Materials and methods: Climate change effect on Maize Yield in LVB- Uganda side

The likely impact on climate change was simulated using DSSAT model and maize as crop. A total of 29 GCM models were downscaled in the different districts of Uganda within the Lake Victoria Basin. These included Mbarara, Jinja, Kalangala, Entebbe, Rakai, Sembabule. Soil information was obtained from Uganda soil memoirs; while planting windows, number of plant per hectare, inorganic fertiliser inputs, days to maturity, amount of manure used were based on the previous study by the AGMIP group and UBOS website. The major soil used in this study included Petric Plinthic, Acric Ferralsol, dystric Regosols (See map and Table 1, 2 and 3 below). Soil parameters such as hydraulic conductivity, Drainage Upper Limit (DUL) and Lower Limit (DLL), air dry, saturation, bulk density were estimated using soil water characteristics Program (Rawls et al.,, 1982) based on soil texture, soil organic carbon content, gravel content, salinity and compaction. The soil profile depth in the models was arranged to a fixed depth per layer (Table 5). Initial soil conditions of stable SOC were set at 44%. The C/N ratio in both models were derived by calculation. In DSSAT, site descriptions such as slope per cent, run-off curve numbers, drainage rate, run-off potential, and soil fertility factor were estimated based on available literature (Soil memoirs). All root growth factors were set at 1.0 as non-limiting in all soil profiles.

Crop management parameters used in setting up simulations were derived from the AGMIP group report.Varieties that are most dominant in the region are local traditional, longe 5, and longe 9. Detailed Information on Longe 5 and Longe 9 varieties was obtained from NASECO seeds. For the local traditional variety, Katumani information was used because of similarities in physiology, phenology and yield potential.

Table 1: Maize varieties used by farmers and the identified equivalent in the model

Variety used by farmer	Duration (days)	Grain Yields (t ha^{-1})	Variety in the Model
Nafa, Ndele, Longe 1, Longe 4	100-105	1.5-1.8	Local traditional (Katumani)
Longe 5, dk	115	4-5	Longe 5
Longe 2H, Longe 6H, Longe 10H	120	7-8	Longe 9
Others	Considered as local		Local- traditional Katumani

Source: NASECO seeds Ltd, Kampala, Uganda

Plant population that were estimated for each individual farms were set based on the amount of seed used by farmers. The plant population normally ranged between 40,000 to 60,000 plants per hectare. Three major categories were used ad per Table 7. In the survey, majority of the farmers did not use inorganic fertilizers. While setting up the models for individual farmers, 5 kg N fertilizer amounts was applied to allow model sensitivity. All model runs for the survey data was conducted using AGMIP tools QuadUIi and ACMO UI that can be availed at www.tools.agmip.org.

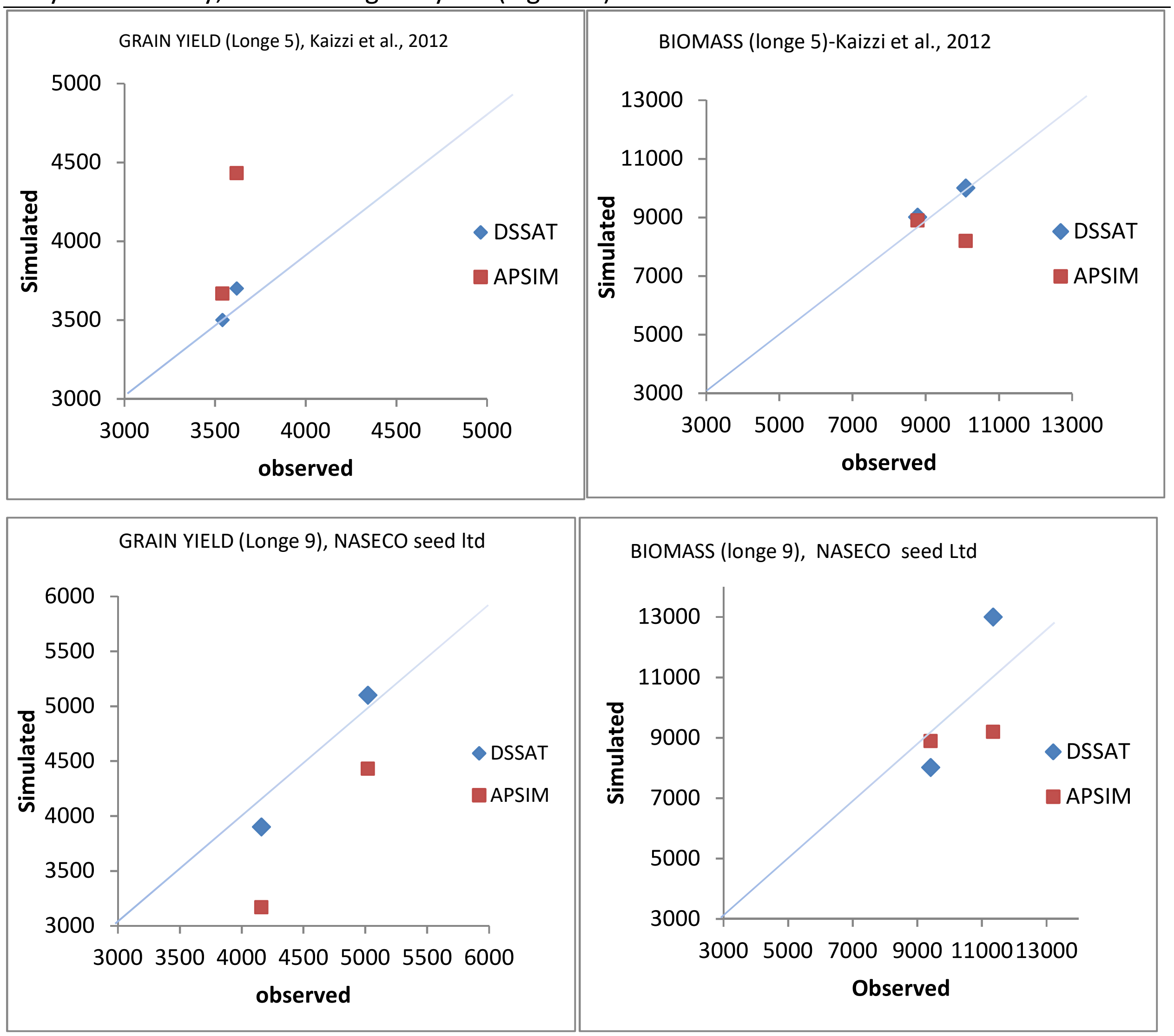
Table 2. Soil profile characteristics used in DSSAT crop model in Uganda

		Soil layer base depth	Lower limit	Drained upper limit	Saturation	Bulk density	Organic C	Clay	Silt	Coarse fraction (stones)	pH	Cation exchange capacity	Sat. hydraulic conductivity, macropore,
		cm	mm3/mm3	mm3/mm3	mm3/mm3	g/cm3	g[C]/100g	%	%	%		cmol/kg	cm h-1
Petro Plinthic	**Good**	15	0.155	0.366	0.512	1.290	2.770	23.00	8.00	0.00	5.50	3.50	0.10
		35	0.172	0.370	0.496	1.330	1.530	29.00	10.00	0.00	5.60	3.50	0.18
		70	0.205	0.400	0.503	1.320	1.100	37.00	8.00	0.00	4.40	3.50	0.13
		101	0.232	0.423	0.585	1.360	0.460	43.00	4.00	0.00	4.60	3.70	0.10
	Medium	15	0.153	0.359	0.502	1.320	2.355	23.00	8.00	0.00	5.50	3.50	0.10
		35	0.171	0.368	0.491	1.350	1.301	29.00	10.00	0.00	5.60	3.50	0.18
		70	0.204	0.399	0.598	1.330	0.935	37.00	8.00	0.00	4.40	3.50	0.13
		101	0.232	0.423	0.596	1.340	0.391	43.00	4.00	0.00	4.60	3.70	0.10
	Poor	15	0.150	0.351	0.490	1.350	1.939	23.00	8.00	0.00	5.50	3.50	0.10
		35	0.170	0.365	0.486	1.360	1.071	29.00	10.00	0.00	5.60	3.50	0.18
		70	0.204	0.398	0.593	1.340	0.770	37.00	8.00	0.00	4.40	3.50	0.13
		101	0.232	0.423	0.593	1.340	0.322	43.00	4.00	0.00	4.60	3.70	0.10
Dystric regosols	**Good**	15	0.160	0.406	0.561	1.160	3.228	23.00	10.00	0.00	5.40	15.13	0.10
		43	0.189	0.408	0.524	1.260	1.176	33.00	20.00	0.00	4.80	10.86	0.18
		81	0.216	0.425	0.530	1.250	1.092	39.00	14.00	0.00	4.80	9.04	0.13
		117	0.235	0.444	0.613	1.290	0.492	43.00	14.00	0.00	4.70	10.88	0.10
		173	0.195	0.403	0.593	1.340	0.372	35.00	18.00	0.00	4.80	5.65	0.10
		203	0.138	0.335	0.448	1.460	0.060	23.00	20.00	0.00	4.90	5.65	0.18
	Medium	15	0.164	0.399	0.553	1.190	2.690	23.00	10.00	0.00	5.40	15.13	0.13
		43	0.188	0.405	0.515	1.290	0.980	33.00	20.00	0.00	4.80	10.86	0.10
		81	0.216	0.424	0.525	1.260	0.910	39.00	14.00	0.00	4.80	9.04	0.10
		117	0.235	0.444	0.610	1.200	0.410	43.00	14.00	0.00	4.70	10.88	0.18
		173	0.194	0.403	0.591	1.350	0.310	35.00	18.00	0.00	4.80	5.65	0.13
		203	0.138	0.335	0.448	1.450	0.050	23.00	20.00	0.00	4.90	5.65	0.10
	Poor	15	0.159	0.384	0.534	1.230	2.152	23.00	10.00	0.00	5.40	15.13	0.10
		43	0.187	0.403	0.510	1.300	0.784	33.00	20.00	0.00	4.80	10.86	0.18
		81	0.215	0.422	0.616	1.280	0.728	39.00	14.00	0.00	4.80	9.04	0.13

		117	0.235	0.444	0.605	1.310	0.328	43.00	14.00	0.00	4.70	10.88	0.10
		173	0.194	0.402	0.588	1.360	0.248	35.00	18.00	0.00	4.80	5.65	0.10
		203	0.138	0.335	0.448	1.460	0.040	23.00	20.00	0.00	4.90	5.65	0.18
Acric Ferralsol	**Good**	13	0.175	0.405	0.564	1.150	3.336	26.00	6.00	0.00	5.10	12.20	0.13
		46	0.219	0.411	0.525	1.260	1.104	40.00	4.00	0.00	4.80	9.63	0.10
		84	0.229	0.427	0.613	1.290	0.612	42.00	8.00	0.00	5.00	7.62	0.10
		122	0.228	0.426	0.604	1.310	0.420	42.00	8.00	0.00	5.30	6.38	0.18
		152	0.208	0.396	0.587	1.360	0.264	38.00	4.00	0.00	5.00	5.83	0.13
		183	0.181	0.364	0.471	1.400	0.240	32.00	4.00	0.00	4.80	7.50	0.10
		213	0.182	0.367	0.479	1.380	0.384	32.00	4.00	0.00	4.60	6.30	0.10
	Medium	13	0.175	0.402	0.561	1.160	2.780	26.00	6.00	0.00	5.10	12.20	0.18
		46	0.219	0.410	0.518	1.280	0.920	40.00	4.00	0.00	4.80	9.63	0.13
		84	0.228	0.426	0.609	1.300	0.510	42.00	8.00	0.00	5.00	7.62	0.10
		122	0.228	0.426	0.601	1.320	0.350	42.00	8.00	0.00	5.30	6.38	0.10
		152	0.208	0.395	0.585	1.370	0.220	38.00	4.00	0.00	5.00	5.83	0.18
		183	0.181	0.363	0.468	1.410	0.200	32.00	4.00	0.00	4.80	7.50	0.13
		213	0.182	0.366	0.476	1.390	0.320	32.00	4.00	0.00	4.60	6.30	0.10
	Poor	13	0.171	0.388	0.543	1.210	2.240	26.00	6.00	0.00	5.10	12.20	0.10
		46	0.218	0.409	0.511	1.290	0.736	40.00	4.00	0.00	4.80	9.63	0.18
		84	0.228	0.426	0.604	1.310	0.408	42.00	8.00	0.00	5.00	7.62	0.13
		122	0.228	0.425	0.599	1.330	0.280	42.00	8.00	0.00	5.30	6.38	0.10
		152	0.208	0.395	0.582	1.370	0.176	38.00	4.00	0.00	5.00	5.83	0.10
		183	0.181	0.363	0.468	1.410	0.160	32.00	4.00	0.00	4.80	7.50	0.15
		213	0.181	0.363	0.470	1.410	0.256	32.00	4.00	0.00	4.60	6.30	0.16

Crop Model calibration and validation

DSSAT Model was calibrated for Longe 5 and Longe 9 using experimental data from Bulindi Zonal Agricultural Research Institute in Hoima (Kaizzi et al., 2012). Validation of model outputs was done using information from National Agricultural Research Laboratories, Kawanda (NARL). The model parameter coefficients for DSSAT were derived after adjusting existing varieties typical of tropical conditions and also by manipulating various growth parameters until the simulated phenology and yields matched the observed. Models were run and relationship between the observed and simulated was demonstrated using observed and simulated days to flowering, days to maturity, stover and grain yield (Figure 2).



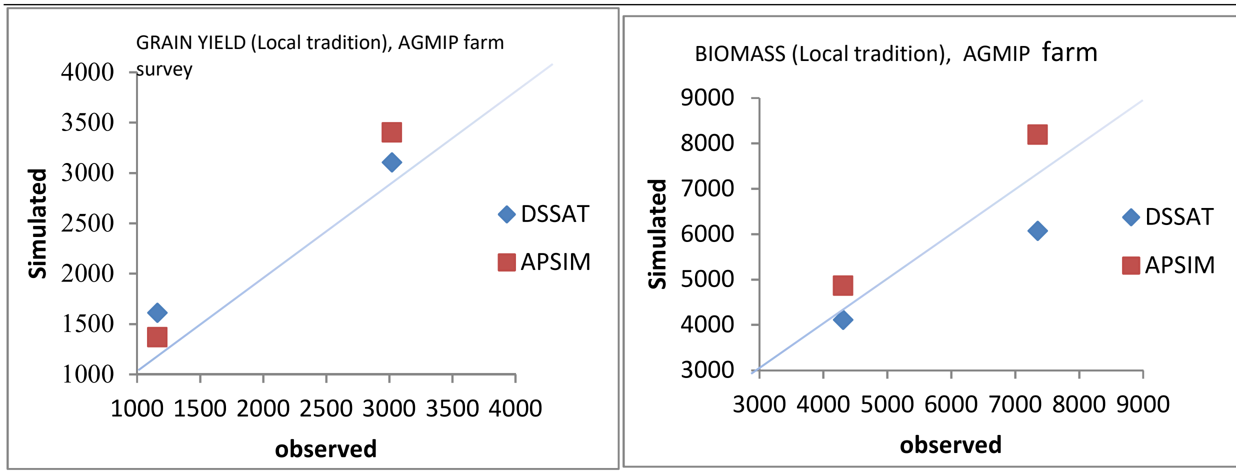


Figure 2. Simulated and observed yield and top weight for Longe 5, Longe 9 and local traditional variety in Uganda

The DSSAT model was then ran under the current soil management conditions of low fertilizer input with no soil and water conservation for historical and future climate conditions for the 29 GCM. Two Representative Concentration Pathways (4.5 and 8.5) and two periods (Mid: 2040-2069 and End: 2070-2099 Century) were considered in this study. The information was aggregated per soil type and aggregated per district.

RESULTS

Table 2 summarizes the historical yield simulated under DSSAT with no inorganic fertilizer inputs for the selected districts of LVB in Uganda. The average yield under local variety ranged between 1607.73 and 1836.83 Kg/ha; Longe 5 varied from 858.98 and 2169.42 Kg/ha; while Longe 9 varied between 1219.66 and 2647.66 Kg/ha. The lowest maize yield values were registered in Rakai for the local variety, in Mbarara for Longe 5 and 9. The highest values were registered in Kalangala for all the three maize varieties.

Maize biomass varied from 4007.92 to 4566.94 Kg/ha for the local variety, 3615.24 and 5614.88 for Longe 9, and 2785.04 and 4887.74 Kg/ha for Longe 5. The lowest biomass was reported in Rakai for the local variety, in Mbarara for Longe 9 and 5. The highest biomass was observed in Kalangala for all varieties.

Table 1: Simulated maize in the selected districts of LVB in Uganda

Districts	Variety	Grain yield (Kg/ha)	Biomass (Kg/ha)
Entebbe	Local Variety	1759.66	4483.54
	Longe 9	2480.94	5407.88
	Longe 5	2014.75	4693.58
	Average	**2297.75**	**5148.32**
Kalangala	Local Variety	1836.82	4566.94
	Longe 9	2647.66	5614.88
	Longe 5	2169.42	4887.74
	Average	**2451.44**	**5338.15**
Mbarara	Local Variety	1700.52	4262.62
	Longe 9	1219.06	3615.24
	Longe 5	858.98	2785.04
	Average	**1198.95**	**3514.81**
Rakai	Local Variety	1607.73	4007.92
	Longe 9	1741.21	4450.48
	Longe 5	1285.49	3654.35
	Average	**1628.94**	**4229.88**
Sembabule	Local Variety	1759.66	4483.54
	Longe 9	2480.94	5407.88
	Longe 5	2014.75	4693.58
	Average	**2297.75**	**5148.32**

Yield per soil type to be inserted

Future yield variations

If land continue to be managed the way it is being done currently, with low inorganic and organic input, yield under the local variety will decline in the mid-century for all parts of Ugandan district within the LVB. It will also decline for the improved varieties in the Kalangala, and Sembabule district.

Districts	Variety	RCP 4.5		RCP 8.5	
		Grain yield	Biomass	Grain yield	Biomass
		Kg/ha			
Entebbe	Local Variety	-3.61	1.12	-5.99	1.74
	Longe 9	0.26	2.45	0.00	3.38
	Longe 5	1.56	3.83	-0.10	4.81
	Average	0.16	2.58	-0.55	3.49
Kalangala	Local Variety	-7.66	-0.73	-17.10	-3.86
	Longe 9	-6.05	-1.33	-13.93	-5.42
	Longe 5	-5.68	-0.29	-14.33	-4.73
	Average	-6.12	-1.07	-14.28	-5.13
Mbarara	Local Variety	-8.23	2.12	-10.46	-2.63
	Longe 9	87.25	45.22	49.37	31.73
	Longe 5	119.08	65.91	58.84	44.82
	Average	76.26	42.59	40.89	29.06
Rakai	Local Variety	-4.78	0.05	13.49	15.97
	Longe 9	1.02	3.19	3.07	4.15
	Longe 5	3.38	6.11	2.28	3.19
	Average	0.75	3.37	4.14	5.28
Sembabule	Local Variety	-0.49	2.08	-2.84	3.50
	Longe 9	-8.43	-1.39	-6.89	0.72
	Longe 5	-11.79	-2.46	-9.57	0.09
	Average	-8.34	-1.24	-7.03	0.88

Under the current land management the end century maize yield is likely to reduce in the parts of the districts of Uganda within the LVB and for all varieties, except for Longe 5 and Longe 9 in Mbarara and Rakai were both grain yield and biomass will be increasing, for both RCPs and Periods. The absolute value of the relative change in historical yield tends to increase for the RCP 8.5 compared to 4.5. Meaning if yield had decreased in RCP 4.5, the decrement tends to be higher in RCP 8.5 and if it had increased for RCP 4.5, yield tends to increase more for RCP 8.5

Table 2: Relative change in maize yield in the end of century

Districts	Variety	RCP 4.5		RCP 8.5	
		Grain yield	Biomass	Grain yield	Biomass
		Kg/ha			
Entebbe	Local Variety	-12.85	-3.53	-21.70	-5.44
	Longe 9	-9.64	-3.83	-16.25	-5.03
	Longe 5	-8.89	-2.88	-17.67	-5.67
	Average	-9.79	-3.62	-17.00	-5.19
Kalangala	Local Variety	-10.03	-1.84	-17.92	-4.21
	Longe 9	-7.05	-1.90	-14.23	-3.26
	Longe 5	-7.35	-0.85	-14.73	-2.59
	Average	-7.36	-1.69	-14.65	-3.23
Mbarara	Local Variety	-3.60	1.20	-13.52	-3.15
	Longe 9	27.26	18.51	40.38	29.73
	Longe 5	27.66	21.53	39.64	34.72
	Average	22.20	16.57	31.33	25.90
Rakai	Local Variety	-4.85	1.14	-13.07	-1.31
	Longe 9	4.71	5.41	3.29	8.73
	Longe 5	6.52	8.97	7.38	14.11
	Average	3.91	5.59	2.09	8.60
Sembabule	Local Variety	-2.04	2.03	-11.44	-0.51
	Longe 9	-7.31	-0.54	-10.38	0.15
	Longe 5	-10.84	-1.71	-12.73	0.16
	Average	-7.50	-0.51	-10.91	0.08

We need to insert yield change per soil unit.