International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Biomass Availability within the Ecosystem of Livestock-Water-Productivity (LWP) in the Free Rangelands of the Blue Nile Basin of Sudan

Muna, M.M. Ahmed[1], Donia, H.K[2]

[1]institute of environmental studies, University of Khartoum
[2]Ministry of agriculture, Federal state, planning and statistics department

Abstract
The present study was initiated with the objective to investigate crop-livestock water interaction ecosystem where crop residue was selected as optimum food sourcing which is considered as biomass supplement for animals as it requires no additional water in the system where water enters as rainfall and is depleted through evapotranspiration from the plant or direct evaporation from the soil. Livestock water productivity (LWP) was used to indicate water utilized by the animal which is converted to useful products. Parameters measured were: biomass availability from rangelands and crop residues, supply versus demand for the different animal species and treated crop residues to improve animal performance. Trends in rangeland productivity, crop residue biomass and animal's number and herd structure were observed through the years 2014 – 2018 in seven the localities of Sennar state. Total biomass in the form of crop residues and biomass from range was calculated to determine the livestock demands during the dry season; this was done utilizing Tropical livestock unit (TLU) equivalents and basal metabolic rates. Rangeland status was estimated using remote sensing. Crop production was projected for the summer season from the 'Ministry of Agriculture', using multiple sets of Sentinel-2 and Landsat images (in case of cloud cover in the Sentinel-2 image). Further available crop residues were calculated as: 1kg sorghum seed gives 3kg sorghum straw, 1kg millet seed gives 3 kg straw, 1kg ground nut pod gives 2kg straw. The biomass demand was calculated based on the data from Arab Organisation for Agricultural Development that annual animal unit demand is 2.4 tons. This was translated to the biomass demand of approximately 6.5 kg per day per animal unit. The International Livestock Research Institute (ILRI) estimation of animal maintenance energy of 11,000 Kcal per LTU per day for grazing cattle in Africa, for maintenance energy, would require about 5 kg per tropical livestock unit per day of feed for maintenance. The amount of evapotranspiration required to produce this feed would be about 1.25 cubic meters per TLU per day or 450 cubic meters per tropical livestock unit per year. This compares with 25–50 liters a day or 9–18 cubic meters per tropical livestock unit per year for drinking water. Hence for each locality biomass demand was calculated as: No. of AU in the locality x 6.5 kg dry matter/day. Animal experimentation utilized dairy goats fed with straws treated with 5% urea and Student t-test was used to obtain the significance between the control and treated animals.
The results showed that contribution of crop residue to the biomass was very important and increased over the years for Abu Hougar was maintained around 90%, for El Dali increased from 3% to 888% in year 2018. For El Dinder , and El Souki and Sinnar increased to reach 454% and 775%, 219% respectively in the year 2018. However, Singa showed a decline in crop residue from 526 to 163%. Biomass demand

versus supply over the years were variable for the different localities, generally showing a steady increase with high or low deficit according to the locality animal number or herd structure, expansion of mechanized farming or soil degradation. Availability of the biomass showed high variability among the localities. Demand versus supply showed deficits over the years; Abu Hougar deficits were observed in the years 2014, 2016, and 2018, Both El Dali and El Dinder at 2018, El Souki at 2017, Sharg Sinnar at 2014, Singa 2015, 2016, Sinnar 2017. Animal's number changed slightly over the years. Except for Sharg Sinnar, sheep population was the highest while camels were the lowest in all localities, but herd structure was not the same where cattle, sheep and goats were comparable at El Souki and Singa. Camels and goats were comparable at El Dinder. Abu Hougar and El Dali showed lower population of cattle and goats. At Sinnar, goats and cattle population was nearly the same. Sharg Sinnar showed comparable ratios for sheep, cattle and goats. As for animal experimentation where dairy goats were used to test the crop residue treated with urea on food intake and milk yield, it was found that while food intake decreased significantly ($P<0.05$), milk yield increased significantly ($P<0.001$). It could be concluded that for crop-livestock-water ecological system, crop residues as feed sourcing is considered the optimum biomass supply for animals during the summer season where there is no additional water is required, LWP could be increased with better management of soil degradation, water runoff and rangeland conservation.

Keywords: Rangelands' Biomass, Supply And Demand, Livestock

1. Introduction

Availability and access to fresh water will likely constrain future food production in many countries. Thus, it is frequently suggested that the limited amount of water should be used more productively. The threat of water scarcity in sub-Saharan Africa is real, due to the expanding agricultural needs, climate variability and inappropriate land use. Livestock keeping is the fastest growing agricultural sector, partly because of increasing and changing demands for adequate, quality and diverse food for people, driven by growing incomes and demographic transitions. Besides the economic benefits, rising livestock production could also deplete water and aggravate water scarcity at local and global scales. The insufficient understanding of livestock–water interactions also led to low livestock productivity, impeded sound decision on resources management and undermined achieving positive returns on investments in agricultural water across sub-Saharan Africa. Innovative and integrated measures are required to improve water productivity and reverse the growing trends of water scarcity (Peden *et al.*, 2007).

Most of the Nile Basin's livestock reside in Sudan, where they sustain millions of poor farmers and herders, contribute about 20 per cent of national GDP, and form a significant part of Sudan's non-oil exports. The majority of the country's domestic animals (including sheep, goats, cattle, camels and equines) are found in the Central Belt of Sudan an area composed of arid and semi-arid livestock-dominated and mixed crop–livestock systems livestock-dominated grazing areas (LGA) and rain-fed mixed crop–livestock systems (MRA), irrigated mixed crop–livestock farming, (MIH) and irrigated mixed crop–livestock farming (MIA) and urban livestock production in the Nile Basin.

Rainfall ranges from below 100 mm yr–1 in its far north to about 800 mm yr–1 in its far south. Limited surface water is locally available from the Nile, its tributaries and other seasonal rivers. The Central Belt encompasses 13 states, covers 75 per cent of the area of the Sudan, accommodates 80 per cent of its people and 73 per cent of its total livestock, and sustains most of the crop production. The belt's link to the Nile Basin is strong in terms of livestock production in schemes irrigated from the Nile, livestock mobility between rain-fed and irrigated areas and livestock trade with other Nile Basin countries (Faki *et al.*, 2008). For example, the only practical way livestock can access vast grazing lands during the more favourable rainy season is by having access to the relatively nearby Nile's blue water system in dry periods. Transhumance and nomadic modes of production, thriving on natural pastures, is the ruling practice, but cropland expansion increasingly impedes pastoral mobility.

The water productivity concept evolved from separate fields. Crop physiologists originally defined water use efficiency as carbon assimilated and crop yield per unit of transpiration (Viets, 1962), and then later as the amount of produce (biomass or marketable yield) per unit of ET. Irrigation specialists have used the term water use efficiency to describe how effectively water is delivered to crops and to indicate the amount of water wasted.

2. Materials and Method

2. Area of study

The area of the study lies in Sinnar state located within the Savanna belt of south central Sudan with its characteristic long dry season. Sinnar State is surrounded by Al-Gazira State in the north, The Blue Nile State in the south, Al-Gedaref State and the Sudanese Ethiopian borders in the east, and the White Nile State and the Upper Nile State of South Sudan in the west. Singa is the capital of Sennar State; another significant town is Sennar, the largest city in the state. Other commercial towns include El-El Soukii and El-Dinder. 7 localities that constituted the state were investigated.

2.1 Biomass measurement

Total biomass in the form of Crop residues and biomass from range was calculated to determine the livestock demands during the dry season. One advantage of using crop residues for feed lies in the fact that this feed source requires little or no additional water for production compared with that used to produce the crop.

Crop Acreage was estimated and crop production was projected for the current summer season for the 'Ministry of Agriculture', using multiple sets of Sentinel-2 and Landsat images (in case of cloud cover in the Sentinel-2 image). Further available crop residues were calculated for the different crops utilizing the following table (2.1)

2.2. Animal demand from biomass

The Biomass Demand was calculated at 'Locality Level' for the different states of the study area. The Biomass Demand was calculated based on the data from Arab Organisation for Agricultural Development which says that annual animal unit demand is 2.4 tonne. This translates to the biomass demand of approximately 6.5 kg per day per animal unit. The following table shows the state wise summary of daily and annual biomass demand within the study area-

Calculation biomass demands from biomass to meet animals' requirements was done as follows:

(i) A synthesis by the International Livestock Research Institute (ILRI) suggests an estimate of animal maintenance energy of 11,000 Kcal per tropical livestock unit (LTU) per day for grazing cattle in Africa, for maintenance energy, would require about 5 kg per tropical livestock unit per day of feed for maintenance. The amount of evapotranspiration required to produce this feed would be about 1.25 cubic meters per tropical livestock unit per day or 450 cubic meters per tropical livestock unit per year. This compares with 25–50 liters a day or 9–18 cubic meters per tropical livestock unit per year for drinking water (table 2.2). The actual energy use and water for feed will be about double this when factoring in growth, work, lactation, reproduction, herd structure, and thermoregulation per animal unit.

(ii) Biomass Demand per Locality = No. of AU in the locality x 6.5 Kg Dry Matter/day

Table 3.2.3 Tropical livestock unit equivalents and basal metabolic rates

Species	Tropical livestock units per head	Basal metabolic unit (calories per tropical livestock unit)	species	Tropical livestock units per head	Basal metabolic unit (calories per tropical livestock unit)
Camel	1.4	4,046	Pig	0.20	6,581
Cattle	1.0	4,401	Sheep or goats	0.10	7,826
Donkey	0.5	5,234	Poultry (chicken)	0.01	13,917

Source: FAO 2004; Kleiber 1975; Jahnke 1982.

2.3 Rangeland status

Using remote sensing for NDVI, rangeland biomass, (non-crop, non-forest) (NCNF Vegetation) was calculated during Late August/September (Sq km) compared with percentage cover for the same season and compared with those during October/ November. To find out about the available food resources in each locality, total crop residues and rangeland biomass (non-crop/non forest vegetation) (tons) for the summer season was calculated. Correlations will be carried out between Pasture Biomass and NDVI.

Table 3.2.1 crop yield of crop residue

Crop	Amount of Produce	Crop Residues
Sorghum	1 Kg Seeds	3 Kg Straw
Millet	1 Kg Seeds	3 Kg Straw
Ground Nut	1 Kg Pods	2 Kg Straw

Results

3 animal population

As shown in table 3, the state of Sinnar is hosting a large wealth of animals with varying numbers for each locality. More than 3 millions for El Dali and one million in both El Dinder and Abu Huggar, which were sustained throughout the year. The numbers varied from than 6000 (Sinnar), to more than 4000 (El Suki), and more than 3000 for both Sharg Sinnar and Singa. Throughout the years, the number did not vary much, however, when surveying the total numbers for all localities throughout the years, there was a great reduction in animal populations from more than 8 millions in the years 2014 to 2016 to more than 3000

3. 1Biomass (2018)

3.1.1Source from rangeland and crop residues

Biomass sources from rangeland and crop residues is shown in table 3.1.1 for the year 2018, it could be seen that for most of the localities, crop residues provide most of the biomass El Dali, El Soukii and EL Dinder then Sinnar and Singa providing more than 100%. 90% for Abu Hougar and 50% for Sharg Sinnar.

3.1.2 Biomass demand, total estimated availability and demand versus supply

Biomass availability, demand versus supply, showed that three localities were deficient in biomass to satisfy animal demand, these were Singa, Sinnar and Abu Hougar with the highest was for Singa (-88418 tons) Sinnar (-385928 tons) and then Abu Hougar (-504982 tons) corresponding to percentages as: for Sinnar (-273%), Abu Hougar (-117%) and Singa (-56%). Availability of the biomass was the highest in Sharq Sinnar supplying 64.6% of the demand, then El Soukii (34.7%), El Dali (29.5%) and El Dinder (20.3%) (Table 4.2.1). Biomass demand compared to the total estimated showed that, it was highest for El Dali, followed by Sinnar, Abu Hougar and Singa (figure 4.2.1), and the demand versus supply showed similar trends (figure 3..1.1).

3.2 Biomass (2017)

3.2.1.Biomass from rangelands and crop residues

Crop residues for the summer season showed higher percentages for Singa (315%), (92%) for Abu Hougar, (81%), with very lower percentages for the rest of the localities. On the other hand, biomass from range land was highest for El Dali and EL Dinder then Sinnar and Sharg Sinnar, El Souki with Singa showing the lowest biomass from range land (Table 3.2.1)

3.2.2 Biomass demand, total estimated availability and demand versus supply

Biomass demand as compared to the total estimated one, showed a surplus in Abu Hougarof about (2.3%). In, Sinnar, El Dinder and Sharg Sinnar, the surplus accounted for 96%, 95%, and 92% respectively. The deffiencies were observed in El Souki (-171%) and Singa (-109%) and El Dali (-98%) (Table 3.2.2).

Table 3. animals' number in each for each locality

Locality	Year 2014	Year 2015	Year 2016	Year 2017	Year 2018
Shargh Sinnr	307,885	314,168	320,375	326,800	333,336
Sinnar	655,462	668,839	680,331	693,937	707,816
El Dinder	1,421445	1,450,454	1,469,258	1,498,642	1,528,615
Singa	340,031	346,970	315,369	358,395	365,563
Abu Hougar	1,227,822	1,252,880	1,262,183	1,287,427	1,313176
El Dali	3,6413,88	3,715,702	3,744,764	3,819,658	3,896,051
El Souki	491,818	501,855	508,335	518,501	528,871
Total	8,052,909	8,217,255	8,300,575	326,800	333,336

Table 3.1. Biomass sources from rangeland and crop residues (Ton) at localities of Sinnar state in 2018

LOCALITY	Projected Crop Residue (Summer Season)	Projected Biomass from Rangelands (NCNF Vegetation Summer Season)	Percent crop residue
	Ton	**Ton**	**Percent (%)**
Abu Hougar	3,878,862	429,968	90
El Dali	7,168,750	807,421	888
El Dindir	8,075,000	148,0631	454
El Souki	4,350,000	560,600	775
Sharq Sinnar (Eastern Sinnar)	346,250	689,750	50

Sinja	2,537,500	155,483	163
Sinnar	3,100,000	141,445	219

Table 3.1.1 Biomass demand, estimated biomass available, demand vs supply (tone), demand vs supply (%) by animals in the different localities in Sinnar state (2018)

LOCALITY	Total Estimated Available Biomass	Total Biomass Demand	Demand Vs Supply	Demand Vs Supply
Tonne/Year	Tons	Tons	Tons	Percentage
Abu Hougar	429,968	934,950	**-504982**	**-117%**
EL El Dali	807,421	569,160	238262	29.5%
El Dindir	148,0631	117,900,0	301631	20.3%
El Souki	560,600	365,848	194725	34.7%
Sharq Sinnar (Eastern Sinnar)	689,750	243,900	445851	64.6%
Sinja	155,483	243,902	**-88418**	**-56.9%**
Sinnar	141,445	527,373	**-385928**	**-273%**

***Biomass Demand per Locality** = No. of animal unit (AU) in the locality x 6.5 Kg Dry Matter/day

Table 3.2.1 Biomass sources from crop residues and rangeland (Ton) at Sinnar state in 2017

LOCALITY	Projected Crop Residue (Summer Season)	Projected Biomass from Rangelands (NCNF Vegetation Summer Season)	Percent crop residue
	Ton	**Ton**	**Percent (%)**
Abu Hougar	562,036	609,351	92
EL El Dali	115,9188	34,143,292	3.4
El Dindir	780,299	32,426,206	2.4
El Souki	594,012	726,688	81
Sharq Sinnar (Eastern Sinnar)	169,871	3,623,360	4.6
Sinja	430,555	136,315	315
Sinnar	580,341	17,524,934	3.3

Table 3.2.2 Demands versus supply of the biomass from rangeland for the year 2017 for the different localities at Sinnar state

Locality (Tonne/Year)	Total Biomass Demand (Tons)	Total Estimated Available Biomass (Tons)	Demand Vs Supply (Tons) - 2017	Demand Vs Supply (%) – 2017
Abu Hougar	595,282	609,351	140,68	2.31%
EL El Dali	400,121	341,43292	337,43171	-98%
El Dindir	139,9653	324,26206	310,26552.3	95%
El Souki	197,4583	726,688	-1247894.96	-171%
Sharq Sinnar (Eastern Sinnar)	270,724	362,3360	335,2636.55	92%
Sinjja	285,151	136,315	-148836.15	-109%
Sinnar	560,088	17,524,934	16,964,845	96%

3.3 Biomass (2016)

3.3.1 Biomass from rangelands and crop residues

It could be shown that from Table 3.3.1 crop residues could provide more than 100% for Singa followed by 68% for Abu Hougar, the rest of the localities showed very little and similar percentages

3.3.2 Biomass demand, total estimated availability and demand versus supply for the year 2016

Total estimated biomass demand as to compared to available biomass showed deficit in Abu Hougar (-151458 ton) and in Singa (-153013) corresponding to -25% and -120% respectively. The localities showed surplus, the highest was for Sinnar, El Dali, El Dinder, Sharg Sinnar, and finally El Souki corresponding to 98, 94, 92, 74, and 51% respectively (3.3.2).

3.4 Biomass (2015)

3.4.1 Biomass from rangelands and crop residues

From table 3.4.1, it could be seen that crop residue would provide part of the biomass for the different localities of Sinnar state, it ranged from as high as 62% (Abu Hougar) to 38 and 17% for El Souki and Singa respectively. The other localities showed very little supply

3.4.2 Biomass demand, total estimated availability and demand versus supply

Total estimated available biomass as compared with biomass demand (ton), showed that the highest surplus was found in El Dali and El Dinder corresponding to 93 and 95% respectively. These were followed by Sinnar and Sharg Sinnar corresponding to 88 and 99% respectively. Abu Hougarand El Souki showed provision from the biomass as 74 and 47% respectively. however, it was shown that Singa was the only locality that had deficit in biomass (-102%) (Table, 3.4.2).

3.5 Biomass sources (2014)

3.5.1 Biomass from crop resdiues and rangeland

Biomass supply from crop residues accounted for as high as 416%, 96% and 46% in Singa, Abu Hougar and El Souki to negligible percentages for the rest of the localities (Table 3.5.1)

3.5.2 Biomass demand, total estimated availability and demand versus supply

Higher estimated biomass availability compared to demand was observed in Singa, El Souki and El Dali and then El Dinder, providing 97, 94, 94 and 68% repectively. Deficits were observed in Sharg Sinnar (-138%) and Abu Hougar (-37%). Total estimated available biomass as compared to biomass demand for the year 2014, showed surpples in El Dali, El Dinder, Sinnar, Singa, El Souki and Abu Hougar. The other tow localities showed deficit in biomass supply (table, 4.10.2).

The available estimated biomass was shown to be higher than the demand expcept for two localities (Abu Hougar and Shrag Sinnar). The surpluses corresponded for 97, 94,94, 68 and 2.3% for Singa, El El Dali, El Souki, El Dinder, and Sinnar respectively. The deficit was higher for Sharg Sinnar (-138%) than Abu Hougar (-37%) (Table 3.5.2).

Table 3.3.1 Biomass sources from crop residues and rangeland (Ton) at Sinnar state in 2016

LOCALITY	Projected Crop Residue (Summer Season)	Projected Biomass from Rangelands (NCNF Vegetation Summer Season)	Percent crop residue
	Ton	**Ton**	**Percent (%)**
Abu Hougar	409,684	599,028	68
El Dali	1,222,256	42,756,840	2.9
El Dindir	1,166,666	33,553,850	3.5
El Souki	303,722	779,382	3.9
Sharq Sinnar (Eastern Sinnar)	439,529	480,5176	9.1
Sinja	666,666	126,547	526
Sinnar	940,276	24,314,112	3.9

Table 3.3.2 Biomass demand, total available and demand versus supply for Sinnar state localities (2016)

Locality (Tone/Year)	**Total Biomass Demand (Tons)**	**Total Estimated Available Biomass (Tons)**	**Demand Vs Supply (Tons) – 2016**	**Demand Vs Supply (%) – 2016**
Abu Hougar	750487.3	599028.81	-151458	-25%
El Dali	2326520.8	42756840	40430319	94 %
El Dindir	2465152.1	33553850	31088698	92%
El Souki	376927.6	779382.81	402455.2	51%
Sharq Sinnar (Eastern Sinnar)	1215510.9	4805176	3589665	74%
Sinjja	279560.2	126547.14	-153013	-120%
Sinnar	244381.6	24314112	24069730	98%

Table 3.4.1 Biomass sources from crop residues and rangeland (Ton) at Sinnar state in 2015

LOCALITY	Projected Crop Residue (Summer Season)	Projected Biomass from Rangelands (NCNF Vegetation Summer Season)	Percent crop residue
	Ton	**Ton**	**Percent (%)**
Abu Hougar	355,276	570,682	62
El Dali	1,308,333.3	34,429,604	3.8
El Dindir	1,241,769.2	29,583,382	4.1
El Souki	272,607.2	702,297	38
Sharq Sinnar (Eastern Sinnar)	24,641.0	2,357,188	1.0
Sinja	233,845.3	136,180	17
Sinnar	25,641	11,750,972	0.21

Table 3.4.2. Biomass demand, total estimated availability and demand versus supply (2015)

Locality (Tone/Year)	Total Biomass Demand (Tones)	Total Estimated Available Biomass (Tones)	Demand Vs Supply (Tons) – 2015	Demand Vs Supply (%) – 2015
Abu Houjar	147,073	570,682	423,609	74%
El Dali	2,301,703	34,429,604	32,127,901	93%
El Dindir	1,401,864	29,583,382	28,181,518	95%
El Souki	370,780	702,297	331,517	47%
Sharq Sinnar (Eastern Sinnar)	601,942	2,357,188	2,096,993	88%
Sinja	275,216	136,180	-139,036	-102%
Sinnar	99,531	11,750,972	11,651,441	99%

Table 3.5.1 Biomass sources from crop residues and rangeland (Ton) at Sinnar state in 2014

LOCALITY	Projected Crop Residue (Summer Season)	Projected Biomass from Rangelands (NCNF Vegetation Summer Season)	Percent crop residue
	Ton	**Ton**	**Percent (%)**
Abu Hougar	508,615	528,501	96
El Dali	1,637,170	37,160,496	4.4
El Dindir	118,820	26,472,718	0.4
El Souki	293,800	642,675.	46

Sharq Sinnar (Eastern Sinnar)	64,102	4,598,820	0.1
Sinja	470,085	112,864	416
Sinnar	352,564	22,516,008	1.5

Table 3.5.2 Biomass demand, total estimated availability and demand versus supply (2014)

Locality (Tone/Year)	Total Biomass Demand (Tones)	Total Estimated Available Biomass (Tones)	Demand Vs Supply (Tons) – 2014	Demand Vs Supply (%) – 2014
Abu Houjar	728,180	528,501	-199,679	-37.78%
El Dali	1,992,491	37,160,496	25,098,891	94.81%
El Dindir	1,373,827	26,472,718	438,631	68.25%
El Souki	204,043	642,675	4,343,829	94.45%
Sharq Sinnar	254,990	4,598,820	-156,849	-138.97%
Sinjja	269,712	112,864	21,987,662	97.65%
Sinnar	52,8345	22,516,008	35,168,005	**2.3%**

3.6 Comparison changes across the years for biomass and crop residue

3.6.1 comparison changes in biomass availability and demand over the years (2014 – 2018)

As shown by table 3.6.1, Abu Hougar showed three deficits in biomass for the years 2014, 2016, and 2018, the deficit increased in 2018. In El Dali, a deficit was only detected in 2018. El Dinder showed a minor deficit in 2018. El Souki showed a deficit in 2017, Sharg Sinnar showed a deficit only in 2014, while Singa deficits were in 2015, increased in 2016 then maintained till 2018

3.6.1.1 Contribution of crop residue to the biomass across the years

Contribution of crop residue to the biomass was very important and increased over the years for Abu Hougar the crop residu was maintained around 90%, for El Dali, it increased from 3% to 888% in year 2018. For El Dinder, and El Souki and Sinnar increased to reach 454% and 775, 219 respectively in the year 2018. However, Singa showed a decline in crop residue from 526 to 163%.

Table 3.6.1 Comparing biomass demand (tons), for the different localities over the years (2014 – 2018)

Locality (Tonne/Year)	2014	2015	2016	2017	2018
Abu Houjar	-199,679	423,609	-151,20458	14,068	-350,838
El Dali	25,098,891	32,127,901	40,4303,19	33,743,171	-1,613,052
El Dindir	438,631	28,181,518	31088698	31026552	-2,303
El Souki	4,343,829	331,517	402,455	-1,247,894	168,854
Sharq Sinnar (Eastern Sinnar)	-156,849	2,096,993	3,589,665	3,352,636	245,018
Sinjja	21,987,662	-139,036	-153,013	-148,836	-135,370
Sinnar	35,168,005	11,651,441	24,069,730	16,964,845	-429,844

Table 3.1.1 Table effect of year on crop residue contribution to biomass

Locality	Year				
	2014	2015	2016	2017	2018
Abu Hougar	96	62	68	92	90
El Dali	4.4	3.8	2.9	3.4	888
El Dindir	0.4	4.1	3.5	2.4	454
El Souki	46	38	3.9	81	775
Sharq Sinnar (Eastern Sinnar)	0.1	1.0	9.1	4.6	50
Sinja	416	17	526	315	163
Sinnar	1.5	0.21	3.9	3.3	219

3. Discussion

Water enters an agricultural system as rain or surface inflow. It is lost or depleted through evaporation, transpiration. Transpiration is the primary form of depletion without which plant growth and farm production are not possible. Within the context of water- crop- animal interaction, the advantage of using crop residues for feed lies in the fact that this feed source requires little or no additional water for production compared with that used to produce the crop. (Peden *et al.*, 2007), The highest livestock water productivity (LWP) was observed in the densely populated mixed crop-livestock systems of the Ethiopian highlands while the lowest was found in Uganda's Cattle Corridor. These analyses suggest that LWP increases as a result of agricultural intensification. It could be revealed from the results that crop residues for most of the localities provide more than 100% as a feed source for animals. The differences between the localities could be due to the extent of expansion of mechanized farming. The differences in biomass demands by the animals for the different localities showed the rate of increase of demand could be correlated with the number of animals as was explained in another paper with more details. Three localities showed deficit in rangeland supply and hence demand for animals could be compensated from crop residues, especially for Sinnar which showed the highest deficit (-273%). For the other localities the supply ranged from 64 to 20%. The demand for the biomass could be related not only with the animal number but also with the herd structure where camels and cattle have higher demands than sheep and goats (as shown elsewhere in another paper).

The effect of years on biomass availability showed different trends for the different localities, where a locality like Abu Hougar showed three deficits while others showed only one deficit in different years which could be correlated with agriculture expansion, animal numbers and herd structure as well as the amounts of rainfall received in these years. The demand as compared with supply was variable over the year showing different trends in the different localities. The increase or decrease over the years could be correlated with animals' number and herd structure to match biomass availability. Rangelands deterioration could be related to several factors as fluctuations in rainfall, expansion of mechanized farming, concentration of livestock in certain areas around points causing overgrazing, population growth and deforestation. Many authors proposed the advantage of crop residue and best food source for animals under water shortage and range deterioration (Peden *et al.*, 2007, Chapagain and Hoekstra, 2003). Large Mechanized farming were found in Sinnar and Al-El Soukii and Al-Dinder, where agriculture composed of 70% . In Singa it comprised 65% and only 25% for Sharg Sinnar.

Similar observations were given by two examples under similar conditions of the Nile basin were obtained under Sudan Nile base conditions. It was concluded that: In Gezira large human population generates a high demand for livestock and livestock products. Thus, demand for animal feed exceeds supply. In Gederif, large quantities of crop residues are also available, but, in contrast to Gezira, lack of drinking water restricts livestock-keeping so that feed supply exceeds local demand. In Gezira, strengthening irrigation water management policy and practice that accommodate livestock and crop production is needed in large-scale irrigation. In Gederif, there is a need to either provide drinking water for livestock or transport the feed to locations where animal demand for feed is high Peden *et al.*, 2007). In our example like that of Gezera, due to large animal demands, feeds exceed supply and hence contribution of crop residue is important to supplement animals' feed

References

1. **Chapagain**,A. K. and Hoekstra, A.Y. (2003) *Virtual Water Flows between Nations in Relation to Trade in Livestock and Livestock Products*,Value of Water Report Series no 13, UNESCO, Delft, The Netherlands.
2. **Faki**, H., El-Dukheri, I., Mekki, M. and Peden, D. (2008) Opportunities for increasing livestock water productivity in Sudan, in *Fighting Poverty Through Sustainable Water Use: Volume II*: Proceedings of the CGIAR Challenge Program on Water and Food 2nd International Forum on Water and Food, Addis Ababa, Ethiopia, 10–14 November, CGIAR Challenge Program on Water and Food, Colombo, Sri Lanka.
3. **Peden, D**.,Tadesse, G. and Misra, A. K. (2007) Water and livestock for human development, in *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*, D. Molden (ed.), pp485–514, Earthscan, London.
4. **Peden, D**., Alemayehu, M., Amede, T., Awulachew, S. B., Faki, F., Haileslassie, A., Herrero, M., Mapezda, E., Mpairwe, D., Musa, M. T., Taddesse, G., van Breugel, P. (2009a) *Nile Basin Livestock Water Productivity*, CPWF Project Report Series, PN37, Challenge Program on Water and Food (CPWF), Colombo, Sri Lanka.
5. **Viets Jr**., F.G., 1962. Fertilizers and the efficient use of water. Advances in Agronomy 14, 223–264.