Assessing Agricultural Land Carrying Capacity for Sustainable Livelihoods and Resettlement of Internally Displaced Persons in South Darfur

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March, 2013

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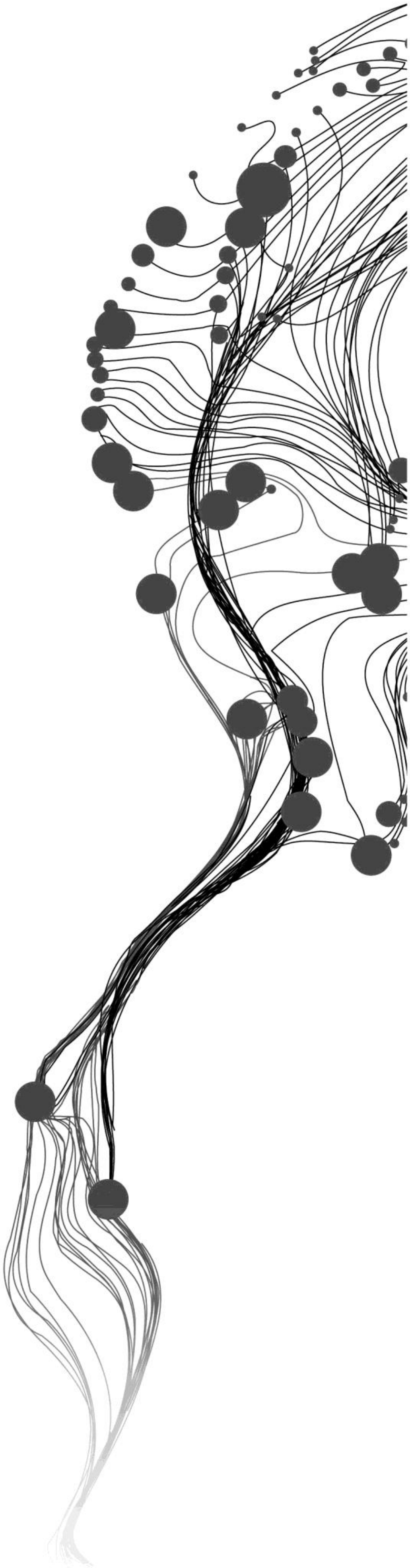

Assessing Agricultural Land Carrying Capacity for Sustainable Livelihoods and Resettlement of Internally Displaced Persons in South Darfur

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Enschede, The Netherlands, March, 2013

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
Specialization: Urban Planning and Management

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ABSTRACT

Conflicts resulting from the resource use are becoming common in the current world. The conflicts have culminated into civil war especially where political, economic and tribal factors are allowed to play part. South Darfur has drawn the attention of the international community since the drought of 1983 which saw people lose their source of livelihoods mainly in the rain fed agriculture sector. The situation was worsened in 2003 when the conflicts turned in civil war as different tribes fought each other. Militia's groups were formed to fight the Government which they felt had denied them development projects. The end result of this massive civil war was internal displacement and citizens being isolated from their sources of livelihoods and creating relief dependence syndrome. The Internally Displaced Persons (IDPs) moved in big number to urban areas. The influence has been pressure to the government to provide social services in camps where IDPs settle despite the fact that the existing urban population is being serviced. The IDPs have also settled on the urban periphery leading to the sprawl of urban towns and loss of agricultural land and environmental degradation as they clear forests to get fuel.

Offering sustainable solutions to IDPs has been a dream of the International Community and the Government of Sudan. Some of the possible solutions include integrating the IDPs within their current areas of settlement. This will mean that the IDPs are given opportunity to settle within the urban centres where their camps are located. The option is not supported by majority of since the Darfur Towns are already under threat of poor service delivery. Some proponents have then supported a second option of allowing IDPs to return to their original homes. Returnee programme is being supported by the Government of South Sudan since the IDPs will be linked to their pervious source of livelihood which is agriculture the major source of income for the Government. Alternatively some policy markets have been proposing the resettlement of IDPs in other areas viewed suitable and safe by the IDPs.

Whichever sustainable solution selected, there is a need to assess its potential to support more population. In this study Agricultural Land Carrying Capacity (ALCC) was assessed (ALCC) in order to determine whether the South Darfur Agricultural System is still able to support more population. The objective of assessing ALCC was considered because settling IDPs in agricultural areas which cannot support more population will be like transferring an urban problem into rural areas. The consequences will be more conflicts and the resettled population will go back to IDPs camps located in urban areas.

To carry out the assessment ALCC, a model was developed. The model was to be used as collaborative tool for allocating available land resource to main crop grown in South Darfur. Knowledge tables were used to convert non spatial criteria (decision rules) formulated by local experts into suitable zones. The model was viewed to be suitable since was easily used to assess land suitability for each crop; the area allocated to each crop was multiplied by production per Ha to get total production. The estimated production and per capita consumption value were used to get potential population (carrying capacity) that can be supported in south Darfur. It has to be noted that Land Carrying capacity which is potential optimum population that can be supported by a system is not constant and can vary depending on level of technology used.
The study results indicated that the livestock production subsystem is beyond the potential sustainable carrying capacity. Settlement options are available is sedentary farming subsystem where there is more potential for IDPs to practice agricultural production as a source of livelihood.

***Keywords**: Land Carrying capacity, IDPs, Return, Resettlement, Knowledge Tables, Conflicts*

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ACRONYMS

CBS	Central Bureau of Statistics
FAO	Food and Agriculture Organization of the United Nations
GoS	Government of Sudan
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDPs	Internally Displaced Persons
IFAD	International Fund for Agriculture
IITA	International Institute of Agriculture
IMWG	Information Management Working Group
NDVI	Normalized Difference Vegetation Index
TLU	Tropical Livestock Units
UAZs	Uniform Analysis Zones
UN	United Nations
UNCHR	United Nations High Commissioner for refugees
UNDP	United Nations Development Programme
UNEP	United Nations
UN-Habitat	United nations Human Settlements Programme
UNICEF	The United Nations Children's Fund
WFP	United Nations World Food Programme

LOCAL TERMS

Feddan	Unit of measuring area (1 Feddan=0.42 hectares)
Hafirs	Traditional Small Water Reservoirs
Khors/ Wadhis	Seasonal Water Courses

1. INTRODUCTION

Chapter one of this thesis puts my study in the research context. The manifestation of Internally Displaced Persons (IDPs) in South Darfur is briefly explained and the resulting consequences on Urban systems and the general economy of Darfur Region. The research problem, justification for the study research objective and questions are then explained. Finally the structure of the thesis is outlined.

1.1. Background

Darfur region has recorded abrupt changes in climatic conditions and land degradation which has resulted to competition over diminishing land resources between sedentary farmers and nomadic communities. For instance there has been long term reduction of rainfall which is a major source of water in the region (UNEP, 2007). To cope up with changing patterns both sedentary farmers and Nomadic communities tend to tussle for a place in Wadhis(seasonal rivers beds/watercourses) which have traces of water during dry season. In return Wadhis have become ecological hotspots as everybody tend to claim a share of it for them to sustain their sources of livelihoods(UNEP, 2007). Farmland lands are spread along this Wadhis which are favourable areas for Nomads during dry season as indicated in Figure 1-2. The convergence zones between sedentary farmers and Nomads which are subject of conflicts as farmlands are located on strategic livestock migratory routes (UNICEF, 2012). Sedentary farmers maintain small irrigation fields on these wet areas during dry season while Nomads prefer them for watering their livestock Figure 1-1 as they contain shallow wells where water is easily found.

Figure 1-1: Farming (photo A) and Livestock at Water point in a Wadhi (photo B)
Photo A Source:The Great Mirror (2012) Photo B Source: Feinstein International Center's (2004)

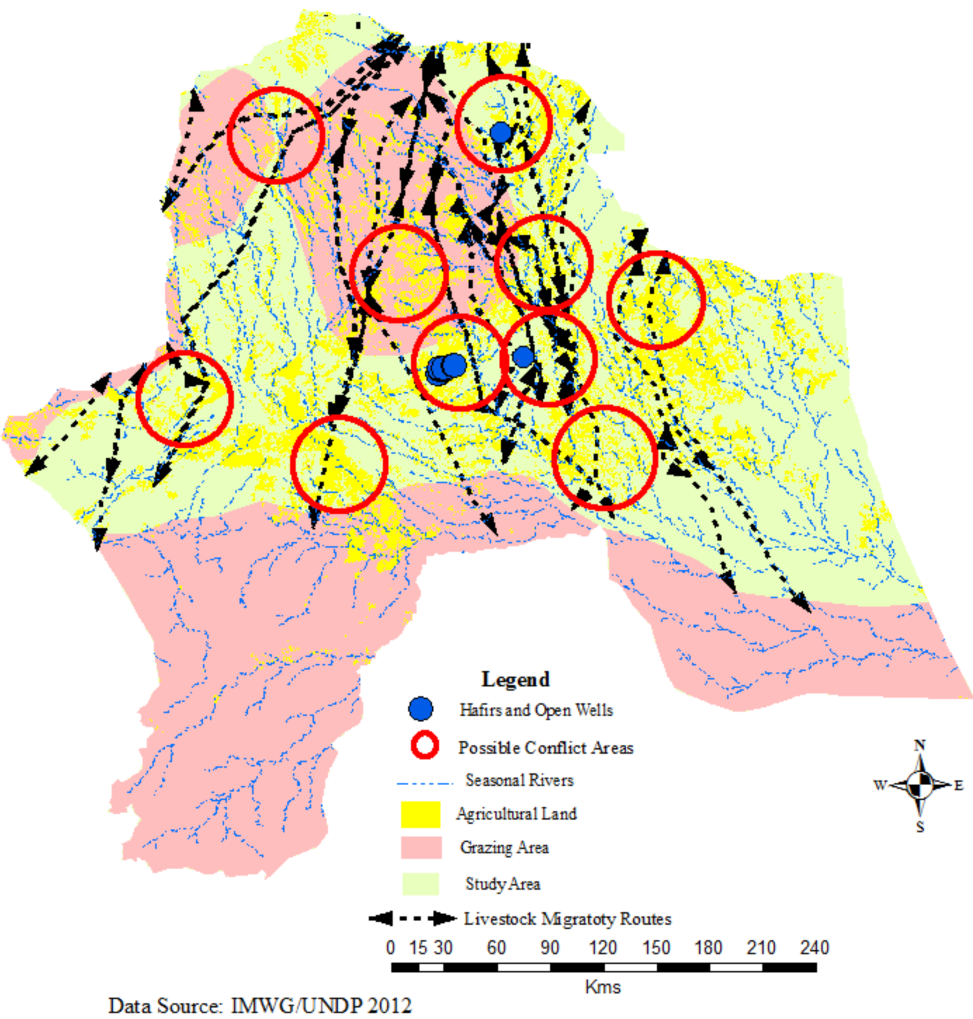


Figure 1-2: Possible Conflict areas In South Darfur

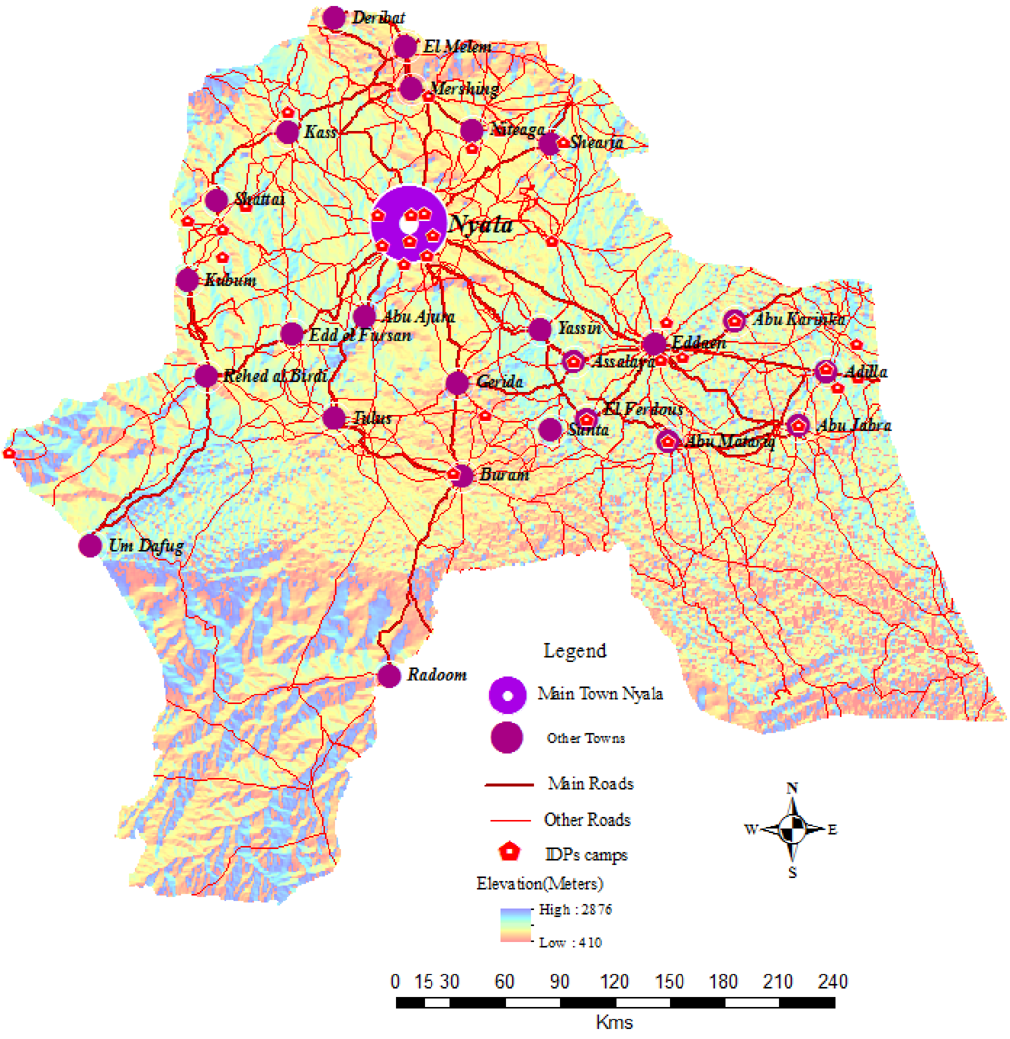
A study by UNEP (2007) on Sudan post conflict highlights the sources of conflicts in the larger Darfur Region. The study report indicates approximately 20 out of the 29 conflict recorded between 1930 and 2000 emanates from grazing and water rights as pointed out in Table 1:1.

	Type of conflict	Frequency /Number of occurrence
1.	Grazing and water rights	20
2.	Administrative boundaries	3
3.	Administrative boundaries	2
4.	Land	2
5.	Grazing, Cross boundary politics	1
6.	Armed robbery	1

Table 1:1: Conflicts in Darfur region
Source: UNEP (2007)

Recurrent of droughts have worsened the food security situation in the region. The 1983 famine which was an outcome of prolonged drought resulted to competition for farming fields and pasture for sedentary farmers and pastoralists respectively(Young et al., 2005). The conflicts related to shrinking of resources became more complicated in the year 2003 as tribal and political factors complicated the Darfur peace situation(Seferis, 2010; UN-Habitat & UNEP, 2010). In April 2003, Sudanese Liberation

Army (SLA) attacked an airbase in El Fasher and retaliatory attacks led into civil war in the region(Alix-Garcia, Bartlett, & Saah, 2012). Attempts to bring peace in the region in May 2006 through Darfur Peace Agreement were frustrated by the presence of several rebel groups. For instance SLA/Abdul Wahid group which was a splinter group from the main SLA felt left out of the discussion. These led to more attacks worsening security situation and reducing accessibility to livelihoods in the region(Kahn, 2008). The outcome of the conflicts and the subsequent civil war has been people being displaced from their homes. The internally Displaced Persons (IDPs) have settled in urban areas or on the periphery of the existing large settlements where there is presence of security and easy access to relief services.



Data Source: IMWG/UNDP 2012

Figure 1-3: Location of IDPs Camps in South Darfur

Majority of IDPs camps are located in urban areas with Nyala having the highest population of IDPs. Pressure has been mounting on the large urban systems which have been the preferred destination for IDPs since they are easily accessed by relief food providers and also offer some security. Environmental impact seems to be negative; this is by the fact that IDPs use timber and charcoal to meet their energy requirements(UNEP, 2007). Prior to 2003 when the civil war started 18 percent of the Darfur was Urbanized, the level has risen to 35 percent has there has been inflow of population from rural areas. Nyala which is the main City of South Darfur has seen its population grow rapidly.

During the 1983 drought Nyala had a population of 100,000 but the figure currently stands at 1.6million. Out of these Nyala population 0.3 million is made up of IDPs (Royal African Society, 2009). The high rate of urbanization has increased unemployment rate, the demand for social services such schools, water supply and health facilities.

1.2. Research Problem

As outlined in section 1.1 above there are two main assumptions explaining the causes of the conflicts in South Darfur and subsequent migration of IDPs to camps mainly located in urban areas. The first assumption is that there is conflict over resource use between sedentary farmers and nomads specifically over grazing land(Flint, 2009; UNEP, 2007). Second assumption is tribal and political reasons which are out of discussion for this study.

Understanding resource abundance and ability of these resources to support the ever increasing population has been a concern for researchers as they try to understand the causes of forced migration in Darfur Region. Some of the studies carried in Darfur region reveals that the available resources are in a stable condition. For instance Brown (2010) used Normalized Difference Vegetation Index(NDVI) to assess the resource availability for the period 1982-2006 and noted that the period 1982-1983 had the worse resource available due to the drought. He argued that the resource base has improved since then and there is no cause for alarm basing on resource availability.

Another study done by Kevane and Gray (2008) establish that rainfall which is a key climatic factor in the region has been stable. The situation was worse 30 years prior to the study but fighting over resources was not recorded. This is supported by Scheffran, Marmer, and Sow (2012) in their study carried out in the Western Sahel region (that is Mali, Mauritania and Senegal) which found out that change in climatic conditions has minimal contribution to forced migration. Some of the coping mechanisms include reduction in consumption and introduction of food from other systems or voluntary migration to other area to get supplementary resources. The study does not put into consideration other factors such land based resources and the level of consumption. The climatic conditions might be favourable but if the available natural resource does not match the consumption level, then conflicts may arise.

The studies by Brown (2010) and Kevane and Gray (2008) focus on resource abundance but do not assess the population to be supported and mainly centre on one factor that is rainfall availability which is a major weak point. Both the two studies contradict the UNEP (2007) report which categorical affirm that the rainfall conditions in the area has been worsening in Darfur as indicated in Table 1:2. This difference was noted since the analysis was based on long term data which made it easy to identify the reduction. Nyala which is located in my study area had a reduction of 16 percent; it is still difficult to make a good judgement at level of aggregation since the actual value of South Darfur average annual Rainfall stands at 530mm.

Meteorology Station	**Average Annual rainfall(mm) 1945-1975**	**Average Annual rainfall(mm) 1976-2005**	**Reduction (mm)**	**Percentage**
Nyala, South Darfur	448.71	376.50	-72.21	-16

Table 1:2: Long-Term Changes in Rainfall Patterns in the Larger Darfur Region
Source:UNEP (2007)

In order to understand the resource availability and their ability to support the population, it better to understand consumption levels and widen the number of indicators considered. This study is important since it will assess the Darfur agricultural land carrying capacity based on multiple factors of agricultural production and per capita consumption levels per annum. Factors of agricultural production which includes rainfall, soils, agricultural inputs and consumption levels will give a better insight on whether South Darfur still has enough resources to support current population sustainably.

1.3. Justification

South Darfur has an approximate of 718,000IDPs who are currently living in camps with 42.8 percent living in the capital town of Nyala(IWMG, 2012). There is unaccounted population of IDPs in either rented space or with relatives. In cases where IDPs are not housed in camps they tend to settle in slums where rent is affordable to them worsening the existing social problems(Crisp, Morris, & Refstie, 2012). Their preference of settling in slums increases the urban population which is staring face to face with problems associated with lack of sanitation facilities, access to safe drinking water and lack of land tenure. The situation is worsened since displacements happen spontaneously the numbers are enormous that they have an impact on both area of origin, destination and the general economy as employment rates of receiving end sky rocket.

Policy makers, urban planners and managers are concerned with the high rate of urbanization rate in South Darfur resulting from displacements resulting from civil war. IDPs settle in urban centres where they feel they are safe, the negative impact is felt on infrastructural facilities and competition for source of livelihood(Tibaijuka, 2010). IDPs faced with uncertainties about their future settle in camps characterized with lack of amenities and long queues of women who come to collect relief food of as shown in Figure 1-4 located in Nyala town. Women who cannot access formal labour are employed in as manual labour with brick making industry one of their choices. Children too are forced to hawk some goods to supplement family earnings and relief food which attract long queues. Access to water and food is key worry for IDPs leading to malnutrition and difficulty is achieving millennium development goals such us access to education, food and safe drinking water.

Figure 1-4: IDPs activities in the camps, IDP camp in Otash Nyala, women queue for food ration
Source: (UNICEF 2012 and Jafarli, B. 2007)

UNHCR (2012) has been advocating for "gradual shift in programming from camp based protection-oriented approach towards a stronger focus on solutions. This will involve agricultural and urban livelihoods-based interventions". The urban based approach is meant to benefit the IDPs who want to be integrated into their current area of settlement. On the other hand the agricultural based approach is to benefit the IDPs who want to return to their farms and continues practicing agricultural production which is the strength of South Darfur economy.

The existence of seasonal returnees who go back to practice farming during the planting season indicates there is a bright future for agricultural intervention. One third of the IDPs population also use their camps as "dormitories"(Royal African Society, 2009) and spent the whole day in farms to supplement their daily rations received from organizations providing relief services. Precautionary measures need to be taken as not all IDPs prefer this option as they feel the areas surrounding the urban areas and even camps have more facilities such as water and proximity to schools for their children as compared to their place of origin. The willingness to return can be improved if security is improved and services provided in rural areas as there are seasonal returnees who go to farm and come back to camps after harvesting (Seferis, 2010)

Currently the idea of returning IDPs to their farms is being advocated by the Government of Sudan (Daun, 2011) as well as it is an idea uphold by the (UNHCR, 2011, 2012) through voluntary return programme. This is viewed as the best of alternative of reducing pressure on the urban system which is suffering from urban poverty due to increase of IDPs (UN-Habitat & UNEP, 2010).

For IDPs who will prefer to return to rural farms, policy makers require information on land carrying capacity of the receiving area. Since resettlement needs to improve livelihoods of IDPs the agricultural land should sustain both pastoral and sedentary farming activities which are the main source of livelihood. Prior knowledge will also help the policy makers to develop coping strategies hence reducing future conflicts.

Preventative measures have to be taken prior to resettle since overshooting the carrying capacity has its own terrible consequences (Bell & Morse, 2008). For instance surpassed carrying capacity can be a source of conflicts leading to new displacements and people scramble to control resources. To balance the carrying capacity and the planned resettlement there is therefore a demand for assessing the available resources and potential population which can be supported.

Keeping in mind this problem, my research will assess the agricultural land carrying capacity and determine whether a gap exists between potential and actual population which can be filled by (re)settling IDPs. The study will also assess whether there are possibility of conflicts if agricultural production is the preferred source of livelihood. Encouraging returnee’s and resettlements programmes will reduce rural urban migration hence reducing pressure on urban systems which has been witnessed in the region.

1.4. Research Objectives and Questions

The main objective of the research is to determine South Darfur agricultural land carrying capacity in view of sustainable settlement of Internally Displaced Persons (IDPs). The specific objectives and research are outlined in Table 1:3.

Specific objectives	Research questions
i. To identify South Darfur main agro economic/livelihood activities and the trend in the actual production.	i. What are South Darfur agro economic/livelihood activities?
	ii. What is the actual agricultural production of these activities for the years 1998, 2008 and 2011?
i. To analyze the actual agricultural production in relation to the required agricultural production to support the population.	iii. What is South Darfur population for the year 1998, 2008 and 2011?
	iv. How much agricultural production is required to support this population?
	v. What is the gap between required and actual production?
	vi. How do the locals and the authorities handle the gap between actual and required production?
i. To develop a model for assessing agricultural livelihood zones and	vii. Which spatial factors determine South Darfur agro economic/livelihood activities?

	determine carrying capacity.	viii.	What is the potential production level for South Darfur?
		ix.	What is the maximum population (carrying capacity) that can be supported by this potential agricultural production?
v.	Analyze the gap between Actual production and potential	x.	Does Darfur actual production match potential production?
		xi.	What factors explain the gap between the actual and potential production?
v.	To assess the Darfur region's potential to absorb IDPs settlements basing on carrying capacity of land.	xii.	Can South Darfur agro economic/livelihood zones support more population sustainably?

Table 1:3: Specific Research Objectives and Questions

1.5. Research Design

The research was undertaken in three main phases which are indicated in Figure 1-5 adopted from (Gachanje, 2010).

Phase 1: pre field activities which include largely literature review leading to formulation of research problem, concept, and objectives research questions.

Phase 2: the phase was undertaken in the field, the main activities included data collection using focus group discussion. Key informant interview and secondary data from existing literature. The spatial data collected was processed in the field by converting them into grids of 100m by 100m and given same spatial reference. Some of the secondary data inform of reports were also summarised.

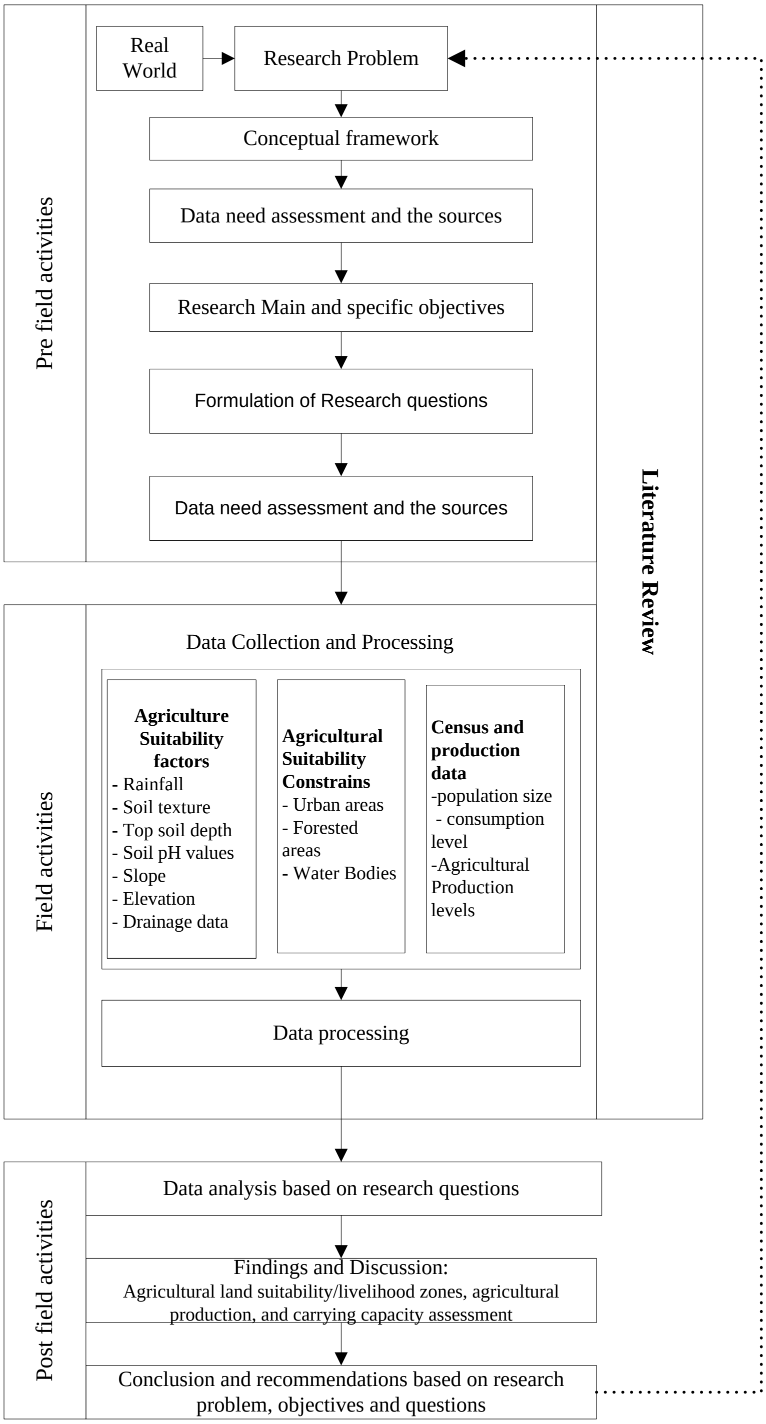


Figure 1-5: Research Design

Phase3: The third phase of the study is composed of post field activities and involved data analysis and presentation into charts, tables and maps for easy interpretation. The stage also involved report writing and making conclusion and recommendations based on the research problem, objectives and questions.

1.6. Thesis Structure

Chapter 1: Introduction

The chapter gives the background information of the study area. Research problem, justification, objectives and questions are also presented here.

Chapter 2: Literature review

Previous scholarly articles and publications will be reviewed with emphasis placed on carrying capacity, agricultural production as a source of livelihoods, sustainability and IDPs displacement and resettlement.

Chapter 3: Data Collection Method and analysis

The chapter gives an insight on how data was collected and analysed based on reviewed literature. The methods used to data analysis and analysis process are also discussed.

Chapter 4: Results

The chapter presents the output of analysis per research question and presented in charts, maps and narratives.

Chapter 5: Discussion

A detailed interpretation of the results presented in chapter four is discussed. Reference is made to studies and reports done within South Darfur or other regions which have the same conditions.

Chapter 5: Conclusions and Recommendations.

2. LITERATURE REVIEW

This chapter gives a review of scholarly articles and publications on sustainable (re)settlement of internally Displaced Persons (IDPs) and is divided into four sections. The first section looks at IDPs (re)settlement process and procedures recommended by UNHCR which includes access to source of livelihoods. There are three options available for (re)settlement of IDPs which includes return to their original places, local integration and settlement in another place. The second part justifies why agricultural production assessment was selected as a source of livelihoods for the study. Section three looks at the concept of land carrying capacity and its application in sustainable agricultural production. The last section gives a glance on methodological approaches used to assess land carrying capacity. Environmental assessment approach is discussed full since agricultural production in South Darfur is reliant on availability of natural resources.

2.1. Resettlement of Internally Displaced Persons(IDPs) and Sustainable Livelihoods

As discussed in chapter one, policy makers and international agencies involved in relief services and settlement planning are overwhelmed with the number of IDPs who have settled in camps located majorly in urban areas. UN-Habitat has been advocating for integration of environmental issues, access to livelihood, getting solutions to land related issues in post conflict reconstruction and development(UN-Habitat, 2010). Out of these concerns accessibility of the target population to sources of their livelihoods is vital as the policy makers try to reduce the population which is reliant to relief food. Planners and policy makers have to ensure that the internally displaced persons can easily access employment opportunities and income generating activities(The Brookings Institution-University of Bern, 2007). There is therefore a need for planners to integrate settlement programmes with sources of livelihoods which are sustainable to ensure that the IDPs are not prone to conflicts over resources which can also lead to further displacements. Figure 2-1 shows the procedure for sustainable (re)settlement where provision of livelihood activities is a core component for providing durable (re)settlement solution.

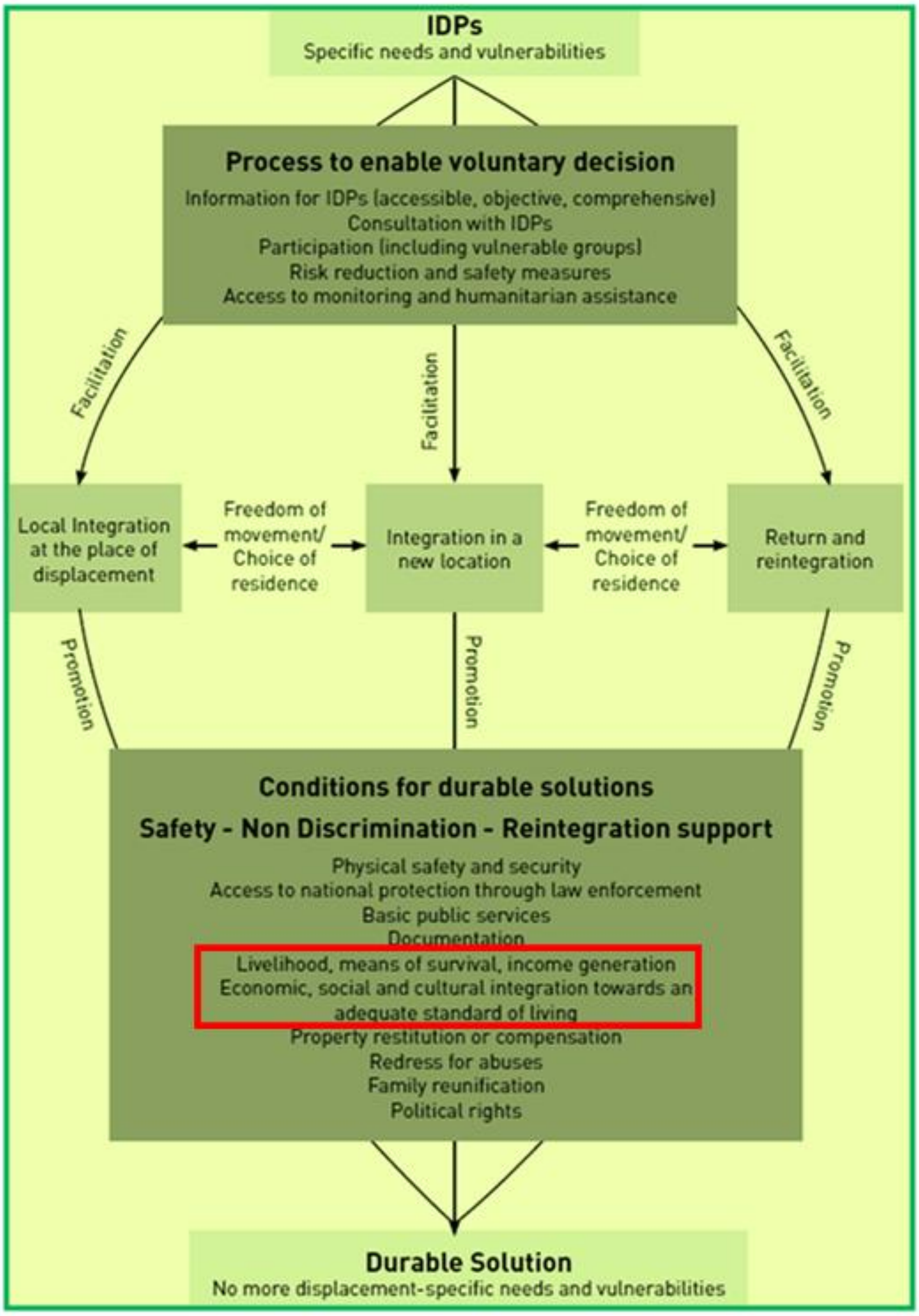


Figure 2-1: Procedure for sustainable (re)settlement.
Source:The Brookings Institution- University of Bern (2007)pg 20

As indicated in Procedure for sustainable (re)settlement. , there are three options which offer IDPs durable solutions and they have to choose voluntarily which options suit them. The first option is return to their place of origin, the second local integration in their current location; option three involves resettlement of IDPs in a new location. The first option and the third one has been of much interest to policy makers who feel that IDPs will return to their normal life and reduce the burden placed on urban settlements and constrained felt by relief food providers such WFP and UNICEF.

This study only focus on the livelihood aspect, other issues which are part of durable solutions includes provision of security, and political rights. IDPs in the South Darfur have shown some signs of returning but only if the above solutions are provided. For example Seferis (2010) noticed there are seasonal returnees where some IDPs family member return to their rural farms to cultivate their land during planning season to supplement rations provided by WFP and earn some income. Other try cultivated their land seasonal to protect it from other users while the vulnerable member's such us women and children are left in camps which are viewed to be safe. She warns against politically instigated return since IDPs are forced to move in areas which have been selected by Government and might be favourable for settlers themselves.

2.2. Agriculture as Source of Livelihood for South Darfur Rural Communities

Access to source of livelihood is a key component of any reconstruction process for areas which have been prone to displacements resulting from conflicts or natural disasters(UN-Habitat, 2010). This is part of durable solution framework as discussed in section 2.1. Agricultural production is considered as source of livelihood in this study since 80 percent of the South Darfur population is rural involved in sedentary farming and livestock keeping. This implies that the south Darfur system is highly dependent on the farming activities that is both Sedentary and nomadic activities for their survival. Both the two farming system depend on natural resources hence a need for getting the balance between availability and consumption levels hence reducing future displacements resulting from overuse or conflicts over utilization.

2.3. Land Carrying Capacity Concept as a Measure of Livelihoods Sustainability

Durable solution is only achieved when IDPs are (re)settled in sustainable manner without worries of future displacements. In case of return or resettlement in another location IDPs must access their current needs without compromising their survival and that of future generations.
The concept of land carrying capacity is mostly used as measure of sustainability as people should leave within the available natural resources(Lane, 2010). Population which consumes more than the system can provide tend to suffer from conflicts resulting from the control of resources (Bell & Morse, 2008). Thus carrying capacity is a good indicator of sustainable resettlement. The resettled population should be within the limit of the carrying capacity(Xiaolu, Tian, & Jie, 2011).

Scott (1975) defines land carrying capacity as the ability of the environment to sustain human population at a certain level of technology. Land carrying capacity concept was initial used animal ecologists who applied it in assessing sustainable stocking levels. Its use in human population assessment gained momentum after the study the Club of Rome (1972) who attempted to estimate the limit at which the World will sustain population. More recent studies by urban environmentalists have been carried out to study the impact of human population on urban system and recommendations made on what policy measures to be adopted. Rural studies have also recorded a number of numbers of researchers on carrying capacity assessment. For instance Komatsu, Tsunekawa, and Ju (2005) applied the carrying capacity principle for evaluating agricultural sustainability of dry lands of Inner Mongolia China. Bernard, Campbell, and Thom (1989) applied land carrying capacity concept to assess the optimum population that can be supported in Eastern Ecological zones of Kenya based on per capita land requirement. The Kenya studies recommended various options to improve carrying capacity which include non-agricultural jobs creation, use of new technology and reducing population growth rate.

For South Darfur region assessing land carrying capacity will determine whether the population is living within the limit of available resources and if not what can be. Assessment of land carrying capacity is paramount for planners who are involved in regional IDPs resettlement process. It helps them understand the available resources upon which informed decisions are made on allocation of various land uses/land use zones which will provide most favourable utilization of resources and link them to optimum population that can be supported. “The carrying capacity imperative is an environmental and ethical initiative of vital future importance. In fact, it is an imperative on which society’s very survival may well depend” (Lane, 2010). It is therefore vital that planners and decision makers need to perform land carrying capacity assessment of the entire planning region system while understanding both social processes and physical conditions that affect various land use decisions. (Fearnside, 1997).

Xiaolu et al. (2011) has been a proponent of land carrying capacity assessment prior to any reconstruction process where IDPs are involved. In the study on analysis of population capacity reconstruction of areas affected by 2008 Wenchuan Earthquake he uses population as an index for carrying capacity. His assessment is based on available land productivity and water availability to get land carrying capacity of his study areas on which resettlement policies can be based.

Prior knowledge of carrying capacity which can also be “expressed as maximum sustainable agricultural production levels or sustainable densities based on such production levels(Kessler, 1994) help planners formulate sustainable land use strategies. Proper planning will therefore reduce over use of resources and possible conflicts resulting from competing interests from settlers and possible new displacements. Furthermore societies which are purely dependent on agricultural production can know the tolerance levels of natural resource exploitation and how improvement can be done.

2.4. Methodological Approches Used in Agricultural Land Carrying Capacity Assessment

2.4.1. Why Assess Agricultural land Carrying Capacity?

Assessing Agricultural Land Carrying is paramount in understanding the system in which internally displaced persons return to or are resettled in. It will help settlement planners and policy makers comprehend whether the existing population at the target (re)settlement zone is at equilibrium, overpopulated or under population meaning that the resources are being underutilized hence considering possibility of adding more people. Figure adopted from Kessler (1994) indicates various phases of land carrying capacity. In the figure:

a. E stands for exploitation level
b. C carrying capacity of renewable resources in a phase (**a**) under-exploitation, phase (b) equilibrium and phase(**c**) Overexploitation $\mathbf{C_0}$ is the carrying capacity for intact agro-ecosystem, $\mathbf{C_d}$ refers to degraded state

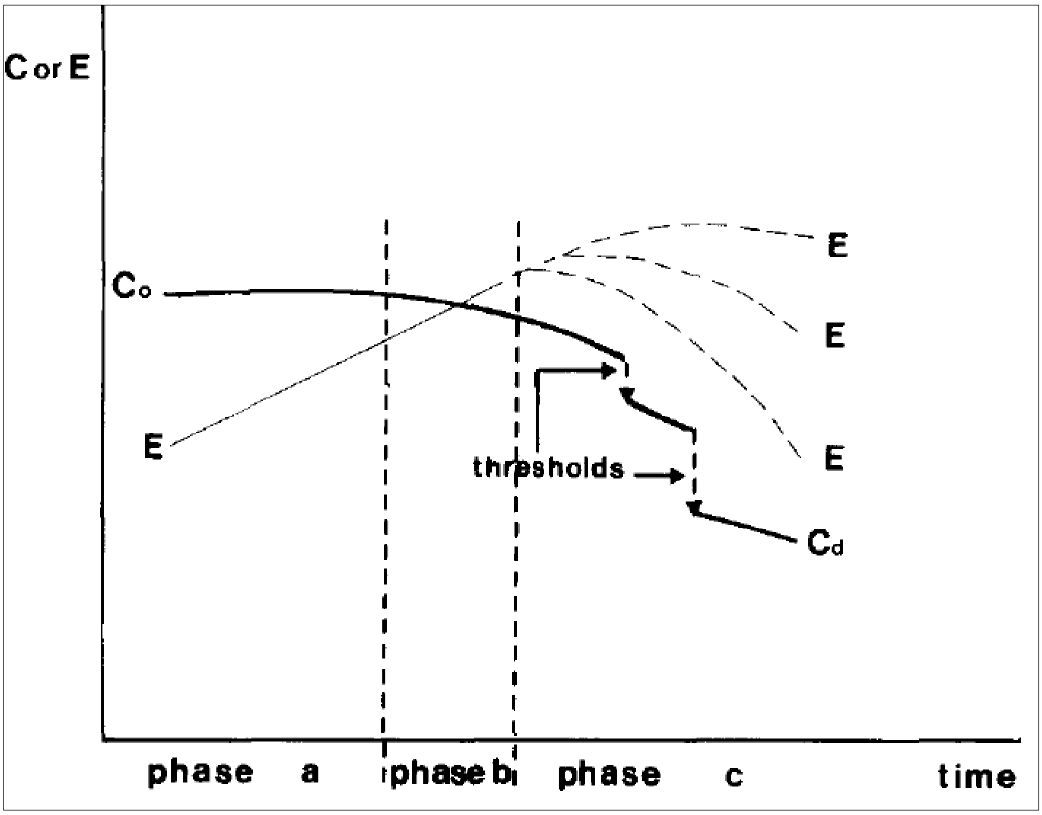


Figure 2-2: Relation between Land capacity and resource utilization

The logic behind land carrying capacity is to necessitate maximum level of resource utilization hence promoting sustainable land use (Kessler, 1994). Darfur population is vulnerable to conflicts over resource use which ends up in displacement hence the need to assess and strike a balance between the available resources and their utilization.

2.4.2. Methodological Approaches

According to Lane (2010) there are three main approaches used to assess land carrying capacity:
The first is the societal methodology which is based on economic indicators such us per capita production to assess the land carrying capacity. The second approach is affirmed on environmental consideration. The approach looks at available resources especially food availability, energy and water and the limit of population supported. The third and last approach utilizes the system approach. The world sub systems are studied and their impact on the population observed. The last approach was used by the Club of Rome (1972) where pollution, resources, capital, agriculture and the relationship with population was done

Most researchers in Land carrying capacity studying land carrying capacity use food production which is supply and consumption levels that is demand to get sustainable population which can be supported. This falls in the second approach that is environmental category as outlined by (Lane, 2010). For Instance (Scott, 1975) who carried his study in Canada define carrying capacity of land as a function of agricultural food production, land area devoted to food production. He too considers the surplus which is not consumed locally (within study area) but exported to area where there is demand. He finally estimates the population which is supported by agricultural product which are valued in monetary terms. From his study he estimated that 3.9 persons could be supported by food valued at $ 1,000 in the year 1971. His study can be summarised in the Eq. 2-1.

$$Carring\ capacity = f(AP, L, Cand\ s)$$

Eq. 2-1: Components of Land carrying capacity

Where AP is agricultural production, L is land devoted to production, C is consumption level and S is surplus which is exported. Here agricultural production is the source of livelihood.

The main source of livelihoods to Darfur rural settlers is agricultural production which is supported by land and climatic conditions. FAO (1990) also recognizes the interaction of the two subsystem, goods flowing from one to another as shown in Figure 2-3.

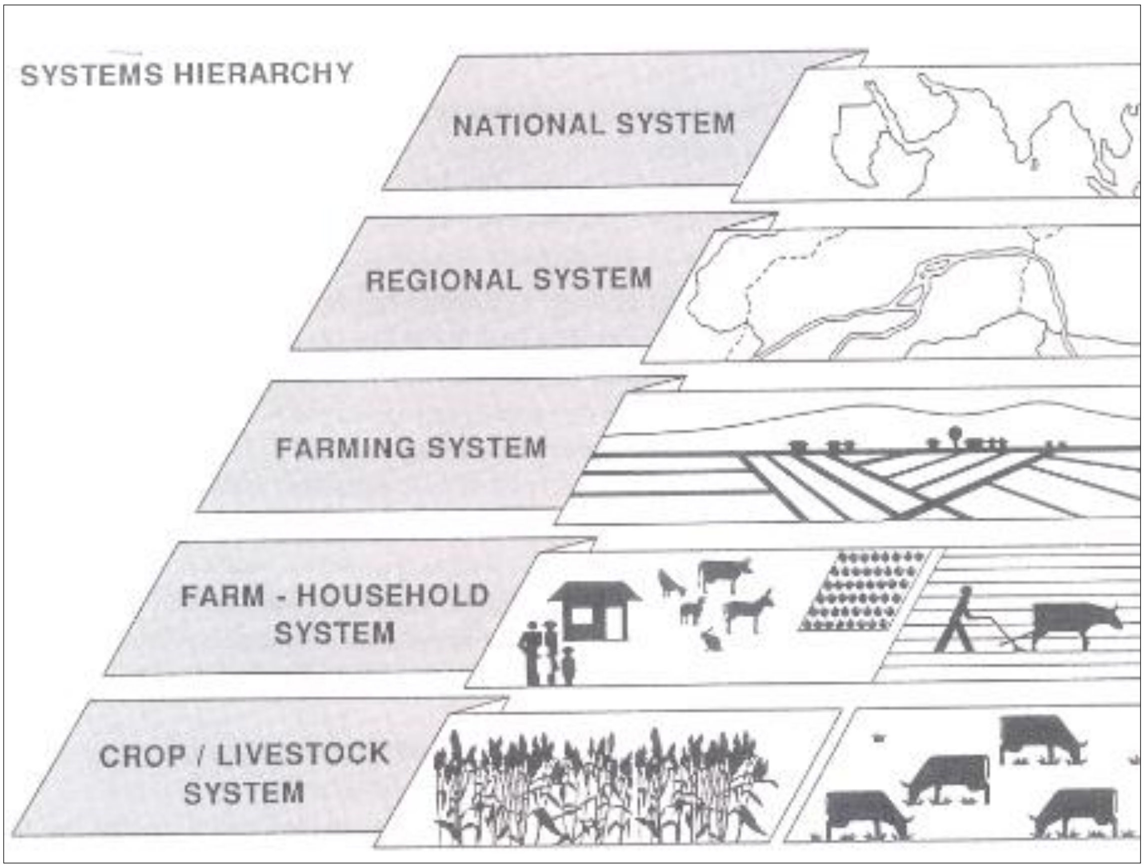


Figure 2-3: The system approach of agricultural production:
Source: FAO (1990)

The farm household system provide labour and at the end the production is used as food or taken to market incase of suplus to get what the household do not produce. This therefore leads us to the question, how is the production of each subfarming system estimated?

2.4.3. Estimating Carrying capacity of the Crop/Sedentary Farming Subsystem

Brush (1975) gives an insight into land carrying capacity from anthropologist point of view and defines it as man-land balance which is maintained by practicing food production. In his study he bases the concept on shifting cultivation which is common in semi arid zones but he further explains that the same principle can be applied in places where high end technology is being employed in agricultural production. The three determining factors in his study is available land, land requirement per capita, number of fallow years and number of productive years per capita and population as indicated in Eq. 2-2.

$$\text{Per Capita land requirement } = (100\text{CL})/\text{P}.$$

Eq. 2-2: per capita Land Requirement for Shifting Cultivation

Where C is Cultivation factor $= (\text{Cultivation period} + \text{fallow period})/(\text{cultivation period})$

L is average per capita land requirement

P is percentage of land which is available for cultivation in the study area

$$\text{Carrying capacity} = \text{X}/(\text{per capita land requirement})$$

Eq. 2-3: Land Carrying Capacity Assessment for Shifting Cultivation

Where X is Total land available for cultivation in the study area

Similarly Chen, Zhou, and Wang (2005) in the study to assess China land carrying capacity used the maximum potential grain production and per capita consumption levels to determine the optimum population which can be supported. Eq. 2-4 developed by him starts with calculating production based on available land. Here land encompasses natural resources such as soils and meteorological data available in the study area. The social economic data was used to gauge consumption levels.

$$Ygs = Yg \times Ag$$

Eq. 2-4: Potential Grain Production

Where Ygs is total potential grain production in study area, Yg is Potential grain production per unit area and Ag is Total area of the study area

To calculate the land carrying capacity as shown in Eq. 2-5 the potential production (Ygs) is divided by the per capita consumption levels (Lg) which gives the optimal population which can be supported by China grain production system.

$$Lc = Ygs/Lg$$

Eq. 2-5: Land Carrying Capacity Assessment

2.4.4. Estimating Carrying Capacity Livestock/Pastoral Farming Subsystem

Calculating carrying capacity of livestock system is complex especially for nomadic communities who are on move most of the time of the year searching for pasture and water. Komatsu et al. (2005) uses the amount of fodder required to sustain one livestock to estimate the production of livestock and population supported. Total value of the fodder grown per each hectare determines size of livestock and hence can be used to calculate population which can be sustained. This method proves difficult for pastoralists who are on move frequently and more so who are surviving in unpredictable area with pasture availability being dictated by climatic and dwindling soil fertility.

(FAO) proposes a common unit of measuring livestock products referred to tropical livestock unit (TLU). Using this principle 1 TLU is equivalent to 250 kilograms. All livestock which are below or above this value are standardized to provide one unit measure which is easy to use as illustrated in Table 2:1. See appendix A for the detailed (FAO, 2012b)conversion table where various livestock body weights are used to arrive at this standardized figures.

Livestock type	**TLU value**
Camel	1.00
Cattle	0.70
Donkey	0.70
Pig	0.20
Sheep	0.10
Goat	0.10
Chicken	0.01

Table 2:1: Standardized values for livestock valuation
Source: (FAO, 2007b, 2012b)

Some calculation can be based on this where livestock experts can expound on how many TLUs are required to sustain one person or household. Basing on this the carrying capacity of the system can be estimated. For example (Don et al., 2011) estimates that areas with Arid-Semiarid conditions in the River Nile basin which a total of TLU of 14.8 million which supports a population of 1.98milion this gives a indication that the per capita consumption is 7.79TLUs. The stocking capacity/density per km^2 is the 19.5TLUs which is close to 20TLUs proposed for North Sudan by Kessler (1994)in his study of semi-arid zones.

2.4.5. Estimating Carrying Capacity for South Darfur

One of the major challenges facing the current decision makers is the increasing population and diminishing non renewable resources. South Darfur has recorded a reduction in average annual rainfall and land degradation as discussed in chapter one. The population is increasing while the land which was once used by pastoralists is being infringed by sedentary farmers who need more land for food production. Some migratory routes which were being used by pastoralists seasonal while accessing water and pasture have been turned into farms which are now hot spots for human conflicts(Darfur Land Commission, 2009).

The major determinants of carrying capacity in this study which also determine the lifestyle of rural population has to be examined. The toughest task is then to balance the production (supply) and consumption (demand) of production. As observed by Scott (1975) in his study carried in Canada these two determinants that is climatic conditions and soils gives room for little improvement leading to competition between various land uses. On the other hand Kessler (1994) proposes the opening up of the system and use of non renewable resources such us chemical fertilizers to boost production which will also improve carrying capacity.

Marten and Sancholuz (1982) proposes a method of dealing with the dilemma of allocating competing land uses by the utilizing a land-use game. The land use game proposes optimum allocation of land. That is allocating every piece of land to crop which will provide maximum production. The objective of the game is to meet the planning objectives under various constraints on agricultural development. By the end more production will be achieved and hence absorbing more population. Eq. 2-6 which is adopted from Marten and Sancholuz (1982) gives an indication of how livelihood zones can be allocated to optimize production and hence boost the population to be settled. It has to be noted as started by Marten and Sancholuz (1982) that each livelihood zone is dependent on the other with decision variables being land type j and land use system i denoted as xij

$$y_k = \sum_{ij}\sum c_{ijk} x_{ij}$$

Eq. 2-6: Land Allocation and production

In Eq. 2-6 a above, C_{ij} is the contribution per square spatial unit to objective k (in this agricultural production needed to determine number settlers) when land type j is allocated to land use i.

While assessing human carrying capacity, various assumptions has to be made (Kessler, 1994). In this study the human carrying is based on agricultural production. The utilization of natural resources such land and rainfalls will determine which source of livelihood farmers choose. Komatsu et al. (2005) developed a method which can be used to link resources to human population

$$HCC = \frac{Si}{Di}$$

Eq. 2-7: Human carrying capacity calculation

In this Eq. 2-7 HCC is human carrying capacity, $\boldsymbol{S_i}$ is the supply of natural resources and $\boldsymbol{D_i}$ is the per capita demand of natural resources $_{\boldsymbol{i}}$**.**

2.5. Summary

Offering durable solutions to IDPs requires the policy makers to understand the system in which IDPs will be resettled or return to especially if they depend on land resources. Assessment of land carrying capacity is key component in this process as indicative figures for optimum population will be derived based on available resources and formulation of policies(Xiaolu et al., 2011). Various policy options can be adopted to boost land carrying capacity which includes introduction of non agriculture based source of livelihoods, population growth management strategies and use of high quality farming inputs(Bernard et al., 1989). The best way to do this is by linking available natural resources that is land and meteorology data to population, that is environmental factors (Lane, 2010). Sustainability is achieved when the population consumption is within what the natural system can provide(Fearnside, 1997). Balancing resource use can also lessen competition among users and hence reducing conflicts and resulting displacement.

3. METHODS FOR DATA COLLECTION AND ANALYSIS

Chapter three of this thesis highlights the data which was collected and analysed and is informed by literature review of chapter two. The collected data was affirmed on environmental assessment approach where land based resources are used as parameters for agricultural suitability. A brief overview of activities in the field are discussed and methods used in data analysis. The chapter is divided into two main sections. Section 3.1 presents data collection and analysis for historical trends of production and consumption patterns. Section 3.2 looks at a small model for assessing livelihood zones suitability and estimation of potential land carrying capacity.

3.1. South Darfur Historical Production and Consumption Patterns

Darfur South has witnessed changes in climatic conditions and land degradation which is linked to competition over resources between nomadic communities and sedentary farmers and subsequent displacements. There is also a shift in cultivation patterns which has an impact on production. Seferis (2010) notes that this is related to the new lifestyle adopted by IDPs to safeguard their land rights and also boost their source of income. On this effect she notes there are seasonal IDPs returnees who go back to their farms during cultivation period. They leave vulnerable members of the community that is women and children in the camps which are deemed to be safe and close to services such as schools and water. The household heads then settle in the farms during the entire growing season and after harvest they return to the camps. It’s a cycle which is repeated every season. The second pattern of returnees is referred to partial community returnees.

The main purpose of this section is then to look at the production trends versus consumption patterns, the analysis are meant to give indicative figures showing whether South Darfur population is within the carrying capacity level, lower or above as noted by (Kessler, 1994; Lein, 1993).

3.1.1. Data Collection in the Field

To understand the historical trends in production and consumption patterns, secondary data was collected from institutions dealing with agricultural production and analysed. Publications too were reviewed. The main source of secondary data was Ministry of Agriculture (MoA), FAO and IGAD. The census data was collected from CBS while per capita consumption was taken from FAO and Ministry of Agriculture (2010) report on the study of cereal availability.

The data collection and analysis is discussed in two sections which describes the two sources of livelihoods for South Darfur which is shaped by the lifestyle. The bigger portion of South Darfur population is involved on sedentary farming. As per the 2008 population census only 25 percent is involved in livestock production, the remaining 75 percent is involved in sedentary farming(Ali, Mohamed, Ibrahim, & Elamin, 2009).

3.1.1.1. Livestock Production System

The livestock production system is made up of nomadic communities which move from South to North in search of water and grazing fields. The grazing fields located in the North support livestock during rainy season, the Southern part is infested by tsetse flies during this period and therefore avoided. When rains have reduced in the in the Northern south Darfur livestock are moved down to the South where there is some water. The movement is along the *Khors* (seasonal river beds) and pass over some *Hafirs* (traditional small water reservoirs). Figure 3-1 illustrates areas Zoned by FAO and migratory routes followed by the Nomads.

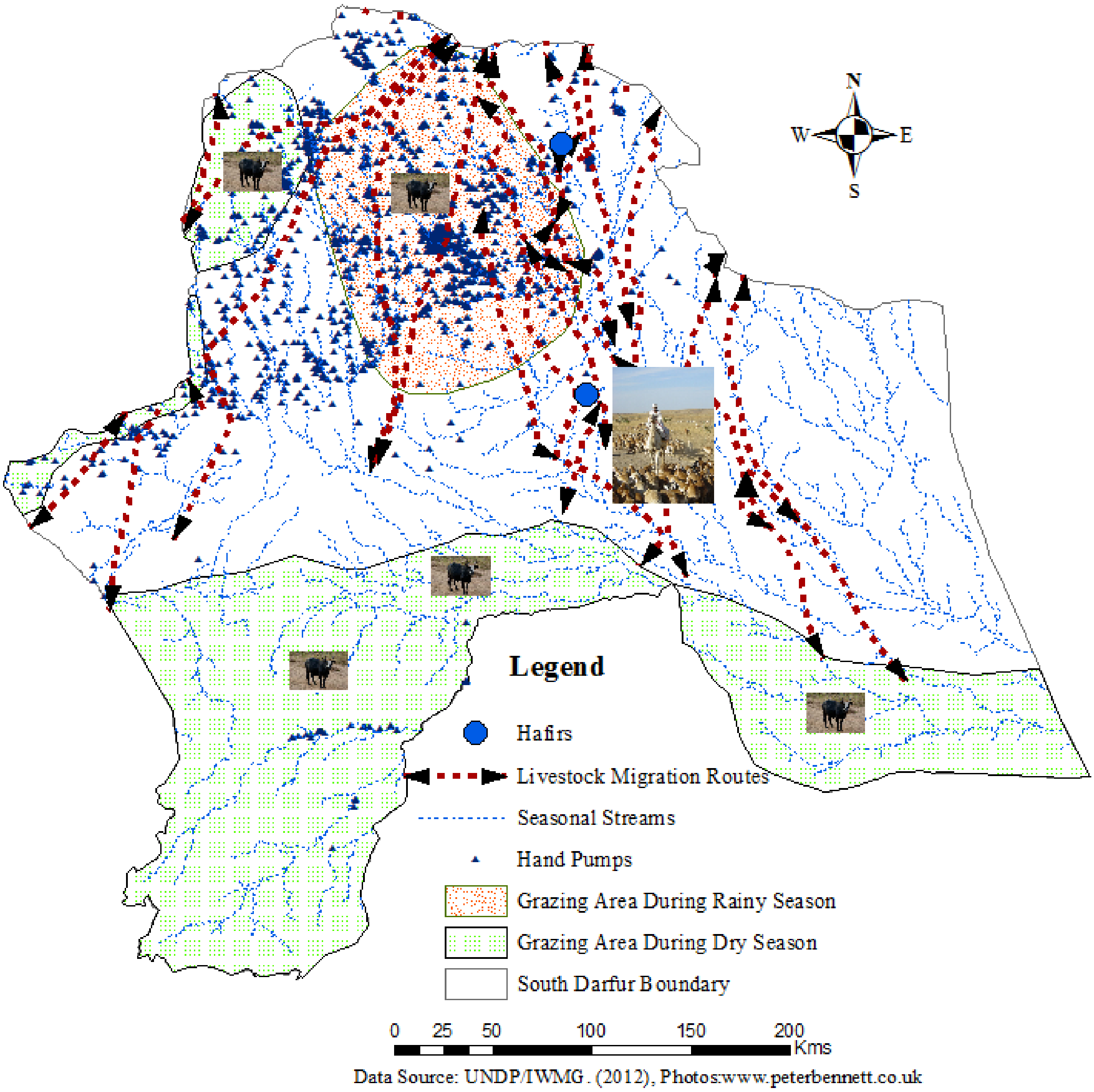


Figure 3-1: Map of South Darfur, Livestock Grazing Areas, Migratory Routes and Water Points

The collected data was in terms of animal heads which are stocked in South Darfur see Appendix B. The livestock which were considered in this study includes cattle, camels, sheep and goats. To standardize the measurement units of the livestock kept, the concept of Tropical Livestock Units (TLUs) were used. The concept of TLUs which was discussed in section 2.4.4 and illustrated in Table 2:1 provides a common unit to give value to different kinds of livestock reared(FAO, 2012b).

The main assumption made in this study is that the Nomads depend majorly on the livestock for their daily subsistence. The assumption is built on the study by Salih, Dietz, and Ahmed (2001) on the pastoral commercialization where they propose per capita consumption of 3 TLUs. In their study they conclude that the producers consume what they produce and can only part with surplus to acquire what is not produced.

For this study the population for the year 1998, 2008, 2011 was used to assess whether the available livestock products can support Nomadic residents. These three periods were chosen in order to understand the trends in production and also try to assess whether the production is sufficient enough to support the population during five years of pre and post 2003 conflicts. The year 2011 was used to gauge the current situation since data on production could be accessed. Population of South Darfur; the values for 1998 and 2011 were projected using geometric progression Eq. 3-1.

$$P_{t+n} = P_t(1+r)^n$$

Eq. 3-1: Formulae for Population Projection

Where P_{t+n} is the future population, P_t is the current population at base year, r annual population growth rate, and n is the period between base year and the year of the projected population.

3.1.1.2. Crop production System

South Darfur is among the agricultural rich States of Sudan. The main crops grown are millet, Sorghum Figure 3-2, Kerkrade, Arabic Gum, Groundnuts, Sesame and some vegetables at small scale mainly along the seasonal river basins where traditional irrigation is practiced. To get an insight into the crop production system, production and consumption data was collected. The crops which are grown were listed by planners which were mainly drawn from the wider Darfur Region and engaged in a focus group discussion.

Figure 3-2: Main crops grown in Darfur South and Livestock
Photo Source: (FAO, 2007a; ICRISAT, 2012)

The consumption levels were derived from the FAO and Ministry of Agriculture (2010) report where the two main cereals that is sorghum and millet is used to gauge the population which can be supported by the crop production system. The annual per capita consumption requirement is 146kgs with detailed values shown in where sorghum forms the bigger part of food stuff taken. It is was assumed that other oil crops such us ground nuts and sesame are sold by the sedentary farmers to get rice, wheat and maize which are not produced at higher scale in the study area.

To assess the impact of internal displacement on crop production, the production period of 2006 to 2010 was assessed. The main source of the secondary data used (FAO & Ministry of Agriculture, 2010; FAO & Ministry of Agriculture and Irrigation, 2012). The change of land under cultivation and the one harvested was analysed. The percentage change was calculated by subtracting the land which was cultivated from the one which was harvested.

3.2. Development and Application of Land Carrying Capacity Assessment Model in South Darfur

South Darfur has witnessed displacements which are associated to conflicts over resource use between sedentary farmers who mainly produce crops and Nomadic communities who rare livestock. Part of population which is currently settled in IDPs camps still has hopes of returning to their farms and continues with their agricultural activities(ITC, 2012). The population which is willing to go back to farms is not well documented but discussion with UN-Habitat staff revealed that approximately 25 percent of the IDPs will be happy to return to farms. The key challenge has then been how to assess the suitable areas for farming activities and the potential of these areas to accommodate more population sustainably. In this effect a model for assessing agricultural land carrying capacity was developed and tested in South Darfur which can be used in decision making.

3.2.1. Methodological Approach to Agricultural Land Carrying Capacity Assessment

In this study, the assessment was affirmed on environmental approach listed by Lane (2010) and discussed in section 2.4.2 where available land resources and precipitation data were converted to consumable agricultural products. The environmental carrying capacity gives indicative figure of population and the level of activities that can be allowed in a certain region without negative effects but at acceptable quality of life(Lein, 1993). The production together with consumption level was then used to determine the population which can be supported. The approach is related to the one used by Zhou, Wang, and Wang (2009) to determine the ecological sustainability of Guangzhou basing on human demand of various land uses. Bernard et al. (1989) has also been a proponent of environmental approach, in their study they assessed land carrying capacity by dividing suitable area for cultivation by the household land size requirement. The output was multiplied by average household size to get the potential population that could be supported in Eastern Ecological Zones of Kenya.

Agricultural land carrying capacity is based on the suitability zoning here referred to livelihood zoning. The areas were zoned basing on the main crops grown, that is sorghum, millet and livestock to cater for the pastoral community. The model utilizes physical data that is soils, and rainfall data. The consumption levels which can also be denoted as demand is derived from the per capita consumption characteristics.

The production of suitability maps are based to the process of by allocating land to the most suitable use which provide the optimum agricultural production using the agricultural expert knowledge. The model borrows a lot from Marten and Sancholuz (1982) in step A and Komatsu et al. (2005) in step B. The model is visualized in Figure 3-3.

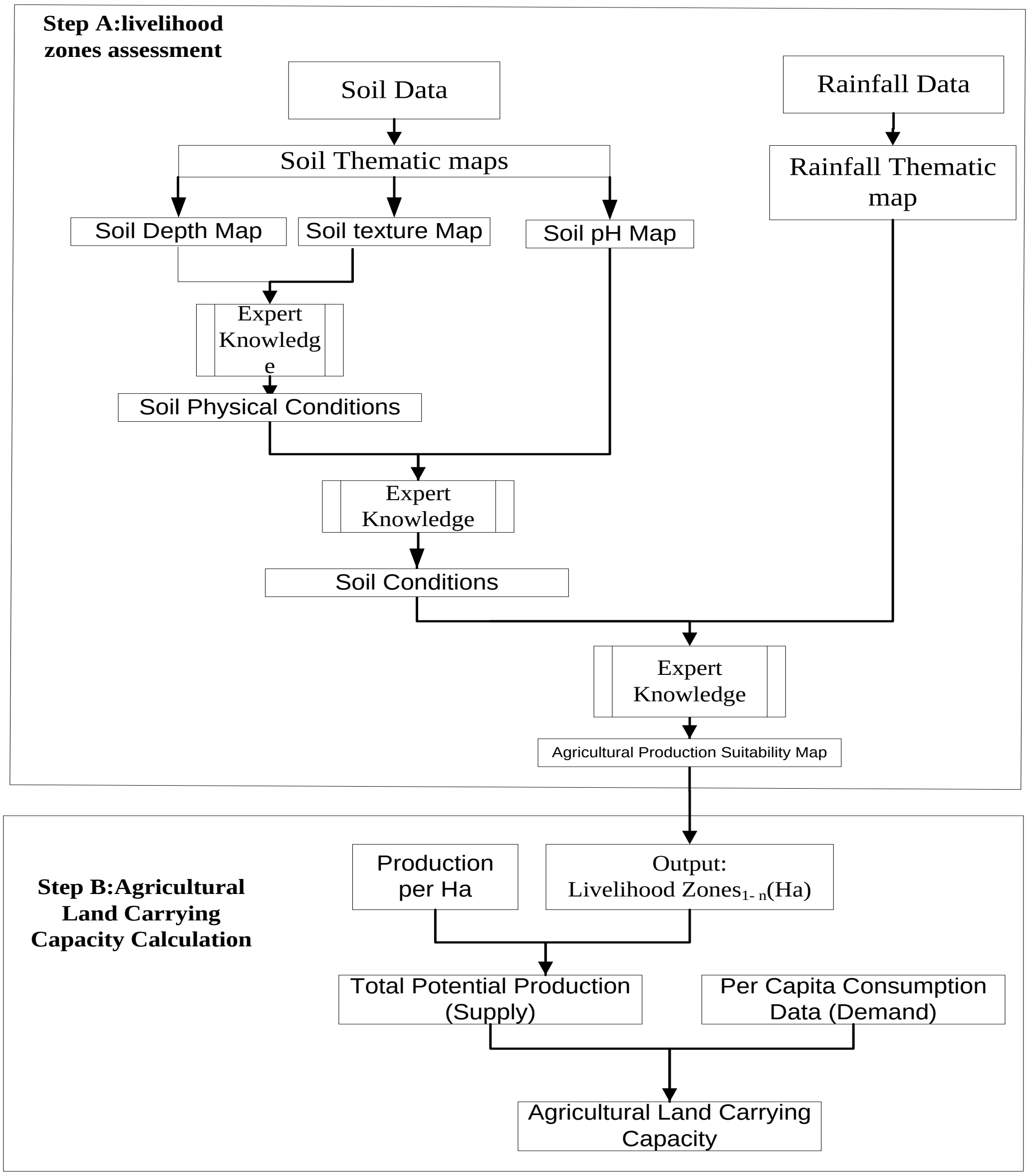


Figure 3-3: Schematic presentation of livelihood zoning and carrying capacity calculation

The first step (A) involves suitability assessment and allocation of land for various crops depending on conditions needed for their survival and determining the maximum production for the crop allocated.

The mathematical model to summarize this procedure is adapted from Marten and Sancholuz (1982) which is indicated in Eq. 3-2.

$$Net\ production\ for\ the\ entire\ agricultural\ system (AP) = \sum_{ax} \sum (P) k_{\mathrm{ax}} D_{\mathrm{ax}}$$

Eq. 3-2: For calculating the Darfur agricultural system Net Production

Where D_{ax} is the number of Ha x allocated to livelihood zone a,(P)k_{ax} is the Production per x Ha for every livelihood zone a.

The production of each livelihood zone was summed up to provide what entire agricultural system produce. The value from were entered in Eq. 3-3 below to get the optimum population which can be supported that is agricultural carrying capacity.

$$ALCC = \frac{AP}{U}$$

Eq. 3-3; for calculating the Darfur agricultural land Carrying capacity

Where $ALCC$ is the Agricultural Land carrying Capacity, AP is the Agricultural Production, U is the per capita consumption.

The assessment was done per individual livelihood zones. Three zones assessed included millet, sorghum and livestock and are discussed in the following subsections.

3.2.2. Assumptions Data Requirement, Collection and Analysis Methods

Land carrying capacity is not a fixed figure and can vary depending on the assumptions made. Any assessment should therefore be accompanied with clear assumptions (Kessler, 1994). The required data was collected from existing and primary sources. The data requirement needs were outlined after reviewing existing literature on land carrying capacity and sustainability. In this study assumptions made included:

i. All agricultural production is rain fed, with no intensive mechanization
ii. The main determinants of agricultural production are land based with rainfall playing a major role.
iii. Suitability of agricultural land used for crop and livestock production is constrained by existing built up areas, water bodies and forested areas.
iv. South Darfur population has adopted two lifestyle that is sedentary farming and Nomadic activities for livestock rearing. The population wholly depend on what they produce, and at times take to the market the surplus to cater for other needs.

It has to be noted that the potential population supported is wholly dependent on the production of the system. The production itself is not static but can change with intervention of human efforts in technology (Lein, 1993). This implies that land carrying capacity for region can vary depending on the assumptions made.

Data collection for agricultural land carrying capacity assessment has been a major challenge because several assumptions have to be made. As highlighted in section 3.2.2 carrying capacity which is the potential population to be supported by a system is not a fixed figure hence calling for precautionary measures. The use of expert knowledge is fundamental as the researchers will get a good insight of the system they are modelling (Lein, 1993). Both secondary data relating to agricultural production was collection. The main source of primary data was key informant interviews and a focus group discussion which made known constraints for agricultural land suitability and factors contributing to suitability.

The main source of secondary spatial data was the United Nations data bank. The data provided in shape files and raster data sets was soils compositions and meteorology data. The land cover map and migratory routes data was also provided. The existing gaps in soils data was filled by secondary information mainly from (FAO, 2006a, 2006b; I. FAO, ISRIC,ISSCA,JRC,, 2008; ISRIC, 2012). The filled gaps related to soils texture which was reduced to three main cases that is sand, clay and loam soils.

Sudan Central bureau of statistics (CBS) website was accessed to get data on population, economic activities and production levels. Documented reports by CBS, IFAD, books and academic papers were also used to get secondary data. Table 3:1 gives a summary of data collected and their source.

Data Collected		**Collection method**	**Source**
Spatial Factors determining livelihood zones	Soil data (type, slope, soil depth ph value).	Secondary data	UNDP data bank
	Meteorological data (rainfall).	Secondary data	UNDP data bank
	Environment(Land cover map)		UNDP data bank
Socio-economic	Household consumption levels	Secondary data	availed by UN-Habitat(CBS publication)
	1998, 2008 and 2011 population data	Secondary	CBS publication
	2011 production	Secondary	data availed by UN habitat
	Strategies to cope with shortages or deal with access	From secondary	IFAD
	Crops grown per zone	Secondary and primary	IFAD, key informant and focus group discussion
	Maximum production per Ha	Secondary and primary	CBS, Key information

Table 3:1: Data collected in the field

A report by IFAD was also analysed and some data retrieved on production levels which were based on field experiments at research stations. From this field stations it was found that there three levels of production per Ha, which provided a room for modelling carrying capacity in three scenarios.

The focus group discussion was organized between the land use planers. The discussion was meant to give an insight into the factors and constrains which are considered in the land use planning. The discussion was also focussed on the existing settlement programmes, where they are located and the population in each IDP camp within the study area. It was clear that South Darfur has the highest number of IDPs camps hence intervention was required. There were also a number of migratory routes which should be classified as livestock livelihood zones and sedentary farming should be minimised on them.

To get expert knowledge on production levels and crops grown two key informant interviews were carried out. One meeting was with a university lecturer, the main purpose of the interview was to identify the main agricultural products. Since the interviewee had first hand information they also listed the type of crops grown, their growth requirements and production levels. The key information also validated the land carrying capacity assessment which I had developed basing on the secondary data. From the interview, the key parameters which determine agricultural production were chosen which included rainfall, and soil characteristics that is pH values, topsoil depth, and soil texture.

The livelihood zoning is based on agricultural production suitability maps. The suitability maps are based on environmental parameters a method mentioned by Lane (2010). The collected data is discussed in below subsections. Qrisp a tool for landscape/ecological analysis was used to process the data. Qrip allow the entry of ESRIGRIDs and Knowledge tables.

The parameters used to assess livelihood zones in this study include Soil texture, slope, soil chemical composition expressed in acidity and alkalinity, soil depth and average annual rainfall. These data was acquired in shape files from UNDP data base and then converted into raster format and stored as ESRIGRID. As noted by Breman and De Ridder, (1991) and quoted by Kessler (1994) these parameter are highly variable in terms of spatial and temporal scale. To reduce the effect of the variations, uniform Analysis Zones (UAZs) of 1 hectare that is cell value of 100m by 100m were used. This was done in order to aggregate areas of homogenous characteristics together. The spatial data was classified into manageable classes. For instance the spatial data on rainfall was classified into five classes with the first class having range values of 234mm-254mm and the fifth class having range values of 1001mm-1110mm. The same procedure was done for soil texture; soil pH values and Top soil depth Figure 3-4.

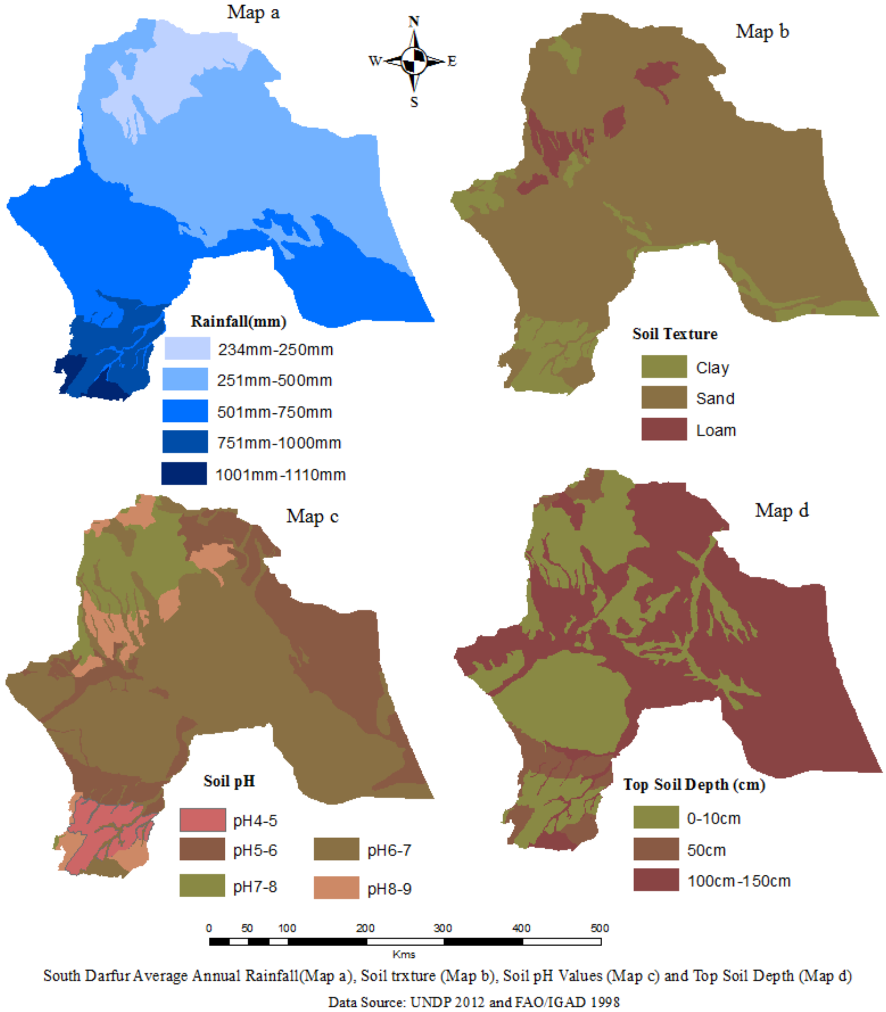


Figure 3-4: South Darfur Soil texture, Slope, Soil Composition, soil depth and Rainfall

Both the ESRIGRIDs for the parameters and their classes were stored in a data base/project library together with expected cases for the final results. Stored in Library were also expected output maps, for instance in the millet folder, parameters are rainfall, soil depth, soil pH and Soil texture. The expected outputs are Soils Physical conditions, Soils Conditions, Millet Zones and millet livelihood Zones Figure 3-5.

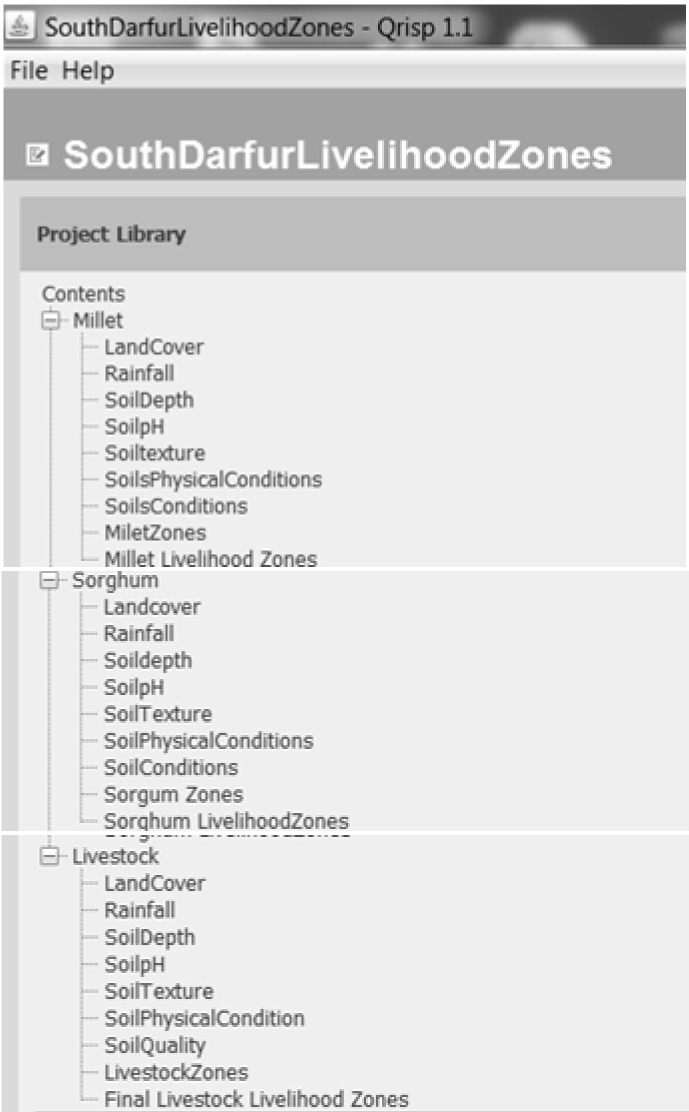


Figure 3-5: Data used for the analysis as stored in the project library database

Every ESRIGrid has also classification which is stored separately. The stored classififfications also have class values Figure 3-6 and Figure 3-7

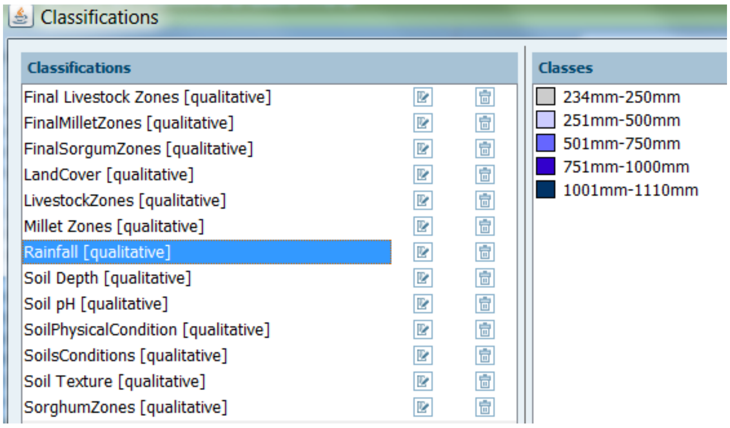


Figure 3-6: Project Classifications

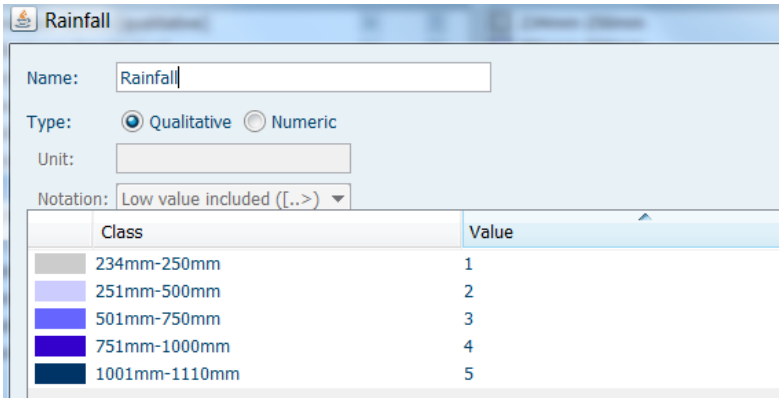


Figure 3-7: Spatial Parameter Colour, Class and Value

The spatial parameters which were to determine livelihoods zones had to be chosen and grouped together with good judgement as specified by (FAO, 1990) principle of overlying various maps to get homogenous zones.

To meet these objectives the ESRIGRIDs discussed in section 3.2.4.2 were grouped using the local expert knowledge and some literature review. The information collected from the local expert through the interview was mainly non spatial and had to be converted into spatial form using QRISP an improved version of OSIRIS software developed by Altera Project of Wageningen University. The first step was to classify the spatial data into groups. The classes of two parameters are combined to provide intermediary map.

The classes of the spatial thematic maps are entered in a table, one on X axis and the other on the Y axis. The outcome of combining these thematic maps is entered in the table cell. The process is run until all the indicators have been grouped and the final map produced see Figure 3-8 for the schematic presentation of this process adopted from M van Eupen, T. Sedze Puchol, S. D. Sharma, and Vijayanand (2007).

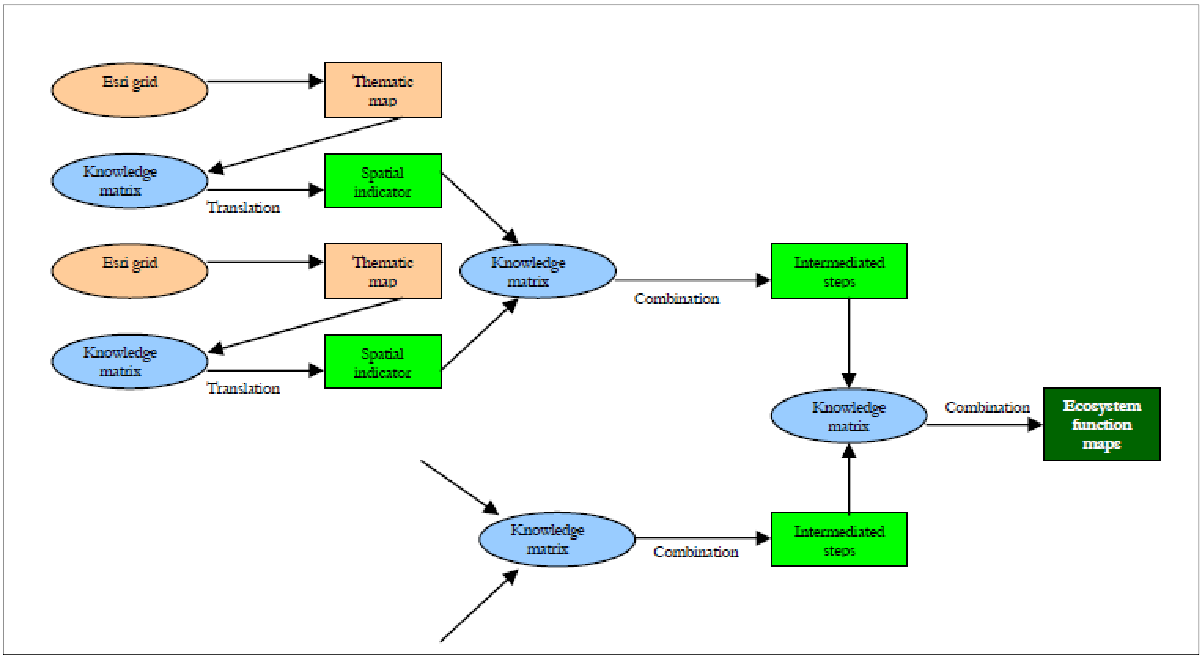
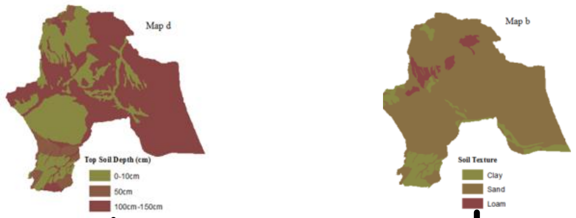


Figure 3-8: Process used to convert non spatial indicators into spatial indicators.
Sources: M van Eupen et al. (2007)

For the South Darfur study, the four parameters which are determinants of agricultural land suitability are used as thematic maps. The thematic maps forms the basis on which various cells are aggregated and allocated. Figure 3-9 shows an example of how the Knowledge table was used to convert the non spatial data using expert knowledge into spatial indicators. In this process, the soil texture and topsoil are used to make an intermediary map of soil physical conditions. The classes for soil texture are on the Y axis while the one for soil depth are on the X axis; the two classes were combined to give new classes in each cell. The values on X and Y are decision variables upon which experts combine to get intermediary result Figure 3-10.



Soiltexture \ Soildepth : SoilPhysicalConditions

	0 - 10cm	50cm	100cm-150cm
Sand	Low Quality	Good Quality	Good Quality
Clay	Low Quality	Moderate Quality	Moderate Quality
Loam	Low Quality	Good Quality	Good Quality

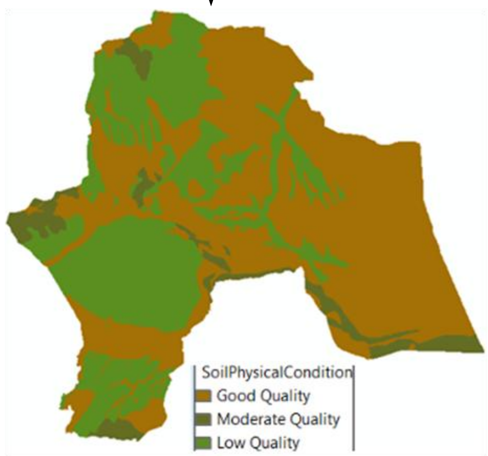


Figure 3-9: Conversion of Non Spatial Data to Spatial Data Using Knowledge Table (KT)

3.2.2.1. Millet production Carrying Capacity Assessment sub model

The purpose of the assessment was to examine whether the current production is below, within or above the current level. This was achieved by setting criteria for suitability assessment, whose results was used to calculate the total area available for millet farming. The first step indicated in Figure 3-3 was operationalized using Qrisp Software. Various thematic maps were aggregated using Knowledge tables (KT) to get intermediary maps. As shown in Figure 3-11, the first aggregation, the classes of every thematic map represents decision parameters which have to be combined with a second map to for new thematic map referred to intermediary maps as illustration in Figure 3-10.

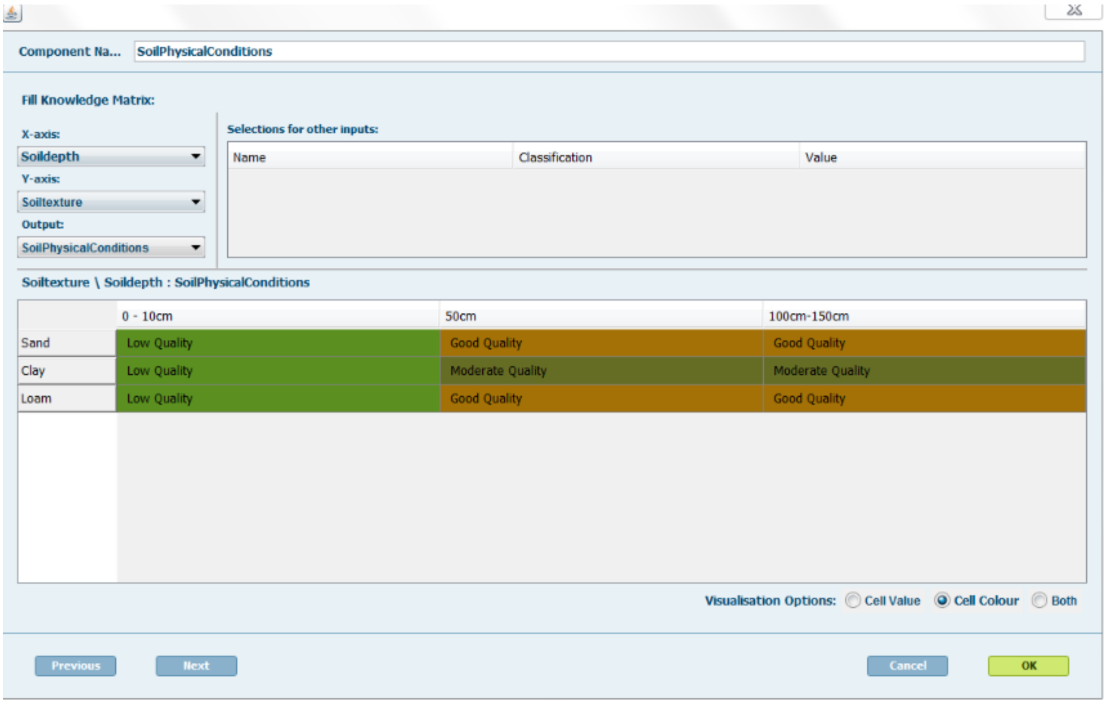


Figure 3-10: Knowledge Table for Combining Soil Texture and Soil Depth

In this process some good judgement has to be made on what will be the output of combining two cells from two different thematic maps. For illustration in Figure 3-10 combining 100m by 100m cell of sand soil and another one of 0-10cm topsoil depth, the outcome is low quality physical condition an outcome of Knowledge Table 1. The process is repeated until all tables 1 to 4 are filled and intermediate maps calculated.

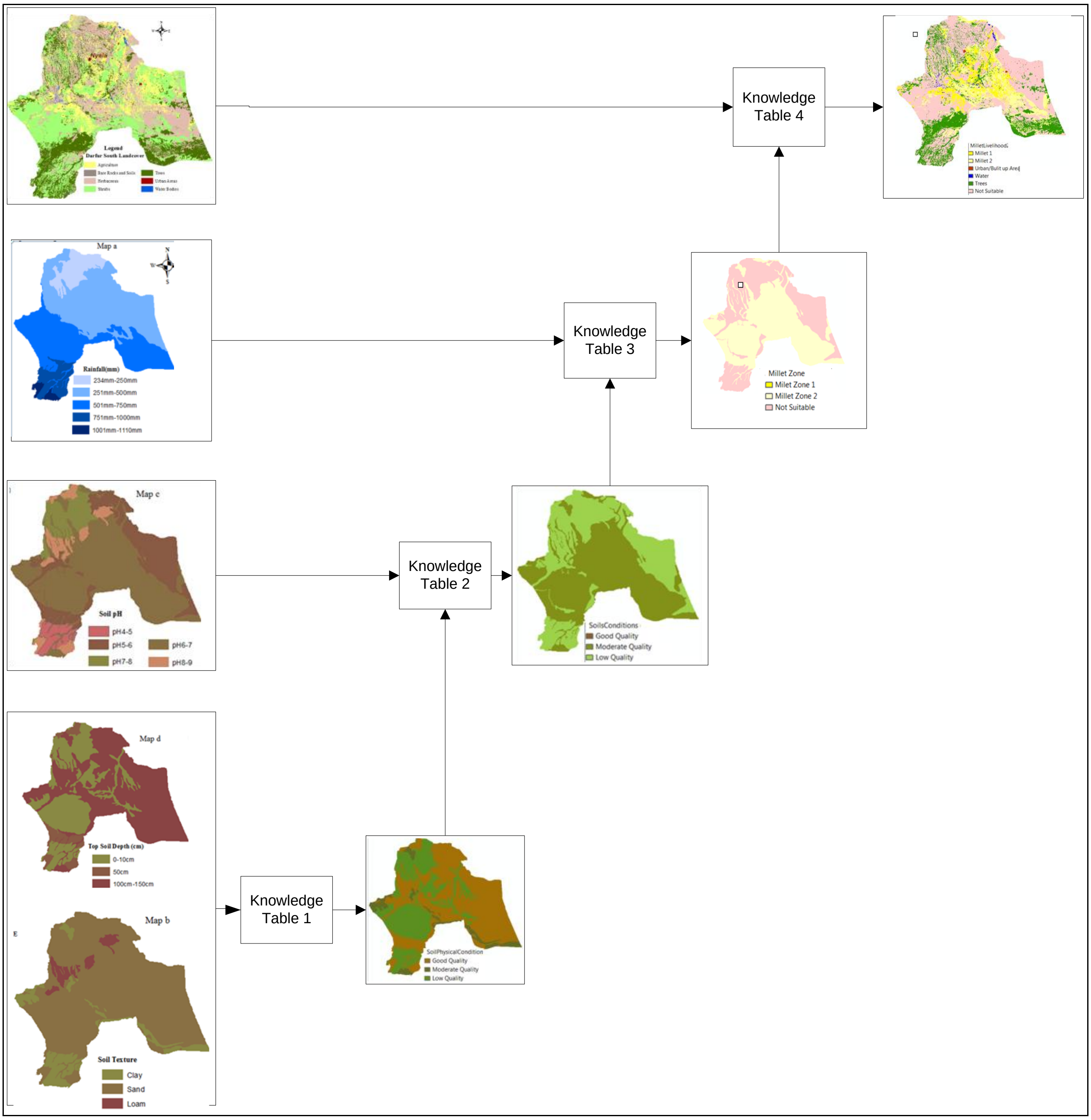


Figure 3-11: Suitability Assessment for Millet Production Zone

3.2.2.2. Sorghum and Livestock Production Carrying Capacity Assessment sub models

The process in section 3.2.5.1 was repeated, for sorghum farming and livestock sub systems. The procedures are illustrated in Figure 3-12 and Figure 3-13 respectively.

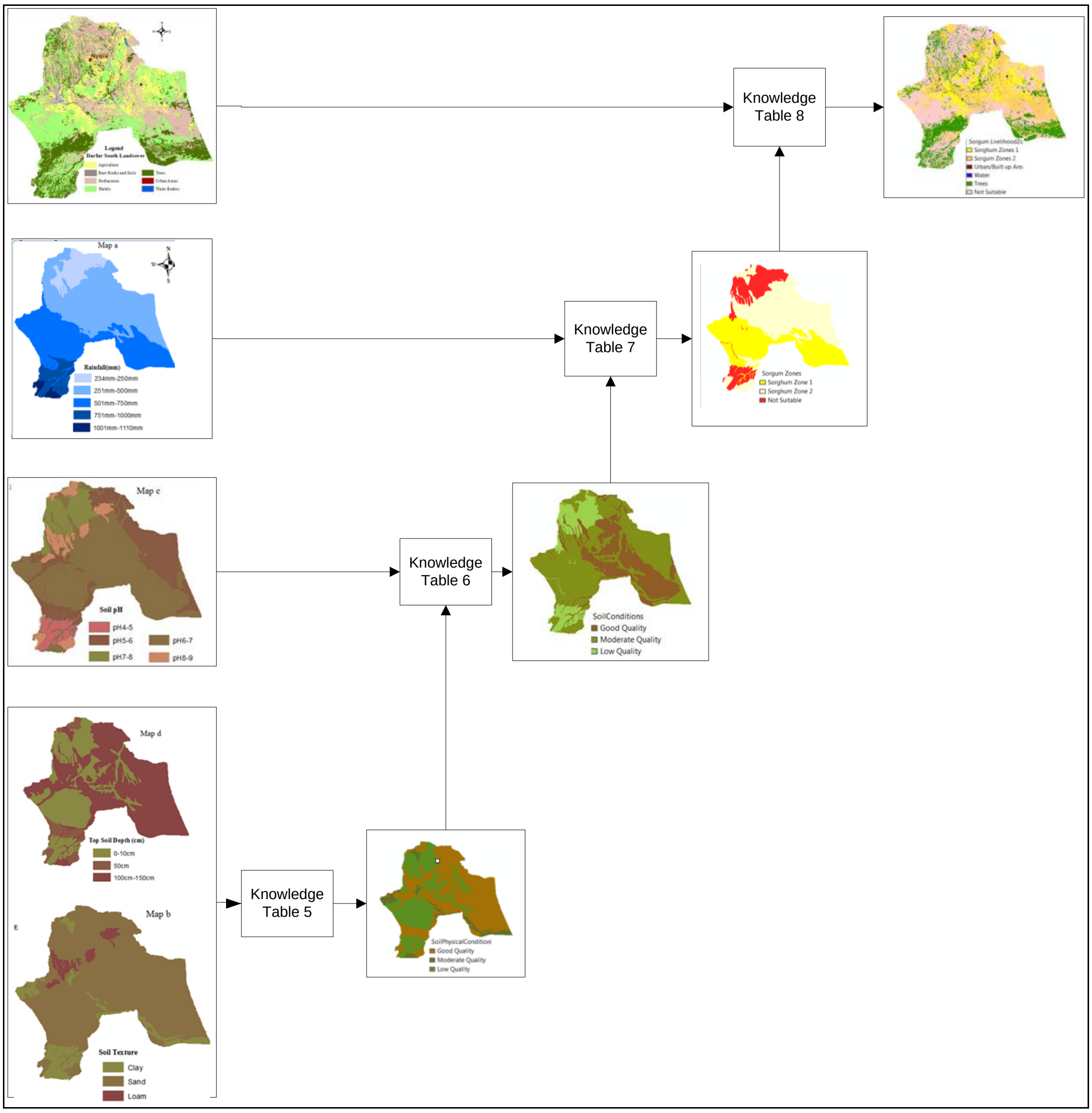


Figure 3-12: Suitability Assessment for Sorghum Production Zone

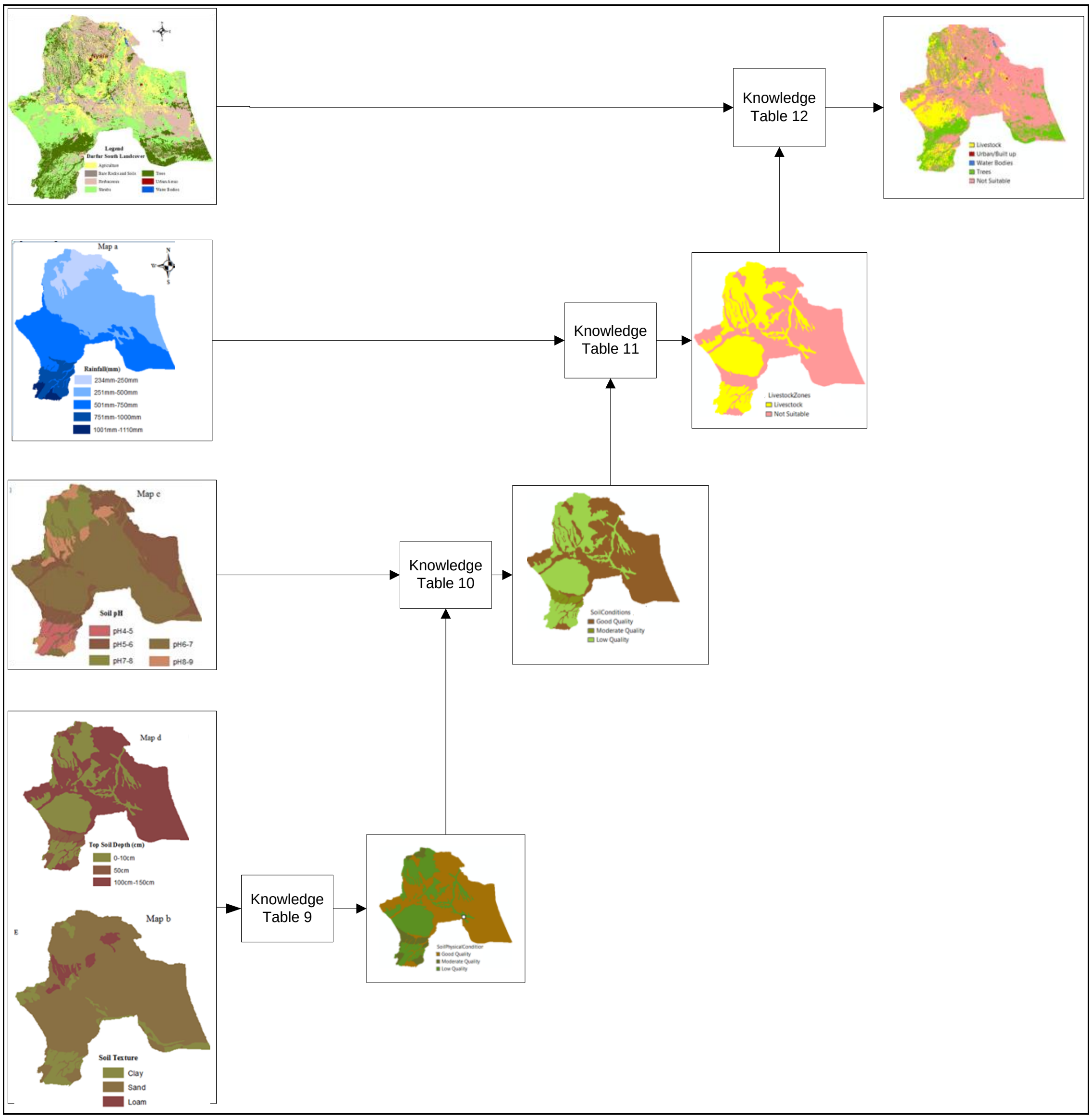


Figure 3-13: Suitability Assessment for Livestock Production Zone

3.2.2.3. Agricultural carrying Capacity Assessment

Step B in Figure 3-3 involves calculating production for each area allocated per sub system, and linking it to consumption to assess population which can be supported. The suitability maps for Millet, Sorghum and Livestock livelihood Zones were joined together in ArcMap to indicate spatial location for each zone. During the Suitability analysis the millet and sorghum were classified into two categories each. The first category met the all criteria set, while the second category met least conditions. After joining the suitability maps, where two zones were overlapping the one meeting all criteria was chosen.

The area under each zone was multiplied by production per Ha, to cater for other crops it was assumed that each household has an average of 12 Feddans, of which 7 are under cereal production while 5 are under other crops such us sesame, and ground nuts. This then gives a factor of 7/12 which was multiplied by all land under each zone to get area under millet and sorghum.

4. RESULTS

The chapter present the output of the analysis made on data collected using various methods discussed in chapter three. First section that is 4.1 examines historical pattern of agricultural activities and production levels it is linked to section 4.2 which analyses surplus or deficit in production. Section 4.3 looks at various options available for bridging the gap between production and consumption levels. Section 4.4 and 4.5 presents modelled results on land carrying capacity; it starts by identifying factors determining production. Section 4.6 identifies factors influencing the gap between actual and potential production. Finally section 4.7 carrying capacity and possible areas of return and or Resettlement. It has to be noted, Land carrying capacity is not a fixed value but vary depending on the assumptions and conditions set in the assessment process.

4.1. South Darfur Agro Economic/Livelihood Activities and production for the year 1998, 2008 and 2011

This section gives a discussion on main agricultural products and their production levels for the years 1998, 2008 which are five years before and after conflicts and 2011 which is used as a reference point. For the year 2011 agricultural activities covered a total of 2.12×10^6 Hectares as per FAO (2012a); Nomads grazed their livestock on the expansive shrub and Herbaceous areas covering a total of 8 million Hectares. The remaining land is under built up areas, water bodies and scattered trees. The state has two distinct farming sub systems; the first one is made up livestock farmers normally known us nomads, since they migrate with their livestock in search of pasture and water. The second is the sedentary farming subsystem which is made up of settled farmers who produce crops for their own consumption and sell the surplus.

For the livestock subsystem, the main domestic animals reared include cattle, camel, sheep and goat. Both the two crops and livestock production has been on the increase since 1998. Five year years prior to conflicts and displacements, the production for millet and millet was 104, 480 and 141, 810 Tons but has increased to 237,000 and 384,000 as at 2011 respectively. This shows that despite the fact that a big portion of populations is housed in camps the production is still increasing. For the livestock sector, the volume of production rose from 782,458 tons to 993,890 in the same period Table 4:1.

	South Darfur Agricultural Production					
	1998		2008		2011	
Product Name	Weight in Tons	TLUs	Weight in Tons	TLUs	Weight in Tons	TLUs
Millet	104,922	N/A	126,000	N/A	237,000	N/A
Sorghum	141,810	N/A	159,000	N/A	384,000	N/A
Livestock	782,458	3,129,832	922,928	3,691,711	993,890	3,975,560

Table 4:1: South Darfur Agricultural Production for the year 1998. 20008 and 2011

The main crops considered in this study are millet and sorghum Figure 3-2 which are the main source of livelihood and staple food of South Darfur people. Results of this study shows sorghum contributes up to 50 percent of the per capita cereal consumption while millet contributes 10 percent. Other crops such as sesame, groundnuts which are grown and sold as cash crops are assumed to cover up for the crops which are not grown in the area such as wheat which are also consumed.

4.2. South Darfur Population for the Year 1998, 2008 and 2011 and Agricultural products consumption requirement

The study results reveal South Darfur Population has been growing rapidly. The 1998 population had few pastoralists as compared to the years 2008 and 2011 Figure 4-1. This is because very few pastoralists were enumerated in 1993 Population Census upon which the geometric projection for 1998 population was calculated (Ali et al., 2009). For the 1998 pastoralists community only accounted for 0.45 percent of the total population and improved to 24 percent for the year 2008 and 2011. In this study it is assumed that the Nomadic community also referred to pastoralists will wholly depend on livestock products to earn their livelihoods. The sedentary farmers will depend on produced crops to support their livelihood and sell the surplus to the market to get what they do not produce.

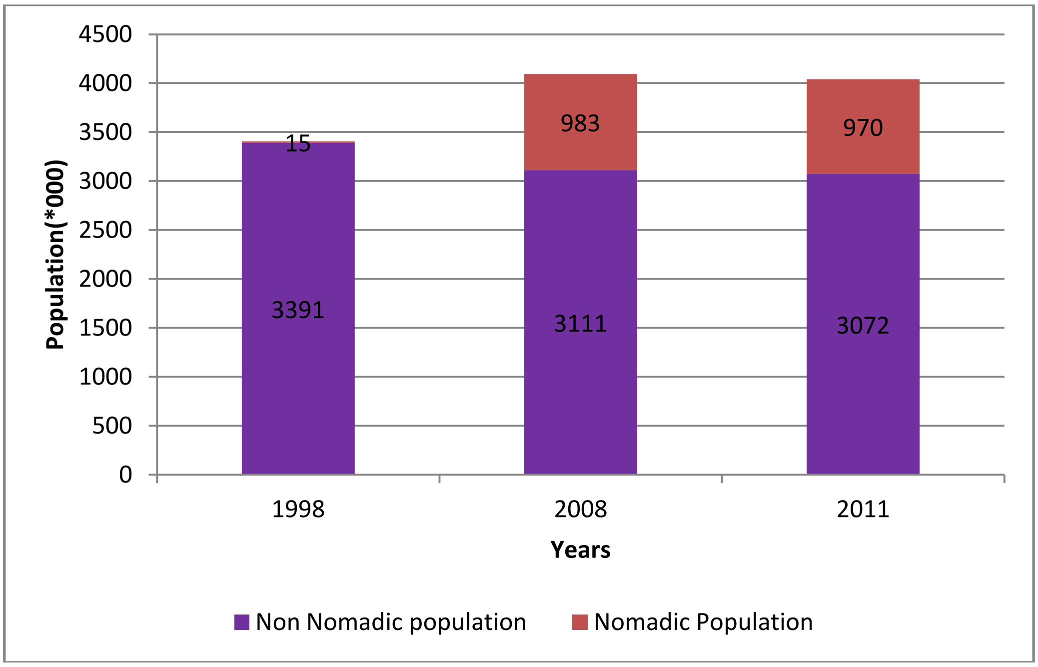


Figure 4-1: South Darfur Population for the year 1998, 2008 and 2011

4.2.1. Consumption Requirement for the Livestock Subsystem

To examine the consumption requirement for livestock product, the Tropical Livestock Units (TLUs) which is the standardized method for valuing livestock as discussed in section 3.1.1.1 was used. The annual per capita consumption proposed by Salih et al. (2001) of 3TLUs was used. By calculating consumption requirement for the Nomadic families, both the 1998, 2008 and 2011 production was sufficiently fed with surplus being recorded Table 4:2. The production has been increasing the same to the extra population to be supported.

Livestock Sub System Production, Consumption, and population Supported			
year	Actual Production (TLUs)	required consumption (TLUs)	Surplus (TLUs)
1998	3,129,832	281,685	2,848,147
2008	3,691,711	332,253	3,580,960
2011	3,975,560	357,801	3,856,292
Note: 1 camel = 1 TLU, 1 cattle =0.7 TLU, 1 sheep=0.01 TLU, 1 goat = 0.01 TLU and 1 TLU=250kgs of live animal (FAO 2012 and Jahnke, H. E. 1982)			
Production Data Source: FAOstat 2012			

Table 4:2: Livestock Sub System Production, Consumption, and population Supported

Basing on the livestock production and assuming that the consumption patterns are maintained, more population can be supported by the current production.

4.2.2. Consumption Requirement for the Millet and Sorghum Subsystem

Sorghum forms the bigger percentage of per capita cereal consumption at 50 percent. For the year 1998 and 2008 the production was below the required consumption. Here the per capita annual consumption is 73 kilograms. Production has improved for the year 2011 with a surplus of 159,750 Tons of Sorghum being recorded Table 4:3.

South Darfur Sorghum Production and Consumption			
Year	Actual Sorghum (Tons)	Required Consumption(Tons)	Deficit/ Surplus(Tons)
1998	141,810	247,519	-105,709
2008	159,000	227,135	-68,135
2011	384,000	224,250	159,750
Actual Production data source FAO 2010, 2012			

Table 4:3: Sorghum Production and Consumption in South Darfur

Millet which is a second staple food in South Darfur has been produced in access for 1998, 2008, and 2011. The consumption rate is 15kilograms person annually (FAO & Ministry of Agriculture, 2010) explaining the reason why the is plenty of it for circulation to other regions. The year 2011 year recorded the highest surplus of 190, 921 Tons. The per capita consumption in 2008 dropped by 8.2 percent as compared to the year 1998 Table 4:4.

South Darfur Millet Production and Consumption			
Year	Actual Millet (Tons)	Required Consumption(Tons)	Surplus(Tons)
1998	104922	50,860	54,062
2008	126000	46,672	79,328
2011	237,000	46,079	190,921
Production data source FAO 2010, 2012			

Table 4:4: Millet Production and Consumption in South Darfur

4.3. South Darfur Agricultural Products Consumption Gap, Imports And Exports

It can be noted that the livestock subsystem has plenty of surplus. During pre and post conflict production is above the required consumption. The livestock products are also brought to the market. IDPs camps too attract sellers of livestock products Figure 5-5. Meat and milk are the major products sold in the Camps and to sedentary farmers who do not produce livestock products. It has to be noted that Nomads only sell their products after satisfying their own needs.

The assessment in section 4.2.2 indicates a shortage of sorghum and surplus of millet. South Darfur Contributes 34.5 percent of the total millet production in Sudan (FAO & Ministry of Agriculture, 2010) giving a clear indication that most of the millet produced in exported to other regions. All millet produced is not consumed by the Darfur population but some is sold in the neighbouring new State of South Sudan and other parts of Sudan.

4.4. Factors Determining Agricultural Land Suitablity in South Darfur

Several factors affect agricultural production, they include natural resources, policies, and inputs used to boast production. For the South Darfur Study, Natural factors are given more weights, the Soils condition which includes topsoil depth, soil acidity and alkalinity are considered. Other consideration includes soil texture and the rainfall. To boast production farm inputs are also given priority in this study, with the output from IFAD research stations.

Crop	Factors affecting agricultural production/Criterion			
	pH	Average Annual Rain(mm)	Texture	Depth(cm)
millet optimum Conditions	6-6.5	500-750	Loam	50-150
millet minimum Conditions	7.0-8.0	251-500, 750-1000	sand, loam, clay	20-50
Sorghum optimum Conditions	6.0-7.0	500-1000	sand, loam	50-150
sorghum Minimum Conditions	5.0-6.0, 7.0-9.0	251-500, 1000-1110	sand, loam, clay	50-150

Table 4:5: Factors Affecting Agricultural Production

The above factors form the decision variables Table 4:5 upon the suitability map for each crop was made. The conditions form the criteria upon when met optimum production will be achieved. Te existing land cover map was used to derive constraints to agricultural land suitability which included urban/built up areas, water bodies, bare rocks and soils which are easily open to soil erosion and areas planted with trees Figure 4-2.

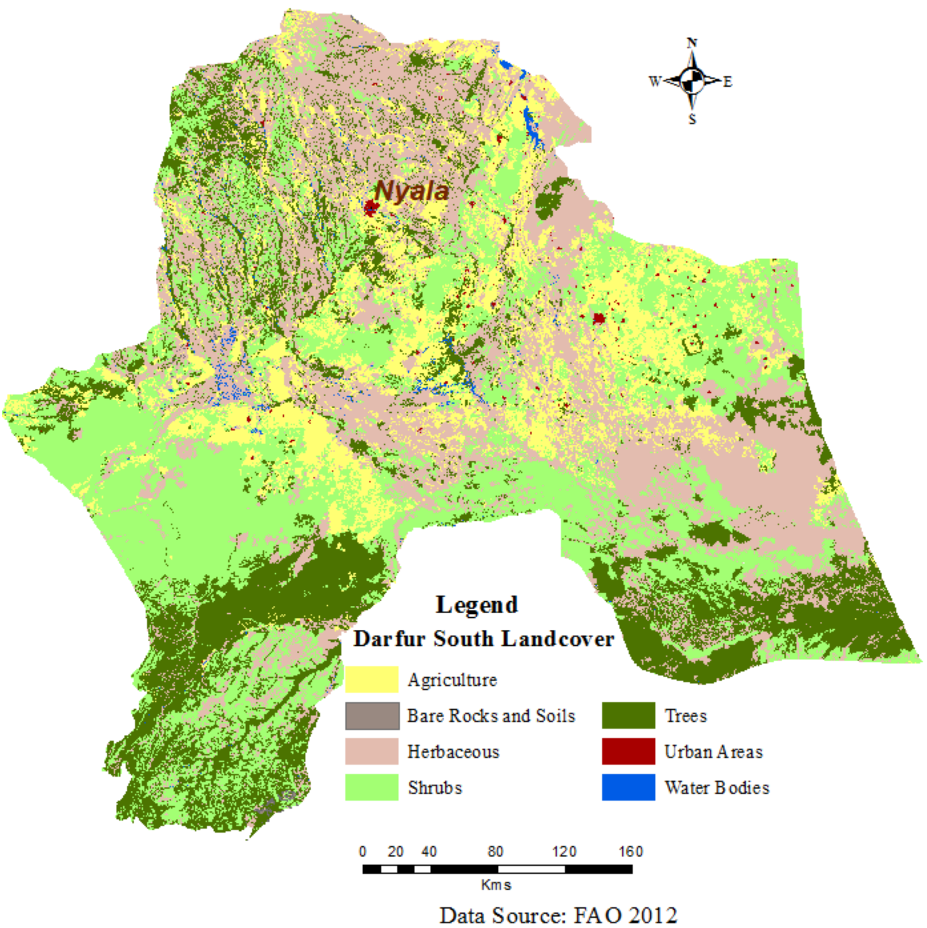


Figure 4-2: South Darfur Land Cover Map

The existing agricultural land cover which measured approximately 2.1 million Hectares was considered to be suitable for farming. Other areas allocated for farming in the modelled result is land under herbs which, the areas covered by shrubs was allocated for livestock activities Figure 4-2.

4.5. Modelled Potential Agricultural Production and Population Supported

The modelled results were based on land suitability assessment. Soils and rainfall data was used to determine the most suitable location for each crop and livestock farming. Each Crop was modelled differently; constraints for agricultural land suitability included urban areas, water bodies and area under forest. Areas meeting optimum criterion in Table 4:5 were allocated for optimum production. Those meeting minimum conditions were allocated for minimum production Figure 4-3. A total of five livelihood suitability zones were mapped. There was only one suitable zone for millet production as the optimum conditions were not met. For Livestock and sorghum production both minimum and optimum criterion was met hence two suitable zones. Most of the suitable areas for millet and sorghum are located in the central low lands where we have Sand and Clay soils the most attracting factor being the presence of seasonal rivers locally known as Wadhis. The soils in these areas have some good moisture content which supports the growth of crops.

4.5.1. Agricultural Production Suitability Maps

From the study livestock production is dedicated to two zones which are viewed to be marginal and cannot support crop production. The first zone falls in area with annual rainfall of 501mm-700mm. The despite the fact that the area has enough rainfall to support drought resistant crops it is characterized with low topsoil depth of 0-10cm which has low water retention rate. The pH value is 7-8 giving an indication of high carbonates concentration a condition which cannot support crops unless under special treatment. This zone is viewed to be optimum production area as the received rain can support a good amount of vegetation for livestock production even during dry seasons. The second zone which has similar pH values, soil depth and soil texture receives less rainfall of 234mm-250mm hence categorized as minimum production zone. The production rate for the area is 1 TLU per 10 Ha as compared to optimum zone where only 4 Ha are required for the same production.

The conditions required for the growth of millet were an average rainfall of 251mm- 500mm, with a pH value of 6-7. Sandy Soils and top soil depth 100-150 cm are needed of the growing of millet. Millet also does well in shallow soils of 0-10cm provided that there is enough rainfall and average pH values of 6-7. For optimum production of sorghum sandy soils are required in addition to annual average rainfall of 501mm-700mm. Optimum conditions needed for sorghum production are sandy soils with top soil depth of 50cm and annual average rainfall of range 251mm-500mm.

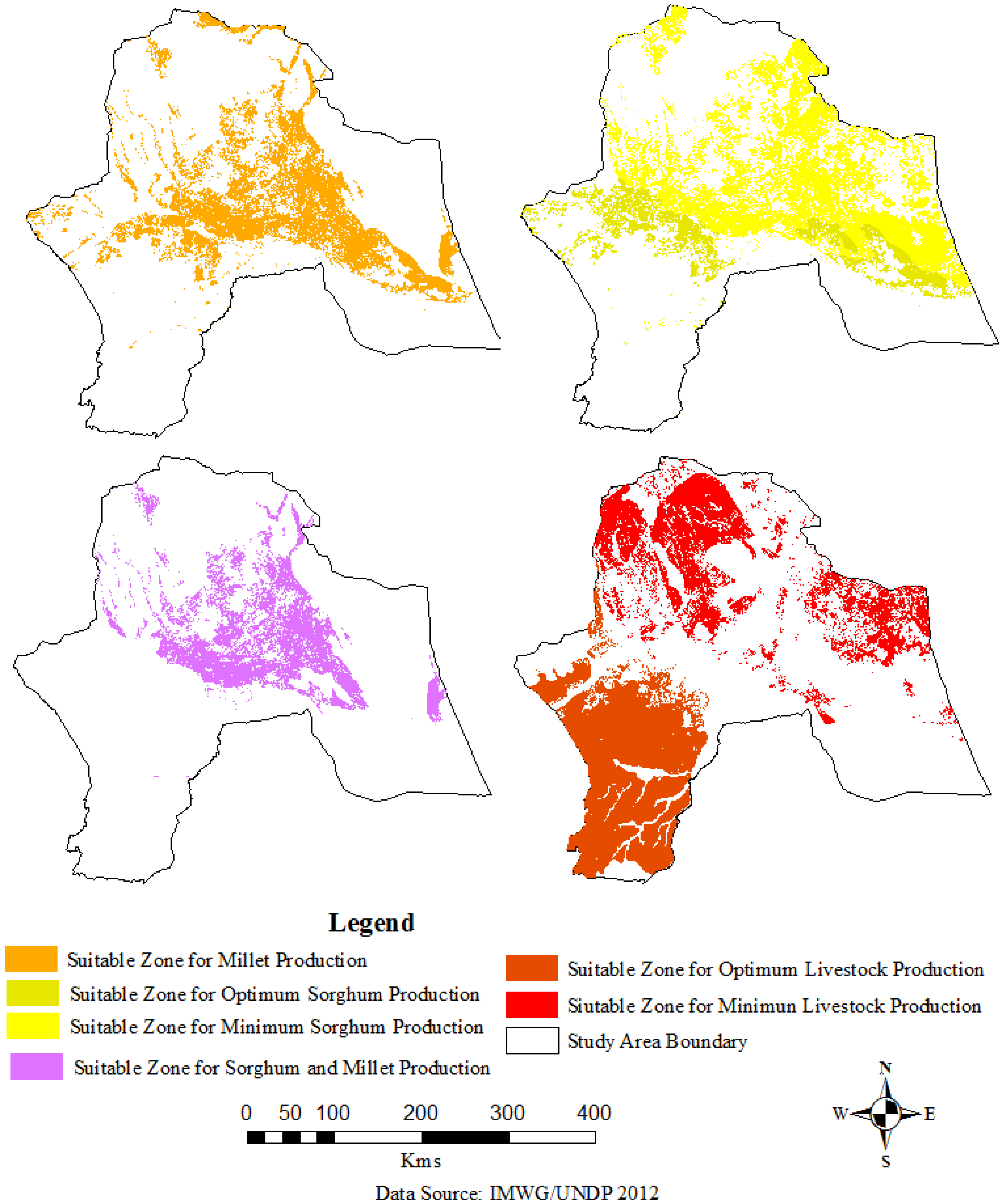


Figure 4-3: Suitable Areas for Millet, Sorghum and Livestock Production

Out of the five suitability zones, the total areas under minimum sorghum production had the highest value of 3.36 million hectares. The total area suitable for maximum sorghum production had the least value 1.01 million hectares Table 4:6 and Figure 4-3.

Agricultural Production Suitability Zone	Area(Ha)
Livestock Optimum Production	2,723,704
Livestock Minimum Production	2,350,190
millet Minimum Production	2,743,163
sorghum Optimum Production	1,013,318
Sorghum Minimum Production	3,360,972

Table 4:6: Suitable Livelihood Zones

4.5.2. Agricultural Livelihood Zones

Agricultural livelihood zones were derived from the suitability maps. In assessing Agricultural Production Suitability, there were some UAZs which were suitable for more than one crop. In such case a decision was to be made and the zone meeting optimum conditions was given priority since it was likely to produce more crops. In circumstances were only one crop was suitable in UAZ the crop was directly allocated to the corresponding zone. To the centre of the study area there were suitable zones for millet and sorghum production. The area was allocated for the two crops the total area divided into two equal parts for the two livelihood zones. A total of 9.53 million hectares was deemed suitable for both livestock, and millet and Sorghum production Table 4:7.

Agricultural Livelihood Zone	Area(Ha)
Livestock Optimum Production Zone	2,723,704
Livestock Minimum Production Zone	2,350,190
millet Zone	1,018,956
Sorghum Zone	3,433,704
Total	9,526,555

Table 4:7: Agricultural livelihood zones

Results from the study shows that the livestock livelihood zones with optimum production were located to the south East of the study area where the soils are shallow, course textured but with some good rainfall of 501mm-700mm. Millet Sorghum livelihood zone is located within the centre of the study area Figure 4-4 characterised with sandy soils and average annual rainfall range of 251mm-500mm.

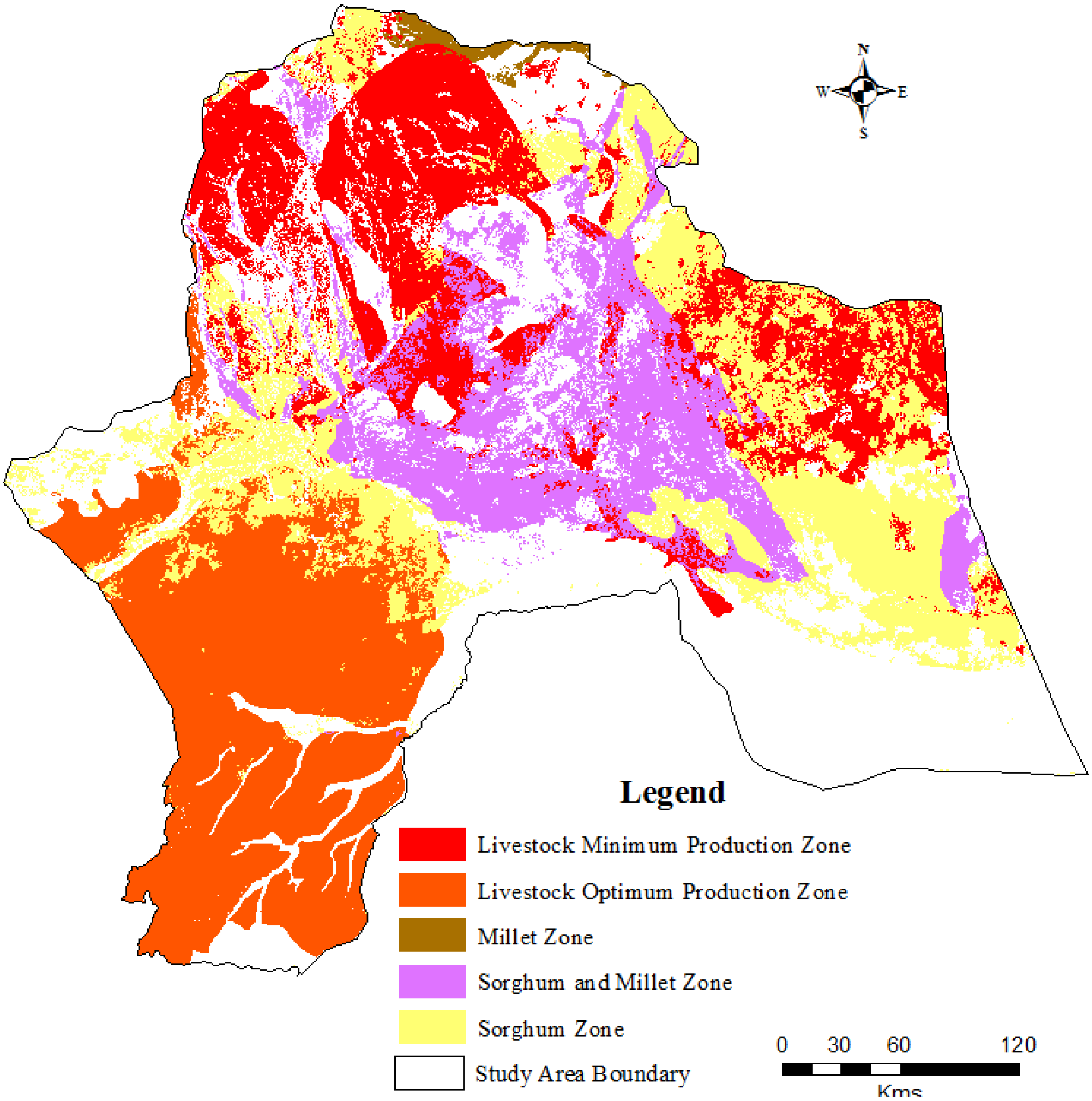


Figure 4-4: South Darfur Modelled Livelihood Zones

4.5.3. Agricultural Livelihood Zones Production

To model potential production three scenarios were considered based on production per Hectare from IFAD research stations documented by Omer (2011). The area under each livelihood zone has different production level depending on the crop which was allocated. Table 4:8 gives a summary of production levels per Ha when seeds are treated differently during planting. The highest production is possible when fertilizer is used at a rate of 0.3 grams per hole. When fertilizer is used sorghum production stands at 0.556 Tons per Ha, least production is recorded when minimum tillage is practiced.

Crop	Crop yield (Tons/ha) under various treatments		
	Control/minimum tillage	Seed soaking	Seed soaking with (0.3 g NPK/hole)
Sorghum	0.328	0.435	0.556
Millet	0.238	0.309	0.407

Table 4:8: Production levels in Tons per Ha

Source: Omer (2011)

The production levels forms the basis of three scenarios discussed in the next subsections. Note that there was no field data for livestock production hence a constant production value of 0.250 TLU per Ha is used for optimum production and 0.100 TLU per Ha is used in zones with minimum factors. The values for livestock production were derived from recommended stocking density for rain fed livestock production in the tropical Africa (FAO, 2007b)

4.5.3.1. Minimum Tillage Scenario

The minimum tillage is based on the least production where crops were planted under controlled conditions. There was no use of fertilizer or any technology used in the production process. The seeds were planted and kept free of weeds during the growing period. The production per Hectare was 0.238 Tons and 0.328 Tons for millet and sorghum respectively (Omer, 2011). The livestock production was not placed under any control and the average carrying capacity for areas receiving average rainfall of 0-1000mm annually was used. In this respect, areas receiving annual rainfall of 500mm-1000 requires 4 ha to produce 1 TLU of livestock while those receiving rainfall of 0-500mm requires 10 Ha to produce 1TLU (FAO, 2007b) and are zoned as optimum and minimum production zone respectively for this study. For the livestock production zones it translates to 1 Ha produce 0.250TLu and 0.100 TLU for optimum and minimum production zones Table 4:9.

	Modelled Suitable Area(Ha)	**Area Dedicated for Livestock/Cereal (Ha)**	**production per Ha (TLU/Tons)***	**Potential Production (TLU/Tons)****
Livestock Optimum Production Zone	2,350,190	2,350,190	0.250	680,926
Livestock Minimum Production Zone	2,723,704	2,723,704	0.100	235,019
Millet Production	1,018,956	594,391	0.238	141,465
Sorghum Production	3,433,704	2,002,994	0.328	656,982
*Livestock Production per Ha is in TLUs, for crops is in Tons ** Potential Production for Livestock is in TLUs, for Crops is in Tons				

Table 4:9: Agricultural Production of Minimum Tillage Scenario

In total the area which was modelled as suitable for crop production was higher than the area used to calculate the production. The reason behind this is in South Darfur each household has an average of 12 Feddans out of which 7 are dedicated for cereal production. The rest is used for other crops; this gives a ratio of 7/12 which was multiplied with modelled land use area to get available land for cereal production. For instance millet has modelled area 1.02 million hectares but the actual available land is 0.59 million hectares. The same principle was applied to area available for sorghum Table 4:9.

4.5.3.2. Use of Local Technology Scenario

The use of local technology involved using soaked seeds. The seeds were soaked overnight in water prior to planting which boasted their changes of germination and hence production per Ha. The production increased by 23 percent and 26.9 percent for millet and sorghum respectively compared to the minimum tillage scenario. The production for livestock did not change since there was data on use of technology. This implies the supply for agricultural production for the sedentary farming will be high hence more population will also be supported Table 4:10.

	Modelled Suitable Area(Ha)	**Area Dedicated for Livestock/Cereal(Ha)**	**production per Ha(TLU/Tons)***	**Potential Production (TLU/Tons)****
Livestock Production Zone 1	2,350,190	2,350,190	0.250	680,926
Livestock Production Zone 2	2,723,704	2,723,704	0.100	235,019
Millet Production	1,018,956	594,391	0.309	183,667
Sorghum Production	3,433,704	2,002,994	0.435	871,302
*Livestock Production per Ha is in TLUs, for crops is in Tons ** Potential Production for Livestock is in TLUs, for Crops is in Tons				

Table 4:10: Agricultural Production; Use of Local Technology Scenario

4.5.3.3. Use of Fertilizer Scenario

In the last scenario NPK fertilizer was used in addition to soaking. The seeds were soaked prior to planting and an addition of 0.3grams of NPK added to each hole during planting. The treating of seeds prior to planting was to guarantee enough moisture on the seeds sine the evaporation rate in South Darfur is very high (Omer, 2011). This process saw the production rise considerably by 41.5 percent for millet and 42.8 percent for sorghum when compared for scenario two on to minimum tillage. The values were 24.1 percent and 21.8 percent for millet and sorghum respectively compared to soaking of seeds alone Table 4:11.

	Modelled Suitable Area(Ha)	**Area Dedicated for Livestock/Cereal(Ha)**	**production per Ha(TLU/Tons)***	**Potential Production (TLU/Tons)****
Livestock Production Zone 1	2,350,190	2,350,190	0.250	680,926
Livestock Production Zone 2	2,723,704	2,723,704	0.100	235,019
Millet Production	1,018,956	594,391	0.407	241,917
Sorghum Production	3,433,704	2,002,994	0.556	1,113,665
*Livestock Production per Ha is in TLUs, for crops is in Tons ** Potential Production for Livestock is in TLUs, for Crops is in Tons				

Table 4:11: Agricultural Production Use of Fertilizer Scenario

4.6. Factors Influencing the Gap between Actual and Potential Production

The study result shows that comparison of the actual and potential production indicates difference in the South Darfur Agricultural production system. For the livestock Subsystem, the gap between modelled results and actual production is too high giving a difference of 77 percent. From this it can be deducted that the livestock system is overstocked assuming that Nomadic activities have to restrained in areas zoned suitable for pastoralist's activities where stocking value is 1 TLU per 4 Ha in and 1TLU for 10 Ha in areas of high and low suitability respectively.

For the sedentary farming subsystem the modelled millet production results are lower than the actual production. By comparing the actual and potential production, there is a reduction by 67.5 percent and 29 percent for minimum tillage and use of local technology scenario. There is a slight of improvement 2 percent in the use of fertilizer. This is attributed to the tendency of the local community planning more millet even in areas which are not suitable because it fetches good money in market. For instance the price in the year 2011 was ranging from 180SDGs-220SDG compared to Sorghum price of 120SDG for 90kgs sack (FAO & Ministry of Agriculture and Irrigation, 2012). Farmers who are economic oriented will therefore plant more sorghum even when knowing that the production per Ha is low.

In both the three scenario the results shows that there is more room for Sorghum production. The potential production levels are far beyond the actual production and improve by 39.9 percent, 55.8 percent and 65.4 percent for minimum tillage, use of local technology and use of fertilizer scenarios respectively. This is values are promising since sorghum forms a bigger portion of cereal consumption of Darfur Households. The production levels for the three scenarios in relation to actual production are illustration in Figure 4-5.

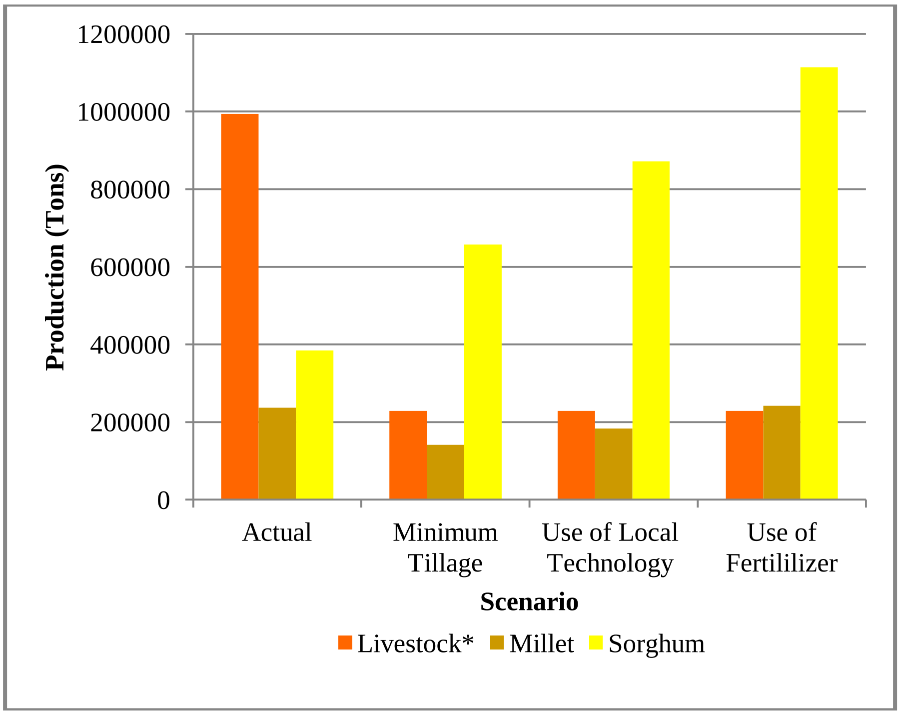


Figure 4-5: Agricultural Production Levels Scenarios

*To get the livestock production in TLUs the values in Tons has to be divided by 250kgs.

The increase in production is also related to the land under cultivation for both millet and sorghum. The area under Sorghum has increased magnificently; the area under millet reached the pick in 2008 but has decreased steadily while production per Ha has increased.

Various factors explain why there is a gap between the actual and potential production in South Darfur. The existence of IDPs Camps and the prevailing security situation contributes a lot to explaining why this gap exists. First some of the area zoned as being suitable for agricultural production is far flanked being located away from urban centres where the security is provided. The areas although not being used currently they were vibrant prior to conflicts as there was no security threats. Currently most farms concentrate close to urban areas which are patrolled by UNAMID security personnel Figure 4-6.

Figure 4-6: Planted Groundnut field in Geraida in South Darfur
Photo Source: (UNAMID, 2012)

The farms which are in proximity to urban centres Figure 4-7 where there is high presence of security officers are deemed to be unsuitable for crop production. 87.6 percent of the areas of 270,101Ha are located in a zone receiving an annual average rainfall of below 300mm, shallow and clay soils which have low water retention rate. There is low harvest when rainfall fails in this area, although they are proffered because of presence of seasonal rivers which dry up when rain fails.

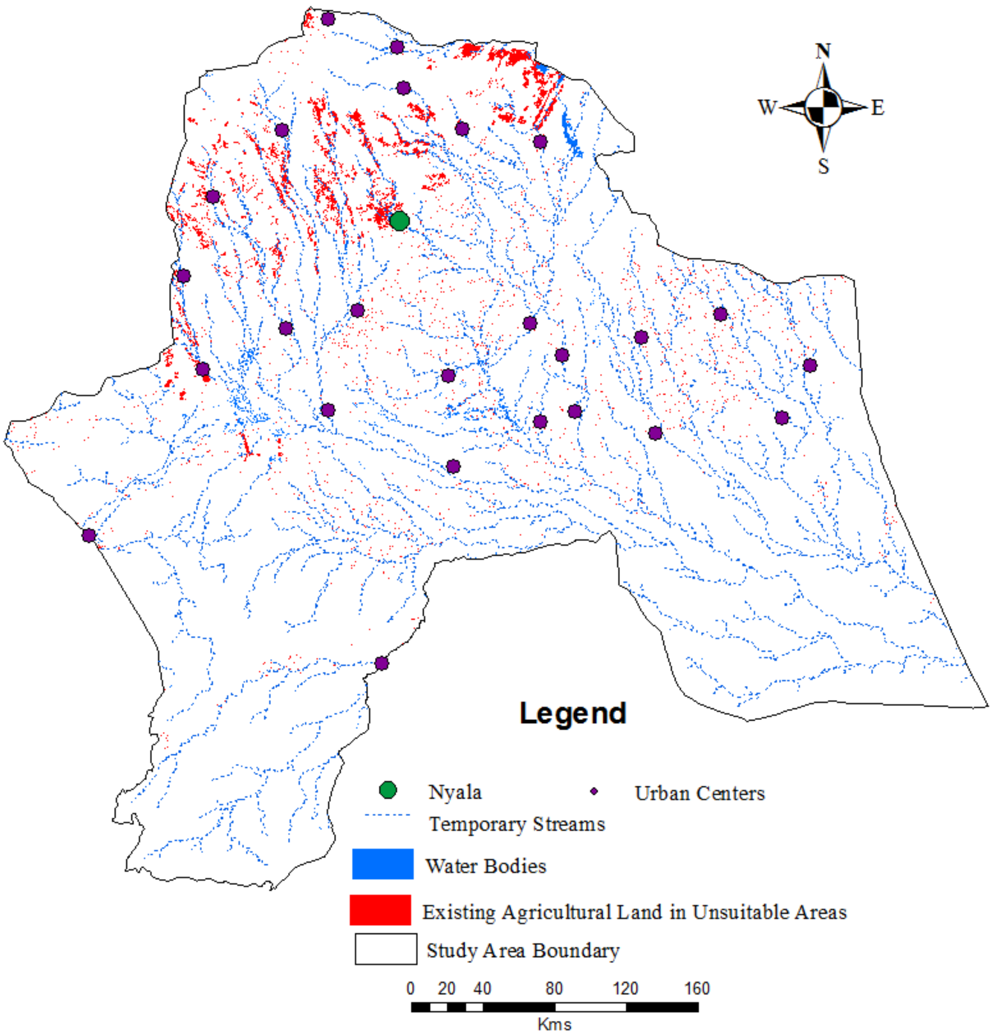


Figure 4-7: Existing Agricultural Land in Unsuitable Areas

Secondly, it was noticed that in most cases the area which was not planted is fully harvested. Despite the fact that more land is being put under farming the rate at which un-harvested land is increasing has raised some concerns. During the planting period 2010, percentage of un-harvested to harvested areas rose to the highest mark of 49 percent for millet and 54 percent for sorghum. This is surprising values indicating that almost more than half of the planted land is not harvested Figure 4-8.

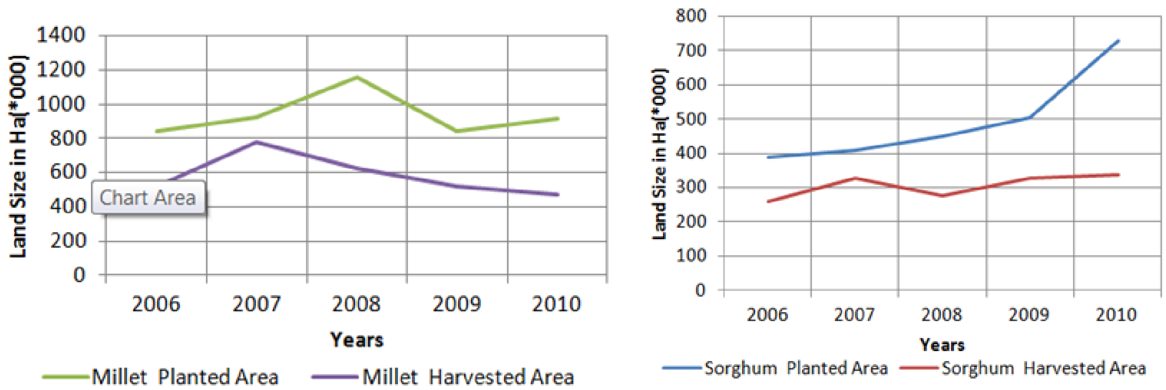


Figure 4-8: Area under Sorghum and Millet Cultivation in South Darfur for the Years 2006 t0 2010

4.7. Actual and Potential population(Carrying Capacity)

Potential population supported by each livelihood zone is a function of agricultural production. The system is viewed to be sustainable in case the actual population is below the potential population that is the carrying capacity. In case the community population is more than what the system can support, cases of struggle for survival may be recorded. Conflicts are the likely outcome of such systems as everybody struggle to survive. More population can only be supported where there is room for accommodation.

4.7.1. Livestock Livelihood Subsystem

The actual production stands at 3.96×10^6TLUs and can support a population of 1.33×10^6 persons at a per capita consumption rate of 3TLUs. On the other hand the potential production is 0.92×10^6 and can support a population of 0.31×10^6 persons at the same per capita per consumption rate of 3TLUs. The actual population is 0.97×10^6 persons; this gives a clear indication that if the same consumption levels are upheld the actual production can support and extra population of 0.36×10^6 persons. In contrast the potential production is below the actual production giving a clear sign that is an access population of 0.68×10^6 persons is being supported by the livestock subsystem. The population supported by each production level are shown in Figure 4-9.

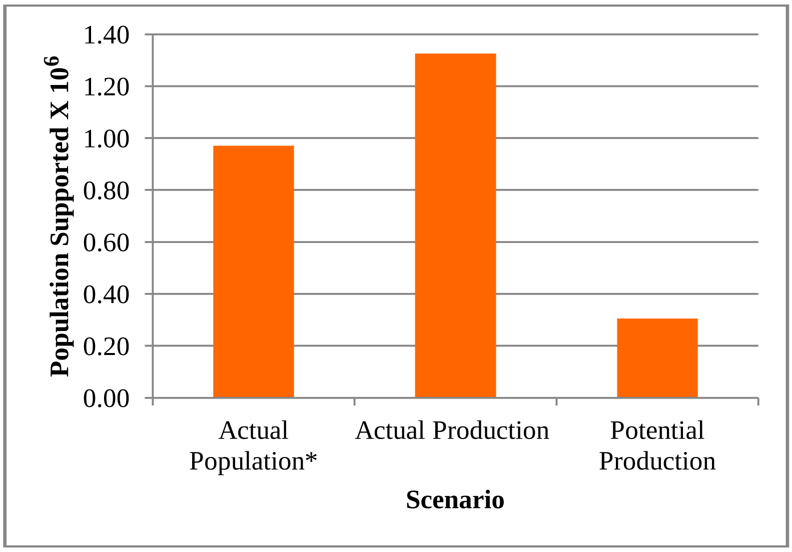


Figure 4-9: Potential Population Supported by Actual and potential Livestock Production
*2011 Nomadic population projected from 2008 population census.

4.7.1.1. Conflicts and Overstretched Livestock Livelihood Subsystem

From the discussion is subsection 4.7.1 it is clear that the livestock subsystem has surpassed its carrying capacity. FAO (2007b) defines levels of conflicts resulted to livestock depending on the ratio of actual stocking density and estimated land carrying capacity values. Any system is deemed to have high risk of livestock driven conflicts when the ratio of actual stocking density to estimated land carrying capacity is greater than one. There is no conflict if risk the ratio is less than 0.5 that is the existing/actual stocking level is less than half the calculated land carrying capacity Table 4:12. The study to of identifying these conflicts was done in Sub-Saharan African Countries of Ethiopia, Kenya, Uganda, Tanzania, Burkina Faso, Mali and Senegal where rainfall nomadic activities are common.

The principle cannot work in South Africa where ranches are well established with other sources of water and feed being exploited to boost production(FAO, 2007b).

Ratio(Actual Stocking/ Land Carrying Capacity)	**Level of Conflict Risk**
>1	High level livestock driven conflict
0.75-0.99	Medium level livestock driven conflict
0.5-0.74	Low level livestock driven conflict
<0.5	No Risk of conflict

Table 4:12: Various levels of Conflict Resulting from Surpassed Land Carrying Capacity

For South Darfur, there is a risk of conflicts related to livestock. There scenario are envisaged, the first is containing livestock in the modelled area, second is allowing livestock in zones categorized by FAO as grazing area. The third involves practicing livestock in the entire study areas assuming that no other activity will take place. I both scenarios there is a likelihood of livestock related conflicts as the ratio of Actual production to potential production is far beyond 1. The ratio stands at 4.34, 4.32 and 2.00 respectively as illustrated in Table 4:13. This explains why 20 out of 29 conflicts incidences recorded in the region are linked to grazing land and water resources.

Scenario	**Actual Livestock Production(TLUs)**	**Potential Livestock Production (TLUs)**	**Ratio(Actual Livestock Production / Potential Livestock Production)**
Modelled/Potential	3,975,560	915,945	4.34
Required Production to support current human population	3,975,560	1,293,440	3.07
Area Zoned by FAO for Grazing*	3,975,560	920,123	4.32
South Darfur Total Area*	3,975,560	1,989,022	2.00
Note: *An average of 7 Hectares are required to produce 1 TLU for Tropical Nomadic livestock systems (FAO, 2007b; Jahnke, 1982)			

Table 4:13: Conflict Resulting from Current Stocking and Land Estimated Carrying Capacity

To support the current population, Darfur Require 1,293,440 TLUs. Basing on the modelled potential production which is based on the suitability assessment, a total of 915,945 can be produced. Using the same assumption as in Table 4:13 the ratio of the required production and potential production was calculated. It was found that the ratio is 1.41 which shows the possibility of conflicts as the area will be overstocked if more livestock will be produced. This indicates that to support more Nomadic population another alternative of livelihood has to be sourced or provide. Another option will be boosting the production of the zoned livelihood zones by providing artificial water points and pasture which is the main determinant of livestock stocking density.

4.7.2. Sedentary Farming Subsystem

The Sedimentary farming is made up of farmers who practice crop production. Two main crop chosen for this study are mainly produced due to high market value and consumption rate. These two cereal crops produced in the area are millet and sorghum and forms the two livelihood zones discussed in this sub section.

Sorghum forms the bulk of the annual cereal per capital consumption in Darfur. Out of the possible annual consumption of 153kgs, sorghums take 50%. The actual production of sorghum is more than required consumption hence an extra population of is 2.20×10^6 persons can be supported. This gives an indication that production is sufficient enough to support existing population and further extra population can be tolerated.

There is more potential of the sub system to support an extra population for both the three modelled scenario scenarios with value rising to 15.26 million persons for use of fertilizer scenario Figure 4-10. This gives more hope of settling IDPs as there is potential of accessing their source of livelihoods whether they move from camps as returnees or resettlement to an alternative site.

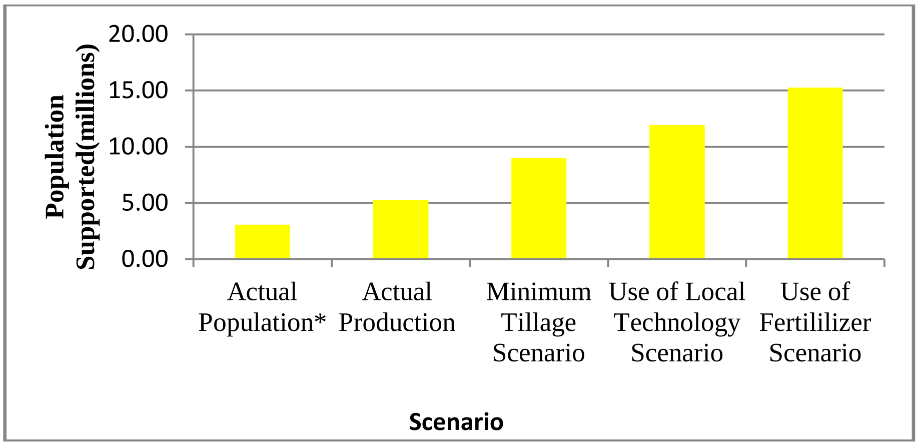


Figure 4-10: Potential Population Supported by Actual and potential Sorghum Production

Millet is produced mostly but its consumption rate is very low. Out of the annual total cereal per capita consumption of 153kgs, only 15kgs is made up of millet. The crop is preferred because of its high market value is it sold in the in the neighbouring states and South Sudan. The actual sedentary population is 3.07 million persons; the actual production is more than what is required to support this population. The actual production can support a population of 15.80 million persons which shows there is surplus in production which is taken to the market. This explains why 34.5 per cent (FAO & Ministry of Agriculture, 2010) of millet is produced in South Darfur. Potential production for minimum tillage and use of local technology are below the population supported by the actual production. The use of fertilizer scenario produces millet which supports the population which is close to the one supported with actual production. The use of fertilizer improves production by 2.07 percent.

Figure 4-11 shows the actual in relation to population supported by actual production the three modelled scenarios. It can be deducted that more population can be supported by all the three scenarios and the actual production.

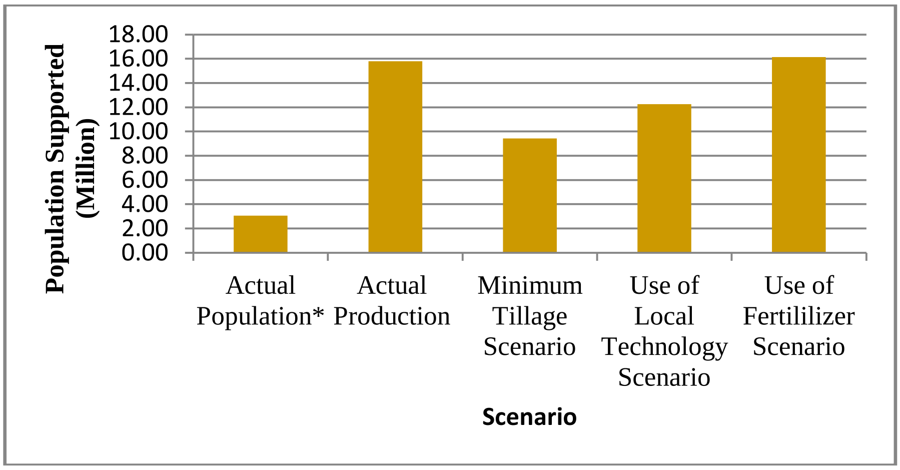


Figure 4-11: Potential Population Supported by Actual and potential Millet Production

4.7.3. Possible area for resettlement and Return

Discussion from previous section indicates that the sedentary farming system has the capability to support more population in case the current rain fed agriculture has to be practiced. The Nomadic/livestock production system is not sustainable as the current production is beyond the carrying capacity and more population cannot be supported. Basing on this only sedentary farming is seen as the only viable option for resettlement purpose. The possibility of the livestock system supporting more population cannot be ruled out but more has to invest since the rain fed production is not being viable.

The proceedings discussion shows that there are seasonal returnees who still own land and it is believed that their farms are within the land classified as agriculture. For those who wish to be resettled there are suitable areas which are zoned outside the existing agricultural land meaning approximately 2.53×10^6 Ha are available for resettlement Figure 4-12. With an average household land holding of 12 Feddans a total population of 6.03×10^6 persons can be resettled. For the South Darfur refugees on 25 percent of the total 718,000 IDPs are currently will to go back to farms. The figure is below the potential value hence any settlement option taken will be sustainable. Return and resettlement in area zoned as unsuitable can also be done with some policy measures being applied. Some of the policy measures should include production more drought resistant crops or use of more farm inputs.

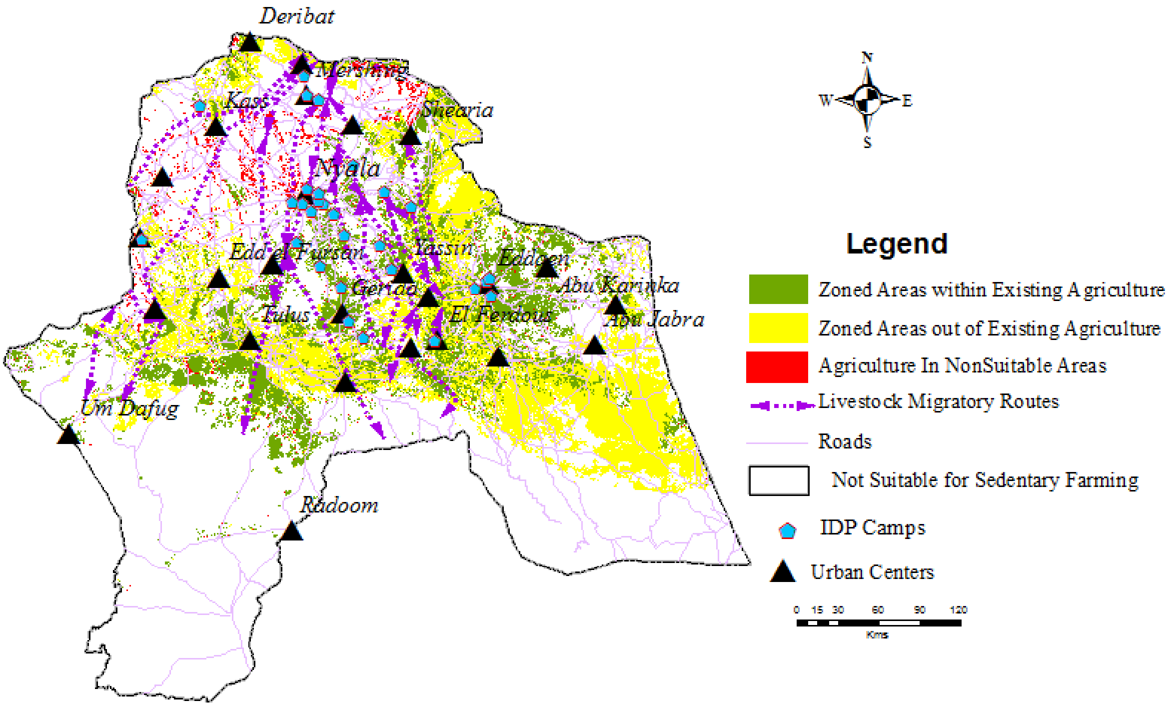


Figure 4-12: Possible areas for resettlement within Millet and Sorghum Livelihood Zones in Relation to Existing Agricultural Land

5. DISCUSSION

This chapter presents the discussion of the study findings and the limitation of this research. The discussion is based on results presented in section four and reference is made to other studies done by different researchers in Darfur or other regions. The first section presents a discussion on the main agricultural livelihood activities, production levels and population supported. In the second section modelled potential production is discussed. The third section looks at the modelled production and explains the gap between the potential and actual production. The fourth section looks at the relationship between actual population and potential population supported by modelled production and it concludes by examining possible areas for resettlement/return. Lastly section five highlights the limitation to this study.

5.1. South Darfur Agro Economic/Livelihood Activities, Actual Production Levels and population Supported

5.1.1. Livestock Production Subsystem

The area under Nomadic activities is not well delineated, as the pastoralists move up down grazing in areas which have not been planted with crops. After harvest livestock also graze on land which has been used by sedentary farmers. The system is also complicated by the fact that the Nomads do not have fix boundaries. They graze their livestock crossing both National and International boundaries. Basing on available figures production has been increasing and stood 3.13 million TLUs, 3.69million TLUs and 3.98TLUs for the years 1998, 2008 and 2011 respectively. This indicates that the upward production trend has been maintained.

On the other hand the population of the Nomadic communities has been marked with fluctuations. In 1998 Nomadic population stood at 0.45 percent of the total population. The value rose with 2008 population census report indicating that the percent rose to 25percent. This is very sharp increase; there is clear indication that very few pastoralists were covered during 1993 population census upon which the 1998 values were calculated (Ali et al., 2009). Thus is a main problem of census data, the Nomads might have been counted in one of the neighbouring states.

5.1.2. Sedentary Farming Subsystem

The results reveal that Sorghum and millet production has been improving. Before and after the conflicts and civil war the trend in the production has been maintained. Despite the fact that the production has been improving, the subsystem is not efficient since a bigger percentage of land is planted and not harvested. The rate at which the land is not harvested has been increasing the year 2010 heating the highest figures of 54percent for Sorghum and 51 percent for millet in the year 2011 Figure 5-1.

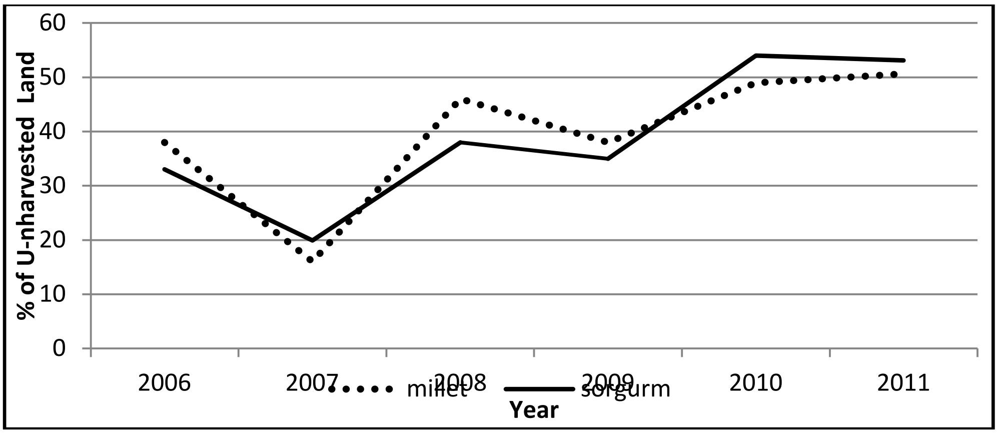


Figure 5-1: Percentage of Un-Harvested Land Compared to Total Planted Land

Reasons to why a lot of land remains un-harvested are varied, but seasonal returnees have been named by Seferis (2010) as a contributing factor. Some of the seasonal and community returnees go back to plant their farms by virtue of maintaining ownership status as land which is not cultivated for long time will be taken by a new owner. Some seasonal returnees stay in the farms for the entire growing period and go back to camps after harvest. The harvested products is sold or used to boast daily rations received in the camps. Those who return to farms are mainly men as vulnerable members of the society that is women and children are left in IDPs camps where they can access schools, security and other services. The seed programme operated by WFP gives farmers free seeds and they do not get losses relating seeds used.

Crop failure is another different reason for un-harvested land. This may be due blame natural calamities such less rainfall or locust which attacks some fields before harvest time. The use of local seeds which cannot withstand weeds and tough conditions also gives a reasonable explanation (ICRISAT, 2012). Striga weed has been blamed on the dwindling harvest with the researchers coming up with better seeds Figure 5-2

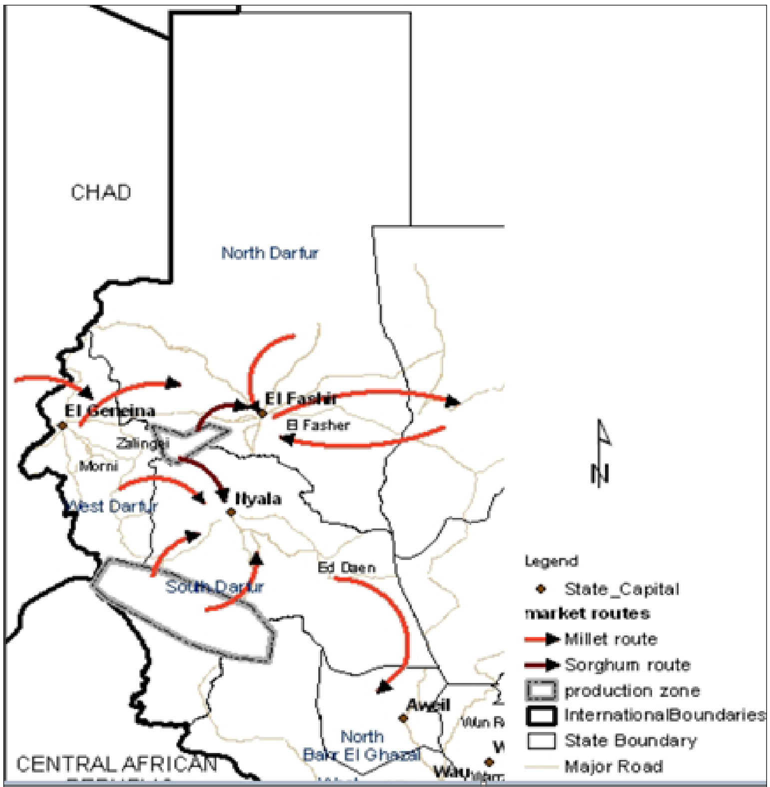
Figure 5-2: a field of Sorghum in Darfur, on left is Striga Resistant Variety and left is Traditional Variety
Source:ICRISAT (2012)

5.1.3. South Darfur Agricultural Products Consumption Gap, Imports And Exports

The study results show that despite the fact the production of sorghum as been improving, the 1998 and 2008 production was below the required consumption. As in shown in Table 4:3 presented in section 4.2.2 there was a deficit of 0.11 million tons and 0.07 million tons for 1998 and 2008 respectively. The gap between the production and consumption has been bridged has the harvest has improve with 2011 recording a surplus of 0.16 million tons. The deficit has been always filled by importing sorghum from West Darfur (El-Dhukheri, Damous, & Khojali, 2004). The presence of IDPs in South Darfur has complicated the matter as the majority of IDPs do not have farms and have to depend on relief food. WFP which is the main relief food provider gets donations from other regions with well wishers such as USAID Figure 5-3 providing the bulk of food. WFP supports approximately 0.782 million persons annually on general food supply with 98.5 percent of this population being based in IDPs camps. The remaining 1.5 percent of the beneficiaries are stay in slums and cannot afford to get their daily bread (WFP, 2012). Other suppliers of food include UNICEF which mostly deals with school feeding programmes and provision of supplementary food to babies and CARE International.

Figure 5-3: Imported bags of Sorghum in WFP Ware house in Nyala
Photo Taken by WFP/Nyala Sub-office Team, Source:WFP (2012)

In the local market Nyala which is the South Darfur Administrative centre is the most attractive point for producers who want to sell their surpluses to the market. The market network is so strong and wide as it spreads to the neighbouring states and Countries Figure 5-4 adapted from FAO and Ministry of Agriculture (2010). Sorghum is mainly produced in The North of South Darfur with some producers exporting their Surplus to North Darfur Capital Town El Fashir while others prefer to take it to Nyala.



Millet and Sorghum flow
Source: (FAO, & Ministry of Agriculture, 2010)

Figure 5-4: Cereal Flow in the Larger Darfur Region

Millet is mainly produced in the Southern Part of South Darfur with Nyala being the main target for the selling of the surplus. Study results presented in Table 4:4 indicated there is surplus of millet. Areas surrounding El Daein Town sell their millet surplus to Aweil which is the Capita of Northern Bahr el Ghazal state of South Sudan as indicated in Figure 5-4 adopted from (FAO & Ministry of Agriculture, 2010). The exported products are mainly sold in retail market Figure 5-5, especially in North Darfur where production is low due to its dry conditions.

Figure 5-5: Left Cereal Market in Kutum North Darfur and right a butcher in IDP Camp
Photos taken by (Feinstein International Center's, 2004)

5.2. Modelled Potential Agricultural Production

In this subsection the results of modelled production are discussed. It has to be noted that the livelihood zones are a product of suitability maps. The area under each livelihood zone was multiplied by production per hectare to get the total agricultural output.

5.2.1. Livelihood Zones

In this study suitability maps formed the basis of the livelihood zones upon which agricultural production was calculated. The process involved allocating land to best use which will give the maximum potential production. Zoning has been a widely used procedure of allocating land to various land uses. FAO has used zoning procedures to map agro ecological zones, allocating crops to individual land unit to optimize food production (Fischer & Antoine, 1994). The method adopted by FAO is complex and requires mathematical knowledge to do the allocation living the job to be done by experts.

With the need to involve stakeholders in the decision making, collaborative tools have been developed. The land carrying capacity assessment model developed in this study used Knowledge Tables (KT) during the land suitability assessment process where the local expects allocated every Ha of land to best use. The assessment tool is easy and can be used easily by all stakeholders. Although other methods are available such us Multi Criteria Decision Analysis (MCDA) as used by Geneletti and van Duren (2008) to make decision on multiple land use allocation, KTs are easy to use as compared to MCDA where the stakeholders have to be knowledgeable on ranking and normalization of values. Qrisp the platform on which the KT are run allows the use of Grid maps which transforms the non spatial data gained from the stakeholders.
The use of local expert in Land carrying capacity assessment is gaining fame as it has been used also by Lein (1993) but his model is complex as computer programming knowledge was needed to process various codes assigned to land use by experts.

The study finds out the suitability of the agricultural land highly depend on soil conditions such as pH value, texture and topsoil depth. The farmers in the study area practice rain fed agriculture hence rain is another key factor. By setting the criteria for land allocation, conditions which are to be made had to be decided. In the Grid maps UAZ had homogenous soil and rainfall characteristics, the crop requirement gave the basis of allocation. It was found that livestock subsystem was allocated marginal land with rainfall determining minimum and optimum production level. In total 9.53 million hectares were found to be suitable for both livestock and sedentary farming. The model allocated 53%, 36% and 11% of the total suitable land to livestock, sorghum and millet production respectively.

5.2.2. Livelihood Zones Potential Production

In this study the livelihood zones provided the base for estimating potential production. The total land under each livelihood zone was multiplied by production per hectare to estimate the total production. Two observations are made from this study, first the livestock production decreases when rain reduce. A nomad in minimum production zone requires 1 Ha to produce 0.1 TLUs, while area with optimum suitability requires 1 Ha to produce 0.25TLUs. The values can rise especially where ranching is practiced and supplementary feeds are provided in addition to bore holes which are sunk to provide water during dry season. The option of ranching was not considered in this study since there was data. But other studies shows that the production per Ha can improve magnificently if ranching is plied is the case in South Africa, Kenya and Tanzania (FAO, 2007b)where quality livestock is kept and external feeds introduced.

The study results in section 4.5.3 show the use of low level of technology can improve production. For instance soaking seeds before planting improves chances of germination and improves production by 32.6 percent and 29.8 percent for sorghum and millet respectively. On the other hand combing the soaking option and use of fertiliser, the production rose further by 69.5 percent and 71.0 percent for sorghum and millet production respectively. This implies more production can be achieved when use of low technology is achieved hence improving food security and reducing the rate at which the population rely on relief food.

5.3. Actual and Modelled Potential Agricultural Production

The study revealed that the actual production of livestock production subsystem is beyond the recommended. There are more livestock than the available resources can support. The actual production stands at 3.98 million TLUs (FAOSTAT, 2012). On the other hand results indicate that sustainable potential production should be 0.916 million TLUs if production is limited to zone deemed suitable for livestock production as discussed in section 4.5.3. Even if the entire study area was allocated to livestock production still the actual production is not sustainable since optimum production will be 1.99 million TLUs which is below the actual production. Previous allocation by FAO locates land found to the South of the study area and those surrounding Nyala town grazing. By considering this area zoned by FAO (IWMG, 2012) a total of 0.920 million TLUs can be produced sustainably a value which is close to 0.916 million TLUs estimated in this study basing on the livestock livelihood zone. Oba, Stenseth, and Lusigi (2000) concurs that livestock system in the Sudano-Sahelian Zone is overstocked as a consequence of policies which were adopted in response to 1983 drought. The Government and donors have offered semi solutions hoping to maintain production equilibrium which include provision of watering points and vaccinations which have increased the survival of livestock. This in turn has led to concentration of livestock in one area causing land degradation. An evaluation of IWMG (2012) data source indicates location of water points along the migratory routes. Another judgement on the overwhelming livestock numbers should be the integration of crop production and livestock system.

It can be concluded that the livestock as a source of livelihood has to be re examined by policy makers in case as it has to be option for offering IDPs a Solution. Nomadic communities should be advised to down size livestock herds and rearing quality breeds which have high returns. Unless an action is taken there is a possibility of frequent conflicts resulting from grazing and sedentary farming land rights. As the livestock herds increase Nomads encroach in areas which have been used by sedentary farmers (Alix-Garcia et al., 2012) which can result into conflicts over resource use. The option of feeding livestock on crop residues has been explored (G.Tarawali, 2009; Gaillard & Sadhana, 1989) and can improve livestock production. In the entire Darfur Region the local leaders have been campaigning for this option (Darfur Land Commission, 2009)but the difficulty has been timing as weather command planting time. In case Nomads decide to move prior to harvest a conflict may occur since they will graze on un-harvested fields.

Study results in section 4.5.3indicate there is some potential for more production for the sedentary farming sub system. There is more potential in the sorghum livelihood zones where in both the three modelled scenarios, the production above the actual production. The recorded results indicate the production can go up by 70%, 126% and 195% for minimum tillage, use of local technology and use of fertilizer respectively. Nevertheless estimated potential production for millet livelihood zones is below the actual production for the minim tillage and use of local technology by 41% and 23% respectively. Alternatively use of the fertilizer improves potential production by 2% as compared to actual production. There is likelihood that more millet is planted even in areas which are not suitable due its high market value.

5.4. Actual and Potential population(Carrying Capacity)

5.4.1. Actual and Potential population (Carrying Capacity)

The actual population was attained from the census data while the potential population is estimated by using per capita consumption and modelled production. It is clear that the livestock livelihood zone cannot support more population if nomadic production is maintained. The results in section 4.7.1 disclose that the actual nomadic population is more than what the modelled livestock livelihood subsystem can support. The actual population stands at 0.97 million persons while the estimated potential livestock production can support a population 0.31 persons. Basing on this result another option has to be embraced by the nomads as their source of livelihood is being threatened due to limited resources. The option may include changing their sources of livelihood or livestock production mechanism. Integrating livestock and crop production subsystems under mutual agreement between sedentary farmers and nomads is a viable option which can be explored. Integration has worked well in Niger where crops provide supplementary feeds to livestock. Alternatively Niger sedentary farmers get manure from Nomads and service such transport of farm produce using livestock drawn carts and farm preparation (Gaillard & Sadhana, 1989). Care should be taken as nomads who decide to become sedentary farmers increase the demand for land and competition with existing farmers can lead to conflicts. Some nomadic families in South Darfur are already choosing the sedentary farming option after realizing that livestock production is no longer feasible(Kahn, 2008). Oba et al. (2000) notes if sedentary farming is not well practiced settlements can be located on livestock seasonal migratory routes. At the end the settlement programme can cause another problem as conflicts may lead to further internal war with displaced going back to urban areas.

Modelled results presented in section 4.7.2 indicate sedentary subsystem can support more population can be supported. An extra population of 5.93 million and 12.19 million persons can be supported for minimum tillage and use of fertilizer in the sorghum livelihood zone. Alternatively the millet livelihood zone supports an extra population of 6.36 million persons and 13.06 million persons as compared to the actual population.

5.4.2. Possible area for resettlement and Return

Result discussed in subsection 5.4.1 indicates that there is no room to accommodate nomadic families within the modelled livestock livelihood zone. The current Nomadic population of 0.97 million persons is already above the land carrying capacity which is estimated to be 0.31 million in 4.7.1. It has to be noted that the potential population (carrying capacity) was estimated basing on the modelled production level of 0.92 million TLUs which is viewed to be sustainable basing on FAO (2007b) policy recommendation. Maintaining this modelled production will not have any diverse effects as it matches the available resources. The current production is beyond the recommended level of production as the ratio of actual to estimated sustainable production level stands at 1:4.34(calculated in section 4.7.1.1) which is far above 1 indicating that there is already the possibility of conflict related to livestock(FAO, 2007b). Any addition of population to the livestock livelihood zone increase tension as the new settlers will require land which is not available.

The study findings indicate that there is more room to settle IDPs in sedentary farming subsystem. Both the millet and sorghum livelihood zones can support more population. The resettlement or return option should consider the existing infrastructural facilities. The better option could be the one near the IDPs camps. It has to be noted that there are seasonal returnees who go to farms during planting seasons and could prefer to settle permanently if services are improves. Royal African Society (2009) notes that some IDPs use camps located in towns as dormitories where they sleep at night in order to access services such as security. This group of IDPs still have their eyes set farming as their source of livelihoods.

As shown in 4.7.3 a total of 1.92 million hectares are found to be suitable for sedentary farming and lie within the existing agricultural lands. These patches of land are mainly located around Eddaen where we have four IDPs camps. The other towns surrounded with area suitable for sedentary farming within existing agricultural farmers includes El Ferdous, Tulus, Edd el Fursan and Shearia as illustrated in

Figure 4-12. The 25 percent of the IDPs who are willing to return should be encouraged to settle in such areas in case this is their original homes.

A further 2.53 million hectares also found to be suitable but is located outside the existing agricultural land. Thes patches of land are located in the Eastern side of the study area. The land is located in the South of Abu Jabra, where there are no major settlements. Deciding to settle IDPs here will be expensive as services have to be provided to make safe and habitable. Although there is a good network of roads in this area, their state could not be established by this study.
Alternatively there is an of area of 0.27 million hectares which is currently being used for farming but the study found it unsuitable since the area lies in the zones with rainfall of less than 250mm per annum and shallow soils. The areas are farmed just because of their proximity to the main town of Nyala, and Mershing where there are plenty of security personnel Figure 4-12. The area is close to the existing settlements meaning there is some services and security concerns should be minimum. But policy measures have to be put in place; small scale irrigation can be an option though expensive.

Although the return or (re)settlement options mentioned in this section is only tied to sedentary farming where the IDPs can choose between sorghum or millet livelihood zones, nomads can change their lifestyle too. Studies in the larger Darfur and other areas indicate that some nomadic families are now settling down as sedentary farming as livestock is not yielding enough food for them. (Kahn, 2008). FAO has also undertaken pilot projects where they have advised nomadic communities to adopt sedentary farming. A good example is the (FAO, 1991) project done in Turkana Kenya where Nomadic families have accepted sedentary farming as their source of livelihood. Cheap methods of small scale irrigation can be developed where water flow in irrigation channels by gravity and crop intensification is done towards the source of water(Gaillard & Sadhana, 1989).

5.5. Limitation to this study

The constraints to this study are enumerated below:

I. The spatial data used in this data was collected by the UN agencies, at higher level mainly at the country level. Disaggregation of the data to the state level meant that there was a problem associated with the accuracy. Some data had gaps which had to be filled by other sources which meant that …
II. There was language barrier especially during focus group discussion. Although there some translators the original message might have been lost during translation process.
III. The used of Qrisp software used to develop Knowledge tables and storing them was still under development. There was no manual and any clarification had to be made to software development. Solving simple problem took a lot of time since the developer was based in a different location.

6. CONCLUSIONS AND RECOMMENDATIONS

This chapter provides the conclusion and recommendations. The research objectives are re-evaluated, and discussion made on whether they were achieved or not. Lastly recommendations for furher studies and actions to be taken are explained in brief.

6.1. Conclusions

Agriculture forms the main source of livelihoods for the South Darfur population. There are two type of agricultural production which includes livestock production and sedentary farming where two main crops that is sorghum and millet are grown. These crops are grown widely because they are the staple food.

The livestock production has been increasing. The results in section 4.2.1 shows the production has been ten times more that the required consumption. For the sedentary farming, sorghum production did not meet the required consumption for instance in 1998 the production fall short of required consumption by 42.2 percent. Nevertheless the production for the sorghum has been improving and by the year 2011, the demand was met and a surplus of 71 percent was recorded as indicated in section 4.2.2. There has been surplus of millet with the year 2011 the excess being sold to the neighbouring states.

The study results revealed that there is a gap between the actual production and the potential sustainable production. Results in section 4.5.3 indicate sustainable production level should be 0.18TLUs per hectare which is an average value for optimum and minimum production zones. The production level of 0.18TLUs per hectare estimated in this study is close to 0.20TLus recommended for the entire of North Sudan by Kessler (1994) . There is a clear indication that the actual production is 4.3 times more than the recommended sustainable production.

In the sedentary farming subsystem, sorghum production can improve by 289 percent as compared to actual production if the modelled land is planted and fertilizer used. Additionally millet production can be improved by 2 percent if modelled suitable areas are planted and fertilizer used. Under minimum tillage and use of local technology scenario modelled millet production is below the actual production by 40% and33% respectively. The reasons behind this production gaps includes a high percentage of land which are planted and not harvested. For the livestock livelihood zones there are more livestock as the nomads keep animals' customary purpose.

Out of the three modelled livelihood zones, resettlement is can be considered in sedentary farming subsystem. The Livestock production subsystem is beyond the recommended optimum production hence encouraging resettlement in this zone will not be sustainable. Nevertheless, livestock production can be improved by implementation of selective new policies such us use of improved breeds and integration of crop and livestock production. The IDPs return or resettlement programmes may therefore be implemented in areas zoned for sedentary farming with priority being given to those close to urban centres where there exist some services. It has to be noted that approximately 25 percent of the 0.78 million IDPs in the camps will prefer to go back to rural life. The movement of this population from the urban centres will reduce demand on public services search schools and health facilities. The number can increase if the program is seen as a success by IDPs who will remain in urban areas hence preferring the return option.

It can be concluded that the use of Knowledge Tables is quite easy and handy as it is helped local experts to participate in decision making where they allocated the available land resources to various livelihood zones. The allocated resources included soil characteristic and rainfall.

6.2. Recommendations

Recommendations specific to the Study area:

1. More stakeholders should be included in the modeling process especially at the suitability mapping process. Local farmers have to be involved while filling knowledge tables. The outcome will be more reflective if the focus group discussion can be expanded to include more experts with integration of the farmer’s knowledge who have been practicing farming.
2. The Livestock migratory have been a bone of contention, in the Study areas. The movement of livestock along these routes which are not clearly marked has been a source of discomfort and conflicts. A though collaborative assessment of the routes has be done and the proper and feasible spatial location identified. Marking of these routes will reduce possible conflicts.
3. In this study it was assumed that the production in the livelihood zones will be dictated by the rainfall. A study on the possible source of water including rain water harvesting and ground water utilization will improve production. It is therefore recommended future studies should put in consideration other sources of water including underground water and rain water harvesting.
4. For the policy options it is recommended that IDPs be involved in making choice in the of proffered settlement areas.

Recommendations on methodological approach:

5. Field verification of the collected secondary data could also improve the accuracy of suitability maps. It is therefore recommended that ground sampling, of soils and use of experimental field in the study areas have to be used.
6. Proper stakeholders’ analysis should be done; this will allow the researcher to get the experts who have first hand information on the topic under discussion.
7. For the stakeholders to participate fully in the modeling process advance trained or communication should be done. This will enlighten the stakeholders on their roles and even give them room to prepare for the process.

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APPENDICES

Appendix A: Exchange ratios for livestock in tropical livestock units based on metabolic body weight.

Body Weight	Metabolic weight ($Kg^{0.75}$)	TLU
5	3	0.05
10	6	0.09
15	8	0.12
20	9	0.15
25	11	0.18
30	13	0.20
35	14	0.23
40	16	0.25
45	17	0.28
50	19	0.30
60	22	0.34
75	25	0.41
100	32	0.50
125	37	0.59
150	43	0.68
200	53	0.85
250	**63**	**1**
300	72	1.15
350	81	1.29
400	89	1.42
450	98	1.55
500	106	1.68
600	121	1.93
700	136	2.16

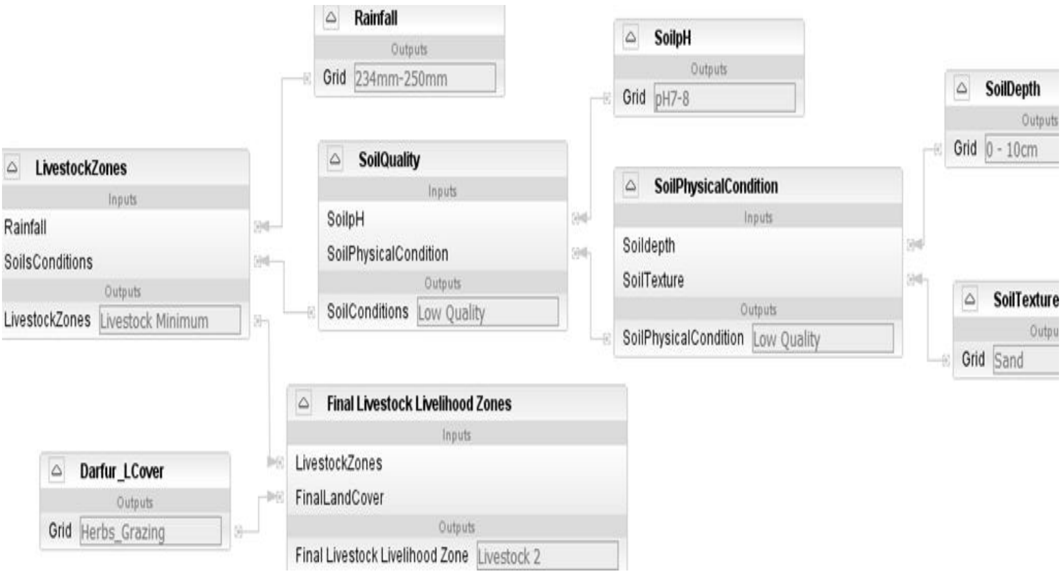
Source: FAO. http://www.fao.org/ag/againfo/programmes/en/lead/toolbox/Mixed1/TLU.htm

Appendix B: Livestock Production in South Darfur

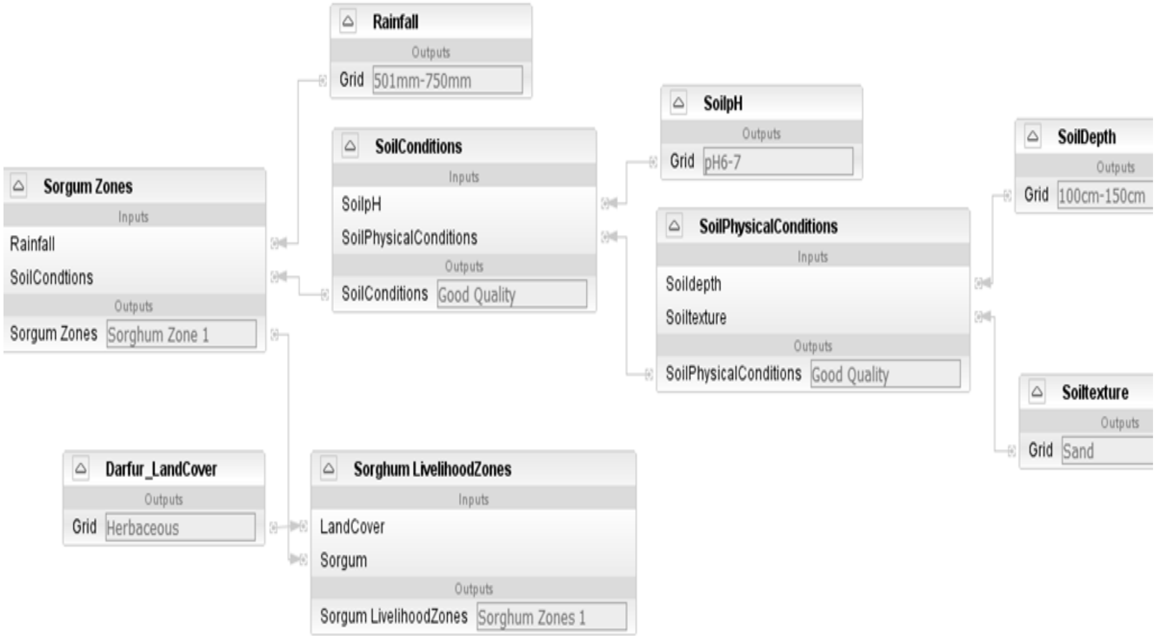
Livestock production in South Darfur for the year 1998, 2008 and 2011						
	YEAR					
	1998		**2008**		**2011**	
livestock	**Heads***	**TLUs**	**Heads****	**TLUs**	**Heads*****	**TLUs**
Cattle	3,435,209	2,404,646	4,163,313	2,914,319	4,269,336	2,988,535
Camels	145,198	145,198	103,100	103,100	95,952	95,952
sheep	3,136,571	313,657	3,768,745	376,875	3,966,637	396,664
goats	2,663,309	266,331	2,974,176	297,418	4,944,086	494,409
total		**3,129,832**		**3,691,711**		**3,975,560**
	Data Source for 1998* and 2008**: (FAOSTAT 2012)				***projected values	
Note: 1 camel = 1 TLU, 1 cattle =0.7 TLU, 1 sheep=0.01 TLU, 1 goat = 0.01 TLU and 1 TLU=250kgs of live animal (FAO 2012 and Jahnke, H. E. 1982)						

Appendix C: Suitability Criteria for Livestock Optimum Production Zone

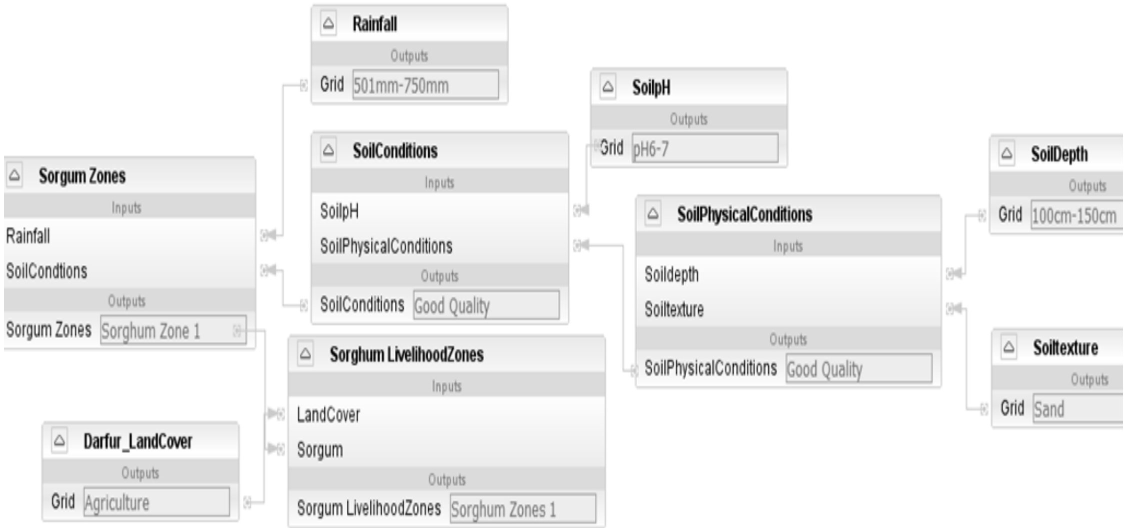
Appendix D: Suitability Criteria for Livestock Minimum Production Zone



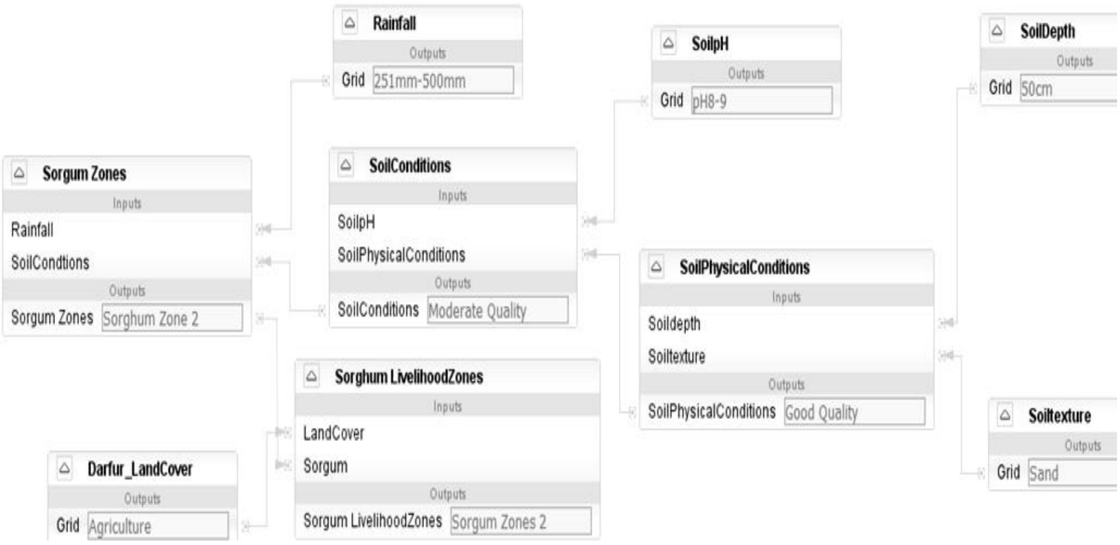
Appendix E: Suitability Criteria for Sorghum Optimum Production Zone



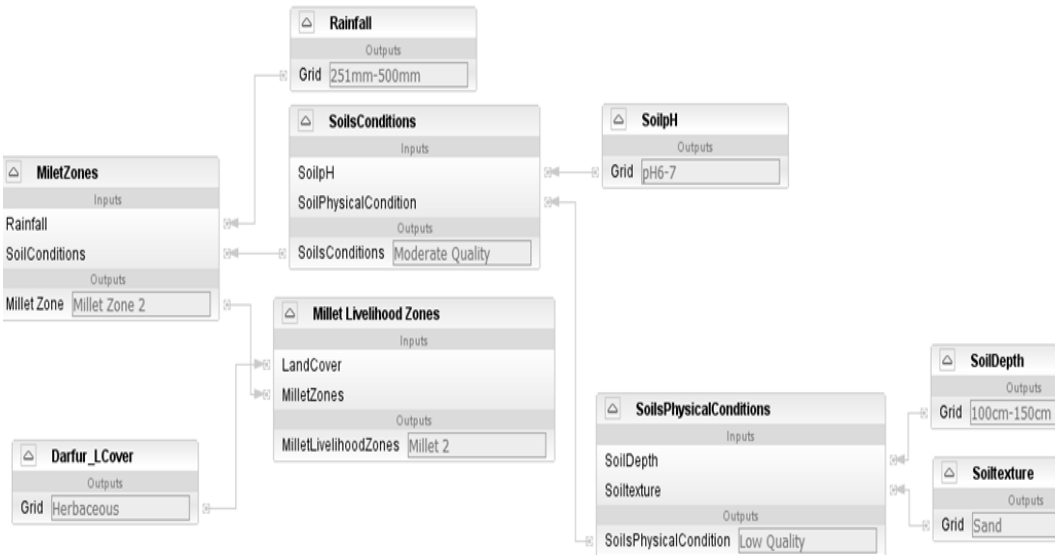
Appendix F: Suitability Criteria for Sorghum Optimum Production Zone



Appendix G: Suitability Criteria for Sorghum Minimum Production Zone



Appendix H: Suitability Criteria for Millet Production Zone



Appendix I: Suitability Criteria for Millet Production Zone