	-	-	-	-	-
Singida	-	-	-	-	-	-	-	-
Tabora	-	-	-	-	-	-	-	-
Tanga	44 911	91 060	80 141	100 419	949 036	128 251	1 036 377	159 053
Total	**45 756**	**124 112**	**88 091**	**132 659**	**1 354 625**	**225 760**	**1 502 780**	**264 654**

TABLE 4D.4b

Expansion: highly and moderately suitable new area available for oil palm by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	-	-	-	7 711	1 939	9 288	1 910
Dodoma	-	-	-	-	-	-	-	-
Iringa	-	-	-	-	-	-	-	-
Kagera	-	-	-	-	-	18 847	-	17 419
Kigoma	-	-	-	-	-	-	-	-
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	-	-	-	-	-	-	-	-
Manyara	-	-	-	-	-	-	-	-
Mara	-	-	-	-	-	-	-	-
Mbeya	-	-	-	-	-	-	-	-
Morogoro	-	-	-	-	-	-	-	-
Mtwara	-	-	-	-	-	-	-	-
Mwanza	-	2 921	-	2 908	4 636	2 998	5 700	3 912
Pwani	351	6 717	4 092	3 085	79 363	4 018	88 029	4 519
Rukwa	-	-	-	-	-	-	-	-
Ruvuma	-	-	-	-	-	-	-	-
Shinyanga	-	-	-	-	-	-	-	-
Singida	-	-	-	-	-	-	-	-
Tabora	-	-	-	-	-	-	-	-
Tanga	1 575	3 461	2 744	4 144	284 934	31 732	321 923	48 126
Total	**1 926**	**13 099**	**6 836**	**10 137**	**376 644**	**59 534**	**424 940**	**75 886**

TABLE 4D.4c

Intensification: highly and moderately suitable area available for oil palm already under crop production by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	-	-	-	54 884	17 671	59 547	16 635
Dodoma	-	-	-	-	-	-	-	-
Iringa	-	-	-	-	-	-	-	-
Kagera	-	-	-	-	-	19 509	-	17 856
Kigoma	-	-	-	-	-	-	-	-
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	-	-	-	-	-	-	-	-
Manyara	-	-	-	-	-	-	-	-
Mara	-	-	-	-	-	-	-	-
Mbeya	-	-	-	-	-	-	-	-
Morogoro	-	-	-	-	-	-	-	-
Mtwara	-	-	-	-	-	-	-	-
Mwanza	-	8 244	-	9 306	15 898	8 761	18 617	15 305
Pwani	468	5 823	3 452	2 875	126 681	5 482	144 346	6 103
Rukwa	-	-	-	-	-	-	-	-
Ruvuma	-	-	-	-	-	-	-	-
Shinyanga	-	-	-	-	-	-	-	-
Singida	-	-	-	-	-	-	-	-
Tabora	-	-	-	-	-	-	-	-
Tanga	37 148	74 349	66 976	78 150	511 784	50 785	550 256	59 285
Total	**37 616**	**88 416**	**70 428**	**90 331**	**709 247**	**102 208**	**772 766**	**115 184**

TABLE 4D.4d

Expansion: potential production of palm oil into new highly and moderately suitable land by region (tons)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	-	-	-	14 068	2 043	43 450	7 716
Dodoma	-	-	-	-	-	-	-	-
Iringa	-	-	-	-	-	-	-	-
Kagera	-	-	-	-	-	18 638	-	75 008
Kigoma	-	-	-	-	-	-	-	-
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	-	-	-	-	-	-	-	-
Manyara	-	-	-	-	-	-	-	-
Mara	-	-	-	-	-	-	-	-
Mbeya	-	-	-	-	-	-	-	-
Morogoro	-	-	-	-	-	-	-	-
Mtwara	-	-	-	-	-	-	-	-
Mwanza	-	2 512	-	10 090	8 550	4 185	25 822	11 931
Pwani	425	5 776	19 845	10 705	155 602	4 831	527 979	15 988
Rukwa	-	-	-	-	-	-	-	-
Ruvuma	-	-	-	-	-	-	-	-
Shinyanga	-	-	-	-	-	-	-	-
Singida	-	-	-	-	-	-	-	-
Tabora	-	-	-	-	-	-	-	-
Tanga	1 905	2 976	13 302	14 371	559 143	51 478	1 877 916	126 264
Total	**2 330**	**11 264**	**33 147**	**35 166**	**737 363**	**81 175**	**2 475 167**	**236 907**

TABLE 4D.4e

Intensification: potential production of palm oil into highly and moderately suitable land already under crop production by region (tons)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	-	-	-	-	-	-	-	-
Dar es Salaam	-	-	-	-	95 565	17 794	327 813	70 318
Dodoma	-	-	-	-	-	-	-	-
Iringa	-	-	-	-	-	-	-	-
Kagera	-	-	-	-	-	19 104	-	77 632
Kigoma	-	-	-	-	-	-	-	-
Kilimanjaro	-	-	-	-	-	-	-	-
Lindi	-	-	-	-	-	-	-	-
Manyara	-	-	-	-	-	-	-	-
Mara	-	-	-	-	-	-	-	-
Mbeya	-	-	-	-	-	-	-	-
Morogoro	-	-	-	-	-	-	-	-
Mtwara	-	-	-	-	-	-	-	-
Mwanza	-	7 088	-	32 289	27 923	16 375	88 546	34 858
Pwani	564	5 007	16 742	9 972	253 289	6 525	838 195	21 812
Rukwa	-	-	-	-	-	-	-	-
Ruvuma	-	-	-	-	-	-	-	-
Shinyanga	-	-	-	-	-	-	-	-
Singida	-	-	-	-	-	-	-	-
Tabora	-	-	-	-	-	-	-	-
Tanga	44 937	63 926	324 789	271 124	976 409	63 422	3 432 981	202 097
Total	**45 501**	**76 021**	**341 531**	**313 385**	**1 353 186**	**123 220**	**4 687 535**	**406 717**

4D.5 SUNFLOWER

TABLE 4D.5a

Highly and moderately suitable land for sunflower by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	332	214 488	593	310 588	920	1 707 562	992	1 730 479
Dar es Salaam	33 765	71 807	46 715	66 122	134 071	3 961	101 973	36 057
Dodoma	272 728	917 386	543 671	1 309 706	2 952 664	463 145	3 031 093	396 760
Iringa	414 702	1 431 995	749 577	1 707 019	2 211 875	2 140 583	2 216 826	2 118 788
Kagera	322 268	557 974	417 183	680 705	933 899	759 519	930 149	763 481
Kigoma	1 117 747	410 967	1 530 332	412 437	2 080 144	298 423	2 077 053	302 559
Kilimanjaro	-	69 393	-	94 827	5 862	341 892	7 665	355 759
Lindi	3 909 123	316 717	5 370 344	382 249	6 121 222	14 174	6 135 399	-
Manyara	271 050	652 679	461 890	1 046 676	1 870 902	1 720 224	1 973 635	1 709 118
Mara	633 139	350 582	935 061	363 334	1 117 931	320 450	1 131 988	314 322
Mbeya	938 509	934 374	1 446 917	1 029 702	2 531 748	730 853	2 468 926	769 571
Morogoro	2 690 869	764 682	3 233 572	901 314	4 155 986	1 098 746	4 156 911	1 097 757
Mtwara	991 850	78 257	1 424 658	99 143	1 621 728	3 112	1 624 837	-
Mwanza	712 728	235 063	1 143 643	182 421	1 432 129	99 624	1 451 821	69 565
Pwani	940 274	391 013	1 428 030	535 628	1 830 468	540 836	1 778 730	598 502
Rukwa	2 963 953	544 131	3 527 829	671 439	4 938 193	12 587	4 937 184	14 216
Ruvuma	4 071 919	625 941	4 807 247	611 116	5 702 722	333 813	5 711 812	325 509
Shinyanga	1 296 683	865 801	2 227 320	885 375	3 514 899	232 454	3 595 188	157 988
Singida	300 063	1 255 969	983 020	1 643 496	3 712 517	213 012	3 729 517	196 033
Tabora	2 804 609	1 066 490	4 426 126	1 255 252	6 346 210	17 027	6 363 236	-
Tanga	971 603	582 768	1 287 420	603 573	1 830 329	414 717	1 825 007	409 523
Total	**25 657 914**	**12 338 477**	**35 991 148**	**14 792 122**	**55 046 419**	**11 466 714**	**55 249 942**	**11 365 987**

TABLE 4D.5b

Expansion: highly and moderately suitable new area available for sunflower by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	255	174 238	456	242 921	657	979 239	708	996 231
Dar es Salaam	11 188	12 782	15 614	11 731	33 240	96	27 877	5 456
Dodoma	48 614	229 649	101 262	359 209	830 925	136 594	854 890	116 745
Iringa	156 131	418 945	234 526	536 073	656 292	952 465	662 731	941 176
Kagera	141 463	260 804	180 304	313 023	364 817	406 948	364 542	407 399
Kigoma	515 870	158 976	668 770	171 750	897 993	154 047	897 352	155 394
Kilimanjaro	-	10 477	-	19 327	5 303	103 426	6 937	111 030
Lindi	1 400 131	118 082	1 754 115	126 386	2 062 321	9 856	2 072 183	-
Manyara	176 838	482 929	306 902	797 459	1 362 725	1 030 903	1 441 932	1 012 154
Mara	109 184	63 515	162 170	55 802	199 617	43 794	202 001	44 328
Mbeya	548 990	682 056	953 257	743 189	1 767 288	475 867	1 715 643	513 125
Morogoro	900 569	354 006	991 071	410 469	1 336 155	516 056	1 335 404	516 815
Mtwara	210 761	21 041	281 135	25 003	339 237	1 391	340 629	-
Mwanza	91 720	67 957	207 178	34 584	251 205	12 435	254 683	7 252
Pwani	371 491	133 492	550 426	193 691	678 466	233 573	665 617	250 738
Rukwa	1 003 343	249 761	1 119 493	291 981	1 731 849	9 134	1 732 053	9 346
Ruvuma	1 977 331	257 982	2 245 163	264 613	2 620 511	176 301	2 624 625	173 215
Shinyanga	227 832	177 265	482 046	161 035	718 496	26 973	724 318	20 463
Singida	45 590	564 714	364 271	714 540	1 573 208	96 694	1 582 600	87 321
Tabora	631 563	329 884	1 106 576	340 242	1 604 164	6 616	1 610 780	-
Tanga	412 597	220 039	569 174	227 139	796 841	75 629	803 185	71 112
Total	**8 981 461**	**4 988 594**	**12 293 909**	**6 040 167**	**19 831 310**	**5 448 037**	**19 920 690**	**5 439 300**

TABLE 4D.5c

Intensification: highly and moderately suitable area available for sunflower already under crop production by region (ha)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	77	34 000	137	58 736	263	336 897	284	341 213
Dar es Salaam	20 418	47 588	26 271	44 042	82 489	3 596	63 214	22 873
Dodoma	219 665	650 061	428 678	880 712	1 956 789	205 582	2 004 741	160 842
Iringa	118 172	417 776	157 185	581 101	438 647	974 544	436 753	965 659
Kagera	122 652	168 874	164 720	214 962	339 351	263 576	335 895	267 064
Kigoma	95 140	91 953	109 039	99 537	208 731	110 937	208 616	111 391
Kilimanjaro	-	55 691	-	70 628	559	204 707	728	210 775
Lindi	719 626	68 241	982 299	83 974	1 101 735	1 217	1 102 948	-
Manyara	92 490	157 273	152 258	225 855	462 562	508 401	483 051	509 818
Mara	394 444	117 441	549 808	107 368	684 151	53 696	695 586	47 258
Mbeya	153 780	194 858	188 984	216 368	306 564	234 027	303 256	227 934
Morogoro	329 470	129 152	398 427	163 874	521 892	297 945	521 988	298 110
Mtwara	694 092	46 099	1 026 013	60 770	1 136 989	1 180	1 138 168	-
Mwanza	552 727	143 333	842 800	125 741	1 064 101	56 196	1 081 052	34 893
Pwani	291 069	131 046	432 409	182 392	556 410	136 516	542 361	150 974
Rukwa	548 760	195 455	591 408	222 949	988 947	2 093	988 693	2 526
Ruvuma	1 296 801	243 059	1 497 192	221 076	1 806 412	118 518	1 808 686	116 004
Shinyanga	784 980	595 760	1 237 174	622 894	2 038 248	87 762	2 109 522	18 685
Singida	4 826	162 535	106 241	348 529	857 753	114 176	865 406	106 522
Tabora	672 421	487 078	1 048 796	613 858	1 835 156	10 372	1 845 526	-
Tanga	383 822	259 619	483 720	261 087	702 876	226 619	696 417	224 797
Total	**7 495 432**	**4 396 892**	**10 423 559**	**5 406 453**	**17 090 625**	**3 948 557**	**17 232 891**	**3 817 338**

TABLE 4D.5d

Expansion: potential production of sunflower seeds into new highly and moderately suitable land by region (tons))

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	215	104 533	1 596	607 274	782	832 301	3 074	3 088 135
Dar es Salaam	9 395	7 667	57 412	29 326	47 070	82	131 267	16 913
Dodoma	41 205	137 765	357 072	897 883	1 102 901	116 074	4 140 495	361 823
Iringa	139 896	251 325	874 690	1 340 014	904 968	809 529	3 329 093	2 917 411
Kagera	124 224	156 456	668 382	782 454	462 734	345 878	1 685 760	1 262 835
Kigoma	451 494	95 375	2 579 768	429 321	1 297 103	130 928	4 699 160	481 678
Kilimanjaro	-	6 284	-	48 311	6 311	87 904	30 107	344 172
Lindi	1 260 946	70 822	6 719 265	315 837	3 092 637	8 343	11 297 727	-
Manyara	154 583	289 689	1 119 510	1 993 348	1 699 198	876 150	6 558 786	3 137 256
Mara	95 097	38 099	608 198	139 482	262 667	37 215	965 088	137 406
Mbeya	466 270	409 160	3 562 183	1 857 688	2 337 096	404 384	8 285 873	1 590 382
Morogoro	850 773	212 356	3 978 273	1 025 985	1 977 339	438 612	7 206 128	1 602 027
Mtwara	184 650	12 622	1 041 170	62 488	507 679	1 176	1 855 792	-
Mwanza	81 734	40 767	802 002	86 439	375 283	10 565	1 379 048	22 479
Pwani	325 005	80 077	2 055 100	484 123	989 984	198 523	3 510 429	777 237
Rukwa	886 105	149 829	4 146 094	729 801	2 583 095	7 756	9 309 494	28 965
Ruvuma	1 901 008	154 750	9 021 817	661 389	3 848 359	149 814	14 064 991	536 895
Shinyanga	197 058	106 341	1 804 858	402 524	1 038 675	22 917	3 815 283	63 419
Singida	38 360	338 787	1 285 702	1 786 065	2 206 399	82 161	8 098 100	270 595
Tabora	549 543	197 900	4 295 041	850 488	2 406 056	5 619	8 786 121	-
Tanga	378 924	131 996	2 189 331	567 748	1 095 791	64 272	4 041 745	220 407
Total	**8 136 485**	**2 992 600**	**47 167 464**	**15 097 988**	**28 242 127**	**4 630 203**	**103 193 561**	**16 860 035**

TABLE 4D.5e

Intensification: potential production of sunflower seeds into highly and moderately suitable land already under crop production by region (tons)

Region	Tillage-Low input		Tillage-High input		Conservation-Low input		Conservation-High input	
	VS + S	MS	VS + S	MS	VS + S	MS	VS + S	MS
Arusha	64	20 396	479	146 821	312	286 352	1 230	1 057 731
Dar es Salaam	17 173	28 550	92 899	110 091	101 515	3 052	281 231	70 898
Dodoma	184 726	389 953	1 502 389	2 201 368	2 670 075	174 692	9 992 233	498 439
Iringa	104 540	250 628	579 734	1 452 578	582 955	828 299	2 112 221	2 993 292
Kagera	108 431	101 308	615 094	537 338	441 750	224 017	1 589 495	827 817
Kigoma	82 649	55 163	397 623	248 806	282 000	94 286	1 016 658	345 277
Kilimanjaro	-	33 415	-	176 559	664	173 996	3 155	653 376
Lindi	649 556	40 928	3 841 873	209 866	1 664 319	1 031	6 076 805	-
Manyara	83 428	94 339	578 118	564 543	586 153	432 102	2 235 045	1 580 300
Mara	346 845	70 455	2 135 392	268 340	957 391	45 630	3 519 602	146 476
Mbeya	132 445	116 884	690 078	540 773	403 088	198 892	1 463 953	706 510
Morogoro	313 236	77 477	1 614 604	409 599	775 701	253 236	2 833 858	924 097
Mtwara	603 434	27 652	3 765 434	151 890	1 718 660	997	6 282 681	-
Mwanza	493 216	85 979	3 289 825	314 268	1 573 600	47 737	5 753 572	108 159
Pwani	254 240	78 615	1 627 038	455 926	795 065	116 029	2 801 672	467 990
Rukwa	488 233	117 240	2 192 772	557 229	1 432 177	1 778	5 221 740	7 834
Ruvuma	1 243 230	145 809	5 978 035	552 567	2 576 309	100 706	9 413 784	359 532
Shinyanga	678 104	357 372	4 599 919	1 556 842	2 954 237	74 530	11 117 491	57 912
Singida	4 052	97 512	372 411	871 176	1 104 421	97 017	4 065 943	330 106
Tabora	571 599	292 196	3 870 122	1 534 443	2 749 805	8 811	10 026 242	-
Tanga	351 350	155 743	1 849 060	652 605	942 768	192 608	3 415 088	696 821
Total	**6 710 551**	**2 637 614**	**39 592 899**	**13 513 628**	**24 312 965**	**3 355 798**	**89 223 699**	**11 832 567**