TRENDS OF PRODUCTIVITY OF WATER IN RAIN-FED AGRICULTURE: HISTORICAL PERSPECTIVE

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ABSTRACT

In Sub-Sahara Africa, rain-fed agriculture is the dominant source of food production. It is likely going to remain so for the next foreseeable future. However, yields from rain-fed agriculture are often very low. But there is an enormous opportunity to raise crop yield of rain-fed agriculture especially by focusing on the aspect of increasing productivity of water. In order to formulate and adopt appropriate and adequate options for increasing productivity of water in rain-fed agriculture, there is a need to have an historical hindsight to the trend of productivity of water in rain-fed agriculture. In this paper, a historical analysis of the trend of productivity of water (PW) for five crops cultivated under rain-fed condition in Mbarali District, Mbeya Region, Tanzania, was carried out using secondary data. The crops include: maize, sorghum, beans, potato, and groundnut. The $PW_{(rainfall)}$ for maize, sorghum, potato, beans, and groundnut had peak values of 0.49kg/m^3 in 1993/94, 0.47 kg/m^3 in 1994/5, 3.06kg/m^3 in 1993/94, 0.33kg/m^3 in 1996/97, and 0.20kg/m^3 in 1994/95 cropping seasons, respectively. Evapotranspiration deficit occasioned by either mid cropping-season dry spell or early cessation of rainfall and low rainfall utilization efficiency are the primary drivers of PW in rain-fed agriculture in the area. Other factors that are usually put forward by agricultural stakeholders in the region, which include poor soil nutrient and lack of proper crop management, are secondary and could be considered as spill over effects from these primary drivers of PW.

Key Words: Productivity of water, crop yield, crop water requirement, evapotranspiration deficit

Introduction

About 95% of current world population growth occurs in tropical developing countries whose rural economy is based on rainfed agriculture *(Rockstrom et al., 2003).* In Sub-Sahara Africa, rain-fed agriculture has been the dominant source of food production. It is likely going to remain so for the next foreseeable future sincemore than 95% *(FAO, 2000, Rosengrant et al., 2002)* of the agricultural farmland is under rain fed agriculture. The common characteristics of rainfed agriculture especially in the tropical and the semi- arid agro ecosystem are low crop yields that are far below potential yields attainable in the regions, and high on-farm water losses. For example, in tropical and semi- arid Sub-Sahara Africa, cereal yields from rainfed cultivation are generally around 1 t ha^{-1} *(Rockstrom, 2001)* as against potential yields of 3-5 t ha^{-1} *(Barron, 2004)* attainable in the region.

This wide yield gap suggests that there is an enormous opportunity to raise crop yield of rain-fed agriculture. According to McCalla (1994) and Young (1999), there is limited new land to be put under agriculture, contrary to the last three decades, where the bulk of food production in Sub-Sahara Africa came from expansion of agricultural lands. The opportunities to increase crop yield under rain-fed agriculture strongly rest on focusing our attention on maximizing yield per unit of water.

In order to formulate and adopt appropriate and adequate options for increasing productivity of water in rain-fed agriculture, it is worthwhile to look at the performance of this sector by carrying out a trend analysis using past. Such hindsight will enable us to identify possible factors that dictate productivity of water in rain-fed agriculture and their magnitude.

The primary objective of this paper therefore is to show the historical trends of productivity of water (PW) for selected crops commonly cultivated under rain-fed and identify the forces dictating PW. The crops include: maize, sorghum, beans, potato, and groundnut. The case study is that of Mbarali District of Mbeya Region, Tanzania.

Methodology

The location of the study area

The Mbarali District, which lies on between latitudes 7^{0}48' and 9^{0}25' South, and longitudes 33^{0}40' and 34^{0}09' East, is one of the districts of Mbeya Region in Tanzania. The District lies in the heart of the plains of the Great Ruaha River Basin. The economic of the district is agrarian- based, with more than 80 % of the adult population involved in farming. Crop production in the District relies largely on rainfall. Beside paddy rice that is cultivated within the formal and indigenous irrigation schemes in the District under supplementary irrigation, other corps cultivated in the district under rainfed includes maize, sorghum, potato, beans, and groundnut. The study reported here was focused on the trends of productivity of water for these crops.

Sources of climatic and crop yield data

In order to develop the historical trend of productivity of water for the rainfed crops, weather data comprising of rainfall, temperatures, relative humidity, sunshine hours and wind speed were obtained from two weather stations within the district. These weather stations are the Kapunga weather station and the Igurusi weather stations. Weather data for a period of 11 years (cropping seasons of 1989/90 to 1999/2000) were used. The crop yield and area cultivated to these major rainfed crops were obtained from the archives of the Mbarali District Agricultural Office. Annual records of the crops yield and the total area cultivated to each crop during the cropping season are kept in District Agricultural office.

Simulation of crop water requirements and water use

The weather data (rainfall, maximum and minimum temperatures, relative humidity, wind speed and sunshine hour data) obtained from the weather stations was input into the FAO CROPWAT model (Smith et al., 2000) to generate the crop water requirements and crop water use (actual evapotranspiration) for each crop and for each year from 1989/90 to 99/2000 cropping seasons. The crop parameters required as input data in the model, which include crop coefficient (Kc), rooting depth and depth of moisture extraction, were assumed to be the default data in the CROPWAT model. The only crop parameters inputted were planting dates and length of crop growing period for each crop, which were adjusted to the cropping calendar in the study area. The cropping calendar for the crops, especially as per planting dates were dictated by the period of the onset of rains, which varies from third dekad of November to second dekad of January. In the simulation model planting dates for the crops were assumed and taken to be from the period when the rainfall is established. On the average, most of the rain-fed crops are planted between the second dekad of December and the first dekad of January.

Computation of crop water productivity

Crop Water Productivity was calculated for each crop for each year. The crop water productivity under rain-fed condition (PW_{rf}) was expressed as:

$PW_{(rainfall)}$ = crop yield (kg)/ rainfall in the cropped area (m^3). .... (1)

The crop water productivity of effective rainfall (PW_{erf}) was expressed as:
$PW_{(erf)}$ = crop yield (kg) / effective rainfall in the cropped area (m^3)..... .. (2)

The crop water productivity of water use (PW_{eta}) was expressed as:
$PW_{(ETa)}$= crop yield (kg)/crop water use (m^3)....................................(3).

Results and Discussion

Rainfall

Table 1 shows the average of the monthly mean weather data (except rainfall, which was average monthly total) from the two stations for the cropping seasons under review. Tables 2 shows the rainfall data from the weather stations from 1989/90 to 1999/2000 cropping seasons. The annual rainfall was 422 mm in the 1996/97 cropping season and 1460mm in the 1989/90 cropping season. The mean annual rainfall for the cropping season is 736.7mm. The high record of rainfall in 1989/90 cropping season was due to torrential rainfall in some few days in the month of March as observed from the daily weather records. The rainfall recorded in March alone was 868mm, which was higher than the total rainfall of the other months in the cropping season put together.

Crop Yield

Table 3 a, b and c (see appendix) shows the crop yields and cropped area for 1989/90 to 1992/93, 1993/94 to 1996/97, and 1997/98 to 1999/2000 cropping seasons, respectively. The total area cultivated each year to maize, sorghum, and potato ranged from 10,000 ha to 34,000 ha; 450 ha to 3,400 ha; 550 to 4800 ha, respectively. The area cultivated to beans and groundnut ranged from 720 ha to 6000ha and 2000 ha to 10,000 ha, respectively. The size of the area cultivated to any of the crop may have been largely influenced by the rainfall amount, the time of the on-set of rains, farmers' preference which is influenced by his labour capability and market value of the crop in the previous year.

Crop water requirement and water use

Table 4 (see appendix) shows the crop water use, evaptranspiration deficit and crop water productivity (PW) for the rain fed crops for the cropping seasons. Crop water use were found to be appreciably lower than crop water requirement for all the crops in all the cropping seasons under consideration except in 1995/96 cropping season where the differences were quite smaller. Crop water use was within the range of 180 mm and 375 mm/season for maize; 160mm and 360 mm/season for sorghum; 320mm and 450 mm/season for potato; 220 mm/season and 320 mm/season for beans, and 175mm and 430 mm/season for groundnut. The values in the lower range were experienced in the 1994/95 cropping season. This may be attributed to low amount of rainfall in March and April. The values in the upper range were experienced in the 1995/96 cropping season, which experienced early on-set of rains and good amount of rainfall in the throughout the cropping season. The average crop water requirements for rainfed maize, sorghum, potato, beans, and groundnut were: 378mm, 359mm, 484mm, 344mm, and 471mm per season, respectively.

Evapotranspiration deficit range from 5.61mm to 202.56mm for maize; 4.46mm to 206.5mm for sorghum; 5.66 to 192.66mm for millet; 74.46 to 199mm for potato; 29.06 to 61.8mm for beans; 75.26 to 258.78mm for sunflower, and 43.58mm to 315.26mm for groundnut, respectively. These deficits are associated with low rainfall, midseason drought or early cessation of rainfall. The 1994/95 cropping season was characterised by late on-set of rains, with only 60mm depth recorded in December, low rainfall in March recording 84.6mm depth, and early withdrawal or cessation of rain in April. The late take-off of rains may have delayed land cultivation and planting till late December to early January. Low rainfall in March and early withdrawal of rains in April led to high evapotranspiration deficit, and consequently low yields. The same trend was noticed in the 1996/97 and 1989/99 cropping seasons, which also recorded very high evapotranspiration deficits and low crop yields.

Table 1. Mean Monthly climatic data for Mbarali District

Month	Rainfall	Max. Temp	Min Temp	Rel. Hum	Wind Speed	Sunshine
	mm	C	C	%	Km/day	Hr
November	33.6	30.9	19.5	61.2	217	9.6
December	122.4	30.6	18.6	76.3	138.2	7.3
January	169.1	28.3	18.4	78.9	79.6	5.8
February	165.4	29.8	17.3	85.8	71.3	5.1
March	168.8	30.2	16.2	78.5	70.6	7.7
April	67.5	30.4	16.3	74.3	102.9	8.9
May	6.7	29.5	13.5	65.8	91.3	9.4
June	0.4	28.5	11.2	56.8	68.1	10.7
July	0	28.9	9.2	55.9	119.6	10.7
August	0	29.7	11.2	59.7	177.9	9.7
September	0.7	30.9	12.1	58.3	174.7	10.5
October	2.1	32.3	16.9	58.9	183.2	9.8
Total	736.7					

Table 2. Total Monthly rainfall from the Weather station2 (1989/90-99/2000 cropping seasons)

Season	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00
November	63	5.4	9.25	39.5	16.7	15.3	0	0	0	0	55
December	135.7	104.8	150.8	40.3	25.5	60.7	189.1	98	245.1	48.9	154
January	152	274.9	102.2	202.2	156.25	137.5	161.1	130.5	228.5	116.3	98.0
February	128.5	136.9	214.65	172.1	158.4	140.4	216.7	131.5	120.2	45.6	113.6
March	868	89.8	110.25	146.25	197.25	84.6	79.4	18.5	39.9	152.7	162.9
April	104	204.8	47.25	31.65	13.75	15.4	67.3	43.5	77.4	87	39.5
May	0	2.4	34.1	9.5	1.5	0	0	0	23	0	0.6
June	0	0	3.25	0	0	0	0	0	0	0	0.0
July	0	0	0	0	0	0	0	0	0	0	0.0
August	0	0	0	0	0	0	0	0	0	0	0.0
September	0	7.3	0	0	0.65	0	0	0	0	0	1.3
October	8.8	10	1.5	0	0.2	0	0	0	0	0	0.0
Total	1460	836.3	597.85	641.5	570.2	453.9	713.6	422	734.1	450.5	624.9

The drought in February 1999 was mainly responsible for the crop failure (and low yields) in the 1998/99 cropping season. The season experienced late onset of rains so that planting was in late December and early January. The drought spell met the crops at their full vegetative and early flowering growth stages and had severe impact on crop yield. Historically, it was said that many farmers were so despised that they abandon their fields. The delusion in that season may be responsible for the cultivation of lesser area in the 1999/2000 cropping season, either because they have lost their capital or were not willing to take risk. The total area cultivated to these major crops was only 17,050 ha. This was the least area ever cultivated to the major rainfed crops for the 11 cropping seasons under review. It may also be noticed that when there is early onset of rains and planting was done in first and second decade of December, drought spell in March or early cessation of rains in April have little impact on crop yield, even though evapotranspiration deficits may be high.

This is because grain crops like maize; sorghum, millet and beans would have entered into their maturity growth stages at this period. This explains why the 1997/98 cropping season good yields despite fairly high evapotranspiration deficit.

Although, low yields in rainfed crops in the area is commonly attributed to farmers not planting high yielding crop varieties and not using of fertilizers, high evapotranspiration deficits as noticed across the years and for all the crops may be the true cause of low yields. With high yielding varieties and adequate fertilization crop yields will still turn out to be low if crop water requirement are not met. In many cases the local crop varieties are more adaptable to moisture stress than the improved, high yielding crop varieties

Crop Water Productivity Trend of Rainfed Crops

Figures 1(a-e) show the trend of crop water productivity (kg/m^3) for each crop across the cropping seasons under review. The crop water productivity of rainfall ($PW_{(rf)}$) varies from 0.19kg/m^3 in 1989/90 to 0.49kg/m^3 in 1993/ 94 cropping season for maize. The crop water productivity of rainfall for sorghum varies from 0.06kg/m^3 in 1989/90 to 0.47kg/m^3 in 1994/95 cropping season. The crop water productivity of rainfall for potato, beans and groundnut varied from 0.712 kg/m^3 in 1989/90 kg/m^3 to 3.07 kg/m^3 in 1993/94, 0.085 kg/m^3 in 1989/90 to 0.328 kg/m^3 in 1996/97, and 0.055 kg/m^3 in 1989/90 to 0.204 kg/m^3 in 1994/95, respectively.

The crop water productivity of water use (PW_{ETa}) for maize varies from 0.33kg/m^3 in 1998/99 to 0.99kg/m^3 in 1997/98 cropping season. The crop water productivity of water use (PW_{eta}) for sorghum varied from 0.25kg/m^3 in 1991/92 to 0.97kg/m^3 in 1994/95 cropping season. And the crop water productivity of water use varied from 1.44 kg/m^3 to 4.23 kg/m^3 for potato, 0.147 kg/m^3 to 4.96 kg/m^3 for beans, and 0.11 kg/m^3 to 0.398 kg/m^3 for groundnut.

The trends did not show very close similarities among the crops. This implies that the circumstances that may induce the crops to attain peak PW were not the same for all the crops. However, the least values of $PW_{(rf)}$ for the five crops were recorded in 1989/90 cropping season; maize and potato attained peak $PW_{(rf)}$ in 1993/94 cropping season, while sorghum and groundnut attained peak $PW_{(rf)}$ in 1994/95 cropping season. Sorghum and groundnut also attained peak $PW_{(ETa)}$ in the same cropping season. The 1989/90 cropping season experienced the highest amount of rainfall with some torrential rainfall in March. These torrential rainfalls only generated runoff, and were not beneficially used by the crop to increase yield or water use. More so, since there was early on-set of rains, planting would have started in the first or second decade of December. From late March, crop would be attaining maturity. High rainfall in April may not necessarily increase crop yield. The implication of torrential rainfall vis-à-vis low PW is that such high values of rainfall only increased the denominator of the PW expression, without any added value to the numerator, the crop yield. Hence low PW. Therefore, low values of $PW_{(rf)}$ may not necessarily be due to poor crop yield but low rainfall utilization efficiency.

The trends also show that high PW may be obtained under poor crop yield with low crop water use and high evapotranspiration deficit. This is the case with groundnut and sorghum in the 1994/95 cropping season. The yield of groundnut was 0.7 t/ha, and crop water use was 175.95mm/season, with evapotranspiration deficit of 315.25mm as compared to 1.2t/ha and crop water use of 308.43mm/season in 1998/98 cropping season. Maize also recorded its highest $PW_{(ETa)}$ in 1997/98 with evapotranspiration deficit of 117.18mm and crop yield of 2.6t/ha, as against 1995/96 cropping season where crop yield was 3t/ha and evaptranspiration deficit was 5.61mm. The implication of these trends is that higher PW may not necessarily mean an improvement in efficiency of water utilization or an indication of an increased benefit in crop production.

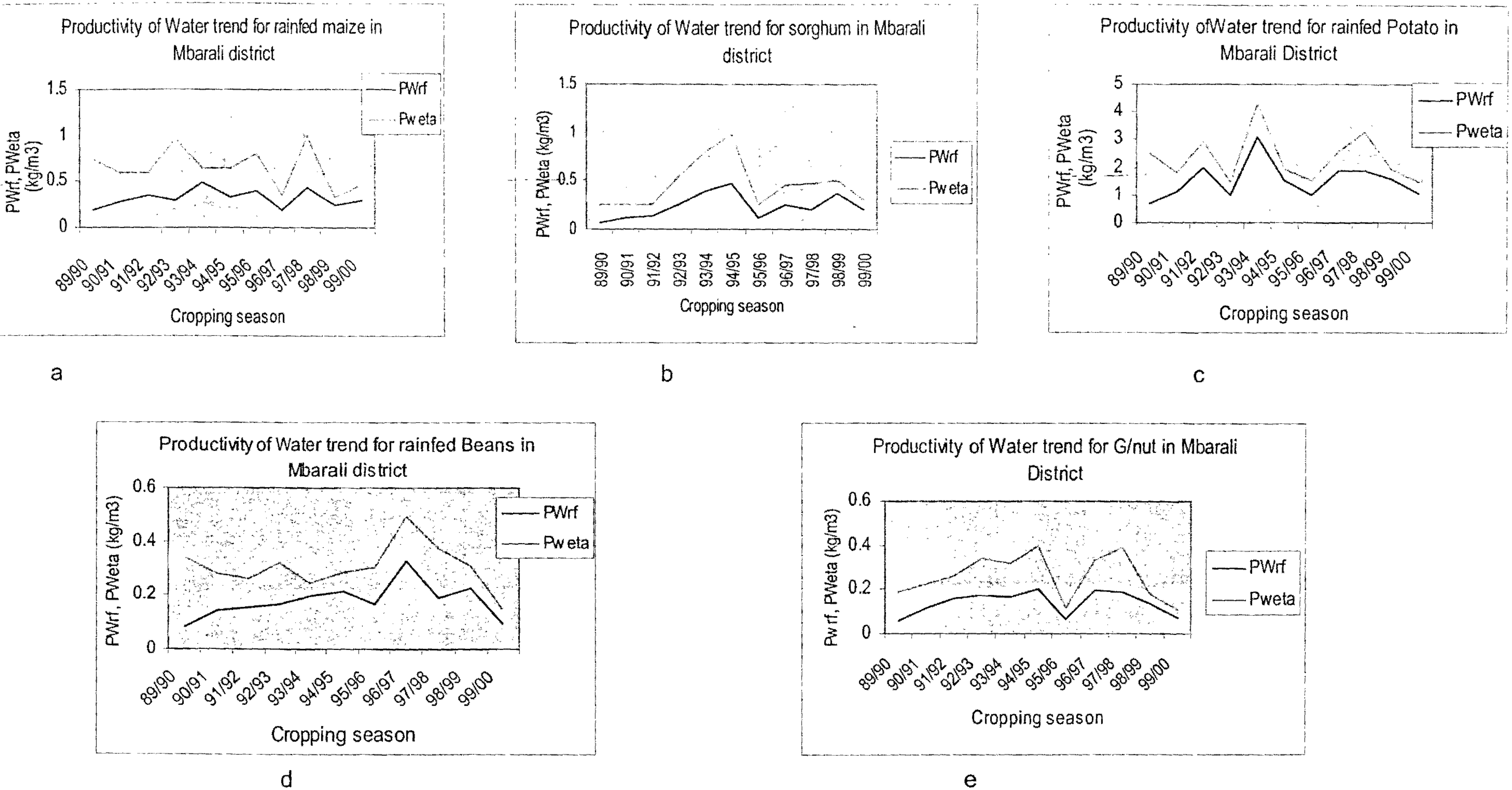

Fig. 1(a-e) Crop water productivity trend for maize, sorghum, potato, beans and groundnut in Mbarali District (1989/90 to 99/2000 cropping season)

Maize and beans recorded the highest value of $PW_{(ETa)}$ in 1997/98 and 1996/97 cropping season, respectively, despite the dry spell recorded in March in the cropping season. Due to early onset of rains, planting could have been done early in December. Since crop growth duration of beans is short, the dry spell did not have impact on bean production. Early planting associated with early onset of rain may also have contributed to better yield and higher $PW_{(ETa)}$ for maize in 1997/98 cropping season. Therefore, early onset of rain is one of the factors that influence the productivity of water in irrigated agriculture in the study area.

Conclusion

The trend of productivity of water under rainfed agriculture is influenced by evapotranspiration deficit, which is caused by mid cropping season dry spell and early cessation of rainfall. Poor rainfall utilization efficiency and early planting also dictate the trend of productivity of water. High PW may not necessarily mean an improvement in efficiency of water utilization or an indication of an increased benefit in crop production, and low PW may not necessarily be due to poor crop yield but low rainfall utilization efficiency.

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Table 3a. Crop yield and area planted to each crop for 1989/90 -1992/1993 cropping season

Crop	1989/90			1990/91			1991/92			1992/93		
	Cropped	Crop Yield	t/ha	Cropped	Crop Yield	t/ha	Cropped	Crop Yield	t/ha	Cropped	Crop Yield	t/ha
	Area (Ha)	Metric ton		Area (Ha)	Metric ton		Area (Ha)	Metric ton		Area (Ha)	Metric ton	
Maize	22700	52210	2.3	28000	50400	1.8	27700	55400	2.0	22888	35798	1.56
Sorghum	490	392	0.8	565	452	0.8	500	400	0.8	757	1011	1.34
Potato	685	6165	9	700	4900	7	735	8820	12	876	4818	5.5
Beans	760	608	0.8	880	704	0.8	800	640	0.8	770	646	0.84
G/nut	2885	2019	0.7	2700	2430	0.9	2300	2100	0.9	3098	2478	0.91

Table 3b. Crop yield and area planted to each crop for 1993/94 -1996/1997 cropping season

Crop	1993/94			1994/95			1995/96			1996/97		
	Cropped	Crop Yield	t/ha	Cropped	Crop Yield	t/ha	Cropped	Crop Yield	t/ha	Cropped	Crop Yield	t/ha
	Area (Ha)	Metric ton		Area (Ha)	Metric ton		Area (Ha)	Metric ton		Area (Ha)	Metric ton	
Maize	21300	51120	2.4	20451	24544	1.20	22346	67035	3.00	25665	17223	0.67
Sorghum	578	1072	1.85	680	1100	1.62	730	660	0.90	800	730	0.91
Potato	556	8891	15.99	1294	7764	6	1000	6700	6.7	1159	8229	7.10
Beans	786	786	1	906	725	0.80	834	800	0.96	840	934	1.11
G/nut	2800	2240	0.8	3200	2240	0.7	2940	1470	0.5	3000	2100	0.7

Table 3c. Crop yield and area planted to each crop for 1997/98 -1999/2000 cropping season

Crop	1997/98			1998/99			1999/2000		
	Cropped	Crop Yield	t/ha	Cropped	Crop Yield	t/ha	Cropped	Crop Yield	t/ha
	Area (Ha)	Metric ton		Area (Ha)	Metric ton		Area (ha)	Metric ton	
Maize	28771	74805	2.60	34984	31486	0.90	10000	15000	1.5
Sorghum	992	1248	1.26	3364	4586	1.36	1000	1000	1
Potato	1660	16600	10	4820	28636	5.94	550	2750	5
Beans	5897	5897	1	6060	4545	0.75	900	360	0.4
G/nut	8364	10037	1.20	9200	4740	0.52	2700	1080	0.4

Source: Mbarali District Agricultural and Livestock Office

Table 4. Crop water use, evaptranspiration deficit and crop water productivity (PW)

89/90 cropping season

Crop	TRF	TER	CWR	ETa	ETd	ACY	PW_{rf}	PW_{erf}	PW_{eta}
	mm	mm	mm	mm	mm	t/ha			
Maize	1226.22	446.99	378.89	310.67	68.22	2.3	0.188	0.515	0.740
Sorghum	1270.41	463.53	360.27	311.21	49.06	0.8	0.063	0.173	0.257
Potato	1264	477.55	461	362.95	98.05	9	0.712	1.885	2.480
Beans	935.69	350.52	310.42	237.5	72.92	0.8	0.085	0.228	0.337
G/nut	1271.61	464.74	473.57	371.71	101.86	0.7	0.055	0.151	0.188

TRF=Total rainfall (from planting to harvesting)
TER= Total effective rainfall
CWR= crop water requirement
ETa= crop water use (actual crop evapotranspiration)
ETd=Evapotranspiration deficit
ACY=Annual crop yield
PW_{rf} =Productivity of water (rainfall)
PW_{erf} =Productivity of water (effective rainfall)
PW_{ETa} =Productivity of water (Evapotranspiration)

90/91 cropping season

Crop	TRF	TER	CWR	ETa	ETd	ACY	PW_{rf}	PW_{eta}	PW_{eta}
	mm	mm	mm	mm	mm	t/ha	Kg/m^3	Kg/m^3	Kg/m^3
Maize	631.81	441.83	378.96	316.78	62.18	1.8	0.285	0.407	0.568
Sorghum	685.49	474.35	360.27	319.48	40.79	0.8	0.117	0.169	0.250
Potato	645.68	455.64	461	390.64	70.36	7	1.084	1.541	1.792
Beans	552.72	376.45	310.44	286.12	24.32	0.8	0.145	0.213	0.280
G/nut	771.32	526.73	473.59	396.92	76.67	0.9	0.117	0.171	0.227

91/92 cropping season

Crop	TRF	TER	CWR	ETa	ETd	ACY	PW_{rf}	PW_{erf}	PW_{eta}
	mm	mm	mm	mm	mm	t/ha	Kg/m^3	Kg/m^3	Kg/m^3
Maize	578.37	427.26	378.96	339.92	39.04	2	0.346	0.468	0.588
Sorghum	571.37	425.48	360.27	320.72	39.55	0.8	0.140	0.188	0.249
Potato	607.31	447.86	461.81	415.08	46.73	12	1.976	2.680	2.891
Beans	520.32	379.7	310.44	304.34	6.1	0.8	0.154	0.211	0.263
G/nut	587.33	441.41	473.59	354.22	119.37	0.91	0.155	0.207	0.258

92/93 cropping season

Crop	TRF	TER	CWR	ETa	ETd	ACY	PW_{rf}	PW_{erf}	PW_{eta}
	mm	mm	mm	mm	mm	t/ha	Kg/m^3	Kg/m^3	Kg/m^3
Maize	530.74	389.9	387.56	264.3	123.26	1.56	0.295	0.401	0.591
Sorghum	519.82	382.35	369.3	244.68	124.62	1.34	0.257	0.349	0.546
Potato	570.88	421.14	461.36	375.36	86	5.5	0.963	1.306	1.465
Beans	502.36	367.43	315.26	262.97	52.29	0.84	0.167	0.228	0.319
G/nut	532.29	391.2	484.21	269.49	214.72	0.91	0.172	0.234	0.339

93/94 cropping season

Crop	TRF	TER	CWR	ETa	ETd	ACY	PW_{rf}	PW_{erf}	PW_{eta}
	mm	mm	mm	mm	mm	t/ha	Kg/m^3	Kg/m^3	Kg/m^3
Maize	487.47	353.33	389.42	248.28	141.14	2.4	0.492	0.679	0.967
Sorghum	487.47	353.33	369.3	234.32	134.98	1.85	0.380	0.525	0.792
Potato	521.63	383.69	517.35	372.94	144.41	16	3.066	4.168	4.288
Beans	510.5	373.02	430.76	410.26	20.5	1	0.196	0.268	0.244
G/nut	487.48	353.32	486.76	252.38	234.38	0.8	0.164	0.226	0.317

94/95 cropping season

Crop	TRF	TERF	CWR	ETa	ETd	ACY	PW_{rf}	PW_{erf}	PW_{eta}
	mm	mm	mm	mm	mm	t/ha	Kg/m^3	Kg/m^3	Kg/m^3
Maize	360	276.11	389.42	186.83	202.59	1.20	0.333	0.435	0.642
Sorghum	342.71	262.48	372.45	165.95	206.5	1.62	0.472	0.616	0.975
Potato	392.17	317.37	517.35	317.36	199.99	6	1.53	1.890	1.890
Beans	375.05	301.25	340.76	278.96	61.8	0.8	0.213	0.266	0.287
G/nut	342.71	262.48	491.21	175.95	315.26	0.7	0.204	0.267	0.398

95/96 cropping season

Crop	TRF	TER	CWR	ETa	ETd	ACY	PW_{rf}	PW_{fr}	PW_{eta}
	mm	mm	mm	mm	mm	t/ha	Kg/m^3	Kg/m^3	Kg/m^3
Maize	756.57	578.76	380.1	374.49	5.61	3.0	0.397	0.518	0.801
Sorghum	757.48	522.92	361.76	357.3	4.46	0.9	0.119	0.173	0.253
Potato	662.33	468.14	517.35	442.89	74.46	6.7	1.012	1.431	1.513
Beans	575.34	405.78	344.26	315.2	29.06	0.96	0.167	0.236	0.304
G/nut	813.39	567.19	473.59	430.01	43.58	0.5	0.061	0.088	0.116

96/97 cropping season

Crop	TRF	TER	CWR	ETa	ETd	ACY	PW_{rf}	PW_{erf}	PW_{eta}
	mm	mm	mm	mm	mm	t/ha	Kg/m^3	Kg/m^3	Kg/m^3
Maize	347.56	283.2	383.57	195.54	188.03	0.67	0.193	0.237	0.343
Sorghum	354.46	289.28	363.63	197.24	166.39	0.91	0.257	0.315	0.463
Potato	382.54	312.39	489.35	277.96	211.39	7.1	1.856	2.273	2.554
Beans	339.45	273.12	340.76	224.32	116.44	1.11	0.328	0.407	0.496
G/nut	359.21	293.37	478.63	211.44	267.19	0.7	0.195	0.239	0.331

97/98 cropping season

Crop	TRF	TER	CWR	ETa	ETd	ACY	PW_{rf}	PW_{erf}	PW_{eta}
	mm	mm	mm	mm	mm	t/ha	Kg/m^3	Kg/m^3	Kg/m^3
Maize	587.85	410.23	378.96	261.78	117.18	2.6	0.442	0.634	0.993
Sorghum	599.43	420.45	359.17	263.35	95.82	1.26	0.300	0.300	0.478
Potato	543.55	393.72	484.77	307.22	177.55	10	1.840	2.540	3.255
Beans	523.03	362.04	344.28	265.81	78.47	1	0.191	0.276	0.376
G/nut	636.91	451.82	471.83	308.43	163.4	1.2	0.188	0.266	0.389

98/99 cropping season

Crop	TRF	TER	CWR	ETa	ETd	ACY	PWrf	PW_{erf}	PW_{eta}
	mm	mm	mm	mm	mm	t/ha	Kg/m^3	Kg/m^3	Kg/m^3
Maize	370.27	304.01	388.17	276.45	111.72	0.90	0.243	0.296	0.326
Sorghum	365.88	300.25	369.3	271.49	97.81	1.36	0.373	0.454	0.502
Potato	378.79	311.34	476.14	311.35	164.79	5.94	1.568	1.908	1.908
Beans	333.18	262.32	333.71	243.87	89.84	0.75	0.225	0.286	0.308
G/nut	370.79	340.53	485.05	284.73	200.32	0.52	0.139	0.151	0.181

99/2000 cropping season

Crop	TRF	TER	CWR	ETa	ETd	ACY	PW_{rf}	PW_{erf}	PW_{eta}
	mm	mm	mm	mm	mm	t/ha	Kg/m^3	Kg/m^3	Kg/m^3
Maize	509.33	399.46	378.34	319.45	58.89	1.5	0.295	0.376	0.470
Sorghum	491.86	388.71	360.27	324.7	35.57	1	0.203	0.257	0.308
Potato	467.5	371.16	484.72	347.09	137.63	5	1.070	1.347	1.441
Beans	419.42	331.86	346.46	274.2	72.26	0.4	0.095	0.121	0.147
G/nut	541.79	426.81	470.57	365.49	105.08	0.4	0.074	0.094	0.109