Technical Annex: FS Characterization with GAEZ Data

The African Farming Systems Update Project

Farming systems and food security: Priorities for science and policy under global change

Harrij van Velthuizen,
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Preface

In 2012, the government of Australia established the Australia International Centre for Food Security (AICFS) to help achieve food and nutritional security in Africa through the provision of focused research and capacity building. Hosted by the Australian Centre for International Agriculture Research (ACIAR), AICFS research will help boost the productivity and commercial orientation of smallholder agriculture and support the improvement of livelihoods in a sustainable manner. The Centre undertakes medium to long-term end-user driven collaborative agricultural research for development and it develops education and training programs as well as strategies that build innovation and R&D capacity; and deploy research outputs and encourage take up by smallholder farmers.

The AICFS research will contribute to informing the agenda for food security in Africa as well as underpin the development of the strategic orientation and program portfolio of AICFS. One of the research foci is the update of earlier farming systems work (Dixon et al 2001) in the African Farming Systems Update Project: “Farming systems and food security in Africa: Priorities for science and policy under global change”. This work aims to fill a current gap for a suitable text on African farming systems for university courses. It will also provide a valuable resource for governments in their efforts to understand and harness the key trends that are expected to influence farming systems evolution over the next fifteen years as well as for academic programs that AICFS plans on developing.

A workable number of farming systems was selected for the purpose of targeting policy makers who need relatively large-scale tendencies for planning. Among the 14 systems identified in the 2001 study, thirteen farming systems were defined based on agro-ecological criteria. Farming systems and subsystems definitions and map classes follow a rigorous basis and explicit set of principles. The first principle applied is to have the continental level farming systems map classes align with length of growing period (LGP) boundaries. LGP is a component of agro-ecological zones (AEZs) that include amongst others, climate, soils, terrain and land cover resources inventories. The LGP map used is from the GAEZ version 3.0, released by the International Institute for Applied Systems Analysis (IIASA) and FAO through their GAEZ data portals in May 2012.

As a further contribution to the African Farming Systems Update Project, IIASA provided farming system characterizations with biophysical and agronomic GAEZ data. This work is documented in this technical annex.

1 Agro-ecological Zones Data and Farming Systems Zones

This section describes the data layers and some aggregate results for the characterization of the 2012 version of Farming System zones (FS zones) of sub-Saharan Africa. The AEZ elements used for characterization include: (i) spatial land resources, (ii) spatial crop suitability and potential yield data, (iii) year 2000 crop harvested areas, yield and production, and (iv) year 2000 yield and production gaps between actual achieved and potentially achievable per hectare outputs. Descriptions of these elements are given in the Appendix "Global Agro-ecological Zones".

2 Land Resources

Global AEZ provides a framework for establishing a spatial inventory of land resources compiled from global environmental data sets and assembled to quantify multiple spatial characteristics required for the assessments of land productivity under location-specific agro-ecological conditions. The GAEZ land resources inventory includes multiple spatial layers of climate, soil, terrain, land use/land cover, protected areas, population density, livestock density, accessibility, and administrative boundaries.

2.1 Agro-ecological zonation

The Global Agro-ecological Zonation layer provides a uniform worldwide classification of bio-physical resources relevant to agricultural production systems. The inventory combines moisture regimes with broad categories of soil qualities. It also indicates locations of areas with irrigated soils, hydromorphic soils and land with severely limiting bio-physical constraints including very cold and very dry (desert) areas and areas with steep terrain. The criteria applied for the compilation of the Agro-ecological Zonation layer are presented in Box 1.

Box 1

Steep terrain: Terrain slopes > 16% for more than two-thirds of grid cell

Cold: Temperature growing period (LGPt) < 60 days

Desert: P/PET ratio < 0.15 during LGPt (and LGPt > 60 days)

Irrigated soils: > 20% of grid cell equipped for irrigation (according to GMIA)

Hydromorphic soils: Grid-cells with >50% hydromorphic soil types in flat terrain (Gleysols, Histosols, gleyic and stagnic units with slopes < 2%)

Moisture regimes

- Dry conditions: P/PET during LGPt between 0.15-0.40
- Moist conditions: P/PET during LGPt between 0.40-0.65
- Sub-humid conditions: P/PET during LGPt between 0.65-1.15
- Humid conditions: P/PET during LGPt > 1.15

Soil qualities (good, moderate or poor soils)

Soil Quality Index (SQI) is used to determine the soil quality of a grid cell as follows: SQI = Area share excellent soils*1.0 + area share good soils*0.666 +Area share marginal soils*0.333. (Poor soils were given a weight 0).

Grid cells with SQI > 0.666 are qualified as ***good soils***, SQI between 0.333 and 0.666 as ***moderate soils*** and SQI≤ 0.333 as ***poor soils.*** In addition miscellaneous units (rocks, sand dunes, etc.) and soils with lithic, stony, petrocalcic, petroferric, petrogypsic, saline, sodic, rudic, salic, takyric and yermic phases are qualified as ***poor.***

Figure 1 presents a map of Sub-Saharan Africa with agro-ecological characteristics by FS zone, Figure 2 provides a chart of agro-ecological characteristics by FS zone based on the agro-ecological zonation data layer.

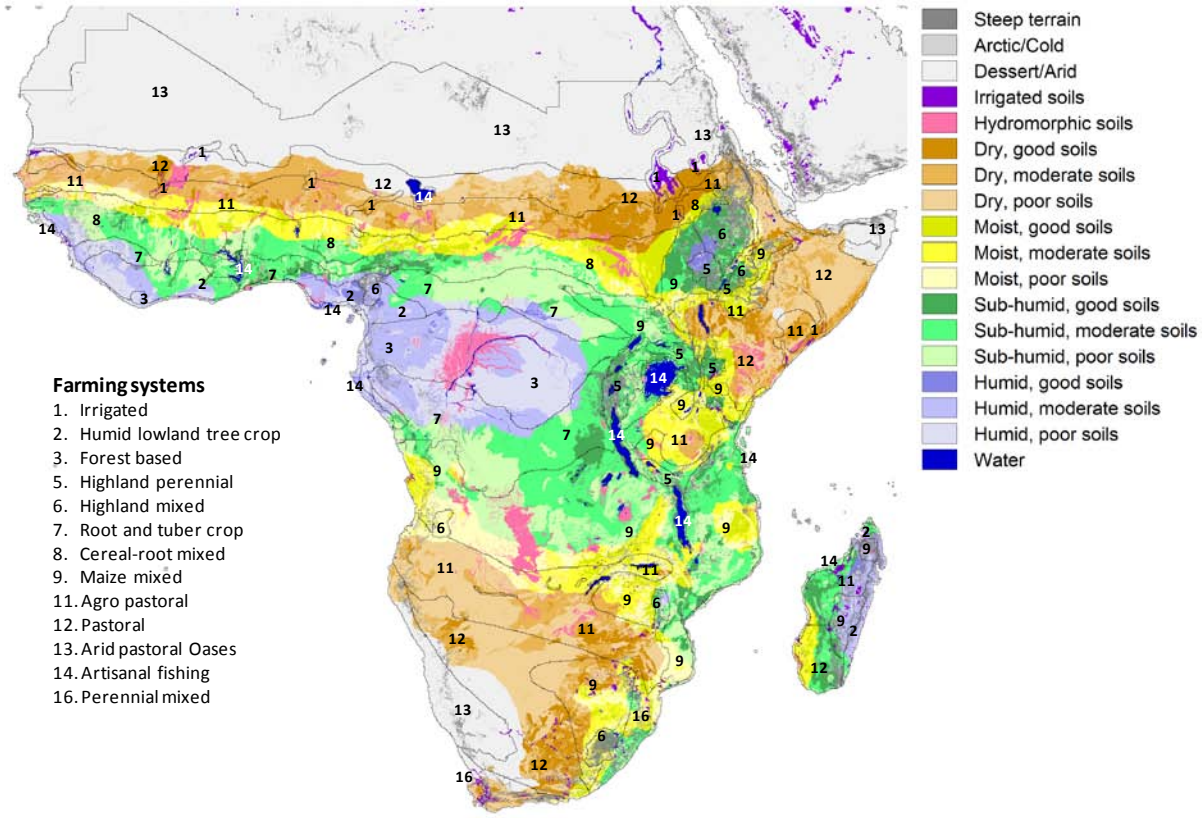


Figure 1 Map of agro-ecological characteristics and farming systems zones

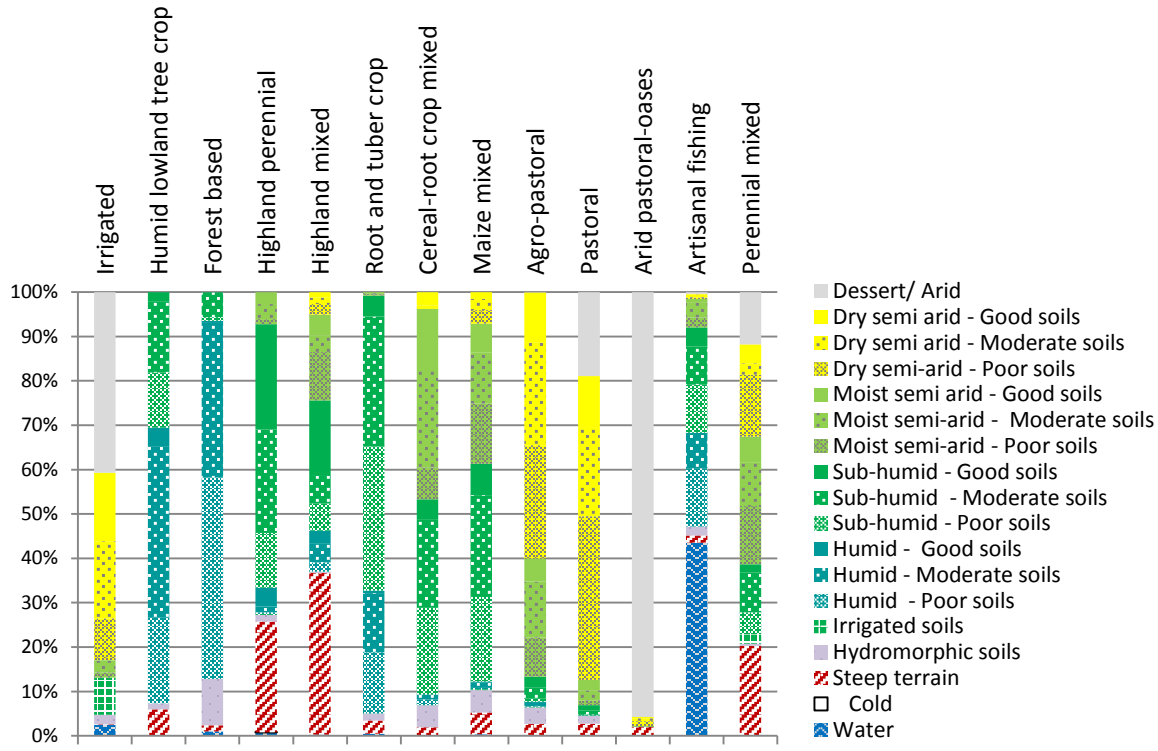


Figure 2 Agro-ecological characteristics of farming systems zones (%)

Table 1 Agro-ecological characteristics of farming systems zones (000ha)

	Irrigated	Humid lowland tree crop	Forest based	Highland perennial	Highland mixed	Root and tuber crop	Cereal-root crop mixed	Maize mixed	Agro-pastoral	Pastoral	Arid pastoral-oases	Artisanal fishing	Perennial mixed	Not assigned	Total land
Dessert/Arid	14906	0	0	0	0	0	0	0	292	69235	444577	157	3583	624	533373
Dry semi-arid Good soils	5638	0	0	0	568	0	6157	6062	40721	42941	1280	75	1310	13	104765
Dry semi-arid Moderate soils	6380	0	0	0	691	0	1506	9985	85099	72724	3089	320	790	61	180644
Dry semi-arid Poor soils	3446	0	0	0	1153	0	5	11904	93447	135167	5313	126	4250	27	254838
Moist semi-arid Good soils	44	0	0	1133	2253	502	28334	25842	18940	8777	0	354	1758	0	87937
Moist semi-arid Moderate soils	982	0	0	1406	1757	528	45221	45418	46134	8514	0	1579	3006	0	154547
Moist semi-arid Poor soils	417	0	0	499	5149	698	14799	53900	32069	3534	0	1021	4026	0	116112
Sub-humid - Good soils	0	1358	77	9995	8122	10613	9205	27997	8670	4254	55	1995	531	36	82908
Sub-humid - Moderate soils	0	10186	7534	9821	2945	65822	41010	90573	9617	3575	74	3915	2752	108	247931
Sub-humid - Poor soils	0	7880	1068	5191	2892	73073	40233	75636	2234	503	12	4970	1536	29	215257
Humid Good soils	0	2768	705	1791	1419	1221	14	944	1126	13	0	137	0	28	10165
Humid Moderate soils	0	24531	47207	556	1974	30070	2302	4555	2661	25	0	3539	0	93	117514
Humid Poor soils	0	12281	61561	140	999	30915	2582	1201	591	25	0	6013	0	142	116449
Irrigated soils	3062	50	0	96	31	9	59	886	499	461	30	27	638	12	5859
Hydromorphic soils	792	820	14210	635	133	3529	10208	19856	13813	6546	8	893	155	0	71597
Steep terrain	62	3783	1788	10528	17298	6735	3869	19676	8894	9464	10047	777	6111	475	99507
Cold	0	0	0	2	0	0	0	0	0	0	0	0	0	0	2
Water	899	58	1421	328	148	1128	204	1363	835	672	29	19951	75	0	27111
Not assigned	1	1	0	0	0	1	1	24	18	2	2	80	5	1	145
Total extents	36628	63716	135570	42122	47532	224843	205709	395823	365660	366430	464516	45928	30526	1648	2426658

The FS zones vary substantially in quality of land resources: **(i)** The *irrigated farming system zone* occurs mainly in dessert (41%) and dry semi-arid environments (42%); **(ii)** the *humid lowland tree crop zone* occurs mainly in sub-humid (31%) and humid environments (62%). Soil conditions are dominantly of moderate and poor quality for agriculture; **(iii)** the *forest based zone* occurs mainly in humid environments (81%). Soil conditions are of moderate and poor quality; **(v)** the *highland perennial zone* occurs for a large part in sub-humid environments (59%). Soil conditions are dominantly of good and moderate quality. Partly this FS zone occurs in steep terrain (25%); **(vi)** the *highland mixed zone* occurs mainly in sub-humid (29%) and moist semi-arid environments (19%). Soil conditions are dominantly of good quality. A substantial part of this zone occurs in steep terrain (36%) **(vii)** the *root and tuber zone* occurs mainly in sub-humid (67%) and humid environments (28%). Soil conditions are of moderate and poor quality; **(viii)** the *cereal-root crop mixed zone* is mainly found in moist semi-arid (43%) and sub-humid.(44%) environments. Soil conditions in the semi-arid part are dominantly of moderate and good quality, and in sub-humid part mainly of moderate and poor quality; **(ix)** the *maize mixed zone* stretches from dry semi-arid (7%) to moist semi-arid (32%) to sub-humid environments (49%). Soil conditions are mainly of moderate and poor quality; **(xi)** the *agro-pastoral zone* occurs mainly in dry semi-arid (60%) and to a lesser extent in moist semi-arid environments (27%). Soil conditions are mainly of moderate and poor quality; **(xii)** the *pastoral zone* occurs mainly in dry semi-arid (68%) and dessert environments (19%). In the dry semi-arid environments soil conditions are generally poor (54%), some are moderate (29%) and few are of good quality (17%); **(xiii)** The *arid pastoral oasis zone* occurs almost entirely in desert environments (96%) a small part (2%) occurs in dry semi-arid environment; **(xiv)** the *artisanal fishing zone* distributes over all climatic zones, but specially in sub-humid (24%) and humid environments (21%). Soil conditions are mainly of poor and moderate quality, and **(xvi)** the *perennial mixed zone* is stretching from desert (12%) to dry semi-arid (21%) to moist semi-arid (29%) and sub-humid environments (16%). Soil

conditions are mainly of moderate (32%) and poor (49%) quality, partly this zone occurs in steep terrain (20%). Table 1 provides extents of specific agro-ecological zones occurring by FS zone.

2.2 Length of growing period

The agro-climatic potential productivity of land depends largely on the number of days during the year when temperature regime and moisture supply are conducive to crop growth and development. This period is termed the length of the growing period (LGP). The LGP is determined based on prevailing temperatures and the above described water balance calculations for a FAO defined reference crop. In a formal sense, LGP refers to the number of days when average daily temperature is above 5°C (i.e. within LGPt5) and actual reference evapotranspiration (Eta) is above a specific fraction of reference potential evapotranspiration (ETo). In the current GAEZ parameterization, LGP days are considered when ETa $\geq$ 0.5 ETo, which aims to capture periods when sufficient soil moisture is available to allow the establishment of a reference crop. The reference length of growing period is based on water balance calculation for a reference soil depth of 1 m and soil moisture holding capacity of 100 mm (Higgins *et al*., 1978).

The length of growing period data is also used for the classification of general moisture regimes classes. The moisture regime within a LGP is characterized by different water supply conditions as follows:

Growing period days without water stress (ETa=ETm): When ETa equals ETm (maximum un-constraint evapotranspiration), crop water requirements are fully met (i.e. no water stress for plants occurs).

Growing period days with water stress (ETa<ETm): ETa falls short of ETm. The crop experiences water stress as not enough readily available water can be obtained from rainfall or moisture stored in the soil profile. Water stress implies that crop growth and yield formation are reduced.

Total annual LGP days may occur in one continuous period or as two or more discontinuous growing periods. When moisture becomes insufficient (ETa < 0.5 ETo), LGP ends and/or is interrupted by a dry period. In the case of temperature limitations (Ta < 5°C), LGP is interrupted by either a dormancy break or a cold-break.

Coefficients of variation (1961-1990) of precipitation (P), aridity index (P/ETo) and reference total LGP days are summarized by FS zones in Figure 3.

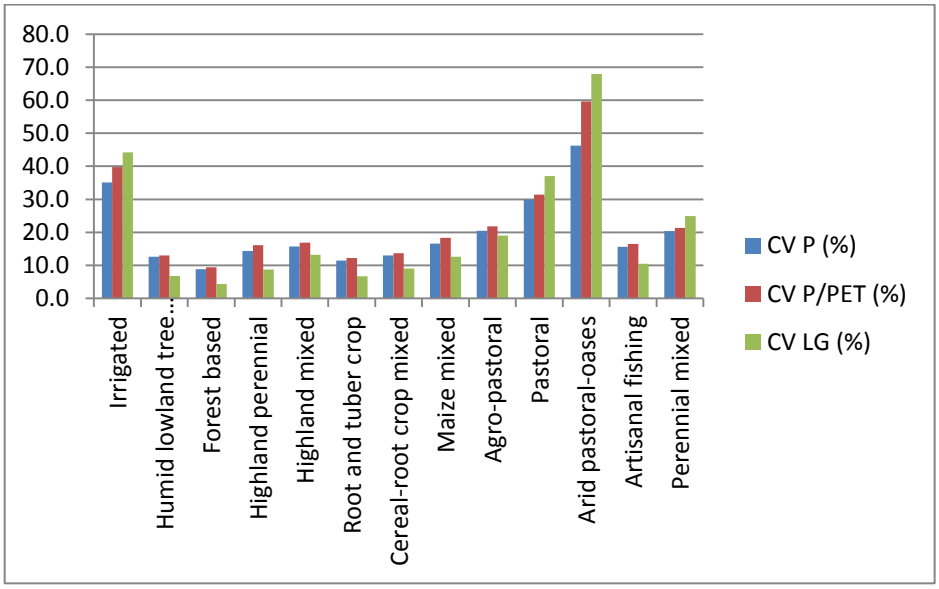


Figure 3 Area weighted CVs (%) for annual precipitation, annual aridity index (P/PET) and reference total LGP days.

Another available climate indicator is the 'Fournier index". It expresses within-year distribution of rainfall, reflecting the combined effect of rainfall amount and distribution:

$$Fm = \frac{12\sum_{i=1}^{12} P_i^2}{\sum_{i=1}^{12} P_i}$$

where P_i = precipitation of month i

Figure 4 presents a map of Sub-Saharan Africa with length of growing periods by FS zone. Figure 5 presents relative LGP conditions in 30 days intervals by FS zone, Table 2 provides actual extents of LGP zones by FS zone.

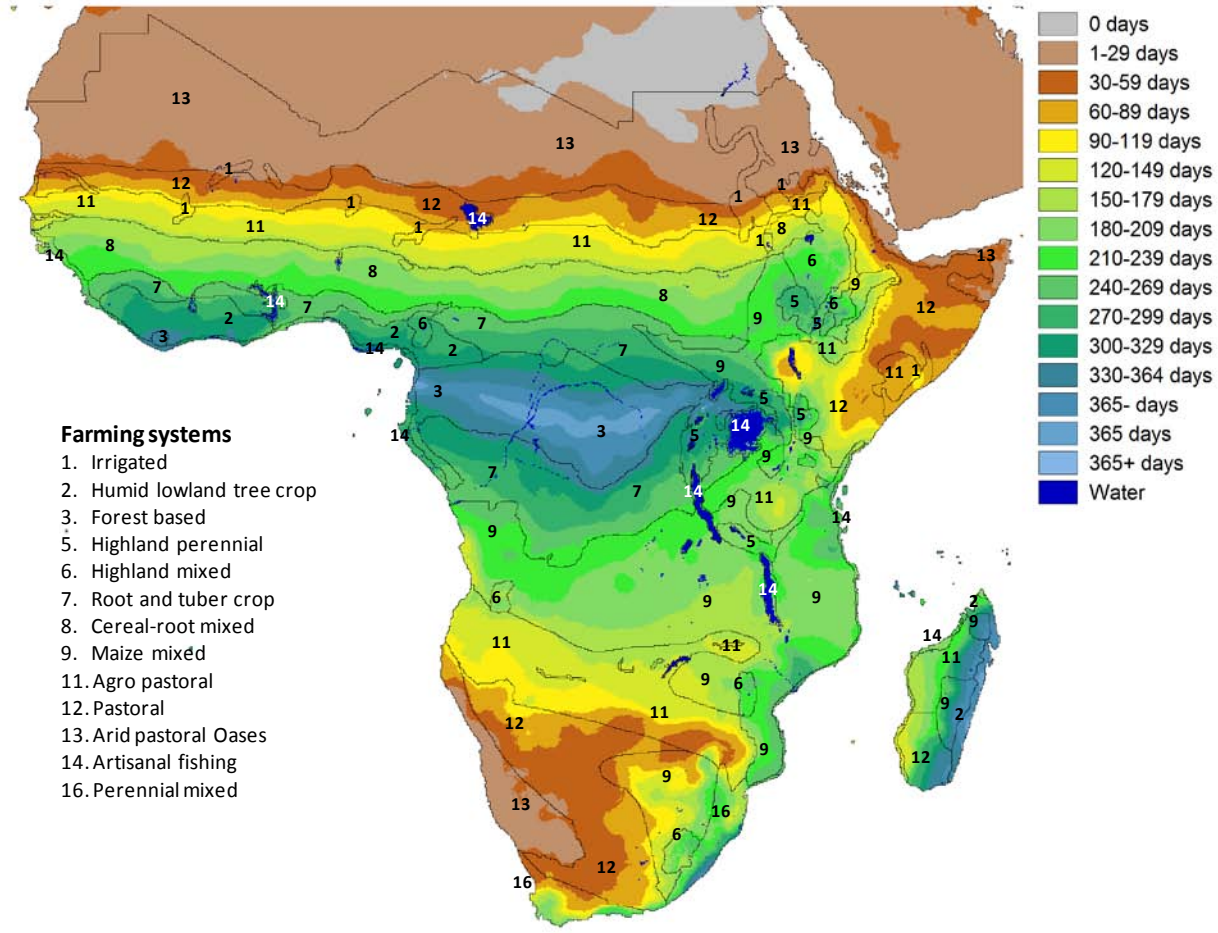


Figure 4 Map of length of growing periods and farming systems zones

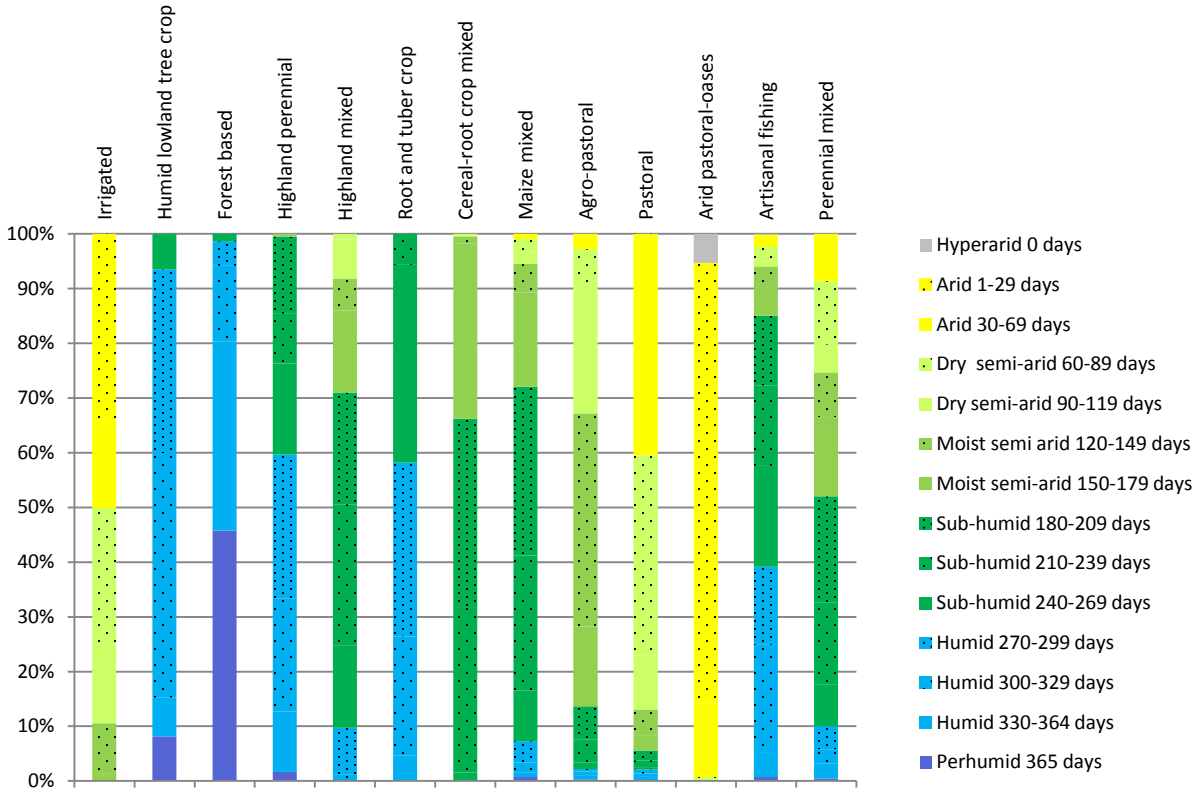


Figure 5 Length of growing periods in farming systems zones (%)

Most of the FS zones are characterized by a wide range total number of annual LGP days. General LGP characteristics of the FS zones are as follows: **(i)** The *irrigated farming system zone* occurs in LGPs between 1 and 180 days; **(ii)** the *humid lowland tree crop zone* occurs in LGPs between 210 and 365 days; **(iii)** the *forest based zone* occurs in LGPs between 240 and 365 days; **(v)** the *highland perennial zone* occurs mainly in LGPs between 180 and 365 days; **(vi)** the *highland mixed zone* occurs in LGPs between 60 and 330 days; **(vii)** the *root and tuber zone* occurs in LGPs between 210 and 364 days; **(viii)** the *cereal-root crop mixed zone* occurs in LGPs between 90 and 270 days; **(ix)** the *maize mixed zone* stretches across LGPs between 30 and 365 days; **(xi)** the *agro-pastoral zone* mainly occurs in LGPs between 30 and 240 days; **(xii)** the *pastoral zone* extends mainly in LGPs between 30 and 210 days; **(xiii)** the *arid pastoral-oases zone* occurs mainly in LGPs between 0 and 60 days; **(xiv)** the *artisanal fishing zone* occurs in all LGPs from 0 to 365 days, and **(xvi)** the *perennial mixed zone* occurs in LGPs between 30 and 365 days.

Table 2 Length of growing periods in farming systems zones (000ha)

	Irrigated	Humid lowland tree crop	Forest based	Highland perennial	Highland mixed	Root and tuber crop	Cereal-root crop mixed	Maize mixed	Agro-pastoral	Pastoral	Arid pastoral-oases	Artisanal fishing	Perennial mixed	Not assigned	Total land
Hyper-arid/cold (0 days)	0	0	0	26	0	0	0	0	0	0	24747	54	0	38	24865
Arid (1-29 days)	12464	0	0	0	0	0	0	0	0	4057	374199	109	0	580	391410
Arid (30-59 days)	5890	0	0	0	8	0	0	3719	10114	144356	62303	944	2634	147	230116
Dry semi-arid (60-89 days)	9165	0	0	0	473	0	0	9124	26051	134187	2366	1192	3545	166	186269
Dry semi-arid (90-119 days)	5236	0	0	9	3393	0	888	8935	83894	36023	749	441	1550	7	141125
Moist semi- arid (120-149 days)	3393	0	0	0	2803	0	2787	20550	142353	17044	0	1738	2479	1	193148
Moist semi-arid (150-179 days)	480	0	0	188	7114	0	65899	68296	53344	10416	0	2414	4440	6	212596
Sub-humid (180-209 days)	0	12	0	5924	9710	0	70686	122180	22046	6667	143	5875	5916	1	249159
Sub-humid (210-239 days)	0	352	0	3837	12278	12715	62287	97350	15305	4302	16	6762	4568	40	219811
Sub-humid (240-269 days)	0	3760	1802	6993	7119	81358	3162	36989	4470	1671	0	8469	2339	0	158132
Humid (270-299 days)	0	21419	6109	11106	4093	71445	0	15460	1824	2678	0	6563	1291	128	142115
Humid (300-329 days)	0	28468	18773	8679	540	48697	0	6904	2451	1780	0	9033	780	152	126257
Humid (330-364 days)	0	4495	46789	4672	0	10630	0	3513	2694	2985	0	2107	856	500	79241
Per-humid (365 days)	0	5212	62097	688	0	0	0	2809	1119	266	0	322	133	28	72675
Total extents	36629	63718	135570	42122	47532	224843	205709	395829	365665	366432	464523	46023	30530	1792	2426925

2.3 Land use/land cover

Six geographic datasets were used in GAEZ v3.0 for the compilation of a year 2000 inventory of the occurrence of seven major land use/land cover categories at 5 arc-minute resolution. The datasets used are:

1. GLC2000 land cover, regional and global classifications at 30 arc-seconds (JRC 2006);
2. IFPRI Agricultural Extent database, which is a global land cover categorization providing 17 land cover classes at 30 arc-seconds (IFPRI 2002), based on a reinterpretation of the Global Land Cover Characteristics Database (GLCCD 2001), EROS Data Centre (EDC 2000);
3. The Global Forest Resources Assessment 2000 and 2005 (FRA 2000 and FRA 2005) of FAO at 30 arc-seconds resolution;
4. Digital Global Map of Irrigated Areas (GMIA) version 4.01 (Siebert *et al.,* 2007) at 5 arc-minute latitude/longitude resolution, providing by grid-cell the percentage land area equipped with irrigation infrastructure;
5. IUCN-WCMC protected areas inventory at 30-arc-seconds (WDPA 2005), and
6. Spatial population density inventory (30 arc-seconds) for year 2000 developed by FAO-SDRN, based on spatial data of LANDSCAN 2003, LandScanTM Global Population Database, with calibration to UN 2000 population figures (FAO 2005).

An iterative calculation procedure has been implemented to estimate land cover class weights, consistent with aggregate FAO land statistics of cultivated land and forest extents and spatial land cover patterns obtained from (the above mentioned) remotely sensed data, resulting in the quantification of major land use/land cover shares in individual 5 arc-minute latitude/longitude grid-cells. The estimated class weights define for each land cover class the presence of respectively cultivated land and forest. Starting values of class weights used in the iterative procedure were obtained by cross-country regression of statistical data of cultivated and forest land against land cover class distributions obtained from GIS, aggregated to national level. The

percentage of urban/built-up land in a grid-cell was estimated based on occurrence of respective mapped land cover classes as well as regression equations, obtained using various sub-national statistical data, relating built-up land with population density. Remaining land, i.e. areas that are not representing cultivated land, forest land or built-up land, were allocated to:

1. Grassland and other vegetated areas, and
2. Barren or very sparsely vegetated areas

In accordance with the land cover classes indicated at 30 arc-seconds in GLC2000. Barren or very sparsely vegetated areas were delineated by (i) using the respective land cover classes in GLC2000 and/or (ii) applying a minimum bio-productivity threshold of 100 kg DM/ha/year.

The resulting seven land use/land cover categories, used for land accounting and to characterize each 5 arc-minute grid-cell, are:

1. Rain-fed cultivated land
2. Irrigated cultivated land
3. Forest
4. Grassland and other vegetated land
5. Barren and very sparsely vegetated land
6. Water
7. Built-up land (urban land and land used for housing and infrastructure).

Figure 6 presents the land use/land cover make-up in terms of the seven categories by FS zone. Table 3 provides actual extents of the land cover/land use categories by FS zone.

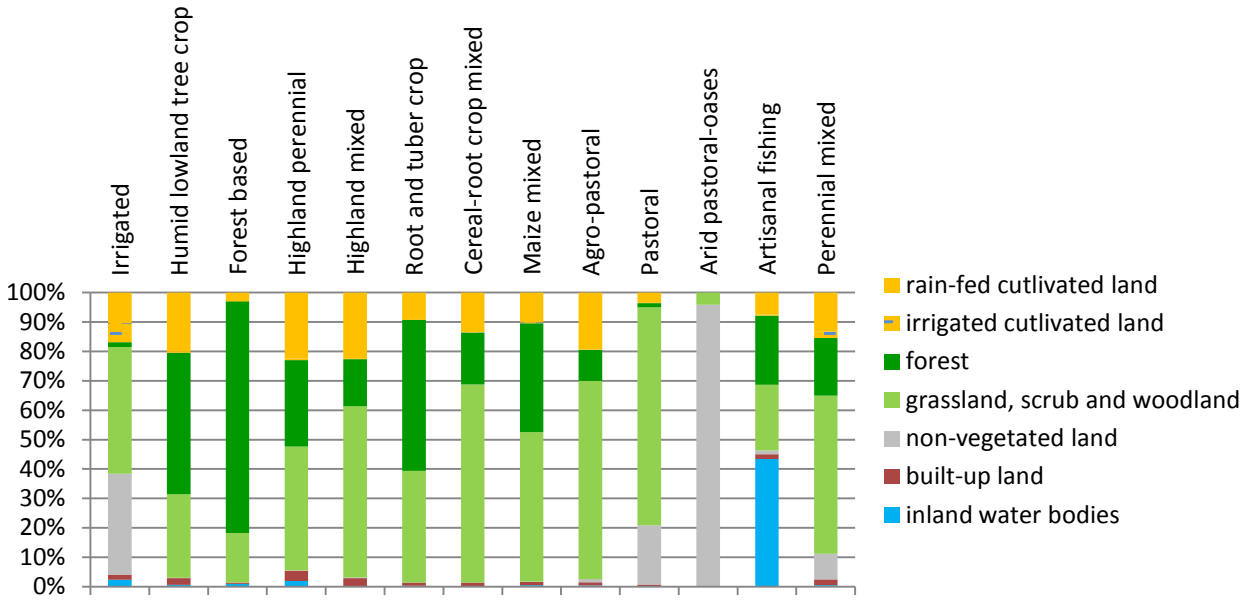


Figure 6 Land use/land cover by farming system zones

In Sub-Saharan Africa cultivated land represents a minor part of the land cover in all FS zones, i.e., only about 9% of the total area. Most intensively used for cultivation are the *humid lowland perennial* FS zone with just over 20% and the *highland perennial* FS zone and *highland mixed* FS zone with each about 23%. The agro-pastoral zone scores about 20% cultivated land.

The dominant land use and land cover characteristics of individual FS zones are as follows: **(i)** The *irrigated zone* occurs mainly in grassland, shrub and woodland (43%) and in non-vegetated land (34%). Only some 6 % of this zone is equipped for irrigation; **(ii)** the *humid lowland tree crop zone* mainly comprises of forest (48%), grassland, shrub and woodland (28%) and rain-fed cultivated land (20%); **(iii)** the *forest based zone* occurs mainly in forest (79%) and partly in grassland, shrub and woodland (17%); **(v)** the *highland perennial zone* occurs mainly in

grassland, shrub and woodland (42%), in forest (29 %) and has rain-fed cultivated land (22%); **(vi)** the *highland mixed zone* occurs mainly in grassland, shrub and woodland (58%) and has rain-fed cultivated land (22%); **(vii)** the *root and tuber zone* occurs mainly in forest (51%) , in grassland, shrub and woodland (38%) and has some rain-fed cultivated land (9%); **(viii)** the *cereal-root crop mixed zone* occurs mainly in grassland, shrub and woodland (67%), in forest (18%) and includes rain-fed cultivated land (13%); **(ix)** the *maize mixed zone* occurs mainly in grassland, shrub and woodland (51%), in forest (37%) and in rain-fed cultivated land (10%); **(xi)** the *agro-pastoral zone* occurs mainly in grassland, shrub and woodland (67%), in rain-fed cultivated land (19%), and in forest (11%); **(xii)** the *pastoral zone* occurs mainly in grassland shrub and woodland (74%) and in non-vegetated land (20%); **(xiii)** the *arid pastoral-oases zone* occurs mainly in non-vegetated land (95%) and in small extents of grassland, shrub and woodland (4%); **(xiv)** the *artisanal fishing zone* includes mainly forest (22%), grassland, shrub and woodland (21%), and 41% is covered by inland water bodies; **(xvi)** the *perennial mixed zone* occurs mainly in grassland, shrub and woodland (53%), in forest (19%) and in rain-fed cultivated land (13%).

Table 3 Land use/land cover of farming system zones (000ha)

	Irrigated	Humid lowland tree crop	Forest based	Highland perennial	Highland mixed	Root and tuber crop	Cereal-root crop mixed	Maize mixed	Agro-pastoral	Pastoral	Arid pastoral-oases	Artisanal fishing	Perennial mixed	Not assigned	Total land
Rain-fed cutlivated land	3780	12759	3916	9444	10593	20767	27631	39878	70115	12547	22	3228	3939	25	218644
Irrigated cutlivated land	2392	211	2	198	169	75	234	1280	859	696	46	175	682	6	7025
Forest	577	30463	106850	12391	7611	115450	36319	146386	38745	5083	70	10220	5846	88	516100
Grassland, shrub and woodland	15793	18044	22846	17769	27646	85320	138601	201088	246048	271441	18778	9666	16075	38	1089153
Non-vegetated land	12531	42		10	142	1		192	4137	73520	443214	550	2591	494	537424
Built-up land	653	1491	670	1484	1287	2398	2359	4686	4042	2061	347	746	570	7	22800
Inland water bodies	872	385	1278	826	84	805	523	1900	1400	771	344	18836	170	29	28222
Total extents	36629	63718	135570	42122	47532	224843	205709	395829	365665	366432	464523	46023	30530	1792	2426925

2.4 Protected areas

The World Database of Protected Areas Annual Release 2009 (henceforth WDPA 2009) was used to identify protected areas by farming system zones in Sub-Saharan Africa (Table 4).

Table 4 Protection status of farming system zones

Farming System Zone	Legally Protected	
	(000ha)	(%)
Irrigated	537	1.4
Humid lowland tree crop	5,257	7.6
Forest based	15,248	10.1
Highland perennial	7,575	15.2
Highland mixed	4,888	9.3
Root and tuber crop	18,708	7.7
Cereal-root crop mixed	20,394	9.0
Maize mixed	69,015	14.8
Agro-pastoral	66,110	15.3
Pastoral	30,222	7.6
Arid pastoral-oases	27,308	5.6
Artisanal fishing	4,234	8.4
Perennial mixed	9,484	23.7
Total extents	278,980	10.3

About 10% of Sub-Saharan Africa is legally protected. Protection status varies between farming system zones from almost a quarter of the *perennial mixed* zone to only just above 1 percent of the *irrigated* zone.

2.5 Population and livestock density

Combining population data and ruminant livestock data with FS zones provides distributions of population and livestock numbers across FS zones. Table 5 presents ruminant and population data (year 2000) by FS zone. Ruminant density refers to the year 2000 spatial grids of cattle, sheep and goats available from the Global Livestock Mapping Project of FAO-AGA "The Gridded Livestock of the World (FAO 2007)". The separate grids were combined with the following weight factors: Cattle weight 1.0, sheep and goats weight 0.2.

Table 5 Population and ruminant livestock numbers by FS zone

	Extents (000ha)	Population		Livestock						
		Person (10^6)	Population density (pers/km^2)	Cattle (10^6)	Sheep (10^6)	Goat (10^6)	Pig (10^6)	Poultry (10^6)	Ruminant (10^6)	Ruminants density (Rum/km^2)
Irrigated	36,629	25.0	68	8.5	10.8	9.7	0.2	17.7	12.6	35
Humid lowland tree crop	63,718	54.4	85	1.9	5.1	6.3	1.8	64.0	4.2	7
Forest based	135,570	11.9	9	0.2	0.4	1.1	0.4	14.1	0.5	0
Highland perennial	42,122	56.2	133	15.4	5.2	9.3	1.4	30.5	18.2	43
Highland mixed	47,532	45.3	95	20.6	10.0	6.4	0.3	25.1	23.9	50
Root and tuber crop	224,843	70.4	31	8.4	8.2	16.1	3.2	83.3	13.3	6
Cereal-root crop mixed	205,709	56.9	28	32.0	24.2	28.6	4.2	107.7	42.5	21
Maize mixed	395,829	114.6	29	27.9	13.3	16.6	3.8	181.1	33.8	9
Agro-pastoral	365,665	105.6	29	65.0	45.6	54.1	2.5	144.6	85.0	23
Pastoral	366,432	40.3	11	28.9	46.1	37.6	0.6	43.4	45.6	12
Arid pastoral-oases	464,523	6.4	1	2.1	9.9	6.7	0.8	23.6	5.4	1
Artisanal fishing	46,023	41.9	91	3.1	2.5	3.3	1.0	25.5	4.2	9
Perennial mixed	30,530	21.3	70	5.3	6.3	3.0	0.4	42.5	7.2	23
Total land	2,426,925	653.6	27	219.3	187.6	198.9	20.5	804.1	296.6	12

Highest ruminant livestock density and population densities coincide. They occur in *highland perennial* and *highland mixed* FS zones. Very low densities are found in various zones with rather poor agro-ecological resources. In particular the *forest based* FS zone stands out with virtual no ruminant livestock and very low average population density of only 9 pers/km^2. Also, the humid conditions of the *forest based zone* may create severe health hazards to human and livestock. Details of population and ruminant livestock data by farming system zone, land cover, land protection status and LGP are provided for download.

3 Land Quality

The GAEZ modeling framework assesses land suitability, potential attainable yields and potential production of crops for specified management assumptions and input levels (Box 2), both for rain-fed and irrigated conditions. for 11 major crop groups, 49 major crops and 92 crop sub-types subdivided into 280 crop/land utilization types (LUTs). Results include agro-climatically attainable yields, climate related yield constraints, crop calendar data and soil/terrain suitability data. Figure 4 and Tables 6 and 7 present land qualities for agricultural use for each farming system zone (based on maize suitability). *Prime land* represents agro-ecologically very suitable land, *good land* is suitable and moderately suitable land, and *poor land* includes marginally, very marginally and not suitable land.

Box 2

Low level inputs

Under a low level of inputs (traditional management assumption), the farming system is largely subsistence based. Production is based on the use of traditional cultivars (if improved cultivars are used, they are treated in the same way as local cultivars), labor intensive techniques, and no application of nutrients, no use of chemicals for pest and disease control and minimum conservation measures.

Intermediate level inputs

Under an intermediate level of input (improved management assumption), the farming system is partly market oriented. Production for subsistence plus commercial sale is a management objective. Production is based on improved varieties, on manual labor with hand tools and/or animal traction and some mechanization, is medium labor intensive, uses some fertilizer application and chemical pest disease and weed control, adequate fallows and some conservation measures.

High level inputs

Under a high level of input (advanced management assumption), the farming system is mainly market oriented. Commercial production is a management objective. Production is based on improved or high yielding varieties, is fully mechanized with low labor intensity and uses optimum applications of nutrients and chemical pest, disease and weed control.

In GAEZ, this variety in management and input levels is translated into yield differences by assigning different parameters for LUTs depending on the input/management level, e.g. such as harvest index and maximum leaf area index. LUTs are parameterized to reflect environmental and eco-physiological requirements for growth and development of different crop types..

Almost 6% of the land resources in Sub-Saharan Africa contain prime rain-fed agricultural land for low input/traditional management farming. For high input advanced management almost 17%. This land is classified agro-ecologically (climate, soil and terrain) very suitable for rain-fed crop production. Prime land is characterized by potentially achievable crop yields in the range 80-100% of maximum attainable yields. Almost 20% of all cultivated land is prime land, 60% good land and the rest, about 20% is poor land for low input farming. For high input farming the numbers are: 38% prime land, 54% good land and almost 8% is poor land. See Table 6a for details in percentages by farming system zone.

Table 6a Prime, good and poor land (%) by farming system zone*

FS zone	High input - all land			High input -cultivated land			Low input - all land			Low input -cultivated land		
	Prime	Good	Poor	Prime	Good	Poor	Prime	Good	Poor	Prime	Good	Poor
Irrigated	5.3	27.5	67.2	12.6	56.0	31.5	1.4	16.2	82.4	5.5	40.6	53.9
Humid lowland tree crop	15.6	56.5	27.9	10.7	87.7	1.6	0.2	48.1	51.7	0.2	80.1	19.6
Forest based	17.9	70.3	11.8	26.1	73.7	0.2	0.0	65.7	34.3	0.0	97.2	2.8
Highland perennial	30.2	27.8	42.0	44.7	39.6	15.7	12.6	36.3	51.1	20.6	56.0	23.4
Highland mixed	18.3	25.1	56.5	32.0	36.5	31.5	9.3	24.6	66.0	20.6	34.8	44.6
Root and tuber crop	19.2	57.7	23.2	33.7	64.8	1.5	0.8	56.6	42.6	1.2	85.0	13.8
Cereal-root crop mixed	36.7	38.8	24.5	52.8	42.6	4.6	14.4	34.7	50.9	34.8	49.9	15.3
Maize mixed	28.7	52.1	19.3	46.3	50.9	2.8	10.6	53.3	36.1	25.5	64.5	10.1
Agro-pastoral	24.4	48.4	27.2	42.0	52.6	5.4	11.0	44.6	44.4	24.4	59.3	16.4
Pastoral	4.4	21.3	74.3	15.5	65.7	18.7	3.1	17.1	79.9	10.8	47.6	41.6
Arid pastoral-oases	0.0	0.8	99.2	22.1	16.2	63.2	0.0	0.7	99.3	20.6	11.8	69.1
Artisanal fishing	10.3	31.2	58.5	31.4	63.8	4.8	3.5	21.0	75.5	14.2	62.1	23.7
Perennial mixed	17.0	23.5	59.5	33.5	42.4	24.1	8.5	31.3	60.2	23.2	48.8	28.1
Total land	16.7	35.5	47.8	38.2	54.0	7.7	5.7	33.4	60.9	20.1	60.6	19.3

* Based on best selected crop (cassava, cotton, cowpea, groundnut, maize, millet, phaseolus bean, sorghum, soybean, sugarcane, sweet potato, white potato, wheat and yam)

Details about shares of extents of prime, good and poor land are presented in Figure 7 for high input farming and Tables 6b and 6c respectively for high and low input farming.

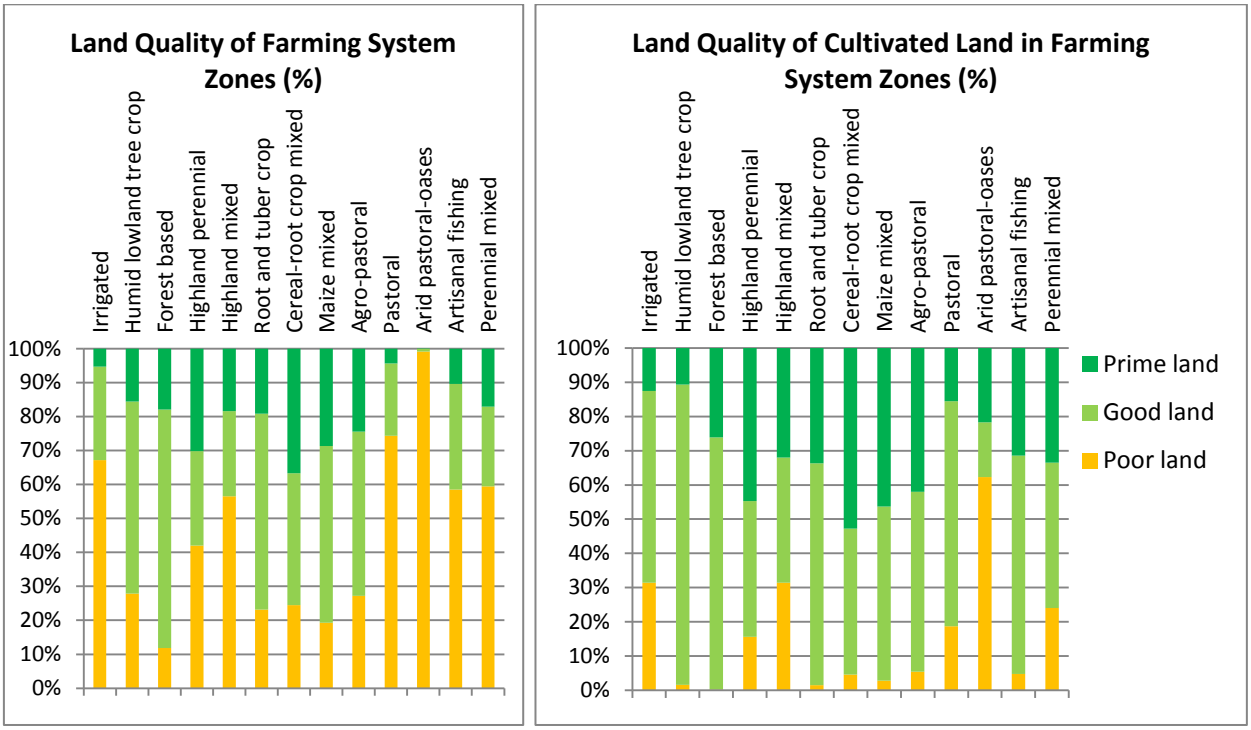


Figure 7 Land quality for high input farming of FS zones*

Table 6b Land quality of farming system zones for rain-fed high input farming (000ha)*

	All land extent	Cultivated land	Prime land		Good land		Poor land	
			all land	cultivated land	all land	cultivated land	all land	cultivated land
Irrigated	36,629	6,171	1,946	776	10,075	3,455	24,609	1941
Humid lowland tree crop	63,718	12,970	9,914	1,387	36,030	11,370	17,775	213
Forest based	135,570	3,918	24,326	1,023	95,256	2,887	15,988	7
Highland perennial	42,122	9,642	12,712	4,310	11,706	3,823	17,704	1509
Highland mixed	47,532	10,762	8,720	3,442	11,939	3,932	26,873	3388
Root and tuber crop	224,843	20,842	43,082	7,025	129,697	13,508	52,065	310
Cereal-root crop mixed	205,709	27,866	75,524	14,708	79,880	11,882	50,304	1276
Maize mixed	395,829	41,158	113,478	19,054	206,131	20,936	76,220	1166
Agro-pastoral	365,665	70,973	89,159	29,810	177,127	37,313	99,379	3849
Pastoral	366,432	13,244	15,967	2,056	78,037	8,706	272,428	2482
Arid pastoral-oases	464,523	68	74	15	3,641	11	460,808	43
Artisanal fishing	46,023	3,403	4,747	1,069	14,351	2,172	26,925	162
Perennial mixed	30,530	4,621	5,204	1,549	7,170	1,960	18,157	1112
Not assigned	1,792	31	116	7	155	18	1,521	7
Total land	2,426,92	225,669	404,969	86,230	861,194	121,972	1,160,76	17467

* Based on best selected crop (cassava, cotton, cowpea, groundnut, maize, millet, phaseolus bean, sorghum, soybean, sugarcane, sweet potato, white potato, wheat and yam)

Table 6c Land quality of farming system zones for rain-fed low input farming (000ha)*

	All land extent	Cultivated land	Prime land		Good land		Poor land	
			all land	cultivated land	all land	cultivated land	all land	cultivated land
Irrigated	36,629	6,171	515	338	5,927	2,504	30,188	3,328
Humid lowland tree crop	63,718	12,970	125	32	30,623	10,392	32,970	2,547
Forest based	135,570	3,918	3	1	89,016	3,810	46,551	109
Highland perennial	42,122	9,642	5,294	1,984	15,294	5,403	21,535	2,255
Highland mixed	47,532	10,762	4,434	2,219	11,707	3,740	31,390	4,804
Root and tuber crop	224,843	20,842	1,746	252	127,205	17,718	95,891	2,873
Cereal-root crop mixed	205,709	27,866	29,595	9,693	71,412	13,918	104,702	4,254
Maize mixed	395,829	41,158	41,972	10,480	211,155	26,538	142,701	4,141
Agro-pastoral	365,665	70,973	40,160	17,310	163,096	42,056	162,408	11,606
Pastoral	366,432	13,244	11,216	1,435	62,516	6,305	292,700	5,503
Arid pastoral-oases	464,523	68	55	14	3,149	8	461,319	47
Artisanal fishing	46,023	3,403	1,599	484	9,679	2,113	34,745	805
Perennial mixed	30,530	4,621	2,597	1,070	9,567	2,254	18,367	1,297
Not assigned	1,792	31	39	3	268	21	1,486	7
Total land	2,426,92	225,669	139,351	45,315	810,616	136,779	1,476,95	43,575

* Based on best selected crop (cassava, cotton, cowpea, groundnut, maize, millet, phaseolus bean, sorghum, soybean, sugarcane, sweet potato, white potato, wheat and yam)

Extents of quality agricultural land vary between FS zones and by level of inputs and management applied. Occurrence of prime and good rain-fed land for high input farming ranges between less than 1% in the arid pastoral oases zone to more almost 90% in the forest based zone. For low input farming, with more severe constraints because of low natural nutrient availability and pest and disease constraints related to wetness, the extents of prime and good agricultural land are lower, varying between <1% and 66% in the forest based zone.

About 39% of the agricultural land resources in Sub-Saharan Africa are prime- or good quality for low input farming compared and 52% at high input farming. In comparison just over 9% was reported cultivated in 2000.

Tables 7a and 7b present by FS zone the shares and quality of cultivated land, forest and grassland/shrub land woodland, respectively for high input farming and low input farming and by protection status.

Table 7a Share of FS zone with prime and good quality land for high input farming in current cultivated land, forest land and grassland/shrub land/woodland

		Cultivated land in which:		Forest land in which:			Grassland/shrubland/ woodland in which:		
	Extent (000ha)	Share of cultivated land in FS zone (%)	Share of prime and good land (%)	Share of forest inFS zone (%)	Share not protected prime and good land (%)	Share protected prime and good land (%)	Share of grassland/ shrubland and woodland in FS zone (%)	Share not protected prime and good land (%)	Share protected prime and good land (%)
Irrigated	36,629	16.9	11.5	1.6	1.1	0.1	43.1	17.9	0.7
Humid lowland tree crop	63,718	20.4	20.1	47.8	27.7	3.8	28.3	16.3	1.4
Forest based	135,570	2.9	2.8	78.8	61.8	8.0	16.9	13.4	1.5
Highland perennial	42,122	22.9	19.3	29.4	9.3	3.9	42.2	18.7	3.0
Highland mixed	47,532	22.6	15.5	16	6.3	0.7	58.2	16.9	1.8
Root and tuber crop	224,843	9.3	9.1	51.3	34.8	3.7	37.9	25.8	2.3
Cereal-root crop mixed	205,709	13.5	12.9	17.7	10.0	1.7	67.4	44.3	5.3
Maize mixed	395,829	10.4	10.1	37	25.6	4.9	50.8	30.2	8.5
Agro-pastoral	365,665	19.4	18.4	10.6	5.6	2.0	67.3	36.2	9.1
Pastoral	366,432	3.6	2.9	1.4	0.7	0.1	74.1	18.4	2.1
Arid pastoral-oases	464,523	0	0.0	0	0.0	0.0	4	0.1	0.0
Artisanal fishing	46,023	7.4	7.0	22.2	11.8	2.6	21	11.3	1.2
Perennial mixed	30,530	15.1	11.5	19.1	8.1	1.0	52.7	15.0	2.2
Not assigned	1,792	1.7	1.3	4.9	0.9	0.1	2.1	0.4	0.1
Total land	2,426,925	9.3	8.0	21.3	14.0	2.3	44.9	21.8	4.0

Table 7b Occurrence of prime and good quality land for low input farming in cultivated land, forest land and grassland/shrub land/woodland

		Cultivated land in which:		Forest land in which:			Grassland/shrubland/ woodland in which:		
	Extent (000ha)	Share of FS zone (%)	Share not protected prime and good land (%)	Share of FS zone (%)	Share not protected prime and good land (%)	Share protected prime and good land (%)	Share of FS zone (%)	Share not protected prime and good land	Share protected prime and good land (%)
Irrigated	36,629	16.9	7.8	1.6	0.6	0.1	43.1	7.7	0.4
Humid lowland tree crop	63,718	20.4	16.3	47.8	17.6	2.6	28.3	8.7	0.9
Forest based	135,570	2.9	2.8	78.8	45.4	6.4	16.9	9.4	1.2
Highland perennial	42,122	22.9	17.5	29.4	7.6	3.5	42.2	14.4	2.6
Highland mixed	47,532	22.6	12.5	16	5.7	0.6	58.2	12.4	1.0
Root and tuber crop	224,843	9.3	8.0	51.3	26.0	2.7	37.9	18.1	1.5
Cereal-root crop mixed	205,709	13.5	11.5	17.7	6.3	1.2	67.4	25.4	3.7
Maize mixed	395,829	10.4	9.3	37	21.3	3.6	50.8	23.1	5.4
Agro-pastoral	365,665	19.4	16.2	10.6	4.6	1.5	67.3	25.9	6.1
Pastoral	366,432	3.6	2.1	1.4	0.5	0.1	74.1	15.0	1.4
Arid pastoral-oases	464,523	0	0.0	0	0.0	0.0	4	0.1	0.0
Artisanal fishing	46,023	7.4	5.7	22.2	5.8	1.2	21	6.7	0.7
Perennial mixed	30,530	15.1	10.9	19.1	8.5	0.9	52.7	15.0	2.3
Not assigned	1,792	1.7	1.4	4.9	1.1	0.2	2.1	0.5	0.1
Total land	2,426,9	9.3	7.5	21.3	10.7	1.7	44.9	15.5	2.7

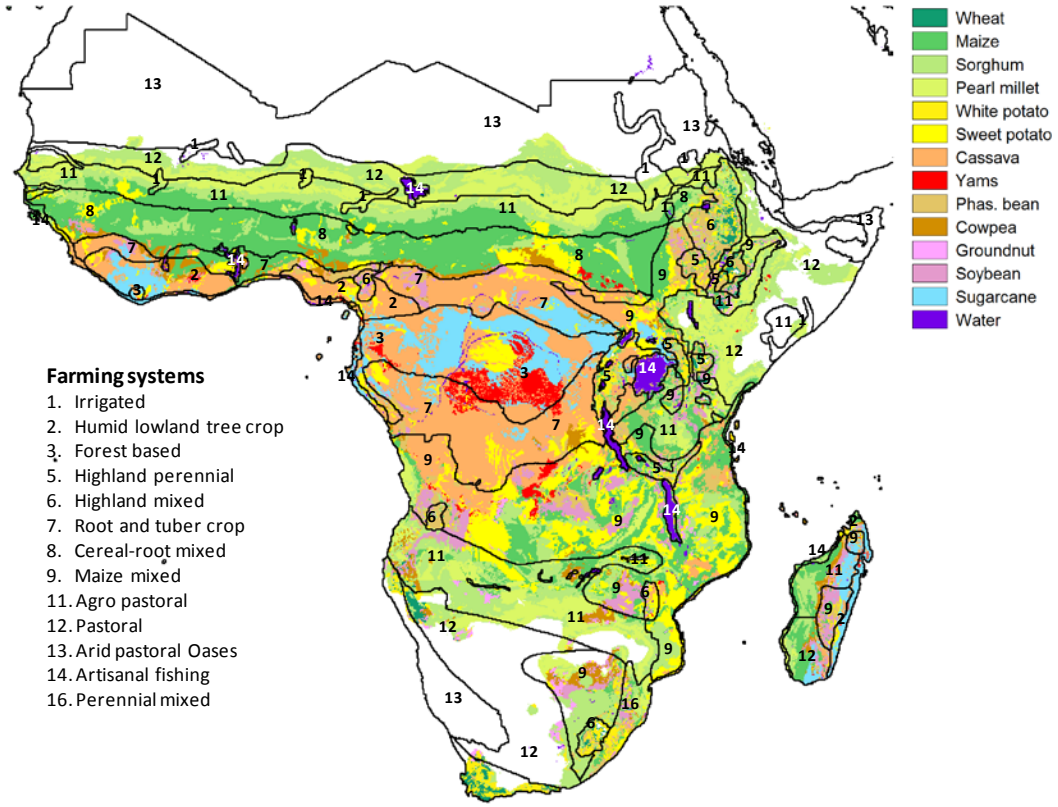


Figure 8a Agro-ecologically best adapted rain-fed crops at high level input farming

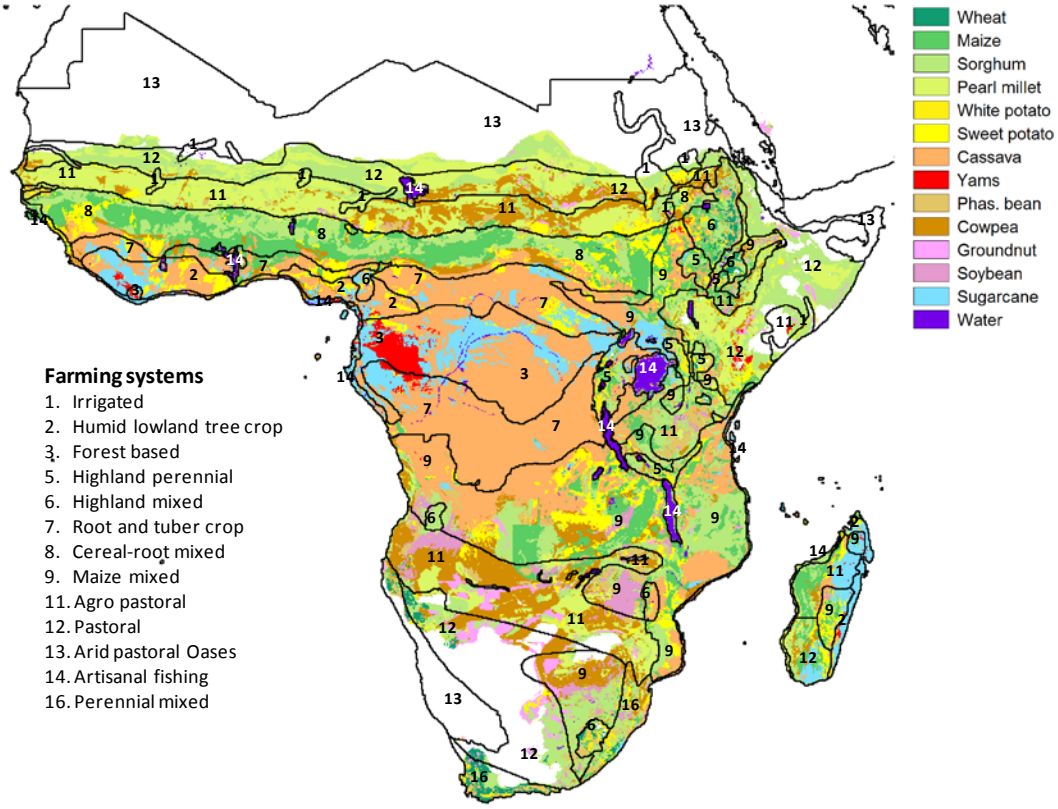


Figure 8b Agro-ecologically best adapted rain-fed crops at low level input farming

Figure 8 presents maps indicating the rain-fed crop that is potentially most adapted to prevailing environmental conditions. Figure 8a presents best adapted rain-fed crops assuming high level inputs and advanced management, and Figure 8b shows best adapted rain-fed crops assuming low input and traditional management. The crops considered are: cassava, cowpea, groundnut, maize, millet, phaseolus bean, sorghum, soybean, sugarcane, sweet potato, white potato, wheat and yam.

Table 8a Occurrences of best adapted rain-fed crops in all land by FS zones (%)

	Irrigated	Humid lowland tree crop	Forest based	Highland perennial	Highland mixed	Root and tuber crop	Cereal-root crop mixed	Maize mixed	Agro-pastoral	Pastoral	Arid pastoral-oases	Artisanal fishing	Perennial mixed
Wheat	0.0	0.0	0.0	2.7	9.9	0.0	0.0	0.2	0.4	0.7	0.0	0.0	10.0
Maize	4.0	4.5	0.1	14.7	7.3	5.4	67.4	20.4	23.8	2.3	0.0	16.8	6.4
Sorghum	15.4	0.0	0.0	11.5	17.0	0.2	11.9	15.9	32.1	25.5	3.5	5.6	16.7
Pearl millet	26.0	0.0	0.0	0.1	2.7	0.0	0.8	3.7	23.7	26.1	1.6	2.1	6.5
White and sweet potato	0.6	10.4	8.0	25.5	18.4	10.0	10.5	24.5	4.5	0.8	0.3	12.8	28.8
Cassava and yam	0.0	48.4	53.3	17.1	5.1	63.4	2.5	12.8	0.9	0.5	0.0	17.6	1.5
Pulses	0.4	9.5	0.5	18.5	29.1	7.8	6.2	8.8	4.6	0.7	0.0	4.9	8.3
Groundnut	0.0	0.1	0.0	0.4	0.1	0.2	0.0	1.1	0.7	0.9	0.0	0.0	0.7
Soybean	0.2	2.4	0.2	4.8	9.2	3.9	0.7	9.0	2.9	0.6	0.0	0.5	7.8
Sugarcane	0.0	24.7	37.9	4.0	0.1	9.1	0.0	1.5	1.0	0.6	0.0	9.9	0.1
None selected*	53.6	0.0	0.0	0.8	1.2	0.0	0.0	2.1	5.3	41.1	94.4	29.8	13.2

* None selected: No suitable crops among wheat, maize, sorghum, millet, white potato, sweet potato, cassava, yam, pulses, groundnut, soybean or sugarcane.

Table 8b Occurrences of best adapted rain-fed crop in rain-fed cultivated land by FS zones (%)

	Irrigated	Humid lowland tree crop	Forest based	Highland perennial	Highland mixed	Root and tuber crop	Cereal-root crop mixed	Maize mixed	Agro-pastoral	Pastoral	Arid pastoral-oases	Artisanal fishing	Perennial mixed
Wheat	0.0	0.0	0.0	1.7	12.5	0.0	0.0	0.3	0.1	0.4	0.0	0.0	13.2
Maize	8.5	7.4	0.4	12.6	9.3	17.2	71.7	20.7	31.4	5.3	54.5	27.3	8.3
Sorghum	28.5	0.0	0.0	11.8	17.1	0.2	13.4	24.4	38.1	26.5	40.9	4.3	18.4
Pearl millet	59.1	0.0	0.0	0.2	3.0	0.0	0.5	3.1	21.4	55.7	0.0	1.6	5.4
White and sweet potato	1.3	9.6	5.4	25.3	17.2	9.9	5.5	20.7	3.3	2.1	9.1	16.0	29.3
Cassava and yam	0.0	45.5	47.6	21.6	3.3	47.3	1.8	8.0	0.7	1.8	0.0	24.3	1.5
Pulses	0.4	14.8	1.6	16.9	29.5	12.8	6.0	8.7	3.0	1.3	0.0	8.6	14.1
Groundnut	0.0	0.1	0.0	0.3	0.0	0.6	0.0	1.6	0.2	1.8	0.0	0.0	0.3
Soybean	0.3	2.3	0.4	3.5	7.5	5.8	1.2	8.6	1.2	0.7	0.0	0.4	8.4
Sugarcane	0.0	20.3	44.7	6.0	0.0	6.2	0.0	3.7	0.3	1.0	0.0	16.0	0.1
None selected*	1.9	0.0	0.0	0.3	0.5	0.0	0.0	0.1	0.4	3.4	0.0	1.5	1.0

* None selected: No suitable crops among wheat, maize, sorghum, millet, white potato, sweet potato, cassava, yam, pulses, groundnut, soybean or sugarcane.

Table 8 lists by FS zone the percentage of occurrence of potentially best adapted rain-fed crops in rain-fed cultivated land and in all land. When none of the listed crops were suitable in a grid cell then this occurrence is provided under “None selected”. Actual occurrences of the same crops derived from downscaling of harvested area statistics are provided in Table 9.

Table 9 Occurrences of rain-fed crops grown in rain-fed cultivated land by FS zones (%)

	Irrigated	Humid lowland tree crop	Forest based	Highland perennial	Highland mixed	Root and tuber crop	Cereal-root crop mixed	Maize mixed	Agro-pastoral	Pastoral	Arid pastoral-oases	Artisanal fishing	Perennial mixed
Wheat	0.2	0.1	0.0	3.2	17.4	0.0	0.0	2.6	0.7	1.6	0.1	0.0	30.7
Maize	6.7	21.1	15.4	20.8	34.5	30.3	16.6	44.3	11.8	12.1	9.4	29.1	29.4
Sorghum	40.2	2.1	0.1	7.5	17.1	6.5	20.3	7.0	24.5	24.0	16.8	7.2	0.4
Millet	29.9	0.7	0.1	2.8	5.4	2.3	10.0	3.9	26.6	38.7	41.1	4.8	0.6
White and sweet potato	0.3	2.9	1.8	15.3	2.0	1.3	1.3	3.7	1.6	1.6	2.3	4.9	2.3
Cassava and yam	2.7	59.9	68.4	19.5	5.7	39.3	26.2	18.9	9.2	4.6	9.6	32.9	3.0
Pulses	10.6	7.9	5.3	27.6	15.1	8.5	12.7	11.6	16.8	11.4	14.1	13.8	4.3
Groundnut	9.3	3.0	6.4	1.5	1.3	8.9	10.4	6.4	8.6	5.6	6.6	5.8	1.7
Soybean	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Sugarcane	0.0	1.3	2.2	0.8	1.2	1.2	0.1	0.5	0.0	0.3	0.0	0.8	23.6
Total (10^6ha)*8	***3.1***	***3.7***	***1.3***	***5.7***	***3.9***	***6.7***	***18.1***	***17.2***	***46.9***	***9.2***	***0.0***	***1.4***	***0.9***

** Total year 2000 harvested area of: wheat, maize, sorghum, millet, white potato, sweet potato, cassava, yam, pulses, groundnut, soybean or sugarcane.

Comparing occurrences of potentially best adapted rain-fed crops in rain-fed cultivated areas (Table 8) with crops that are actually grown (year 2000) in these areas (Table 9), confirms reasonable correspondence with the exception of sugarcane in the *humid lowland tree crop* zone, the *forest based* zone and the *artisanal fishing* zone, where sugarcane belongs to the best adapted crops, but is hardly grown. The reverse can be seen for the *perennial mixed* zone where sugarcane clearly does not rank as best adapted crop but is nevertheless extensively grown.

4 Crop Suitability

GAEZ agro-ecological suitability and productivity procedures combine LUT specific results of the agro-climatic evaluation for biomass and yield with agro-edaphic suitability (see Box 3).

Box 3.

The algorithm used for assessing agro-ecological crop suitability steps through the grid cells of the spatial soil association layer of the Harmonized World Soil Database (FAO/IIASA/ISRIC/ISS-CAS/JRC 2009) and determines for each grid cell the respective make-up of land units in terms of soil types and slope classes. Each of these component land units is separately assigned the appropriate suitability and yield values and results are accumulated for all elements. Processing of soil and slope distribution information takes place at 30 arc-second grid cells. One hundred of these produce the edaphic characterization at 5 arc-minutes, which is the resolution used for providing GAEZ results. As a result, information stored for 5 arc-minute grid cells represents distributions of the individual sub-grid evaluations.

The grid-cell database stores for each crop or crop group the aggregated evaluation results that summarize processed sub-grid information. Computations include the following steps:

- Reading agro-climatic yields calculated for separate crop water balances of six broad soil AWC classes;
- applying AEZ rules for water-collecting sites (defined as Fluvisols and Gleysols in flat terrain);
- applying yield reduction factors due to soil evaluation and terrain slope rating for the specific combinations of soil types/slope classes making up a grid-cell;
- aggregating results over component land units (soil type/slope combinations), and
- calculating applicable fallow requirement factors depending on climate characteristics, soil type and crop group.

The results of crop evaluations are stored as a large number of separate databases organized by crop, input level, water supply system and scenario/time period and containing sub-grid distribution information in terms of suitable extents and potential production by suitability classes.

As an example, in Figure 9 the suitability distribution of rain-fed maize at high input level is shown by FS zone. Accordingly, different rain-fed maize LUTs are very suitable or suitable in more than 30% of an FS zone's land is the *highland* perennial zone, the *cereal-root crop mixed zone*, the *maize mixed zone*, and the *agro-pastoral zone*. Conversely, very little or no suitable land for rain-fed maize types could be found in the *humid lowland tree crop zone*, the *forest based zone* and the *arid pastoral-oases zone*.

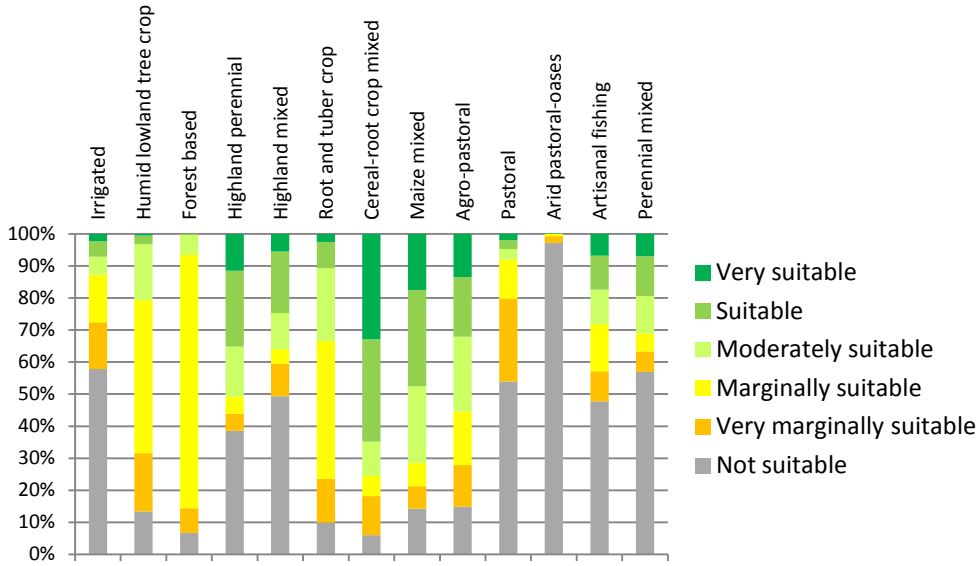


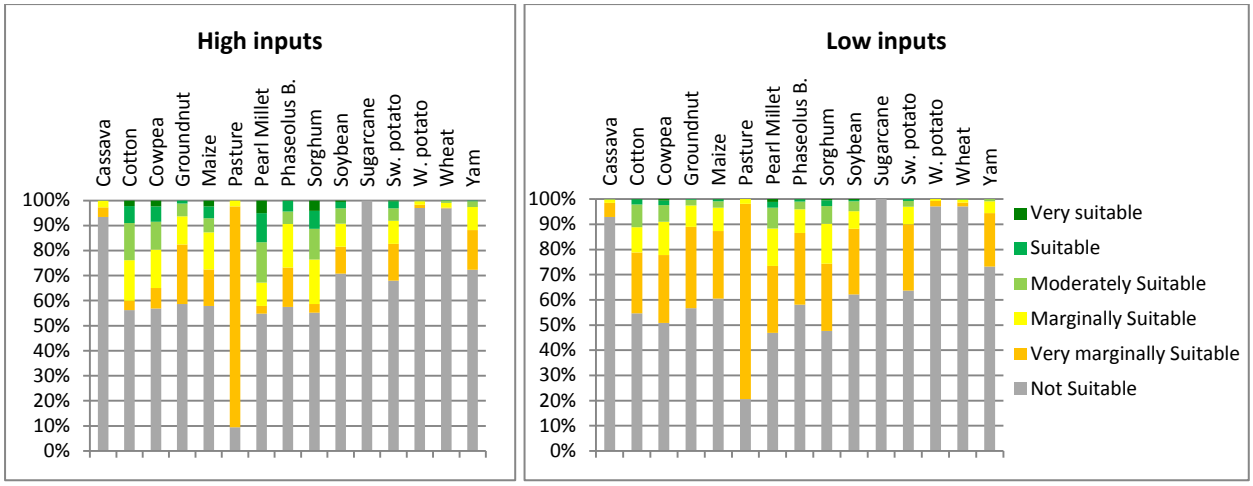
Figure 9 Suitability of rain-fed maize by FS Zones (%)

Rain-fed suitability profiles

Rain-fed suitability for major crops under respectively high inputs with advanced management and low inputs with traditional management are summarized in the charts presented below by farming system zone.

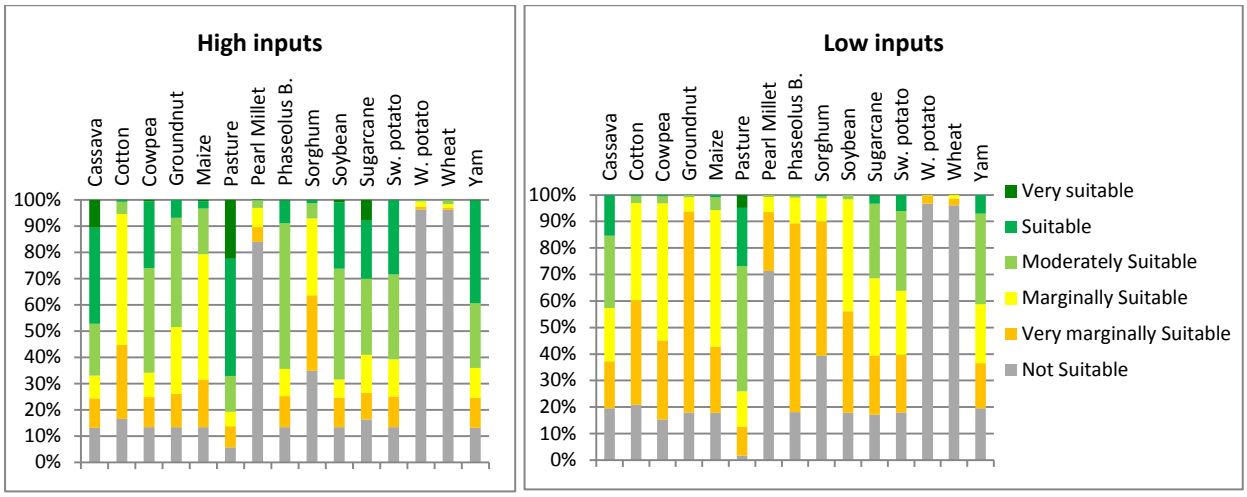
(i) Rain-fed suitability profiles for the irrigated farming system zone

The *irrigated farming system zone* occurs mainly in desert and dry semi-arid environments. Under rain-fed conditions, in this dominantly very dry FS zone, apart from marginal pasture, only short duration and drought resistant crops can be grown (e.g., cowpea, millet, sorghum and cotton). In this FS zone about 17 percent of the land is currently used for cultivation of which little more than one third is equipped with irrigation infrastructure. About 33% of this FS zone consists of prime or good land for rain-fed farming. The difference between the high inputs and low inputs suitability profiles points to natural soil fertility constraints. Nutrient availability constraints can partly be compensated under high inputs with application of fertilizer. Best adapted rain-fed crops in *the irrigated zone* include pearl millet, sorghum, cotton and cowpea.



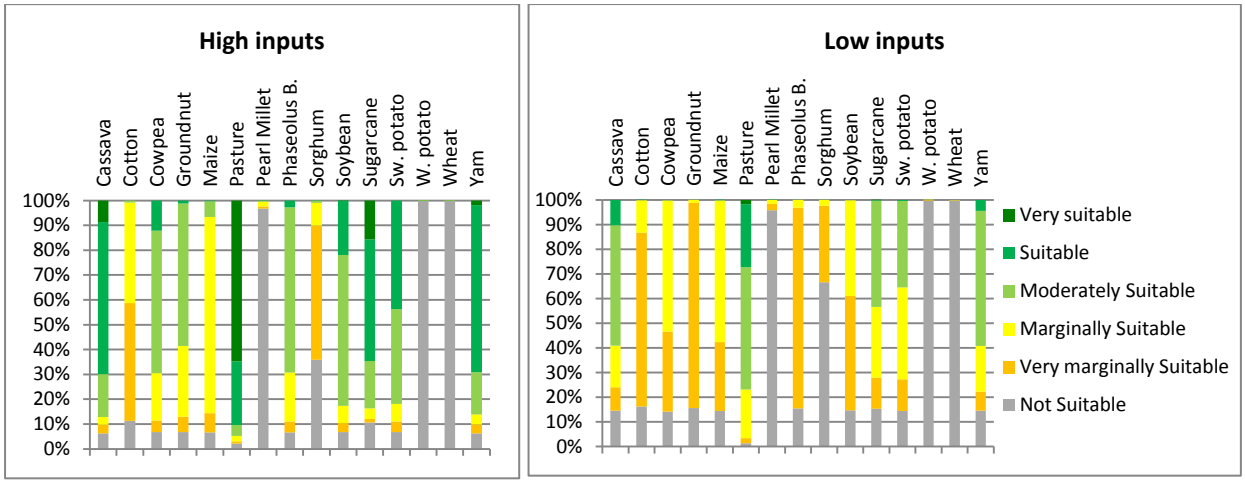
(ii) Rain-fed suitability profiles for the humid lowland tree crop farming system zone

The *humid lowland tree crop zone* occurs mainly in sub-humid and humid environments with dominantly moderate to poor soil quality. In this FS zone with LGP's typically between 240 and 365 days, long duration crops are adapted. About 72% of this FS zone consists of prime or good land for high input rain-fed farming; for low input farming 48%. In the wetter part, suitability and yields are affected by the occurrence of wetness related pest, disease and workability constraints. These constraints hinder mostly low input farming. In addition, in the part with poor soils, low natural soil fertility (nutrient availability) affects low input farming. These climate related and soil fertility constraints are causing pronounced differences between high and low input suitability profiles. Best adapted crops in *humid lowland tree crop zone*, as is clearly noticeable especially under low input conditions, include foremost cassava, yam, sweet potato and sugarcane.



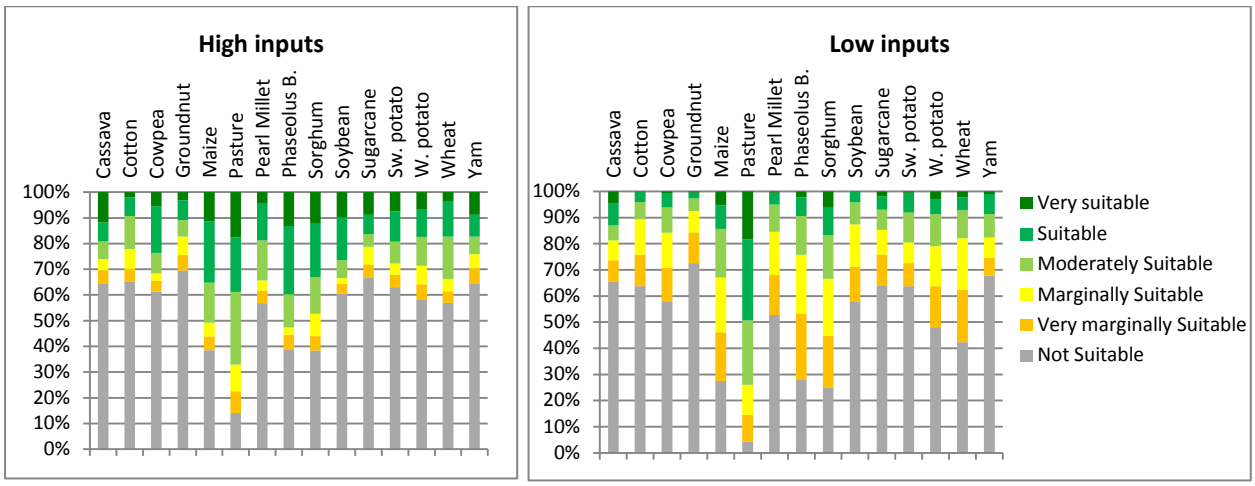
(iii) Rain-fed suitability profiles for the forest based farming system zone

The *forest based zone* occurs in humid environments with LGP's mainly between 300 and 365 days to which especially long duration and perennial crops are adapted. Land suitability and yields attainable under low level farming are affected by wetness related pest, disease and workability constraints. This zone has a prevalence of moderate and poor quality soils with low nutrient availability which affects low input farming most. Still as much as 88% of the *forest based zone* consists of prime or good land for high input farming; for low input farming this is 66%. This result is foremost dominated by the suitability of cassava and yam, and to a lesser extent sugarcane and sweet potato. The humid conditions of the *forest based zone* create severe health hazards to human and livestock; only just below 3% of this FS is currently cultivated.



(v) Rain-fed suitability profiles for the highland perennial farming system zone

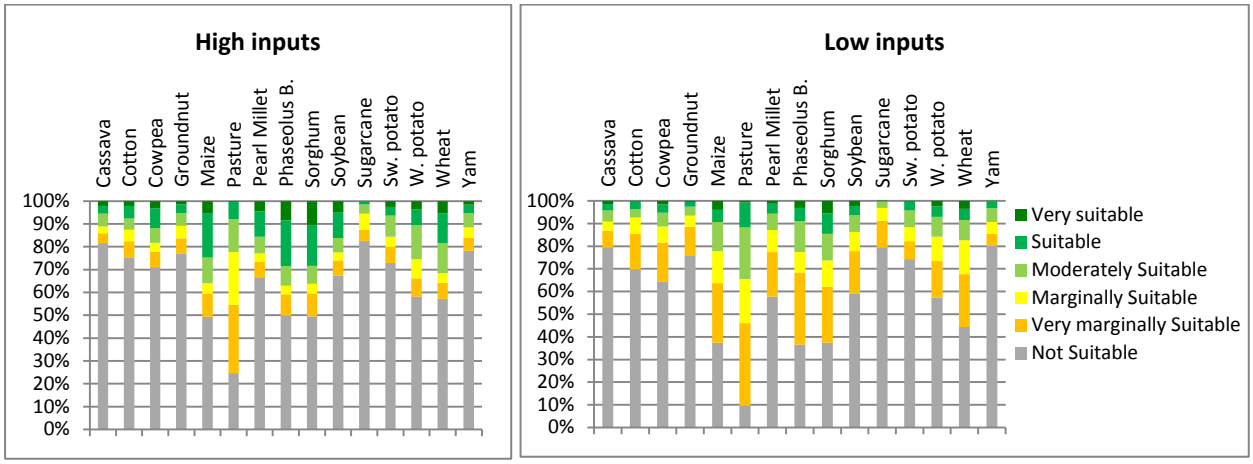
The *highland perennial zone* occurs mainly in LGPs between 180 and 365 days, but foremost (87%) in environments with LGP < 330 days with good and moderate quality soils. This FS zone is suitable for short duration and longer duration crops. The higher elevations and lower temperatures in this FS zone permit growing cryophilic crops such as wheat and white potato. A substantial part of this FS zone occurs however in steep terrain (25%) which restricts suitability to pasture or perennials with high groundcover such as tea. About 58% of this zone consists of prime and good land for high input farming; for low input farming this is about 50%. Almost 23% of the *highland perennial zone* is actually cultivated. Due to generally favorable soil conditions and only slight climatic and climate related crop production constraints, the suitability profiles of high input advanced management and low input farming are quite similar. As shown in the diagram, a wide range of crops is well adapted to the conditions of the *highland perennial zone.*



(vi) Rain-fed suitability profiles for the highland mixed farming system zone

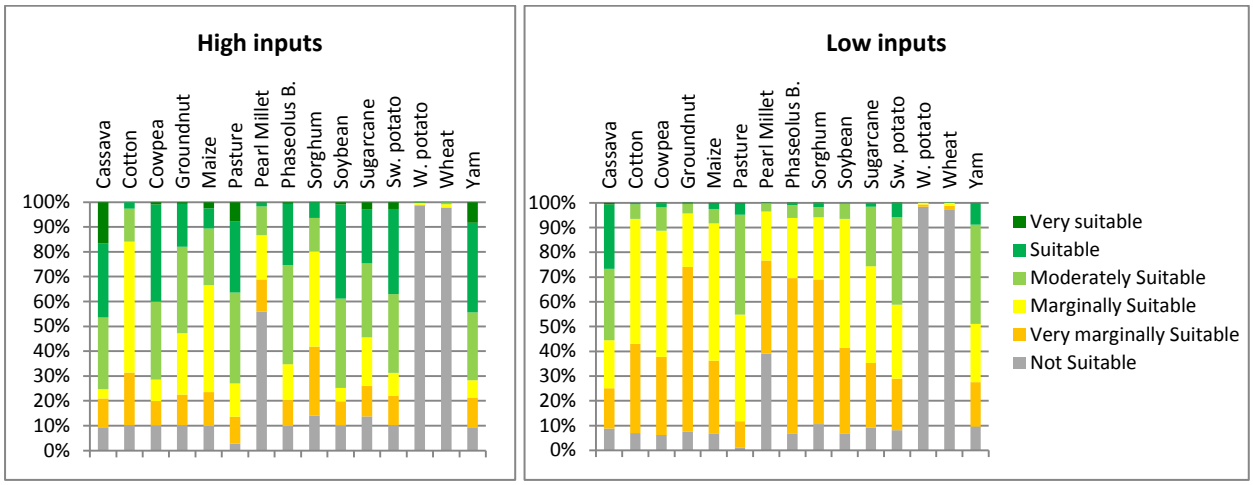
The *highland mixed zone* occurs foremost in LGPs between 60 and 330 days, but with more than 75% of the zone in an LGP range of 150-270 days with dominantly good soil conditions. A little more than one third (35%) of the highland mixed zone has steep terrain. Similar to the highland perennial zone, this FS zone is suitable for a wide range of short duration and longer duration crops. Best adapted crops in the highland mixed zone include maize, sorghum and phaseolus bean. Its higher elevations and lower temperatures make it also quite suitable for wheat and white potato. About 44% of this zone consists of prime and good land for high input farming; for low input farming this is 34%. Almost 23% of *highland mixed zone* is actually cultivated. Due to the favorable soil conditions and only slight climatic and climate related crop production constraints, differences between the suitability profiles of high input farming and low input

farming are minor. Differences are mainly due to wetness related constraints in the humid part of this FS zone.



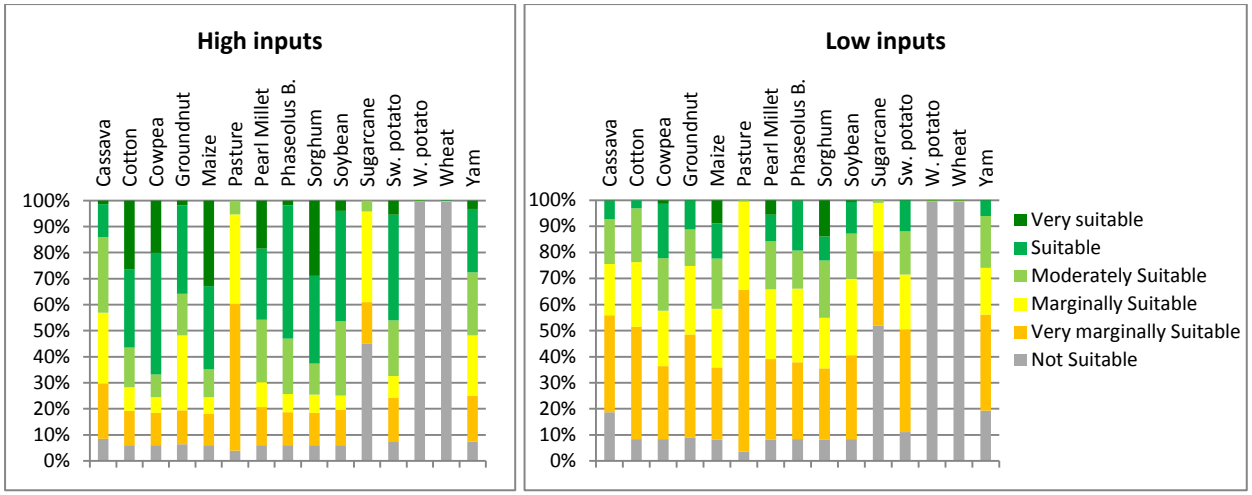
(vii) Rain-fed suitability profiles for the root and tuber crops farming system zone

The *root and tuber zone* occurs for 90% in LGPs between 240 and 330 days with moderate or poor soil conditions. Almost 77% of this zone consists of prime and good land for high input farming; for low input farming this is 57%. The best adapted crops are cassava and yam. Pest and disease pressure is very high under low input conditions. Only 9% of the *root and tuber crops zone* is cultivated. The substantial differences between the high and low input farming suitability profiles are mainly to soil conditions, in particular to poor nutrient availability and to pest and disease and workability constraints in the humid parts of this FS zone.



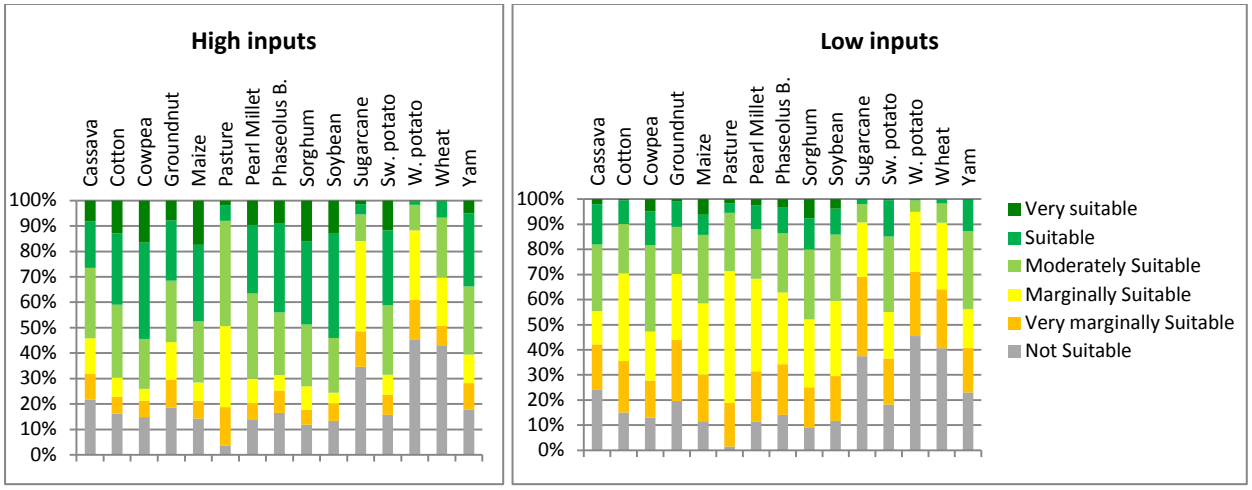
(viii) Rain-fed suitability profiles for the cereal-rootcrop mixed farming system zone

The *cereal-root crop mixed zone* occurs for 97 % in LGPs between 150 and 240 days, i.e., it is mainly found in moist semi-arid and sub-humid environments. Soil conditions in the semi-arid part are dominantly of moderate and good quality, in sub-humid part however moderate to poor. About 75% of this zone consists of prime and good land for high input farming; for low input farming this is 49%. A broad range of crops is adapted to cultivation in the *cereal-root crop mixed zone*, including sorghum, maize, cowpea, phaseolus bean and soybean, but also cassava, yam and sweet potato. About 14% of *the cereal-rootcrop mixed zone* is cultivated. Main constraints in sub-humid part are natural soil fertility and wetness related constraint for susceptible crops like traditional sorghum and millet varieties. These constraints are causing the pronounced differences between high and low input suitability profiles.



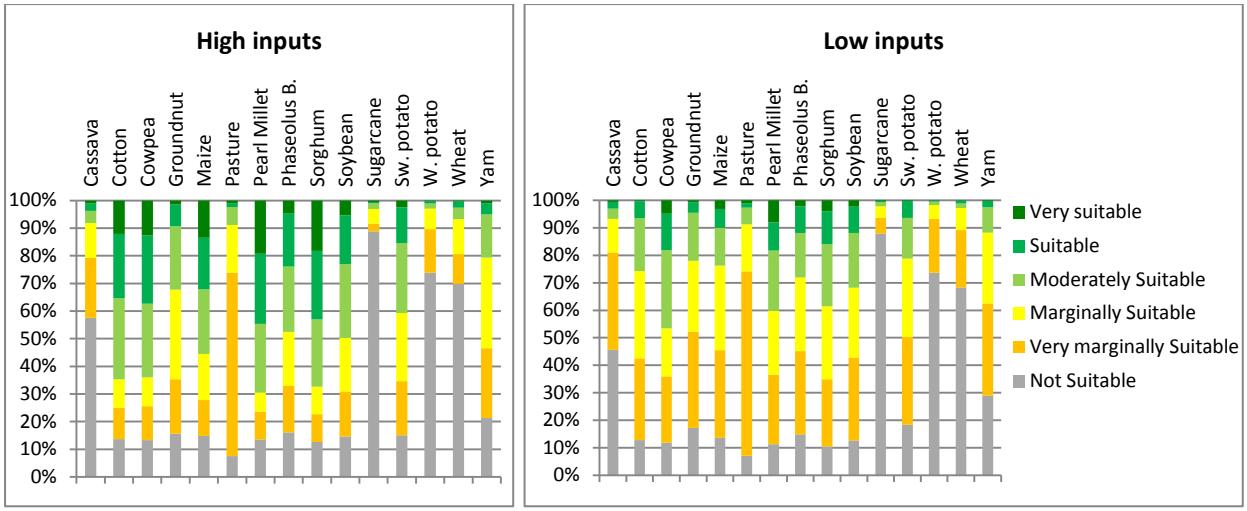
(ix) Rain-fed suitability profiles for the maize mixed farming system zone

The *maize mixed zone* occurs in wide range of LGPs. More than 90% of the zone occurs between 120 -300 days and stretches mainly from dry semi-arid to sub-humid environments. Soil conditions are mainly moderate or poor. About 80% of this zone consists of prime and good land for high input farming; for low input farming this is 64%. Only about 10% of the *maize mixed zone* is cultivated. The differences between high input and low input suitability profiles are explained by pest, disease and workability constraints in the wetter part of the FS zone and overall, due to natural soil fertility constraints. There is a wide range of crops that are well adapted for cultivation in this zone, including food staples such as maize, sorghum, pearl millet and pulses.



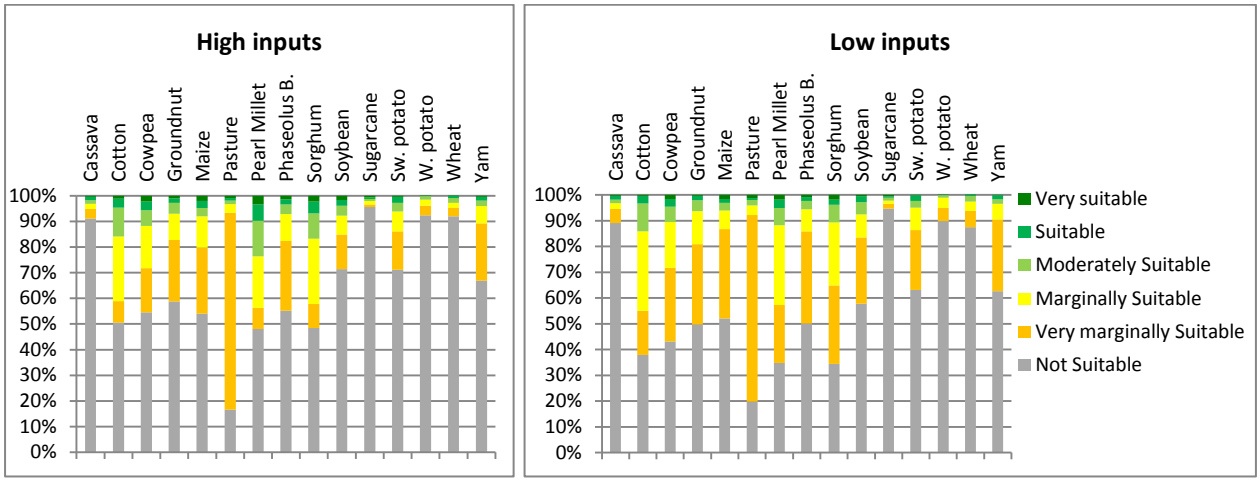
(xi) Rain-fed suitability profiles for the agro-pastoral farming system zone

The *agro-pastoral zone* occurs in LGPs between 30 and 365 days. More than three quarters are found in LGPs of 90-180 days in dry semi-arid and to a lesser extent in moist semi-arid environments. Soil conditions are generally moderate or poor. About 73% of this zone consists of prime and good land for high input farming; for low input farming this is 56%. Almost 20% of the *agro-pastoral zone* is cultivated. The differences between the high and low input farming suitability profiles are explained by the sub-optimal soil conditions (low soil nutrient availability). In the dominant dry and moist semi-arid environments water stress constraints affect yield and production for high input and low input farming to a similar degree. Best adapted rain-fed crops include pearl millet, sorghum and cowpea, but also soybean, phaseolus bean and cotton.



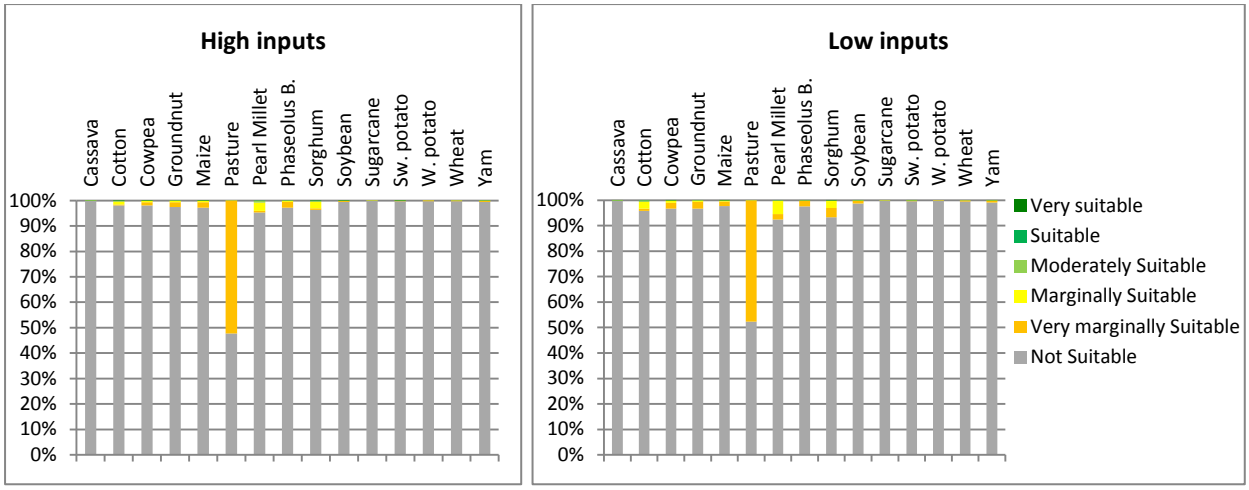
(xii) Rain-fed suitability profiles for the pastoral farming system zone

The *pastoral zone* is found in all LGPs between 1 and 365 days, but more than 75% occur in LGPs between 30-90 days, i.e., mainly in dry semi-arid and desert environments. In the dry semi-arid environments soil conditions are generally poor, in some areas soils appear however moderate or good for agricultural production. The pastoral zone, as demarcated, is partly suitable for short duration and drought resistant crops such as pearl millet and sorghum. About 26% of this zone consists of prime and good land for high input farming; for low input farming this is 20%. Less than 4% of the *pastoral zone* is cultivated. Relatively small differences between the high and low input suitability profiles, indicate that dominating water stress constraints and soil constraints quite similarly affect high and low input farming.



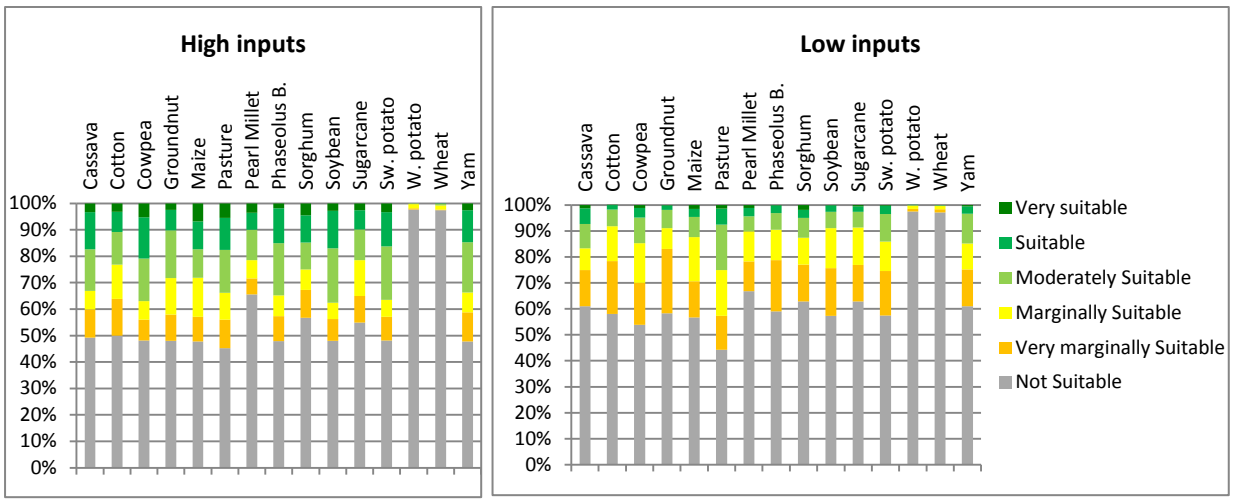
(xiii) Rain-fed suitability profiles for the arid pastoral-oases farming system zone

The *arid pastoral-oases zone* occurs for 99% in LGPs between 0 and 60 days. It covers almost entirely desert environments. This FS zone is very marginally suitability for pasture and very little land is marginal or very marginally suitable for rain-fed short duration drought resistant crops. Less than 1% of the *arid pastoral-oases zone* is cultivated.



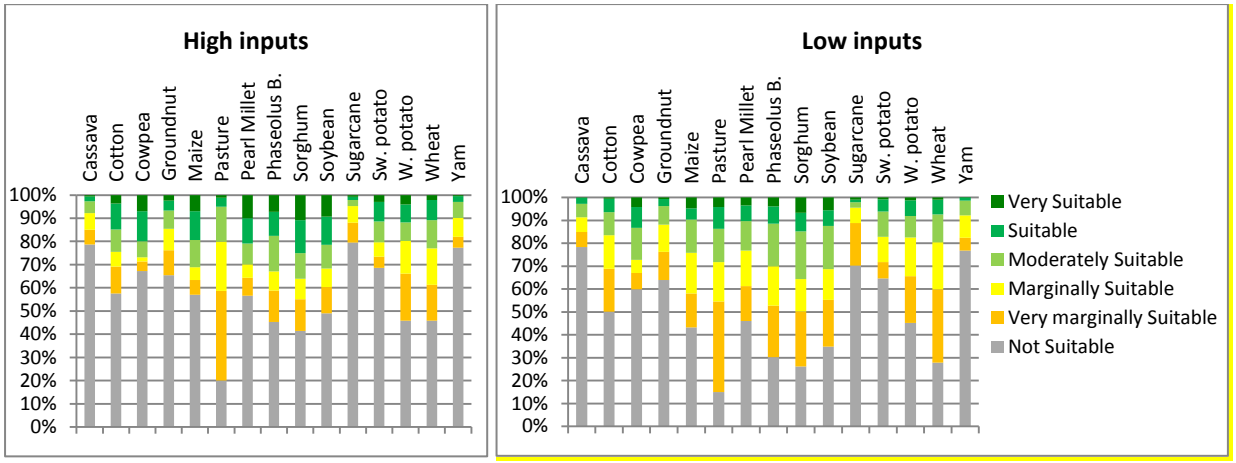
(xiv) Rain-fed suitability profiles for the artisanal fishing system zone

The *artisanal fishing zone* is not defined by any specific climatic niche. It occurs in all LGPs from 0 to 365 days, but with a bias in sub-humid and humid environments. Soils are dominantly of poor or moderate quality. Less than half of this zone (42%) consists of prime and good land for high input farming; for low input farming this is only 25%. About 7% of the *artisanal fishing zone* is cultivated. The differences between high input and low input suitability profiles are explained by pest, disease and workability constraints in the wetter part and overall, due to natural soil fertility constraints. Due to very wide climate range found in the *artisanal fishing zone,* all except cool-loving crops are climatically adapted in parts of the zone.



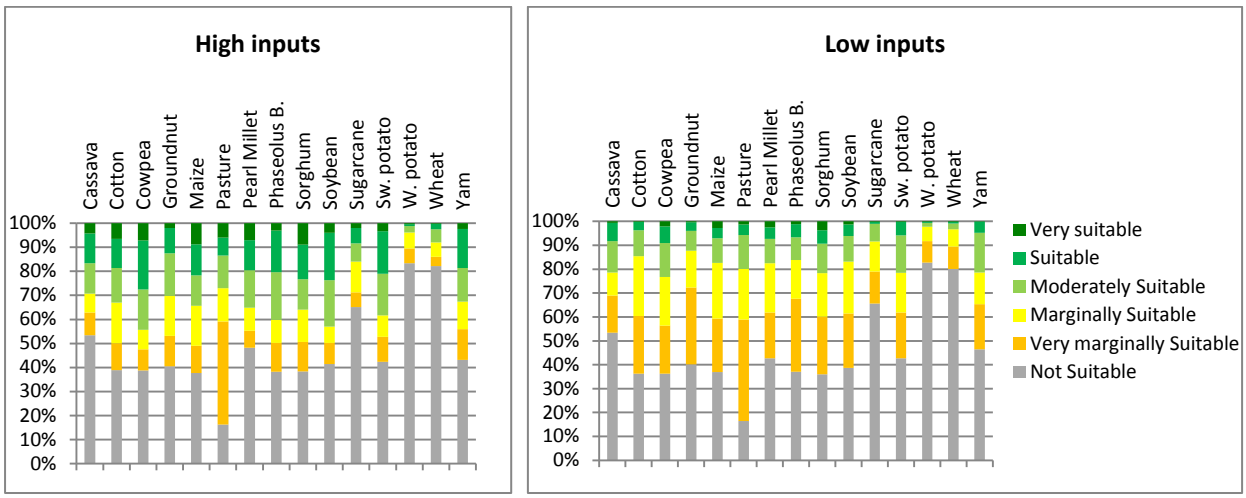
(xvi) Rain-fed suitability profiles for the perennial mixed farming system zone

The *perennial mixed zone* occurs in LGPs between 30 and 365 days and is stretching from desert to dry semi-arid to moist semi-arid and sub-humid environments. Soil conditions are dominantly moderate or poor and a part of the perennial mixed zone occurs in steep terrain (20%). About 40% of this zone meets the criteria of prime and good land for high input and similarly for low input farming. Sorghum, maize, phaseolus bean and soybeans are among the best adapted rain-fed crops in this zone. About 15% of the *perennial mixed zone* is cultivated.



Rain-fed suitability profiles for crops in Sub-Saharan Africa

Yields are two to four times higher under high input and advanced management as compared to low inputs and traditional management, also due to unfavourable soil nutrient conditions and locally severe wetness related pest, disease and workability constraints. The very suitable and suitable land extents are about twice as high under high input and advanced management as compared to low input farming. The AEZ analysis estimates that land under low input farming requires 6 to 7 years out of ten years to be left fallow in order to maintain nutrient balances and break pest and disease cycles. With high input and advanced management, AEZ assumes that fallow is required one year out of ten years. The analysis concludes that production potentials of an average piece of land in Sub-Saharan Africa is very different between high input and advanced management compared to low input and traditional management farming, due to higher yields, more suitable land and much reduced fallow land requirements[1] at high inputs. About 52% of Sub-Saharan Africa consists of prime and good land for high input farming. For low input farming this less than 40%. However note that just over 9% was cultivated in the year 2000.



Appendix 3 provides detailed tables by FS zone with high inputs/advanced management and for low inputs/traditional management suitability profiles of individual crops.

[1] In AEZ, fallow factors have been established by main crop groups and environmental conditions. The crop groups include cereals, legumes, roots and tubers, and a miscellaneous group consisting of long term annuals/perennials. The environmental frame consists of individual soil units, thermal regimes and moisture regimes.

Agro-climatic yield variability by FS zone

The AEZ analysis indicates the occurrence of different levels of average area weighted yield variability in individual FS zones (Table 10). FS zones with high inter-annual variability of potential achievable rain-fed yields are: (i) *irrigated*; (xii) *pastoral* and (xvi) *perennial mixed*. Moderate yield variability occurs in (v) *highland perennial*, (vi) highland mixed (ix) *maize mixed*, (xi) *agro-pastoral*, and (xiii) *arid pastoral oases* (the latter, with only tiny extents of cultivated land). Relatively low yield variability is found in (ii) *humid lowland tree crop*, (iii) *forest based*, (vii) *root and tuber crop*, (viii) *cereal-root crop mixed,* and (xiv) *artificial fishing* FS zones.

Table 10 Coefficients of variation (%) of agro-climatically attainable rain-fed yields (high level inputs) for maize, sorghum, pearl millet, groundnut, cassava, phaseolus bean, soybean and sweet potato LUTs in cultivated land (1961-90)

	Maize	Sorghum	Pearl millet	Groundnut	Cassava	Phaseolus bean	Soybean	Sweet potato
Irrigated	28.6	24.2	19.1	20.0	46.5	25.3	23.3	29.0
Humid lowland tree crop	2.9	2.8	2.5	2.5	1.9	2.6	2.6	2.5
Forest based	2.5	2.5	2.1	2.0	1.4	2.3	2.0	1.9
Highland perennial	12.1	11.4	7.9	7.7	9.8	15.1	11.6	11.7
Highland mixed	18.9	15.6	14.2	20.6	26.9	20.6	18.3	23.4
Root and tuber crop	3.1	3.0	2.7	2.7	3.4	2.9	2.6	2.6
Cereal-root crop mixed	2.4	2.3	2.3	2.3	13.7	2.6	2.3	2.3
Maize mixed	14.1	10.6	4.5	9.9	18.0	13.0	9.1	11.8
Agro-pastoral	12.5	10.5	6.1	7.5	42.4	11.9	9.9	13.7
Pastoral	34.8	29.6	24.2	26.1	37.2	31.4	28.7	34.6
Arid pastoral-oases	16.0	14.6	4.6	4.4	12.9	14.5	4.6	5.1
Artisanal fishing	3.8	3.5	3.0	3.1	7.8	3.7	3.4	3.7
Perennial mixed	28.2	17.1	8.4	27.1	38.1	21.4	17.9	33.9
Sub-Saharan Africa	11.9	9.9	6.2	8.2	22.5	11.3	9.2	11.6

Figure 10 shows an example representation of occurrences of CV classes for maize within cultivated land of individual FS zones. Highest shares of areas with high yield variations occur in the dryer FS zones, *agro-pastoral*, *pastoral* and *irrigated* zones, and in the *maize mixed*, *highland perennial*, *highland mixed* and *perennial mixed* zones.

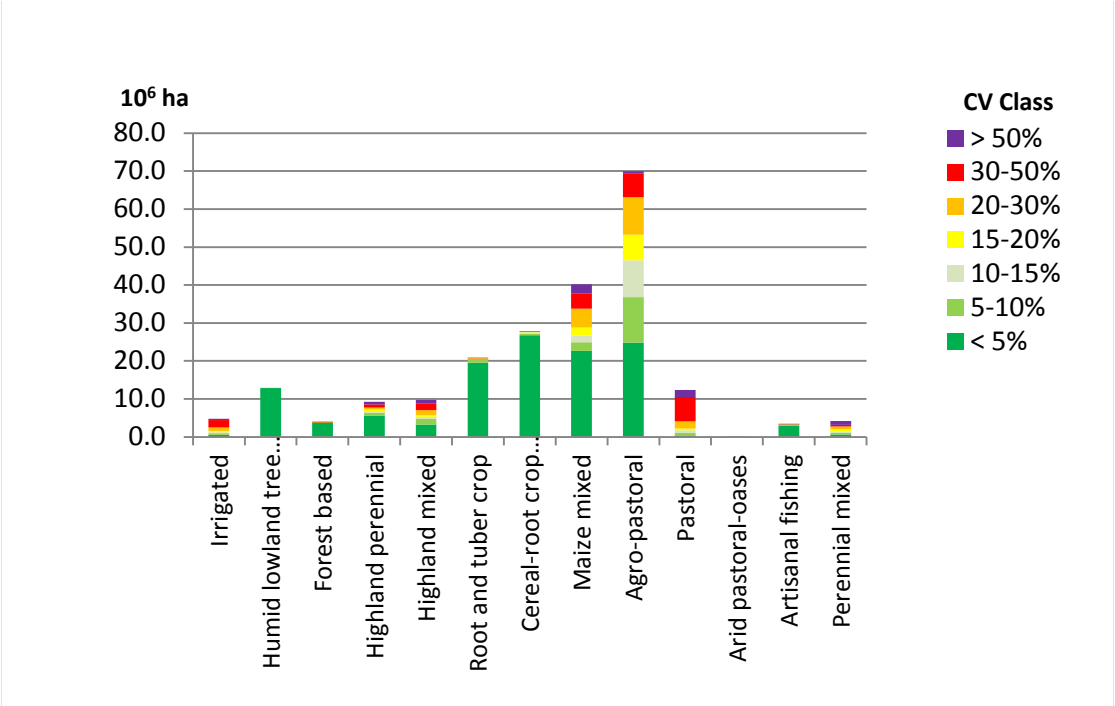


Figure 10 Variability of attainable yields (CV %) of rain-fed maize (1961-1990)

Figure 11a presents a map of sub-Saharan Africa with classes of CV ranges calculated for attainable rain-fed maize yields (1961-1990). Figure 11b shows patterns of CV classes for cassava.

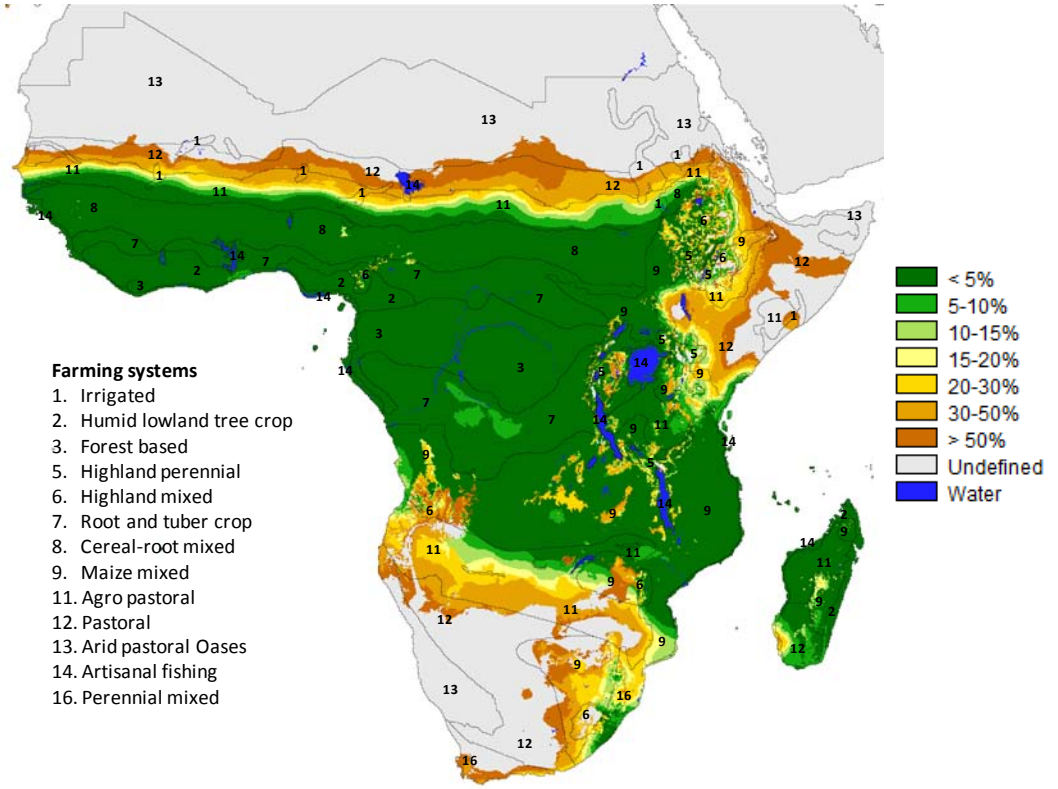


Figure 11a Coefficient of Variation of attainable rain-fed maize yields, 1961-1990

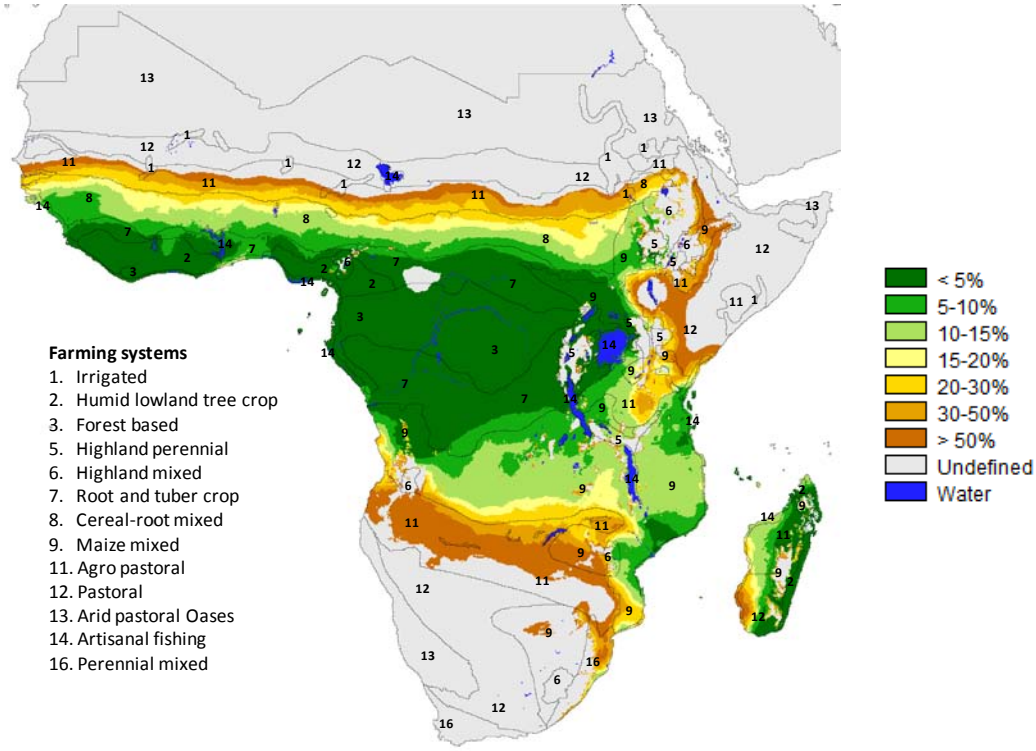


Figure 11b Coefficient of Variation of attainable rain-fed cassava yields, 1961-1990

Areas with bi-modal rainfall patterns may cause LGPs to break up in two or more component LGPs which are of short and varying durations. These component LGPs may cause extra year-to-year variations of moisture stress constraints and yields. To account for increased yield variations in bi-modal rainfall zones, we distinguished three types of zones, namely: (i) *dry zones* with median total LGP≤ 120 days; (ii) dominantly *mono-modal rainfall zones* where the median longest LGP is greater than 80% of the median total LGP, and (iii) dominantly *bi-modal rainfall zones* with broken up growing periods, where the median longest LGP is less than 80% of the median total LGP.

In Appendix 4, coefficients of variation of yields for maize, sorghum, pearl millet, cassava, groundnut, phaseolus bean, soybean and sweet potato over the reference period 1961-90 are tabulated by FS zone and by total LGP, separately for the “dry zones”, the “mono-modal rainfall zones” and “bi-modal rainfall zones” as defined above. Figure 12 presents a map of Sub-Saharan Africa with the delineations of these LGP pattern zones.

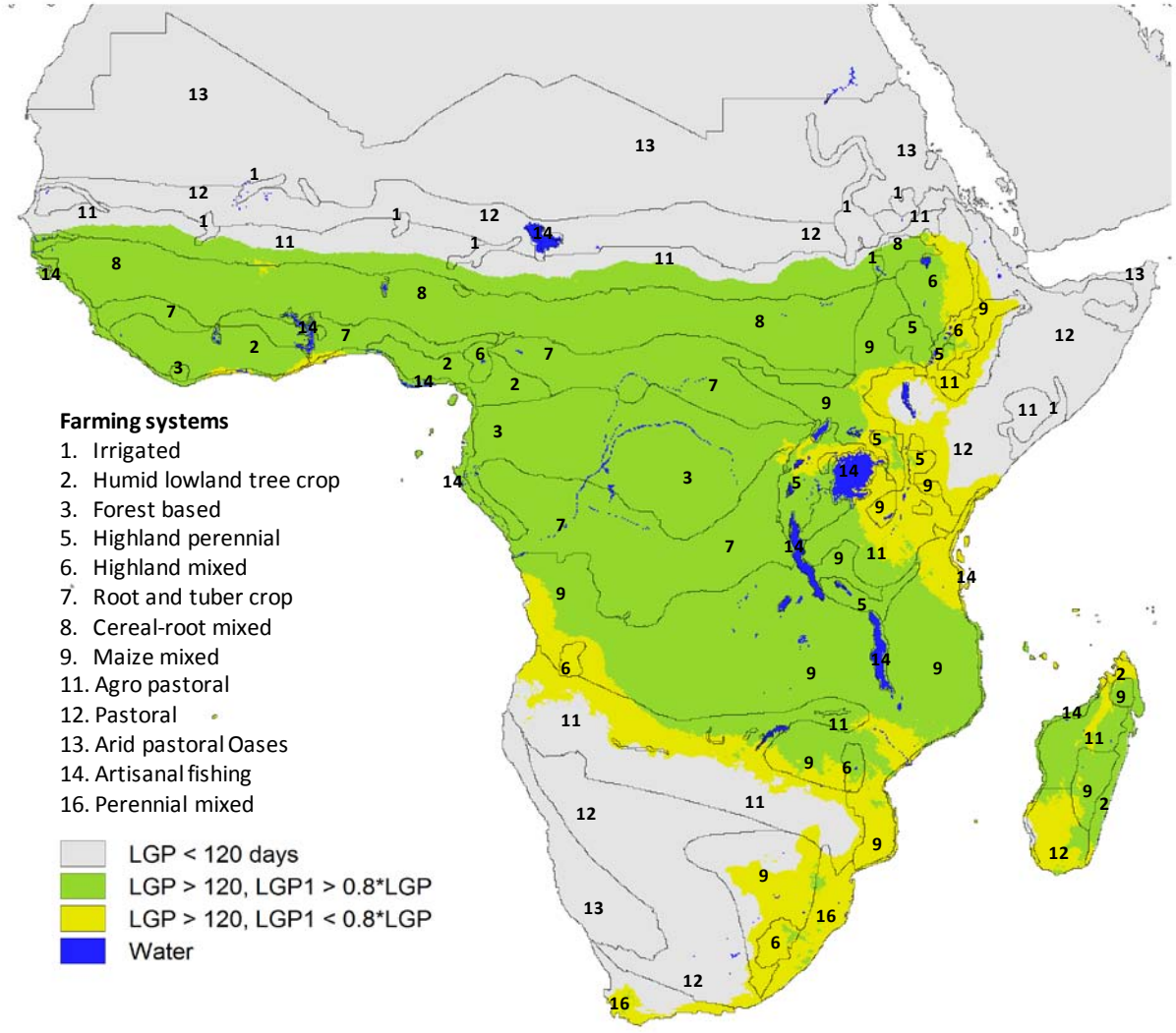


Figure 12 LGP pattern zones

5 Crop Summary Tables

Crop summary tables, compiled for farming system zone characterization, provide standardized information on distributions of crop suitability and crop yield data aggregated by administrative units, farming system zones, legal land protection status, year 2000 land use/land cover, length of growing period zone and accessibility.

The crop summary tables list suitable areas, potential yield and production, and fallow land requirements (cultivation factor). They include tables, separately for rain-fed production under high input/advanced management and low input/traditional management, for the following crops/commodities: cotton, cowpea, cassava, groundnut, millet, maize, phaseolus bean, pasture, soybean, sweet potato, sorghum, sugarcane, wheat, white potato, yam and for an 'umbrella' crop locally defined as best adapted crop among these crops.

6 Yield and Production Gaps

Apparent yield and production gaps have been estimated by comparing potential attainable yields and production (estimated in GAEZ v3.0) and actual yields in current (year 2000) cultivated land. GAEZ potentials production potentials are separately assessed in rain-fed and irrigated cultivated areas. For the yield and production gap estimation potential yield and production result are based on results for high input and advanced management. Actual yield and production were derived by downscaling year 2000 statistics of main food and fiber crops.

Apparent yield and production gaps are presented as ratios. The calculated gap factor is obtained by dividing actual over respective potential yield. The comparisons are done separately for the rain-fed and irrigated cultivated land shares occurring within 5 arc-minute grid-cells.

In Sub-Saharan Africa, yield and production gaps between actual achieved production and potentially attainable production are, on the average, in the order of 80 percent (i.e., a 20% calculated ratios of actual over potential yield). Main reasons for these very substantial gaps is widespread occurrence of soils with low nutrient status and limited application of fertilizer on the one hand, and on the other hand, scarcity of agro-chemicals for combatting common pests and diseases, lack of quality seed and sub-optimal traditional field management. The production constraints are, at least in part, related to widespread poverty, lack of access to markets and capital and due to deficient extension services.

Figure 13 presents for Sub-Saharan Africa actual and potential production and yield gap factors for major crops and crop groups. For the ease of comparison of yield and production values across crops, these are expressed in Geary-Khamis Dollars[2] (1999-2001).

Yield gap graphics for Sub-Saharan Africa and the 13 individual farming system zones are presented in the Appendix. Data for actual and potential yield and production levels and gap-factors by FS zone are available for: 'all crops' (i.e., all major crops combined), cereals (i.e., all cereal crops combined), cotton, groundnut, millet, maize, pulses, sweet and white potato combined (referred to as Potato), cassava and yam combined, soybean, sorghum, sugarcane and wheat.

Data is uploaded on ftp.

[2] The Geary-Khamis price weights (fresh weight) are taken as follows: Cassava and yams: 85 GK$ per ton of roots and tubers; cotton: 630 GK$ per ton of seed and lint; groundnut 436 GK$ per ton of grain in shells; maize: 125 GK$ per ton grain; millet 170 GK$ per ton of grain; pulses: an average price weight of 365 GK$ per ton of grain; sorghum: 130 GK$ per ton of grain; soybean: 250 GK$ per ton of grain; sugarcane: 20 GK$ per ton of fresh cane; wheat: 155 GK$ per ton of grain, and potato (sweet potato): 85 GK$ per ton of fresh tuber.

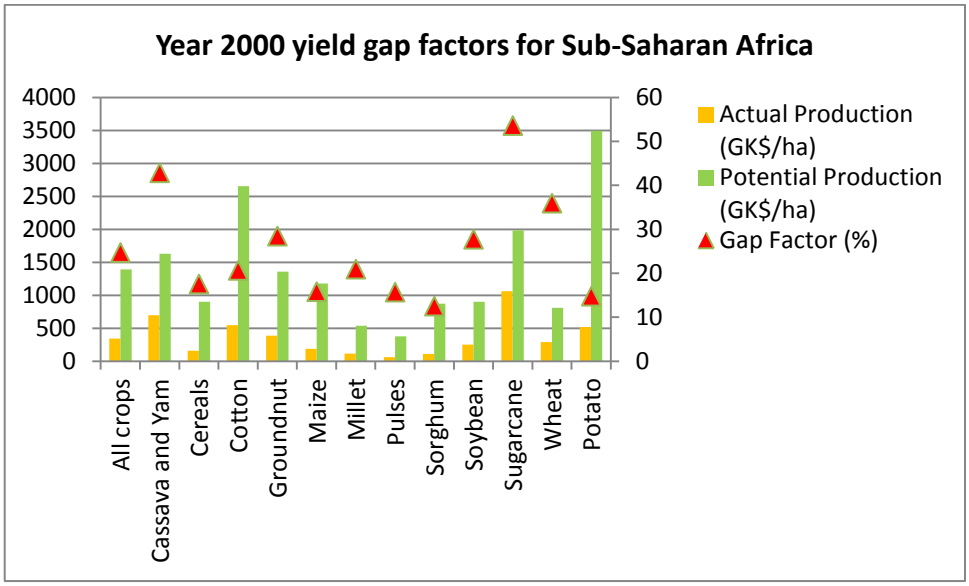


Figure 13 Actual production and potential production of year 2000 harvested areas (GK$/ha) and respective estimated yield gap factors (%)

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Appendix 1 FS background

Under the umbrella of NEPAD AU, the Comprehensive Africa Agriculture Development Program provides a framework for agricultural development in Africa, emphasizing that agriculture lies at the heart of any resolution of the rural development crisis in Africa. The challenge for developing countries is to identify specific agricultural and rural development needs and opportunities, and to focus investment in areas where the greatest impact on food security and poverty will be achieved. This identification and resource allocation process can be facilitated by analyzing farming systems in order to identify and quantify the driving forces and interactions that shape and constrain farming systems and the management of natural resources. In the course of this analytical process it is also helpful to be able to map and aggregate locations with similar constraints and investment opportunities through the application of a farming systems framework. Farming systems, which encompass all agricultural (including cropping, pastoral, forestry, aqua-cultural) production-to-processing activities and rural household livelihoods, thus represent a key entry point for analysis and the development of strategic priorities for addressing poverty and food insecurity that affect millions of farmers in Sub-Saharan Africa.

Based on spatially explicit analyses, the present project aims to produce an updated comprehensive synthesis of the major Sub-Saharan farming systems including characterization of their setting and resources, recent trends, drivers of change and performance, as well as highlighting most relevant science and policy priorities for investment in their development (Garrity *et al.,* 2012).

Specifically the objectives of this research activity are to:

1. Provide at least 20 continental spatial data sets for the characterization of farming systems and food security maps for the Australian Centre for International Agricultural Research (ACIAR) and develop a web tool for their visualization.
2. Contribute a booklet highlighting interim findings on trends and drivers to the strategic planning processes of the new Australian International Food Security Centre.
3. Produce a comprehensive report that analyses some 15 major African farming systems, based on expert knowledge that includes drivers, trends, development priorities and poverty escape scenarios for each system taking into account relevant continental, national and subnational data and knowledge.

Farming systems and subsystems definitions and map classes follow a rigorous basis and explicit set of principles. The first principle applied is to have the continental level farming systems map classes align with length of growing period (LGP) boundaries. LGP is a fundamental component of agro-ecological zones (AEZs) that include climate, soils, and landform. The LGP map used is from GAEZ version 3.0 jointly released by FAO and IIASA in May 2012 (Fischer *et al.,* 2012).

The second principle is (input/output/service) market access as a critical factor shaping the development of systems and the spatial distribution of crops; for instance distinguishing the West African Tree Crops system defined by its linkages to markets from the more subsistence-oriented Central African Forest-Based System. Simplicity and the capability to generalize have been the strengths of the 2001 farming systems map. Similarly, an effort is made to analyze and identify with the 2012 map the ‘central tendencies’ or the defining characteristics of systems driving local livelihoods, that make up appropriate system entities for policy prescriptions. It is obviously recognized that crop enterprises span system boundaries but that the role of the main crops will shift between adjoining farming systems boundaries. Given this gradient, systems cannot be defined exclusively according to the spatial distribution of individual crops, or even AEZs, but rather by meaningful combinations of these.

Within each farming system, subsystems that capture the variation within the system are determined. Subsystems are characterized and mapped to the extent possible, or described qualitatively when not mappable. Some small but significant atypical systems that exist within subsystems are considered as “inclusions”.

Appendix 2 Global agro-ecological zones

The International Institute for Applied Systems Analysis (IIASA) and the Food and Agriculture Organization of the United Nations (FAO) jointly developed the global Agro-Ecological Zones (AEZ) methodology for assessing agricultural resources and their sustainable production potential. Rapid developments in information technology have produced increasingly detailed and manifold global databases, which made the first global AEZ assessment possible in 2000. Since then global AEZ assessments have been performed every few years, with the data being published on CD or DVD (Fischer et al 2000, 2002, 2012). With each update of the system, the issues addressed, the size of the published datasets and the number of results have multiplied. GAEZ v3.0, launched in May 2012, is the most ambitious assessment yet and the goal was to make publicly available the entire database and all results of this assessment (GAEZ Data Portals of IIASA and FAO resp. <www.gaez.iiasa.ac.at> and http://gaez.fao.org). GAEZ has been tested and applied in many applications, it is an integral part of an ecological-economic modeling framework of IIASA to study the development of the world's food and agricultural system.

A start has been made with data collection and database compilation for a further update of GAEZ during 2013 to include spatial and statistical data focusing on land use and agricultural production around the year 2010.

Methodology

The adequate quality and availability of land and water resources, together with important socio-economic and institutional factors, is essential for food security. Crop cultivation potential describes the agronomically possible upper limit for the production of individual crops under given agro-climatic, soil and terrain conditions for a specific level of agricultural inputs and management conditions. The AEZ approach is based on principles of land evaluation (FAO 1976, 1984 and 2007a) to identify sound and sustainable land use options. In addition to evaluating land production potentials, current GAEZ v 3.0 incorporates two important new global data sets, on "Actual Yield and Production' and "Yield and Production Gaps" between potential and actual yield and production (Fischer *et al.*, 2012).

Geo-referenced global climate, soil and terrain data are combined into a land resources database, commonly assembled on the basis of global grids, typically at 5 arc-minute and 30 arc-second resolutions. Climatic data comprises monthly values of precipitation, temperatures, wind speed, sunshine hours and relative humidity, which are used to compile various agronomically meaningful agro-climatic indicators including quantified thermal and moisture regimes in space and time. Application of matching procedures to identify crop-specific limitations of prevailing climate, soil and terrain resources and comprehensive simulations with AEZ crop models, under assumed levels of inputs and management conditions, provides maximum potential and agronomically attainable crop yields for basic land resources units under different agricultural production systems.

Actual yields and production are derived through downscaling year 2000 agricultural statistics of main food and fiber crops for all rain-fed and irrigated cultivated areas. Sequential rebalancing procedures that were developed in the framework of GAEZ v3.0 rely on appropriate optimization principles (Fischer *et al.*, 2006), e.g., cross-entropy maximization, and combine the available samples of real observations in the locations with other "prior" hard (statistics, accounting identities) and soft (expert opinion, scenarios) data. Results are presented as (i) Crop production value, and (ii) crop area, production and yields for major commodities.

The comparison of simulated potential yields and production with observed yield and production of crops currently grown (year 2000), provides estimates of apparent yield and production gaps.

In summa, GAEZ generates large databases of (i) natural resources endowments relevant for agricultural uses and (ii) spatially detailed results of suitability and attainable yields, (iii) spatially detailed results of estimate/actual yields of main food and fiber commodities for all rain-fed and

irrigated cultivated areas, and (iv) spatially detailed yield and production gaps for main food and fiber commodities. Results are commonly aggregated for current major land use/cover patterns and by administrative units, land protection status, or broad classes reflecting infrastructure availability and market access conditions.

Overview of AEZ procedures

The AEZ methodology uses a land resources inventory to assess, for specified management conditions and levels of inputs, a comprehensive range of agricultural land-use options and to quantify anticipated production of cropping activities relevant in the specific agro-ecological context. The AEZ approach allows stepwise review of results.

Calculation procedures for establishing crop suitability estimates in AEZ include five main steps of data processing, namely:

(i) Climate data analysis and compilation of general agro-climatic indicators;
(ii) Crop-specific agro-climatic assessment and water-limited biomass/yield calculation;
(iii) Yield-reductions due to agro-climatic constraints;
(iv) Edaphic assessment and yield reductions due to soil and terrain limitations, and
(v) Integration of agro-climatic and agro-edaphic results into crop-specific grid-cell databases of agro-ecological suitability and yields.

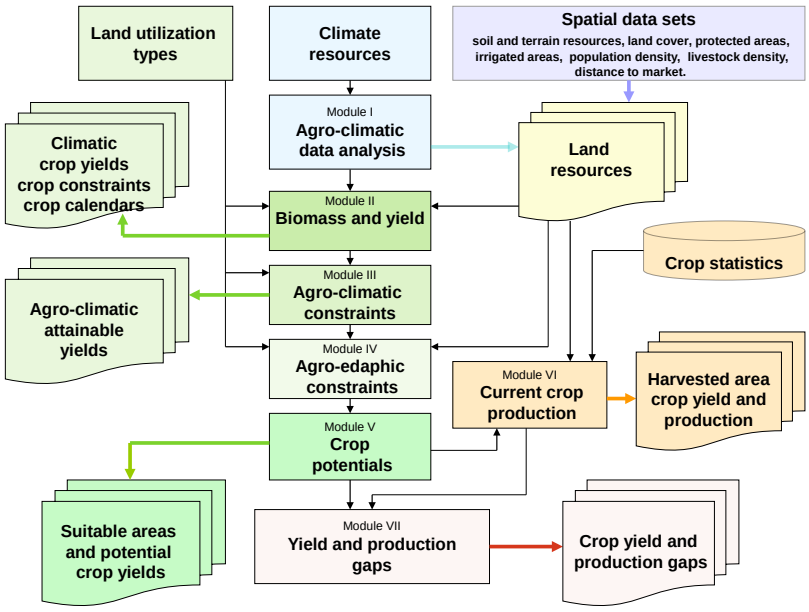
For attributing statistical data to spatial land units, i.e., obtaining grid-cell level area, yield and production of prevailing main crops, two main activities are involved, namely:

(vi) Estimation of shares of rain-fed and irrigated cultivated land in each grid-cell, and estimation of harvested area, yield and production of the main crops in the rain-fed and irrigated cultivated land shares

Finally, inventories of apparent yield gaps are compiled through:

(vii) Quantification of achievement ratios separately for rain-fed and irrigated cultivated land shares between downscaled current crop yield statistics, and potential attainable crop yields.

The overall AEZ model structure is schematically shown in below.



Overall structure of AEZ Model

Climate data analysis and compilation of general agro-climatic indicators

This AEZ component calculates for each grid cell a variety of climate-related variables and indicators. Spatial grids of historical (1961-2000), baseline (1961-1990 average) and projected future climates are processed to create layers of agro-climatic indicators relevant to plant production. Temporal interpolations are used to transform monthly data to daily estimates required for characterization of thermal and soil moisture regimes. The latter includes calculation of reference potential and actual evapotranspiration through daily soil water balances.

Thermal regime characterization includes thermal climates, thermal zones, temperature growing periods, temperature sums (for average daily temperature respectively above 0°C, 5°C and 10°C) and quantification of temperature profiles, i.e., distributions of location specific average daily temperatures within a calendar year. Soil water balance calculations determine potential and actual evapotranspiration for a reference crop, number of growing period days (LGP, days), including LGP quality (P/PET), dormancy periods and cold brakes, and begin and end dates of one or more LGPs. Various agro-climatic indicators are used for multiple-cropping zones classifications separately for rain-fed and irrigated conditions.

Crop-specific agro-climatic assessment and potential water-limited biomass/yield calculation

Water-limited biomass and yields of about 280 crop types and pasture types are assessed, each at three assumed levels of inputs and management. At low input level traditional crop varieties are considered, which may have different qualities that are preferred but may have low yield efficiencies and because of management limitations are grown in relatively irregular stands with inferior plant densities. In contrast, with high input level high-yielding varieties are deployed with advanced field management and machinery providing optimum plant densities.

Calculation of maximum attainable biomass and yield as determined by radiation and temperature regimes precedes the computation of crop water balances and the establishment of optimum crop calendars for each of these conditions. Crop water balances are used to estimate actual crop evapotranspiration, accumulated crop water deficit during the growth cycle and attainable water limited biomass and yields for rain-fed conditions. A window of time is determined when conditions permit cultivation. The growth of each crop type is tested for the days during the permissible window of time with separate analysis for irrigated and rain-fed conditions. The growth cycle duration and calendar producing the best yield define the crop calendar of each crop-type in individual grid-cells.

Results include temperature/radiation defined maximum yields, yield reduction factors accounting for sub-optimum thermal conditions, for yield impacts due to soil water deficits, estimated amounts of soil water deficit, potential and actual LUT evapotranspiration, temperature sums during each crop cycle, and crop calendars.

Yield reduction due to agro-climatic constraints

Grid cell specific multipliers are calculated, and are used to reduce yields for various agro-climatic constraints. This step estimates effect of limitations due to soil workability, pest and diseases, and other constraints. Five groups of agro-climatic constraints are used, these are:

(a) Yield adjustment due to year-to-year variability of soil moisture supply; this factor is applied to adjust yields calculated for average climatic conditions
(b) Yield losses due to the effect of pests, diseases and weed constraints on crop growth
(c) Yield losses due to water stress, pest and diseases constraints on yield components and yield formation of produce (e.g., affecting quality of produce)
(d) Yield losses due to soil workability constraints (e.g., excessive wetness causing difficulties for harvesting and handling of produce)
(e) Yield losses due to occurrence of early or late frosts.

The obtained agro-climatic constraints are yield reduction factors of different constraints and severities by crop and by level of inputs. Due to paucity of empirical data constraint ratings have been based on recorded expert opinion.

Yield reduction due to soil and terrain limitations

Crop-specific yield reduction due to limitations imposed by soil and terrain conditions, are determined from soil attribute data contained in the Harmonized World Soil Database (FAO/IIASA/ISRIC/ISS-CAS/JRC 2009). Soil nutrient availability, soil nutrient retention capacity, soil rooting conditions, soil oxygen availability, soil toxicities, soil salinity and sodicity conditions and soil management constraints are estimated on crop by crop basis and are combined in a crop and input specific suitability rating.

The soil evaluation algorithm assesses for soil types and slope classes the match between crop soil requirements and the respective soil qualities as derived from soil attributes of the HWSD. Thereby the rating procedures result in a quantification of suitability for all combinations of crop types, input level, soil types and slope classes.

Integration of climatic and edaphic evaluation

The final step in the GAEZ crop suitability and land productivity assessment combines results of the agro-climatic evaluation for biomass and yield calculated for different soil classes and it uses the edaphic rating produced for each soil/slope combinations. The algorithm steps through the grid cells of the spatial soil association layer of the Harmonized World Soil Database and determines for each grid cell the respective make-up of land units in terms of soil types and slope classes. Each of these component land units is separately assigned the appropriate suitability and yield values and results are accumulated for all elements.

Processing of soil and slope distribution information takes place at 30 arc-second grid cells. One hundred of these produce the edaphic characterization at 5 arc-minutes, the resolution used for providing GAEZ results.

Cropping activities are the most critical in causing topsoil erosion, because of their particular cover dynamics and management. The terrain-slope suitability rating used in the GAEZ study accounts for the factors that influence production sustainability and is achieved through: (i) defining permissible slope ranges for cultivation of various crop types and setting maximum slope limits; (ii) for slopes within the permissible limits, accounting for likely yield reduction due to loss of fertilizer and topsoil; and (iii) distinguishing among a range of farming practices, from manual cultivation to fully mechanized cultivation. In addition, the terrain-slope suitability rating is varied according to amount and distribution of rainfall, which is quantified in GAEZ by means of the Fournier index.

Application of the procedures in the modules described above result in an expected yield and suitability distribution regarding rain-fed and irrigation conditions for each 5-minute grid-cell and each crop/LUT. Land suitability is described in five classes: very suitable (VS), suitable (S), moderately suitable (MS), marginally suitable (mS), and not suitable (NS) for each crop type. Large databases are created, which are used to derive additional characterization and aggregations. Examples include calculation of land with cultivation potential, tabulation of results by ecosystem type, quantification of climatic production risks by using historical time series of suitability results, impact of climate change on crop production potentials, and irrigation water requirements for current and future climates.

Actual Yield and Production

This GAEZ module estimates actual yields and production from downscaling year 2000 statistics of main food and fiber crops (statistics derived mainly from FAOSTAT[3] and the FAO study AT

[3] The FAOSTAT data used to characterize 1999-2001 production were obtained in 2005/06. Note in the current version of FAOSTAT time series have in selected cases been revised significantly for some countries and commodities, e.g., maize harvested area in Tanzania.

2015/30). Results are presented as (i) crop production value, and (ii) crop harvested area, production and yields for major commodities.

Two main activities were involved in obtaining grid-cell level area, yield and production of prevailing main crops:

(i) Estimation of shares of rain-fed or irrigated cultivated land by 5' grid cell, and

(ii) estimation of area, yield and production of the main crops in the rain-fed and irrigated cultivated land shares

Estimation of cultivated land shares

Land cover interpretations schemes were devised that allow a quantification of each 5-arc-min. grid-cell into seven main land use cover shares. Shares of cultivated land, subdivided into rain-fed and irrigated land, were used for allocating rain-fed and irrigated crop production statistics.

Allocation of agricultural statistics to cultivated land

Agricultural production statistics are available at national scale from FAO. Various layers of spatial information are used to calculate an initial estimate of location-specific crop-wise production priors. These priors are adjusted in an iterative downscaling procedure to ensure that crop areas and production are consistent with aggregate statistical data, are allocated to the available cultivated land and reflect available ancillary data, e.g., selected crop area distribution data (Monfreda *et al*., 2008[4]) and agronomic suitability of crops estimated in AEZ.

Yield and Production Gaps

Yield gaps and production gaps have been estimated by comparing potential attainable yields and production (estimated in GAEZ v3.0) and actual yields and production from downscaling year 2000 statistics of main food and fiber crops (statistics derived mainly from FAOSTAT and the FAO study AT 2015/30).

For main commodities yield and production gaps were estimated by comparing actual achieved yields and production with potential attainable yields and production of the same 'observed' land use.

[4] Used in countries, where at least 50% of area was reported in sub-national statistics.

Appendix 3 Suitability profiles of rain-fed crops by FS zone and crop

Suitability profiles for rain-fed maize (high inputs)

Farming System Zone	Suitability profile (000ha)						Prime and good land (VS+S+MS)			
	Very suitable (VS)	Suitable (S)	Moderately Suitable (MS)	Marginally Suitable (mS)	Very marginally Suitable (VmS)	Not Suitable (NS)	Area (000ha)	Yield (kg/ha)	Production (000t)	Cultivation factor
Irrigated	839	1740	2073	5448	5334	21194	4652	7582	31745	0.9
Humid lowland tree crop	291	1768	11144	30435	11568	8511	13203	6011	71430	0.9
Forest based	0	495	8493	107121	10410	9052	8988	5372	43455	0.9
Highland perennial	4820	9992	6574	2263	2252	16222	21385	7446	143307	0.9
Highland mixed	2609	9117	5346	2177	4833	23450	17072	7122	109423	0.9
Root and tuber crop	5674	18234	51270	96685	30698	22281	75179	6714	454284	0.9
Cereal-root crop mixed	67595	65822	21893	13017	25008	12374	155310	9102	1272243	0.9
Maize mixed	69049	118987	95293	28155	27755	56590	283329	8077	2059648	0.9
Agro-pastoral	49423	67894	85506	60961	47591	54290	202824	7999	1460228	0.9
Pastoral	7281	10022	11804	45162	94315	197848	29107	7954	208370	0.9
Arid pastoral-oases	64	38	37	3126	9772	451486	140	8484	1067	0.9
Artisanal fishing	3135	4841	4972	6772	4310	21993	12947	8093	94307	0.9
Perennial mixed	2126	3785	3576	1697	1957	17389	9487	8584	73289	0.9
Not assigned	9	12	139	117	110	1406	160	6291	907	0.9
Total land	212915	312748	308119	403137	275913	914093	833782	8027	6023703	0.9

Suitability profiles for rain-fed maize (low inputs)

Irrigated	39	258	952	3402	9821	22156	1250	2023	903	0.4
Humid lowland tree crop	12	580	3030	32834	15856	11407	3622	2009	1793	0.2
Forest based	0	1	518	77563	37919	19570	519	1845	282	0.3
Highland perennial	2251	3770	7844	8833	7826	11598	13864	2096	9571	0.3
Highland mixed	1901	2549	6096	6713	12492	17780	10546	2136	8319	0.4
Root and tuber crop	626	4991	13183	124720	66028	15295	18800	2122	11256	0.3
Cereal-root crop mixed	18234	27627	39787	46133	56895	17033	85648	2422	63725	0.3
Maize mixed	24778	31497	107826	112789	73213	45726	164101	2217	126639	0.3
Agro-pastoral	11403	25012	50306	112679	116566	49699	86721	2278	65022	0.3
Pastoral	5890	5322	10715	26509	126968	191027	21927	2510	19182	0.3
Arid pastoral-oases	51	13	36	2252	8233	453938	100	2544	85	0.3
Artisanal fishing	706	1397	3563	7843	6418	26096	5666	2268	4002	0.3
Perennial mixed	1456	1489	4433	5420	4508	13225	7378	2686	6865	0.3
Not assigned	8	52	87	181	140	1324	147	2226	86	0.3
Total land	67356	104558	248373	567871	542885	895881	420288	2283	317730	0.3

Note: The cultivation factor indicates the fraction of time the land can be used for cultivation. For example, a cultivation factor 0.3 means that land can be used for crop cultivation in 3 out of 10 years.

Suitability profiles for rain-fed cotton (high inputs)

Farming System Zone	Suitability profile (000ha)						Prime and good land (VS+S+MS)			
	Very suitable (VS)	Suitable (S)	Moderately Suitable (MS)	Marginally Suitable (mS)	Very marginally Suitable (VmS)	Not Suitable (NS)	Area (000ha)	Yield (kg/ha)	Production (000t)	Cultivation factor
Irrigated	838	2476	5418	5931	1360	20605	8733	717	5639	0.9
Humid lowland tree crop	4	406	2945	31850	17983	10531	3354	624	1884	0.9
Forest based	0	0	1046	54909	64323	15292	1046	537	505	0.9
Highland perennial	839	3091	5387	3253	2041	27511	9318	767	6430	0.9
Highland mixed	1023	2632	2307	2368	3513	35688	5962	854	4584	0.9
Root and tuber crop	0	5975	29806	118625	47313	23125	35781	660	21256	0.9
Cereal-root crop mixed	54209	62057	31310	18770	26910	12453	147576	949	126012	0.9
Maize mixed	50762	111496	113305	29737	26076	64453	275563	854	211685	0.9
Agro-pastoral	44413	85070	107196	37418	41503	50065	236679	823	175270	0.9
Pastoral	4093	12758	41101	92551	30580	185348	57953	710	37021	0.9
Arid pastoral-oases	53	49	1659	5668	1506	455589	1760	484	766	0.9
Artisanal fishing	1495	3495	5692	5936	6422	22982	10682	798	7672	0.9
Perennial mixed	1131	3413	2953	1925	3531	17577	7497	815	5498	0.9
Not assigned	0	9	46	245	185	1308	55	670	33	0.9
Total land	158860	292927	350171	409187	273246	942534	801958	837	604256	0.9

Suitability profiles for rain-fed cotton (low inputs)

Irrigated	40	749	3292	3676	8868	20004	4081	145	148	0.3
Humid lowland tree crop	0	256	1713	23373	25092	13283	1969	153	79	0.3
Forest based	0	2	206	17759	95619	21983	209	143	10	0.3
Highland perennial	70	1652	2739	5675	5103	26882	4462	168	242	0.3
Highland mixed	140	1612	1737	3404	7489	33150	3488	179	221	0.4
Root and tuber crop	0	1347	13258	113490	81095	15653	14605	157	634	0.3
Cereal-root crop mixed	0	6396	42340	50961	88822	17190	48736	170	2328	0.3
Maize mixed	1843	37268	77578	138703	81176	59262	116689	166	6514	0.3
Agro-pastoral	1096	22855	70103	116332	108699	46580	94054	163	4710	0.3
Pastoral	1034	11247	39596	112902	62584	139068	51877	159	2291	0.3
Arid pastoral-oases	0	181	2815	12245	4436	444847	2997	130	101	0.3
Artisanal fishing	5	825	2908	6219	9350	26715	3738	160	172	0.3
Perennial mixed	169	1786	3066	4492	5738	15280	5020	171	300	0.3
Not assigned	0	26	91	278	227	1171	117	155	5	0.3
Total land	4396	86203	261443	609509	584297	881078	352041	164	17756	0.3

Suitability profiles for rain-fed cowpea (high inputs)

Farming System Zone	Suitability profile (000ha)						Prime and good land (VS+S+MS)			
	Very suitable (VS)	Suitable (S)	Moderately Suitable (MS)	Marginally Suitable (mS)	Very marginally Suitable (VmS)	Not Suitable (NS)	Area (000ha)	Yield (kg/ha)	Production (000t)	Cultivation factor
Irrigated	855	2262	4063	5601	3001	20846	7181	1897	12259	0.9
Humid lowland tree crop	358	16174	25478	5868	7323	8517	42010	1912	72297	0.9
Forest based	0	16544	77654	25911	6348	9113	94198	1772	150247	0.9
Highland perennial	2270	7705	3337	1207	1773	25830	13311	2225	26659	0.9
Highland mixed	1469	4138	3047	1925	3179	33773	8655	2176	16947	0.9
Root and tuber crop	2137	87918	70726	19137	22487	22438	160781	1993	288389	0.9
Cereal-root crop mixed	41346	95955	18004	12446	25524	12434	155305	2355	329166	0.9
Maize mixed	65585	149692	77957	18419	25203	58972	293235	2256	595431	0.9
Agro-pastoral	46487	89848	97629	38110	44728	48864	233963	2130	448583	0.9
Pastoral	8092	12486	22343	60291	63405	199815	42921	2011	77692	0.9
Arid pastoral-oases	54	45	52	3052	6035	455286	151	2231	302	0.9
Artisanal fishing	2445	7170	7411	3203	3660	22134	17026	2111	32354	0.9
Perennial mixed	2116	3967	2123	549	1266	20510	8206	2253	16641	0.9
Not assigned	47	137	55	91	124	1340	239	2293	493	0.9
Total land	173260	494041	409880	195809	214055	939881	1077180	2133	2067460	0.9

Suitability profiles for rain-fed cowpea (low inputs)

Irrigated	202	687	2386	4844	9876	18633	3275	692	673	0.3
Humid lowland tree crop	0	297	1717	32945	19036	9723	2014	590	306	0.3
Forest based	0	0	366	71943	44028	19232	366	523	61	0.3
Highland perennial	372	2206	4094	5576	5455	24419	6672	688	1574	0.3
Highland mixed	749	1706	2937	3312	8249	30579	5392	729	1439	0.4
Root and tuber crop	20	4201	21253	114360	71109	13900	25474	607	4394	0.3
Cereal-root crop mixed	2889	42827	41345	43909	57626	17112	87062	744	19150	0.3
Maize mixed	19703	52969	135985	77115	58577	51479	208657	708	49069	0.3
Agro-pastoral	17899	48596	103674	64226	87885	43385	170169	730	36831	0.3
Pastoral	5702	11014	21989	65071	104682	157974	38705	725	8972	0.3
Arid pastoral-oases	27	31	355	4527	10505	449078	414	570	108	0.5
Artisanal fishing	504	1697	4543	7046	7440	24792	6744	698	1432	0.3
Perennial mixed	1264	2785	4253	1780	2156	18292	8302	735	2065	0.3
Not assigned	0	9	87	213	270	1214	95	652	17	0.3
Total land	49332	169026	344985	496868	486894	879821	563343	717	126091	0.3

Suitability profiles for rain-fed cassava (high inputs)

Farming System Zone	Suitability profile (000ha)						Prime and good land (VS+S+MS)			
	Very suitable (VS)	Suitable (S)	Moderately Suitable (MS)	Marginally Suitable (mS)	Very marginally Suitable (VmS)	Not Suitable (NS)	Area (000ha)	Yield (kg/ha)	Production (000t)	Cultivation factor
Irrigated	0	0	87	926	1402	34214	87	5422	422	0.9
Humid lowland tree crop	6747	23318	12574	5564	7117	8399	42639	7745	297199	0.9
Forest based	11841	82960	23448	4107	4696	8518	118249	8069	858776	0.9
Highland perennial	4990	3006	2930	1860	2249	27086	10927	9051	89013	0.9
Highland mixed	1012	1582	2707	1381	2077	38772	5301	7516	35861	0.9
Root and tuber crop	37204	67224	65009	8232	26077	21097	169436	7869	1200033	0.9
Cereal-root crop mixed	2799	26245	59507	56214	43508	17436	88552	6777	540102	0.9
Maize mixed	32788	71918	109541	55378	40575	85630	214247	7570	1459598	0.9
Agro-pastoral	4060	9459	16305	46066	79473	210302	29824	7323	196565	0.9
Pastoral	1211	5348	5091	7363	13497	333921	11650	7681	80537	0.9
Arid pastoral-oases	0	38	39	24	22	464400	78	7296	509	0.9
Artisanal fishing	1508	6478	7254	3205	4902	22676	15240	7416	101724	0.9
Perennial mixed	195	635	1553	2169	1970	24008	2383	6863	14720	0.9
Not assigned	50	105	75	22	116	1424	230	7822	1621	0.9
Total land	104405	298318	306120	192510	227680	1297892	708843	7644	4876680	0.9

Suitability profiles for rain-fed cassava (low inputs)

Irrigated	0	0	74	484	2020	34051	74	1897	42	0.3
Humid lowland tree crop	0	9812	17396	12726	11367	12417	27208	2511	12717	0.2
Forest based	0	13997	66154	22764	12857	19797	80151	2320	34383	0.2
Highland perennial	1871	3589	2453	3171	3385	27653	7912	2991	6890	0.3
Highland mixed	659	1311	2385	1875	3484	37817	4356	2637	3609	0.3
Root and tuber crop	1494	58534	64664	43681	36646	19825	124691	2646	76971	0.2
Cereal-root crop mixed	241	14744	35203	40500	76648	38373	50187	2391	31148	0.3
Maize mixed	7868	63377	105298	52441	71496	95350	176543	2547	137908	0.3
Agro-pastoral	2144	8742	13718	44643	129748	166671	24603	2597	20711	0.3
Pastoral	1017	5770	4788	8303	20199	326355	11574	2799	9966	0.3
Arid pastoral-oases	0	32	28	30	16	464417	60	2705	53	0.3
Artisanal fishing	570	2797	4331	3824	6438	28063	7698	2545	4553	0.2
Perennial mixed	45	813	1790	1936	2041	23906	2647	2415	1966	0.3
Not assigned	1	104	94	121	76	1397	198	2699	141	0.3
Total land	15909	183621	318374	236498	376422	1296101	517904	2534	341058	0.3

Suitability profiles for rain-fed groundnut (high inputs)

Farming System Zone	Suitability profile (000ha)						Prime and good land (VS+S+MS)			
	Very suitable (VS)	Suitable (S)	Moderately Suitable (MS)	Marginally Suitable (mS)	Very marginally Suitable (VmS)	Not Suitable (NS)	Area (000ha)	Yield (kg/ha)	Production (000t)	Cultivation factor
Irrigated	0	439	1891	4126	8688	21484	2330	2054	4307	0.9
Humid lowland tree crop	0	4309	26536	16273	8078	8522	30846	2053	56983	0.9
Forest based	0	1696	77625	38685	8348	9216	79321	1978	141192	0.9
Highland perennial	1370	3221	2669	3021	2555	29286	7260	2632	17197	0.9
Highland mixed	694	1790	2685	2572	3212	36579	5170	2427	11292	0.9
Root and tuber crop	1619	38876	78018	55641	27841	22848	118514	2201	234725	0.9
Cereal-root crop mixed	3841	69855	32972	59114	26862	13064	106668	2496	239625	0.9
Maize mixed	30858	93674	95793	58735	43608	73161	220325	2497	495088	0.9
Agro-pastoral	5364	28701	83703	118532	72235	57130	117768	2192	232316	0.9
Pastoral	3808	6477	15294	37771	87680	215402	25579	2370	54555	0.9
Arid pastoral-oases	0	61	32	3246	8663	452522	93	2493	209	0.9
Artisanal fishing	1124	3560	8339	6306	4610	22083	13023	2279	26716	0.9
Perennial mixed	755	1289	2396	2813	3307	19970	4440	2458	9821	0.9
Not assigned	0	106	76	131	139	1341	181	2464	402	0.9
Total land	49434	254056	428028	406966	305825	982616	731518	2315	1524429	0.9

Suitability profiles for rain-fed groundnut (low inputs)

Irrigated	0	94	834	3103	11848	20750	928	606	166	0.3
Humid lowland tree crop	0	6	533	3399	48356	11424	539	597	85	0.3
Forest based	0	0	2	1633	112790	21145	2	627	0	0.0
Highland perennial	194	948	1985	3458	4983	30554	3127	690	707	0.3
Highland mixed	175	1041	1846	2354	6009	36107	3062	712	765	0.4
Root and tuber crop	7	871	8872	48621	149598	16875	9749	610	1647	0.3
Cereal-root crop mixed	37	22985	28691	54188	81666	18142	51714	693	9727	0.3
Maize mixed	3605	39980	74428	103643	96809	77364	118013	687	26631	0.3
Agro-pastoral	2466	14038	64055	94155	128088	62863	80559	645	15692	0.3
Pastoral	1185	6263	15378	47206	114362	182038	22826	684	4979	0.3
Arid pastoral-oases	0	48	17	2837	12436	449185	65	772	17	0.3
Artisanal fishing	76	770	3244	3711	11369	26853	4090	643	757	0.3
Perennial mixed	218	944	2447	3626	3789	19506	3609	694	846	0.3
Not assigned	0	7	9	107	559	1110	16	669	3	0.3
Total land	7965	87994	202341	372042	782660	973924	298299	673	62021	0.3

Suitability profiles for rain-fed millet (high inputs)

Farming System Zone	Suitability profile (000ha)						Prime and good land (VS+S+MS)			
	Very suitable (VS)	Suitable (S)	Moderately Suitable (MS)	Marginally Suitable (mS)	Very marginally Suitable (VmS)	Not Suitable (NS)	Area (000ha)	Yield (kg/ha)	Production (000t)	Cultivation factor
Irrigated	1849	4238	5916	3424	1098	20103	12003	3162	34156	0.9
Humid lowland tree crop	1	24	1848	4706	3537	53602	1873	2358	3975	0.9
Forest based	0	69	563	2647	1079	131213	632	3745	2129	0.9
Highland perennial	1784	6116	6573	1665	2055	23930	14473	4423	57612	0.9
Highland mixed	2140	5258	3480	1798	3325	31532	10878	4678	45801	0.9
Root and tuber crop	460	3293	26105	39953	29306	125726	29858	3054	82057	0.9
Cereal-root crop mixed	37920	56326	49235	19668	30134	12427	143481	3325	429321	0.9
Maize mixed	38204	106197	132858	37655	26559	54357	277259	4014	1001570	0.9
Agro-pastoral	70301	93093	91008	24992	36621	49649	254402	3901	893257	0.9
Pastoral	12416	23384	50617	73699	30142	176173	86418	3188	247987	0.9
Arid pastoral-oases	0	62	3516	15390	2945	442609	3579	2353	7579	0.9
Artisanal fishing	1659	2917	5316	3193	2788	30150	9892	3322	29572	0.9
Perennial mixed	3066	3328	2712	1785	2352	17288	9106	4995	40931	0.9
Not assigned	0	13	46	135	113	1485	59	3605	193	0.9
Total land	169800	304318	379794	230709	172055	1170249	853913	3742	2876141	0.9

Suitability profiles for rain-fed millet (low inputs)

Irrigated	405	846	3013	5454	9722	17189	4264	689	906	0.3
Humid lowland tree crop	0	5	513	3553	14170	45477	518	536	74	0.3
Forest based	0	2	32	2051	3554	129930	34	1409	14	0.3
Highland perennial	209	1898	4402	6976	6407	22231	6508	1392	3071	0.3
Highland mixed	593	2079	3433	4659	9312	27455	6105	1403	3182	0.4
Root and tuber crop	57	372	7564	44339	84592	87919	7993	764	1824	0.3
Cereal-root crop mixed	11262	21097	37797	55211	63330	17012	70155	661	13987	0.3
Maize mixed	9427	37631	78234	145871	79946	44720	125292	1107	48018	0.3
Agro-pastoral	29247	37602	80156	84968	92539	41153	147005	881	39983	0.3
Pastoral	6697	11596	24549	113545	82321	127724	42842	933	12520	0.3
Arid pastoral-oases	0	45	632	24723	9700	429424	677	472	152	0.5
Artisanal fishing	508	1522	2663	5296	5299	30734	4694	790	1157	0.3
Perennial mixed	1049	2121	3927	4709	4676	14047	7098	1525	3808	0.4
Not assigned	0	0	14	116	507	1156	14	841	4	0.3
Total land	59455	116816	246927	501471	466076	1036179	423199	937	128701	0.3

Suitability profiles for rain-fed phaseolus bean (high inputs)

Farming System Zone	Suitability profile (000ha)						Prime and good land (VS+S+MS)			
	Very suitable (VS)	Suitable (S)	Moderately Suitable (MS)	Marginally Suitable (mS)	Very marginally Suitable (VmS)	Not Suitable (NS)	Area (000ha)	Yield (kg/ha)	Production (000t)	Cultivation factor
Irrigated	89	1533	1792	6392	5772	21050	3415	2535	7790	0.9
Humid lowland tree crop	123	5502	35403	6601	7579	8511	41028	2348	86697	0.9
Forest based	0	3820	90068	26688	5942	9052	93889	2250	190092	0.9
Highland perennial	5542	11201	5405	1245	2353	16376	22147	3291	65607	0.9
Highland mixed	4029	9517	4082	1775	4500	23630	17627	3217	51033	0.9
Root and tuber crop	1659	55386	89783	32234	23484	22296	146829	2577	340571	0.9
Cereal-root crop mixed	3829	105170	43736	14432	26122	12420	152735	2916	400785	0.9
Maize mixed	35032	138769	97715	23943	34906	65465	271516	2857	698106	0.9
Agro-pastoral	16724	70768	86158	71666	61531	58819	173649	2691	420570	0.9
Pastoral	5154	7157	13675	38661	99735	202049	25986	2621	61295	0.9
Arid pastoral-oases	0	91	17	2446	10254	451715	108	3001	292	0.9
Artisanal fishing	884	6033	9072	3633	4364	22037	15989	2631	37863	0.9
Perennial mixed	2222	3162	4669	2522	4113	13843	10053	2848	25766	0.9
Not assigned	51	115	79	89	96	1362	246	2973	657	0.9
Total land	75339	418224	481652	232324	290751	928634	975215	2720	2387125	0.9

Suitability profiles for rain-fed phaseolus bean (low inputs)

Irrigated	31	312	1118	3442	10441	21284	1460	742	343	0.3
Humid lowland tree crop	0	76	543	6173	45360	11566	619	733	121	0.3
Forest based	0	0	86	4101	110421	20962	86	592	15	0.3
Highland perennial	988	2966	6231	9448	10739	11751	10185	872	2991	0.3
Highland mixed	1472	2781	6457	4299	15134	17388	10710	878	3402	0.4
Root and tuber crop	104	1960	11739	54702	141010	15329	13802	719	2811	0.3
Cereal-root crop mixed	341	39303	30122	58085	60743	17117	69765	837	17373	0.3
Maize mixed	12378	41424	93598	112966	79576	55887	147401	793	40333	0.3
Agro-pastoral	8139	35022	59603	97882	110817	54203	102763	807	26522	0.3
Pastoral	3079	5500	11835	31166	131373	183479	20414	813	5573	0.3
Arid pastoral-oases	0	52	14	803	10341	453313	66	950	21	0.3
Artisanal fishing	86	1375	2913	5417	9045	27187	4374	770	1022	0.3
Perennial mixed	1193	2291	5694	5254	6846	9252	9178	836	2587	0.3
Not assigned	0	8	7	120	430	1227	15	822	4	0.3
Total land	27812	133069	229958	393857	742276	899953	390839	808	103119	0.3

Suitability profiles for rain-fed pasture species (high inputs)

Farming System Zone	Suitability profile (000ha)						Prime and good land (VS+S+MS)			
	Very suitable (VS)	Suitable (S)	Moderately Suitable (MS)	Marginally Suitable (mS)	Very marginally Suitable (VmS)	Not Suitable (NS)	Area (000ha)	Yield (kg/ha)	Production (000t)	Cultivation factor
Irrigated	0	0	0	861	32323	3445	0	470	0	
Humid lowland tree crop	14313	28432	8722	3467	5199	3585	51467	1464	75354	1.0
Forest based	87688	34916	5797	3040	1230	2898	128401	1682	215991	1.0
Highland perennial	7448	8897	11887	4403	3534	5953	28232	1431	40394	1.0
Highland mixed	184	3552	6864	10991	14237	11705	10599	1195	12667	1.0
Root and tuber crop	17322	64561	82341	30170	24183	6267	164224	1226	201398	1.0
Cereal-root crop mixed	0	0	11031	70381	116101	8196	11031	867	9567	1.0
Maize mixed	7014	24786	163817	125828	59592	14793	195617	1043	204002	1.0
Agro-pastoral	3367	5363	23833	62997	242607	27498	32563	1144	37253	1.0
Pastoral	3085	3970	4844	12277	281462	60793	11900	1391	16551	1.0
Arid pastoral-oases	0	0	125	28	242744	221626	125	1044	131	1.0
Artisanal fishing	2543	5559	7444	4730	4955	20792	15546	1260	19593	1.0
Perennial mixed	358	1192	4592	6482	11812	6094	6143	1198	7357	1.0
Not assigned	238	98	121	72	463	801	456	1629	743	1.0
Total land	143558	181326	331419	335728	1040443	394451	656303	1281	841000	1.0

Suitability profiles for rain-fed pasture species (low inputs)

Irrigated	0	0	0	677	28415	7536	0	0	0	
Humid lowland tree crop	3085	13998	30121	8468	6958	1088	47204	497	23454	1.0
Forest based	2407	34586	67179	26723	2916	1758	104172	474	49397	1.0
Highland perennial	7735	13046	10353	4848	4311	1829	31134	593	18453	1.0
Highland mixed	314	5265	10776	9279	17325	4574	16354	479	7827	1.0
Root and tuber crop	783	10002	90794	96731	24102	2431	101579	426	43285	1.0
Cereal-root crop mixed	0	0	1113	69458	127647	7491	1113	346	385	1.0
Maize mixed	6525	14918	91910	208131	68669	5677	113352	456	51688	1.0
Agro-pastoral	3893	5648	22499	62345	245681	25599	32040	491	15732	1.0
Pastoral	4496	2607	7924	13354	265562	72489	15027	569	8546	1.0
Arid pastoral-oases	0	0	99	42	221165	243217	99	418	41	1.0
Artisanal fishing	627	2861	8066	8120	5959	20391	11554	480	5544	1.0
Perennial mixed	1273	2910	4412	5279	12089	4567	8595	534	4586	1.0
Not assigned	279	179	126	7	552	649	585	719	421	1.0
Total land	31416	106019	345372	513464	1031351	399304	482807	475	229358	1.0

Suitability profiles for rain-fed soybean (high inputs)

Farming System Zone	Suitability profile (000ha)						Prime and good land (VS+S+MS)			
	Very suitable (VS)	Suitable (S)	Moderately Suitable (MS)	Marginally Suitable (mS)	Very marginally Suitable (VmS)	Not Suitable (NS)	Area (000ha)	Yield (kg/ha)	Production (000t)	Cultivation factor
Irrigated	188	947	2241	3369	3960	25924	3376	2917	8864	0.9
Humid lowland tree crop	555	16158	26897	4433	7159	8515	43611	2909	114159	0.9
Forest based	3	29764	82315	9487	4890	9109	112083	2777	280144	0.9
Highland perennial	4110	7072	2917	880	1642	25501	14099	3580	45422	0.9
Highland mixed	2301	5418	2970	1642	3204	31997	10689	3476	33441	0.9
Root and tuber crop	2166	85090	80899	12367	21900	22421	168155	3009	455419	0.9
Cereal-root crop mixed	8073	87256	58673	11455	27773	12480	154002	3310	458739	0.9
Maize mixed	50556	163347	85161	16962	26688	53116	299064	3403	915990	0.9
Agro-pastoral	19463	64599	97636	70970	59570	53428	181698	3087	504861	0.9
Pastoral	5776	8477	14372	26875	49306	261625	28625	3250	83717	0.9
Arid pastoral-oases	3	88	23	657	1627	462126	113	3335	339	0.9
Artisanal fishing	1330	6477	9501	2811	3819	22085	17308	3032	47235	0.9
Perennial mixed	2849	3685	3144	2451	3456	14947	9677	3530	30745	0.9
Not assigned	76	123	52	77	46	1419	250	3650	822	0.9
Total land	97447	478500	466802	164435	215040	1004700	1042750	3175	2979897	0.9

Suitability profiles for rain-fed soybean (low inputs)

Irrigated	106	205	1453	2549	9543	22772	1765	697	400	0.3
Humid lowland tree crop	0	22	1037	26920	24329	11410	1059	630	173	0.3
Forest based	0	0	207	52569	62860	19932	207	568	38	0.3
Highland perennial	60	1702	3541	6801	5560	24458	5303	740	1311	0.3
Highland mixed	1089	1907	3526	3995	8856	28159	6522	814	1924	0.4
Root and tuber crop	0	705	13932	117136	77542	15529	14637	661	2738	0.3
Cereal-root crop mixed	1276	25045	35643	60326	66265	17154	61964	779	14243	0.3
Maize mixed	14851	40834	104537	118828	70707	46072	160222	752	40713	0.3
Agro-pastoral	8480	34860	72752	92986	110413	46175	116092	759	27531	0.3
Pastoral	1796	8681	17083	32892	94272	211707	27560	769	6936	0.3
Arid pastoral-oases	0	3	59	1161	4715	458585	62	717	15	0.3
Artisanal fishing	51	1142	2887	7084	8482	26376	4080	715	884	0.3
Perennial mixed	1682	2099	5760	4103	6238	10649	9541	804	2581	0.3
Not assigned	0	5	70	216	290	1211	75	681	14	0.3
Total land	29391	117211	262488	527567	550072	940196	409090	757	99500	0.3

Suitability profiles for rain-fed sweet potato (high inputs)

Farming System Zone	Suitability profile (000ha)						Prime and good land (VS+S+MS)			
	Very suitable (VS)	Suitable (S)	Moderately Suitable (MS)	Marginally Suitable (mS)	Very marginally Suitable (VmS)	Not Suitable (NS)	Area (000ha)	Yield (kg/ha)	Production (000t)	Cultivation factor
Irrigated	120	1017	1825	3388	5387	24891	2963	6576	17534	0.9
Humid lowland tree crop	78	18027	20628	9010	7419	8557	38733	7238	252320	0.9
Forest based	0	59379	51642	9615	5812	9121	111021	7141	713513	0.9
Highland perennial	3109	5012	3586	1789	2090	26535	11707	8182	86209	0.9
Highland mixed	1218	1821	4410	2124	3296	34663	7449	7373	49429	0.9
Root and tuber crop	6124	77168	71177	20550	26885	22939	154470	7179	997984	0.9
Cereal-root crop mixed	11169	83579	43943	16972	35012	15034	138691	7506	936901	0.9
Maize mixed	46701	116298	108104	30768	31628	62331	271103	7732	1886498	0.9
Agro-pastoral	9144	47325	92142	90268	71727	55059	148611	6762	904411	0.9
Pastoral	1383	8794	12174	28311	55247	260523	22351	7168	144193	0.9
Arid pastoral-oases	6	75	19	268	1254	462901	100	7869	708	0.9
Artisanal fishing	1550	5954	9271	2985	4119	22143	16775	7164	108160	0.9
Perennial mixed	891	2584	2740	1878	1502	20935	6215	7357	41152	0.9
Not assigned	37	95	110	23	101	1427	241	7712	1675	0.9
Total land	81529	427128	421772	217950	251480	1027066	930430	7333	6140687	0.9

Suitability profiles for rain-fed sweet potato (low inputs)

Irrigated	0	266	837	2558	9642	23325	1103	2185	700	0.3
Humid lowland tree crop	0	3858	19143	15393	13873	11452	23000	2217	9714	0.2
Forest based	0	518	47485	50558	17339	19670	48003	2035	18549	0.2
Highland perennial	218	3170	4817	3326	3756	26836	8204	2486	6162	0.3
Highland mixed	118	1900	3476	2940	3778	35320	5493	2399	4496	0.3
Root and tuber crop	31	12998	79430	67171	46935	18279	92458	2209	49255	0.2
Cereal-root crop mixed	26	24572	34048	43191	81019	22853	58646	2510	38574	0.3
Maize mixed	1977	56941	118815	73224	73064	71807	177733	2404	135258	0.3
Agro-pastoral	736	22552	54232	104115	116988	67042	77520	2342	55385	0.3
Pastoral	213	8361	9398	31716	85175	231568	17972	2488	14057	0.3
Arid pastoral-oases	0	58	9	301	1667	462488	67	2697	59	0.3
Artisanal fishing	102	1486	4892	5245	7859	26438	6480	2382	3955	0.3
Perennial mixed	263	1625	3373	3344	2197	19729	5261	2442	4200	0.3
Not assigned	0	93	102	132	242	1223	195	2511	128	0.3
Total land	3683	138396	380056	403215	463536	1038039	522136	2334	340493	0.3

Suitability profiles for rain-fed sorghum (high inputs)

Farming System Zone	Suitability profile (000ha)						Prime and good land (VS+S+MS)			
	Very suitable (VS)	Suitable (S)	Moderately Suitable (MS)	Marginally Suitable (mS)	Very marginally Suitable (VmS)	Not Suitable (NS)	Area (000ha)	Yield (kg/ha)	Production (000t)	Cultivation factor
Irrigated	1512	2630	4470	6537	1255	20225	8612	5753	44592	0.9
Humid lowland tree crop	9	774	3681	18718	18293	22242	4464	4865	19548	0.9
Forest based	0	27	1293	12342	73255	48653	1320	4237	5033	0.9
Highland perennial	5194	8750	5950	3709	2364	16155	19894	5072	90816	0.9
Highland mixed	4934	8551	3741	2067	4723	23516	17227	5088	78879	0.9
Root and tuber crop	31	14415	29984	86269	62617	31528	44430	5121	204754	0.9
Cereal-root crop mixed	59480	69403	24399	14487	25566	12374	153282	7028	969582	0.9
Maize mixed	63910	129007	96225	36360	23377	46951	289141	6146	1599416	0.9
Agro-pastoral	66815	90366	89025	36514	36949	45995	246206	6411	1420509	0.9
Pastoral	8296	16797	36311	93096	34511	177422	61404	5436	300388	0.9
Arid pastoral-oases	68	34	2762	11215	2933	447511	2864	3195	8236	0.9
Artisanal fishing	2098	4718	4708	3540	4844	26116	11523	6174	64027	0.9
Perennial mixed	3292	4363	3376	2677	4160	12662	11031	6194	61496	0.9
Not assigned	8	7	18	274	177	1307	33	4899	148	0.9
Total land	215647	349841	305944	327804	295023	932667	871431	6206	4867424	0.9

Suitability profiles for rain-fed sorghum (low inputs)

Irrigated	171	831	2578	5789	9824	17435	3581	1278	1510	0.3
Humid lowland tree crop	3	236	555	5581	32281	25061	794	1319	276	0.3
Forest based	0	0	110	3074	42085	90301	110	1079	36	0.3
Highland perennial	2640	4437	6999	9153	8312	10581	14076	1531	7222	0.3
Highland mixed	2594	4289	5595	5500	11767	17787	12479	1580	7213	0.4
Root and tuber crop	5	3948	9249	56497	131393	23752	13202	1299	4837	0.3
Cereal-root crop mixed	28593	18979	45227	39935	56028	16946	92799	1583	44323	0.3
Maize mixed	29913	49134	110405	107099	62965	36314	189452	1496	96731	0.3
Agro-pastoral	14491	43929	82527	96948	89818	37953	140946	1446	63617	0.3
Pastoral	6674	7364	25056	89801	111562	125975	39094	1517	20406	0.3
Arid pastoral-oases	51	19	456	13731	16955	433313	525	1220	358	0.6
Artisanal fishing	893	1382	3523	4762	6511	28952	5797	1484	2721	0.3
Perennial mixed	2062	2471	6334	4308	7367	7988	10867	1681	6138	0.3
Not assigned	0	12	20	167	422	1171	33	1206	11	0.3
Total land	88091	137030	298633	442344	587288	873538	523755	1499	255399	0.3

Suitability profiles for rain-fed sugarcane (high inputs)

Farming System Zone	Suitability profile (000ha)						Prime and good land (VS+S+MS)			
	Very suitable (VS)	Suitable (S)	Moderately Suitable (MS)	Marginally Suitable (mS)	Very marginally Suitable (VmS)	Not Suitable (NS)	Area (000ha)	Yield (kg/ha)	Production (000t)	Cultivation factor
Irrigated	0	0	0	0	0	36629	0	0	0	
Humid lowland tree crop	5019	14071	18537	9245	6450	10396	37627	8202	277751	0.9
Forest based	21216	66310	25890	5846	1874	14435	113416	9096	928415	0.9
Highland perennial	3730	3105	2130	2868	2208	28081	8966	9794	79033	0.9
Highland mixed	4	711	1878	3416	2285	39238	2593	7153	16692	0.9
Root and tuber crop	6791	48677	67063	43611	27689	31012	122531	7861	866846	0.9
Cereal-root crop mixed	0	0	8807	71468	32523	92911	8807	5886	46654	0.9
Maize mixed	5626	15799	41376	140623	55282	137123	62801	7472	422337	0.9
Agro-pastoral	1681	1910	7385	19491	10513	324684	10976	7595	75029	0.9
Pastoral	2394	2166	2960	4671	3933	350307	7521	9085	61496	0.9
Arid pastoral-oases	0	0	7	79	32	464405	7	5409	35	0.9
Artisanal fishing	1202	3358	5298	6277	4592	25295	9859	8036	71301	0.9
Perennial mixed	236	424	777	2215	2611	24267	1437	8137	10523	0.9
Not assigned	92	79	49	67	42	1463	220	10059	1996	0.9
Total land	47993	156611	182158	309877	150034	1580253	386761	8211	2858107	0.9

Suitability profiles for rain-fed sugarcane (low inputs)

Irrigated	0	0	0	0	0	36629	0	0	0	
Humid lowland tree crop	117	2023	17924	18502	14206	10946	20064	2207	9775	0.2
Forest based	5	384	58445	38875	16958	20903	58834	2101	26319	0.2
Highland perennial	799	2128	3242	3967	4976	27011	6168	2619	4853	0.3
Highland mixed	3	134	1322	2661	5586	37825	1460	2127	974	0.3
Root and tuber crop	0	3475	54108	87789	58839	20633	57582	2071	27674	0.2
Cereal-root crop mixed	0	0	2130	38010	58999	106570	2130	1901	1100	0.3
Maize mixed	920	7125	28785	85679	125166	148154	36830	2233	26281	0.3
Agro-pastoral	576	1950	5660	14663	21337	321480	8186	2373	6250	0.3
Pastoral	2280	1805	3818	4625	6752	347152	7903	2790	6513	0.3
Arid pastoral-oases	0	0	17	59	39	464408	17	1980	12	0.4
Artisanal fishing	219	1016	2739	6634	6475	28940	3974	2387	2615	0.3
Perennial mixed	290	344	725	2063	5663	21446	1359	2589	1236	0.4
Not assigned	42	69	115	88	82	1397	226	2728	159	0.3
Total land	5251	20453	179030	303615	325077	1593500	204734	2188	113760	0.3

Suitability profiles for rain-fed wheat (high inputs)

Farming System Zone	Suitability profile (000ha)						Prime and good land (VS+S+MS)			
	Very suitable (VS)	Suitable (S)	Moderately Suitable (MS)	Marginally Suitable (mS)	Very marginally Suitable (VmS)	Not Suitable (NS)	Area (000ha)	Yield (kg/ha)	Production (000t)	Cultivation factor
Irrigated	0	25	317	689	116	35481	342	2437	750	0.9
Humid lowland tree crop	0	42	919	878	542	61337	961	2689	2326	0.9
Forest based	0	2	183	40	1	135344	185	3218	535	0.9
Highland perennial	1437	5821	7011	2000	1848	24004	14269	5013	64371	0.9
Highland mixed	2552	6180	6255	2040	3306	27198	14987	5248	70781	0.9
Root and tuber crop	0	91	1641	3064	476	219571	1732	2645	4123	0.9
Cereal-root crop mixed	8	124	325	205	207	204839	457	3398	1399	0.9
Maize mixed	893	25615	92982	75575	31191	169573	119491	2976	319991	0.9
Agro-pastoral	918	8732	15086	46334	39355	255239	24736	3234	71988	0.9
Pastoral	231	3222	6517	7253	12311	336899	9970	3533	31697	0.9
Arid pastoral-oases	0	0	7	367	1047	463103	7	2105	12	0.8
Artisanal fishing	2	102	275	694	130	44820	379	2790	953	0.9
Perennial mixed	652	2637	3718	4805	4723	13995	7007	4764	30045	0.9
Not assigned	0	17	60	31	55	1630	77	3691	257	0.9
Total land	6693	52610	135296	143977	95308	1993041	194599	3421	599228	0.9

Suitability profiles for rain-fed wheat (low inputs)

Irrigated	0	26	54	412	584	35553	80	779	34	0.5
Humid lowland tree crop	0	0	10	875	1634	61199	10	756	2	0.3
Forest based	0	0	0	192	122	135255	0	0	0	
Highland perennial	901	2149	4464	8351	8406	17850	7515	1319	3253	0.3
Highland mixed	1676	2359	4196	7145	11095	21062	8230	1405	4251	0.4
Root and tuber crop	0	7	150	2398	3409	218880	157	618	30	0.3
Cereal-root crop mixed	1	41	79	222	643	204724	121	986	48	0.4
Maize mixed	249	6812	30137	105035	92555	161042	37198	877	11523	0.4
Agro-pastoral	172	4048	5713	29607	76221	249904	9933	959	3583	0.4
Pastoral	4	1462	7762	13386	23124	320694	9229	960	2726	0.3
Arid pastoral-oases	0	0	7	615	1782	462119	7	593	1	0.2
Artisanal fishing	0	58	153	560	528	44723	211	703	57	0.4
Perennial mixed	297	1957	3699	6291	9765	8521	5954	1378	2822	0.3
Not assigned	0	3	22	64	119	1584	26	980	6	0.2
Total land	3300	18923	56446	175152	229986	1943118	78669	1032	28335	0.3

Suitability profiles for rain-fed white potato (high inputs)

Farming System Zone	Suitability profile (000ha)						Prime and good land (VS+S+MS)			
	Very suitable (VS)	Suitable (S)	Moderately Suitable (MS)	Marginally Suitable (mS)	Very marginally Suitable (VmS)	Not Suitable (NS)	Area (000ha)	Yield (kg/ha)	Production (000t)	Cultivation factor
Irrigated	0	0	120	499	475	35533	120	4397	476	0.9
Humid lowland tree crop	0	5	313	1311	667	61423	317	4531	1294	0.9
Forest based	0	16	35	85	90	135344	51	6670	306	0.9
Highland perennial	2749	4575	4741	3039	2546	24471	12066	8257	89663	0.9
Highland mixed	1782	3256	7068	3971	3821	27633	12106	7254	79041	0.9
Root and tuber crop	3	76	564	1684	950	221566	643	5346	3094	0.9
Cereal-root crop mixed	7	53	111	295	223	205020	171	6035	927	0.9
Maize mixed	994	5518	39967	108105	62361	178885	46479	5697	238331	0.9
Agro-pastoral	879	2945	6886	27084	57646	270225	10710	6269	60422	0.9
Pastoral	15	631	4973	8463	13731	338619	5618	5830	29480	0.9
Arid pastoral-oases	0	0	0	132	1355	463037	0	0	0	
Artisanal fishing	2	31	121	682	231	44956	154	5132	710	0.9
Perennial mixed	1222	2374	2446	4317	6172	13999	6042	8179	44476	0.9
Not assigned	0	7	41	46	67	1632	47	6194	264	0.9
Total land	7652	19485	67387	159714	150336	2022351	94524	6447	548484	0.9

Suitability profiles for rain-fed white potato (low inputs)

Irrigated	0	0	0	260	775	35593	0	0	0	#
Humid lowland tree crop	0	0	1	211	1922	61583	1	2064	1	0.5
Forest based	0	0	17	46	252	135255	17	1830	9	0.3
Highland perennial	1252	2389	5155	6444	6644	20237	8796	2847	7914	0.3
Highland mixed	1135	2185	4195	5075	7715	27228	7515	2807	7593	0.4
Root and tuber crop	0	0	140	1275	2292	221136	140	1735	71	0.3
Cereal-root crop mixed	1	14	81	154	468	204991	95	2072	77	0.4
Maize mixed	184	1862	17853	94688	101399	179844	19899	2008	13424	0.3
Agro-pastoral	440	1251	4721	18083	71736	269433	6413	2303	5387	0.4
Pastoral	5	118	3824	14372	18729	329385	3947	2069	2416	0.3
Arid pastoral-oases	0	0	0	102	920	463502	0	0	0	
Artisanal fishing	0	5	99	617	431	44870	104	1637	62	0.4
Perennial mixed	367	2091	2849	5175	6247	13801	5307	2905	4910	0.3
Not assigned	0	0	7	51	146	1589	7	2321	3	0.2
Total land	3385	9914	38942	146553	219676	2008455	52241	2395	41865	0.3

Suitability profiles for rain-fed yam (high inputs)

Farming System Zone	Suitability profile (000ha)						Prime and good land (VS+S+MS)			
	Very suitable (VS)	Suitable (S)	Moderately Suitable (MS)	Marginally Suitable (mS)	Very marginally Suitable (VmS)	Not Suitable (NS)	Area (000ha)	Yield (kg/ha)	Production (000t)	Cultivation factor
Irrigated	0	106	835	3392	5796	26500	940	4920	4163	0.9
Humid lowland tree crop	81	24991	15756	7214	7289	8387	40828	6562	241123	0.9
Forest based	2508	91242	23070	5386	4881	8483	116820	7001	736019	0.9
Highland perennial	3715	3573	2881	2280	2583	27091	10168	7639	69904	0.9
Highland mixed	751	1761	2985	2181	2695	37159	5497	6405	31691	0.9
Root and tuber crop	18722	81049	61545	15513	26926	21088	161315	6693	971757	0.9
Cereal-root crop mixed	6710	49954	49820	47804	36297	15125	106484	5925	567789	0.9
Maize mixed	20196	113363	106392	43908	41371	70599	239951	6491	1401765	0.9
Agro-pastoral	3526	14905	56917	120133	92358	77825	75348	5262	356868	0.9
Pastoral	1269	5478	7969	24615	81814	245286	14716	6131	81200	0.9
Arid pastoral-oases	0	66	17	229	2480	461732	82	6295	465	0.9
Artisanal fishing	1200	5574	8763	3458	5024	22005	15537	6210	86830	0.9
Perennial mixed	164	749	2112	2491	1408	23606	3025	5513	15011	0.9
Not assigned	44	109	73	25	138	1403	226	6811	1385	0.9
Total land	58887	392919	339133	278632	311059	1046296	790939	6414	4565971	0.9

Suitability profiles for rain-fed yam (low inputs)

Irrigated	0	0	293	1721	7797	26818	293	1289	128	0.3
Humid lowland tree crop	0	4461	21781	14193	10866	12417	26241	1682	8300	0.2
Forest based	0	6074	74113	25213	10388	19781	80187	1667	24927	0.2
Highland perennial	427	3233	3749	3266	2894	28553	7409	1866	4033	0.3
Highland mixed	66	1453	2882	2434	2603	38093	4401	1631	2379	0.3
Root and tuber crop	458	19298	90152	53058	40257	21619	109909	1660	42837	0.2
Cereal-root crop mixed	9	12391	40913	36886	75705	39806	53312	1525	21288	0.3
Maize mixed	979	49276	123098	61030	70492	90954	173353	1609	86921	0.3
Agro-pastoral	823	8505	33587	94047	122654	106049	42915	1498	20754	0.3
Pastoral	52	6007	6351	22466	101956	229599	12410	1702	6524	0.3
Arid pastoral-oases	0	24	37	252	3792	460419	61	1736	35	0.3
Artisanal fishing	221	1355	5230	4610	6544	28063	6807	1665	2698	0.2
Perennial mixed	6	424	1967	2953	1735	23445	2398	1485	1152	0.3
Not assigned	5	97	84	106	237	1263	186	1905	92	0.3
Total land	3045	112600	404237	322236	457921	1126887	519882	1621	222069	0.3

Appendix 4 Coefficients of variation of agro-climatic attainable rain-fed yields by FS zones and LGP

The coefficient of variation of crop yields over the reference periods 1961-90 is shown for three distinct areas, namely for areas with (i) median total LGP ≤ 120 days; (ii) for areas where median total LGP >120 days and the median longest LGP > 80% of the median total LGP, and (iii) for areas where median total LGP >120 days and the median longest LGP ≤ 80% of the median total LGP. (For a delineation of these LGP pattern zones see Figure 12 in Section 4)

Coefficient of variation (%) of maize yields in cultivated land (1961-90)																		
	LGP			Median of longest LGP > 0.80* median LGP days							Median of longest LGP < 0.80* median LGP days							All Land
	< 60	60-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	>300	120-149	150-179	180-209	210-239	240-269	270-299	>300	
Irrigated	56.6	39.3	21.7	6.3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	15.2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	28.6
Humid lowland tree crop	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3.0	2.8	2.8	2.9	n.a.	n.a.	3.0	3.8	3.4	3.3	3.5	2.9
Forest based	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1.4	2.0	2.6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3.0	2.5
Highland perennial	n.a.	n.a.	n.a.	n.a.	4.7	10.9	10.6	15.2	20.5	8.9	n.a.	13.2	16.2	13.1	11.2	6.8	9.2	12.1
Highland mixed	72.5	53.6	37.2	67.1	12.0	10.8	13.6	9.9	6.7	14.7	26.0	20.7	18.2	20.0	34.8	n.a.	n.a.	18.9
Root and tuber crop	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3.0	3.0	3.2	3.5	n.a.	n.a.	n.a.	5.9	5.0	4.0	3.0	3.1
Cereal-root crop mixed	n.a.	n.a.	15.7	5.3	2.2	1.9	2.2	2.8	n.a.	n.a.	2.0	32.5	n.a.	n.a.	n.a.	n.a.	n.a.	2.4
Maize mixed	n.a.	50.9	54.1	7.8	7.1	5.8	6.5	7.1	2.5	3.4	35.6	24.6	14.7	6.4	6.8	3.1	6.1	14.1
Agro-pastoral	54.0	36.1	18.6	4.7	3.2	2.9	4.4	16.5	3.3	16.8	18.1	13.3	14.0	9.4	9.5	12.3	18.6	12.5
Pastoral	59.2	40.6	36.1	2.0	2.2	2.3	8.2	47.0	4.1	3.9	26.1	16.2	11.8	14.0	6.2	5.3	4.6	34.8
Arid pastoral-oases	78.5	56.7	52.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.8	n.a.	n.a.	n.a.	n.a.	16.0
Artisanal fishing	53.0	39.9	28.2	2.6	2.4	2.3	2.5	2.6	2.5	3.2	9.4	6.9	5.0	4.7	3.4	2.7	2.8	3.8
Perennial mixed	n.a.	97.3	75.7	n.a.	n.a.	64.8	13.7	13.4	2.5	2.0	57.1	39.0	23.0	13.0	6.2	4.0	2.6	28.2
Sub-Saharan Africa	58.3	39.5	22.6	4.9	4.0	4.1	4.7	4.8	4.5	4.1	29.7	21.7	15.9	9.9	7.1	5.0	9.6	11.9

Coefficient of variation (%) of sorghum yields in cultivated land (1961-90)																		
	LGP			Median of longest LGP > 0.80* median LGP days							Median of longest LGP < 0.80* median LGP days							All Land
	< 60	60-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	>300	120-149	150-179	180-209	210-239	240-269	270-299	>300	
Irrigated	50.8	33.1	18.1	4.2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	12.4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	24.2
Humid lowland tree crop	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3.0	2.7	2.8	2.9	n.a.	n.a.	3.0	3.5	3.2	3.3	3.5	2.8
Forest based	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1.4	2.0	2.6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3.0	2.5
Highland perennial	n.a.	n.a.	n.a.	n.a.	4.6	8.1	9.5	14.4	20.0	8.8	n.a.	9.6	13.0	10.9	10.1	6.4	9.1	11.4
Highland mixed	62.2	39.0	23.3	40.1	7.4	9.9	13.4	9.5	6.7	14.5	16.7	15.0	17.2	21.6	34.8	n.a.	n.a.	15.6
Root and tuber crop	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.8	2.9	3.1	3.4	n.a.	n.a.	n.a.	4.8	4.5	4.0	3.0	3.0
Cereal-root crop mixed	n.a.	n.a.	13.4	4.5	2.1	1.9	2.2	2.8	n.a.	n.a.	2.0	18.8	n.a.	n.a.	n.a.	n.a.	n.a.	2.3
Maize mixed	n.a.	40.5	38.4	5.9	4.8	5.0	5.8	6.4	2.6	3.7	22.9	16.3	11.1	5.3	6.3	3.0	5.6	10.6
Agro-pastoral	49.4	29.5	15.6	4.0	2.8	2.8	4.3	16.3	3.1	18.1	15.1	9.7	11.4	8.5	9.8	11.4	18.4	10.5
Pastoral	55.2	34.8	30.2	2.0	2.1	2.3	6.9	42.0	3.9	3.7	17.9	11.6	8.9	11.6	5.9	5.2	4.7	29.6
Arid pastoral-oases	71.5	50.1	46.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.7	n.a.	n.a.	n.a.	n.a.	14.6
Artisanal fishing	46.8	33.6	17.8	2.3	2.3	2.2	2.5	2.6	2.6	3.1	7.0	5.6	4.3	3.9	3.2	2.7	2.7	3.5
Perennial mixed	79.6	53.6	39.2	n.a.	29.7	21.3	9.8	11.6	2.8	3.0	23.2	15.9	13.0	9.0	5.0	3.7	3.0	17.1
Sub-Saharan Africa	55.4	33.3	18.6	4.1	3.2	3.7	4.4	4.6	4.4	4.1	19.7	13.9	12.4	8.6	6.5	4.8	9.4	9.9

Coefficient of variation (%) of pearl millet in cultivated land (1961-90)																		
	LGP			Median of longest LGP > 0.80* median LGP days							Median of longest LGP < 0.80* median LGP days							All Land
	< 60	60-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	>300	120-149	150-179	180-209	210-239	240-269	270-299	>300	
Irrigated	47.6	26.8	11.0	2.6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	9.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	19.1
Humid lowland tree crop	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.0	2.6	2.5	2.2	n.a.	n.a.	3.0	3.4	3.1	2.8	2.8	2.5
Forest based	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1.6	2.0	2.1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3.0	2.1
Highland perennial	n.a.	n.a.	n.a.	n.a.	2.8	8.2	10.9	19.1	11.7	3.7	n.a.	4.8	6.7	16.2	9.3	3.3	5.1	7.9
Highland mixed	59.0	26.3	18.4	32.1	10.3	24.0	11.8	5.7	2.6	2.0	11.7	16.0	22.7	13.9	n.a.	n.a.	n.a.	14.2
Root and tuber crop	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.7	2.8	2.6	2.4	n.a.	n.a.	n.a.	3.1	3.0	3.0	3.0	2.7
Cereal-root crop mixed	n.a.	n.a.	5.4	3.0	2.2	2.0	2.3	2.3	n.a.	n.a.	2.0	29.7	n.a.	n.a.	n.a.	n.a.	n.a.	2.3
Maize mixed	n.a.	37.9	31.6	3.0	3.4	3.3	4.2	6.3	2.1	2.3	11.8	7.1	7.9	4.0	5.6	2.6	3.3	4.5
Agro-pastoral	47.4	21.3	7.9	2.7	2.4	2.7	2.6	24.5	3.4	7.2	8.8	5.9	6.2	7.6	5.9	3.4	11.1	6.1
Pastoral	51.4	28.9	20.6	2.0	2.3	2.4	12.3	30.0	3.2	1.7	11.4	7.0	5.4	10.0	3.5	4.3	3.9	24.2
Arid pastoral-oases	61.2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3.0	n.a.	n.a.	n.a.	n.a.	4.6
Artisanal fishing	42.1	25.8	13.3	2.5	2.3	2.5	2.1	2.4	2.4	2.3	3.2	4.5	2.8	3.1	3.0	2.4	2.5	3.0
Perennial mixed	n.a.	n.a.	24.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	12.6	10.9	7.4	4.9	2.9	n.a.	n.a.	8.4
Sub-Saharan Africa	50.0	26.2	9.1	2.8	2.7	2.8	3.2	3.7	2.8	2.4	10.0	8.1	7.7	5.5	5.0	2.9	5.5	6.2

Coefficient of variation (%) of cassava in cultivated land (1961-90)																		
	LGP			Median of longest LGP > 0.80* median LGP days							Median of longest LGP < 0.80* median LGP days							All Land
	< 60	60-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	>300	120-149	150-179	180-209	210-239	240-269	270-299	>300	
Irrigated	n.a.	n.a.	67.3	35.5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	60.8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	46.5
Humid lowland tree crop	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	6.0	2.6	1.9	1.1	n.a.	n.a.	11.7	8.1	4.2	2.0	1.2	1.9
Forest based	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1.7	1.4	1.4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.0	1.4
Highland perennial	n.a.	n.a.	n.a.	n.a.	13.2	18.5	16.9	17.3	14.9	2.5	n.a.	31.3	20.3	20.2	10.2	4.2	4.1	9.8
Highland mixed	n.a.	n.a.	61.2	58.0	21.8	29.1	20.8	4.9	3.9	1.0	39.7	36.1	33.7	35.5	n.a.	n.a.	n.a.	26.9
Root and tuber crop	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	5.7	3.9	1.5	1.5	n.a.	n.a.	n.a.	10.7	7.5	3.2	2.0	3.4
Cereal-root crop mixed	n.a.	n.a.	44.5	30.0	18.5	12.2	8.0	5.4	n.a.	n.a.	25.3	41.3	n.a.	n.a.	n.a.	n.a.	n.a.	13.7
Maize mixed	n.a.	n.a.	96.2	41.6	18.0	12.3	9.1	9.9	1.9	3.6	66.2	42.0	19.5	11.4	8.9	1.9	2.9	18.0
Agro-pastoral	n.a.	n.a.	70.3	33.7	21.0	10.6	6.8	23.8	2.0	7.6	59.8	31.8	21.5	13.3	5.2	2.9	11.2	42.4
Pastoral	n.a.	n.a.	90.8	22.3	16.1	7.4	9.1	52.0	10.5	16.8	61.0	32.1	21.2	18.4	6.7	2.6	1.0	37.2
Arid pastoral-oases	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	12.9	n.a.	n.a.	n.a.	n.a.	12.9
Artisanal fishing	n.a.	n.a.	88.5	32.4	16.1	11.8	6.7	4.5	1.9	1.8	44.3	27.7	13.4	10.3	6.5	1.9	1.7	7.8
Perennial mixed	n.a.	n.a.	102.5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	58.9	51.4	36.3	23.7	23.9	58.8	n.a.	38.1
Sub-Saharan Africa	n.a.	n.a.	70.7	34.0	18.8	12.4	8.1	4.7	2.3	1.7	60.7	36.3	22.2	13.2	9.5	4.2	4.7	22.5

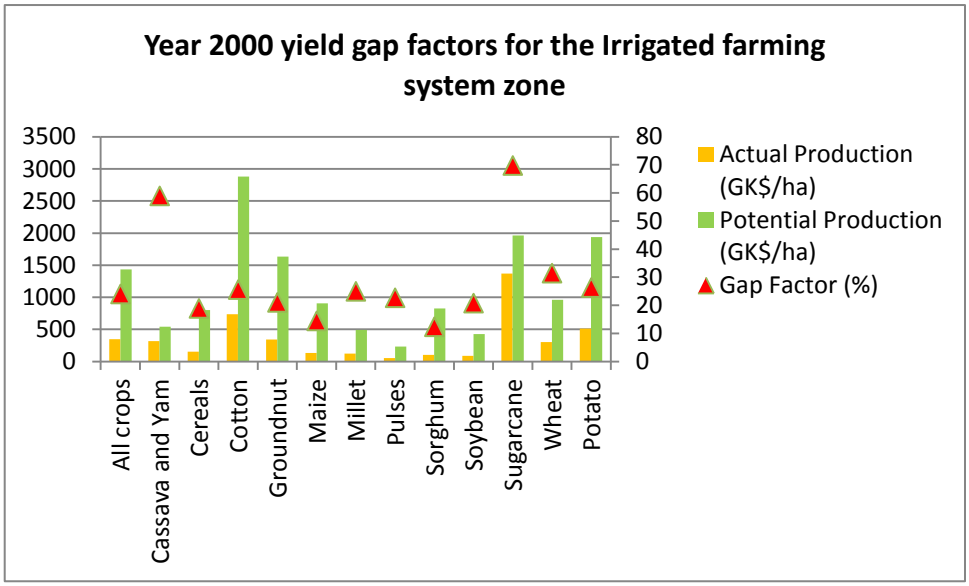
Coefficient of variation (%) of groundnut in cultivated land (1961-90)																		
	LGP			Median of longest LGP > 0.80* median LGP days							Median of longest LGP < 0.80* median LGP days							All Land
	< 60	60-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	>300	120-149	150-179	180-209	210-239	240-269	270-299	>300	
Irrigated	47.1	27.3	13.3	3.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	10.5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	20.0
Humid lowland tree crop	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3.0	2.3	2.5	2.4	n.a.	n.a.	3.0	3.1	2.8	2.8	2.8	2.5
Forest based	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1.9	2.0	2.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.0	2.0
Highland perennial	n.a.	n.a.	n.a.	n.a.	3.0	11.9	13.6	20.4	5.9	4.6	n.a.	5.8	9.8	17.6	10.1	4.3	3.7	7.7
Highland mixed	57.5	29.1	25.6	29.3	8.1	31.3	20.2	14.7	4.2	2.7	17.4	21.4	32.3	35.9	n.a.	n.a.	n.a.	20.6
Root and tuber crop	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.5	2.8	2.7	2.8	n.a.	n.a.	n.a.	3.0	3.0	3.0	2.0	2.7
Cereal-root crop mixed	n.a.	n.a.	7.3	3.7	2.3	2.0	2.2	2.2	n.a.	n.a.	2.0	26.3	n.a.	n.a.	n.a.	n.a.	n.a.	2.3
Maize mixed	n.a.	37.0	34.6	3.8	3.6	4.3	4.8	8.2	2.8	3.6	32.0	13.4	11.7	4.6	5.4	2.9	4.9	9.9
Agro-pastoral	47.5	22.5	10.6	3.1	2.5	2.5	3.3	36.6	3.9	6.8	10.1	6.9	9.8	8.8	5.0	5.2	14.2	7.5
Pastoral	51.4	30.6	25.2	2.0	2.5	2.6	22.2	38.0	4.5	9.6	14.0	9.3	7.0	10.9	3.9	5.0	4.3	26.1
Arid pastoral-oases	60.2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.8	n.a.	n.a.	n.a.	n.a.	4.4
Artisanal fishing	41.3	25.9	12.4	2.6	2.3	2.7	2.1	2.4	2.4	2.3	4.1	4.4	2.9	3.0	3.1	2.6	3.1	3.1
Perennial mixed	77.4	59.8	48.6	n.a.	n.a.	68.0	28.4	n.a.	30.7	40.0	40.4	20.0	23.4	15.9	13.6	16.3	67.2	27.1
Sub-Saharan Africa	51.5	27.8	13.7	3.2	2.9	3.5	3.6	4.0	2.9	2.7	21.4	12.2	13.1	7.3	6.7	4.7	5.3	8.2

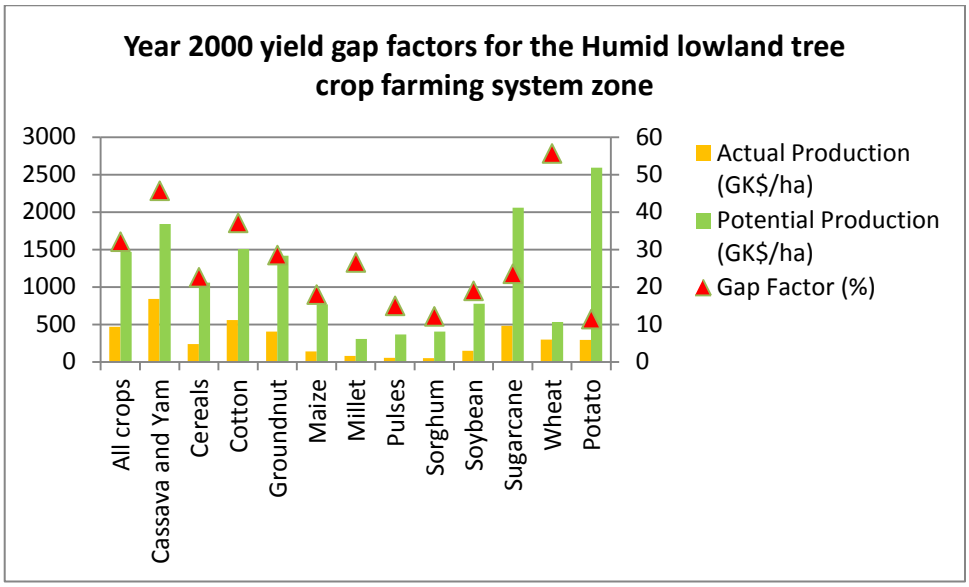
Coefficient of variation (%) of phaseolus bean in cultivated land (1961-90)																		
	LGP			Median of longest LGP > 0.80* median LGP days							Median of longest LGP < 0.80* median LGP days							All Land
	< 60	60-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	>300	120-149	150-179	180-209	210-239	240-269	270-299	>300	
Irrigated	52.8	33.7	18.5	5.6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	15.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	25.3
Humid lowland tree crop	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.0	2.2	2.6	2.7	n.a.	n.a.	3.0	3.5	2.9	2.8	3.4	2.6
Forest based	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.0	2.0	2.3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.0	2.3
Highland perennial	n.a.	n.a.	n.a.	n.a.	5.1	19.0	14.5	20.2	21.4	10.4	n.a.	13.4	18.1	15.1	11.0	7.8	13.6	15.1
Highland mixed	65.5	45.0	35.0	50.1	13.8	17.4	17.1	13.5	7.9	29.8	24.7	23.4	19.9	18.9	26.3	n.a.	n.a.	20.6
Root and tuber crop	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.7	2.7	3.0	3.4	n.a.	n.a.	n.a.	5.4	4.4	3.0	2.0	2.9
Cereal-root crop mixed	n.a.	n.a.	14.0	6.1	2.6	2.2	2.3	2.2	n.a.	n.a.	2.0	35.3	n.a.	n.a.	n.a.	n.a.	n.a.	2.6
Maize mixed	n.a.	46.5	40.4	8.0	9.2	7.5	7.1	9.2	3.2	5.2	28.8	25.5	14.2	6.6	8.2	4.1	8.6	13.0
Agro-pastoral	52.1	29.4	16.9	5.6	3.0	2.7	6.8	22.6	3.9	12.6	17.6	12.4	15.4	10.3	15.0	17.3	18.6	11.9
Pastoral	56.3	36.2	30.6	3.7	3.1	2.6	15.7	46.0	6.2	5.7	22.7	15.3	12.5	15.3	7.9	5.4	4.8	31.4
Arid pastoral-oases	66.1	49.9	46.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3.0	n.a.	n.a.	n.a.	n.a.	14.5
Artisanal fishing	48.2	33.4	23.3	4.3	2.3	2.5	2.1	2.4	2.6	3.0	10.4	7.9	5.5	4.7	3.2	2.7	3.2	3.7
Perennial mixed	85.5	64.2	43.0	n.a.	44.5	26.3	25.7	11.0	6.4	10.6	26.4	19.4	19.6	13.2	8.3	6.4	5.0	21.4
Sub-Saharan Africa	57.0	34.2	19.4	5.8	4.9	5.4	5.3	5.3	4.4	4.2	24.1	20.3	16.1	10.2	8.7	6.2	12.5	11.3

Coefficient of variation (%) of soybean in cultivated land (1961-90)																		
	LGP			Median of longest LGP > 0.80* median LGP days							Median of longest LGP < 0.80* median LGP days							All Land
	< 60	60-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	>300	120-149	150-179	180-209	210-239	240-269	270-299	>300	
Irrigated	49.6	31.0	17.7	4.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	13.7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	23.3
Humid lowland tree crop	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3.0	2.4	2.5	2.6	n.a.	n.a.	3.0	3.3	2.9	2.8	3.0	2.6
Forest based	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1.9	2.0	2.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.0	2.0
Highland perennial	n.a.	n.a.	n.a.	n.a.	2.4	19.5	19.4	20.4	12.8	5.3	n.a.	9.8	10.4	19.3	9.7	4.9	8.2	11.6
Highland mixed	59.9	26.1	22.8	19.3	10.3	27.4	18.8	12.4	2.8	2.8	13.6	18.1	24.6	8.5	4.0	n.a.	n.a.	18.3
Root and tuber crop	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.5	2.5	2.6	3.0	n.a.	n.a.	n.a.	4.8	4.2	3.3	2.0	2.6
Cereal-root crop mixed	n.a.	n.a.	11.3	5.0	2.4	1.9	2.2	2.2	n.a.	n.a.	2.0	18.1	n.a.	n.a.	n.a.	n.a.	n.a.	2.3
Maize mixed	n.a.	40.5	30.4	5.4	2.6	4.1	4.4	7.6	2.8	5.0	21.2	14.0	10.4	4.5	6.2	2.7	2.8	9.1
Agro-pastoral	50.0	27.1	15.0	4.3	2.4	2.2	6.4	27.6	3.6	3.9	13.8	7.9	8.1	6.5	5.5	3.3	5.5	9.9
Pastoral	53.7	33.6	28.6	2.1	2.6	3.0	12.3	16.0	4.7	8.6	18.3	11.8	9.7	8.9	4.5	5.8	5.5	28.7
Arid pastoral-oases	62.4	63.7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.6	n.a.	n.a.	n.a.	n.a.	4.6
Artisanal fishing	44.3	29.4	17.7	3.0	2.2	2.5	2.3	2.5	2.5	2.9	7.9	5.9	4.2	3.8	3.2	2.4	2.9	3.4
Perennial mixed	79.6	53.5	38.3	n.a.	26.4	26.1	22.3	6.6	3.0	3.0	23.8	17.5	15.3	8.2	4.7	4.1	3.0	17.9
Sub-Saharan Africa	54.0	31.3	17.4	4.4	2.6	3.8	3.7	4.2	3.1	2.9	18.4	13.1	11.7	6.1	5.3	3.6	6.6	9.2

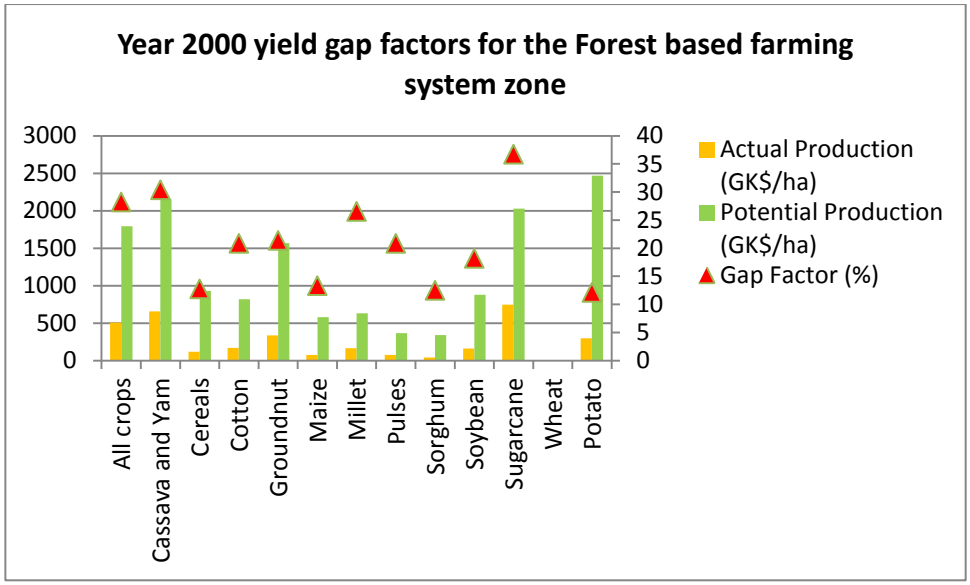
Coefficient of variation (%) of sweet potato in cultivated land (1961-90)																		
	LGP			Median of longest LGP > 0.80* median LGP days							Median of longest LGP < 0.80* median LGP days							All Land
	< 60	60-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	>300	120-149	150-179	180-209	210-239	240-269	270-299	>300	
Irrigated	60.5	37.2	23.0	7.7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	18.4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	29.0
Humid lowland tree crop	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.0	2.0	2.4	2.6	n.a.	n.a.	2.7	3.2	2.8	2.6	2.9	2.5
Forest based	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1.7	2.0	1.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.0	1.9
Highland perennial	n.a.	n.a.	n.a.	n.a.	2.9	15.2	13.9	21.9	18.5	5.7	n.a.	15.5	14.9	18.3	10.6	6.3	7.2	11.7
Highland mixed	63.7	37.7	29.5	35.9	11.8	30.8	21.6	16.5	3.9	3.1	20.4	26.0	31.4	28.4	n.a.	n.a.	n.a.	23.4
Root and tuber crop	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.2	2.6	2.6	2.9	n.a.	n.a.	n.a.	5.5	4.4	3.0	2.0	2.6
Cereal-root crop mixed	n.a.	n.a.	14.0	7.1	2.3	1.7	2.0	2.2	n.a.	n.a.	2.8	30.4	n.a.	n.a.	n.a.	n.a.	n.a.	2.3
Maize mixed	n.a.	45.9	40.4	9.0	3.2	4.2	4.7	9.6	3.1	4.6	36.4	18.6	14.4	5.7	6.6	2.6	3.3	11.8
Agro-pastoral	57.5	33.1	19.9	7.5	2.8	2.2	5.1	33.1	3.9	7.4	18.6	11.8	11.3	9.2	7.2	5.6	8.8	13.7
Pastoral	61.2	40.1	34.8	4.2	3.2	2.0	16.3	26.0	5.3	11.6	24.0	17.2	12.7	11.8	4.7	5.3	5.0	34.6
Arid pastoral-oases	66.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3.2	n.a.	n.a.	n.a.	n.a.	5.1
Artisanal fishing	52.8	38.8	23.2	5.8	2.1	2.3	2.0	2.2	2.3	2.6	12.4	9.7	6.3	5.0	3.2	2.3	2.5	3.7
Perennial mixed	n.a.	84.8	72.3	n.a.	n.a.	85.0	35.5	61.0	27.9	36.4	60.5	37.7	28.4	23.7	18.0	16.3	32.2	33.9
Sub-Saharan Africa	60.8	37.5	22.8	7.5	2.8	3.5	3.6	4.3	3.4	2.9	29.0	19.2	16.4	9.1	8.7	5.2	6.5	11.6

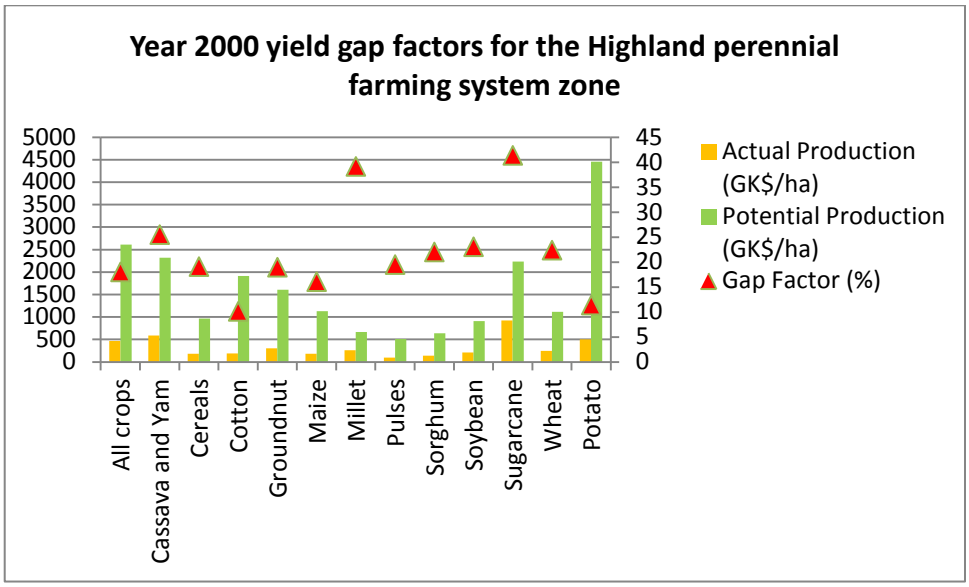
Appendix 5 Yield Gap Profiles of Farming System Zones

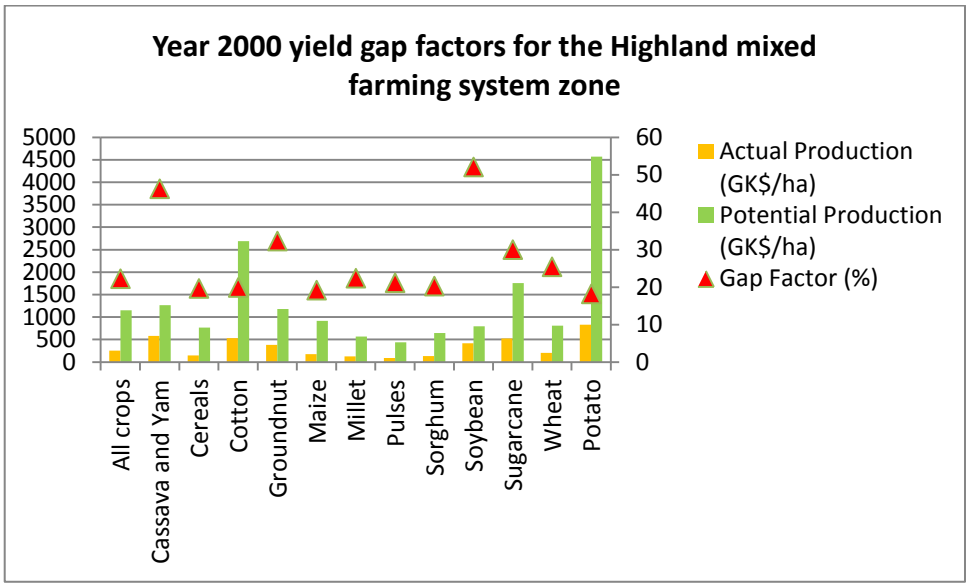


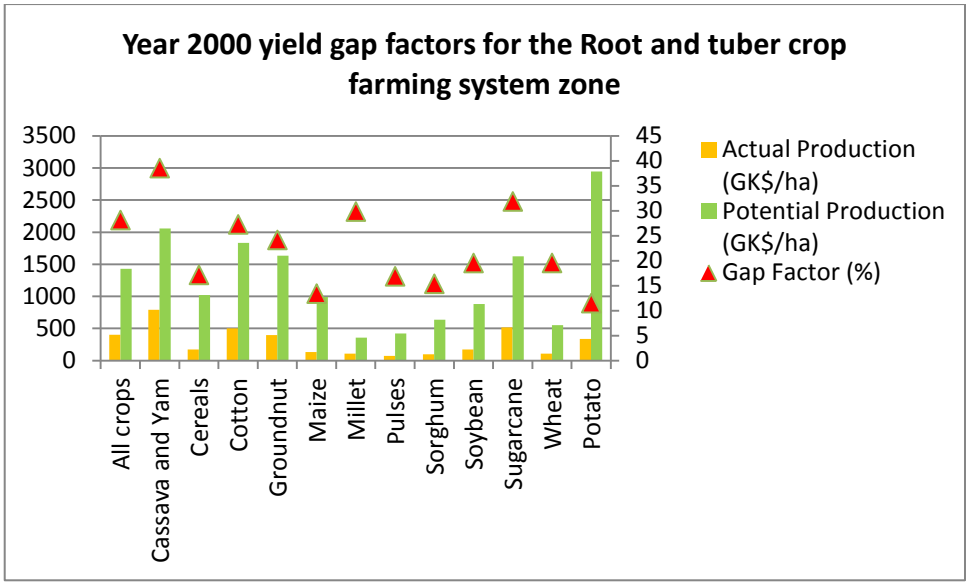


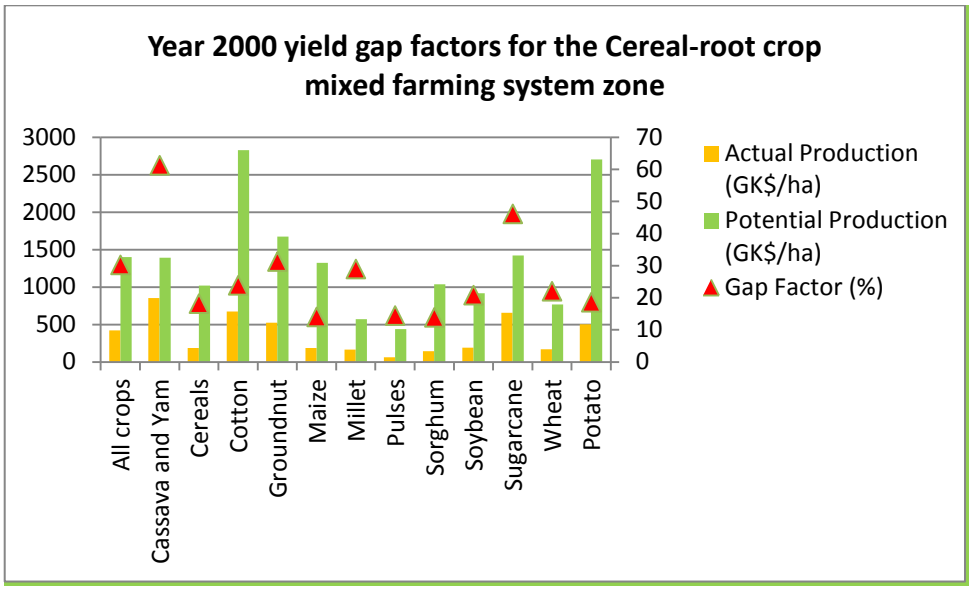
Note: Apparent yield gap factors are calculated by dividing downscaled actual yields by high input level potential attainable yields, using the respective rain-fed and irrigated crop-harvested area shares produced by downscaling of year 2000 statistics. Hence the red triangles labeled as gap factor, represent achievement ratios of actual yields relative to potential attainable yields.

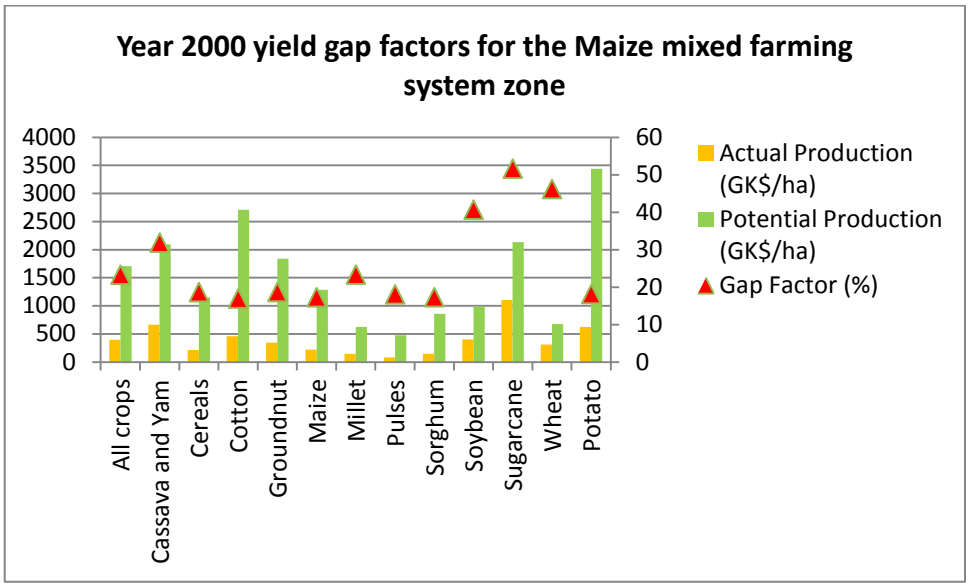

Year 2000 yield gap factors for the Forest based farming system zone
3000
2500
2000
1500
1000
500
0
40
35
30
25
20
15
10
5
0
All crops
Cassava and Yam
Cereals
Cotton
Groundnut
Maize
Millet
Pulses
Sorghum
Soybean
Sugarcane
Wheat
Potato
Actual Production (GK$/ha)
Potential Production (GK$/ha)
Gap Factor (%)

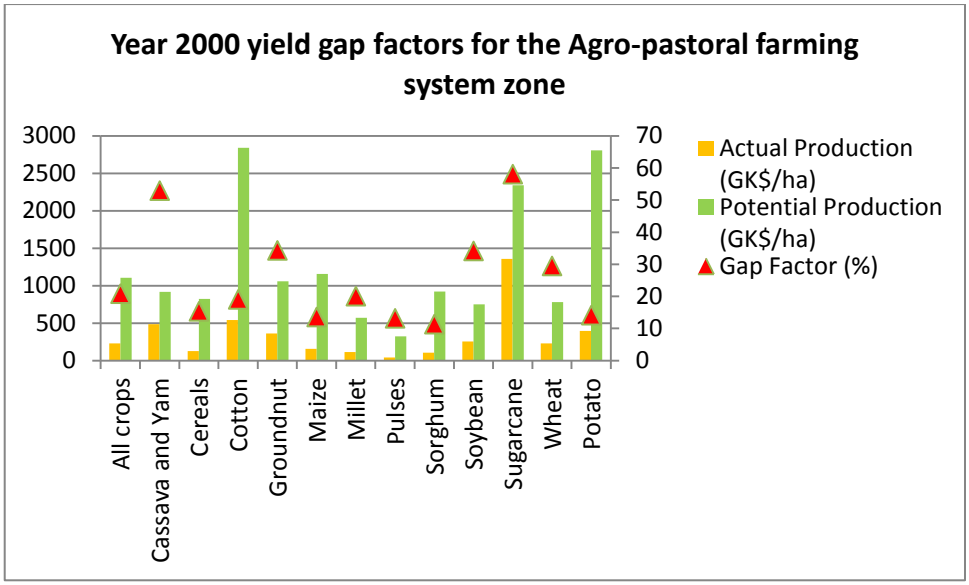

Year 2000 yield gap factors for the Highland perennial farming system zone
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
45
40
35
30
25
20
15
10
5
0
All crops
Cassava and Yam
Cereals
Cotton
Groundnut
Maize
Millet
Pulses
Sorghum
Soybean
Sugarcane
Wheat
Potato
Actual Production (GK$/ha)
Potential Production (GK$/ha)
Gap Factor (%)

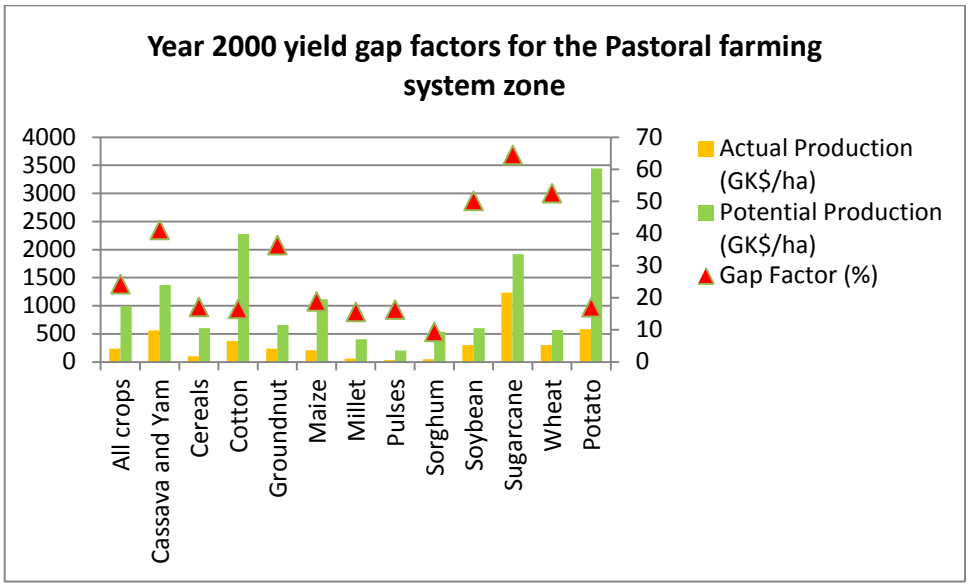

Year 2000 yield gap factors for the Highland mixed farming system zone
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
60
50
40
30
20
10
0
All crops
Cassava and Yam
Cereals
Cotton
Groundnut
Maize
Millet
Pulses
Sorghum
Soybean
Sugarcane
Wheat
Potato
Actual Production (GK$/ha)
Potential Production (GK$/ha)
Gap Factor (%)

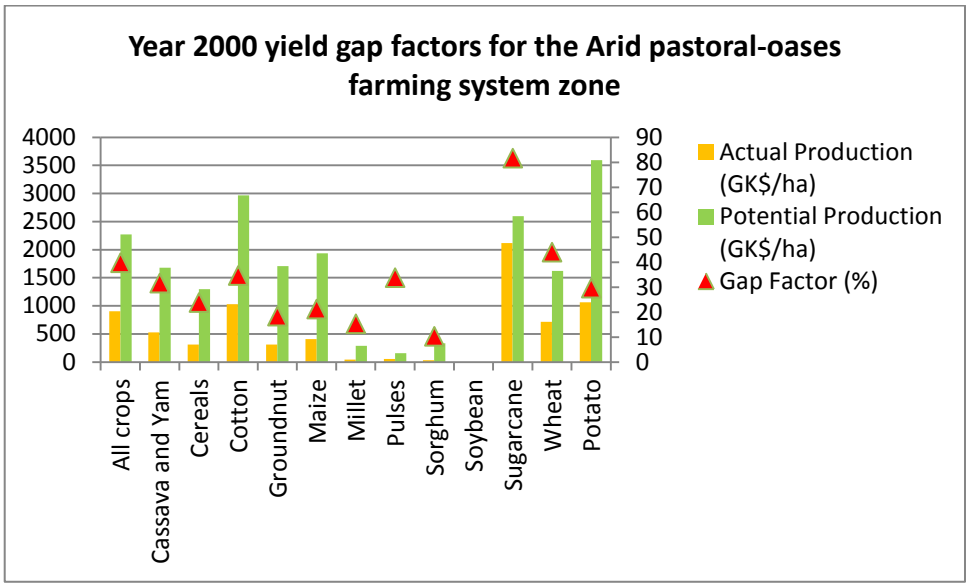

Year 2000 yield gap factors for the Root and tuber crop farming system zone
3500
3000
2500
2000
1500
1000
500
0
45
40
35
30
25
20
15
10
5
0
All crops
Cassava and Yam
Cereals
Cotton
Groundnut
Maize
Millet
Pulses
Sorghum
Soybean
Sugarcane
Wheat
Potato
Actual Production (GK$/ha)
Potential Production (GK$/ha)
Gap Factor (%)

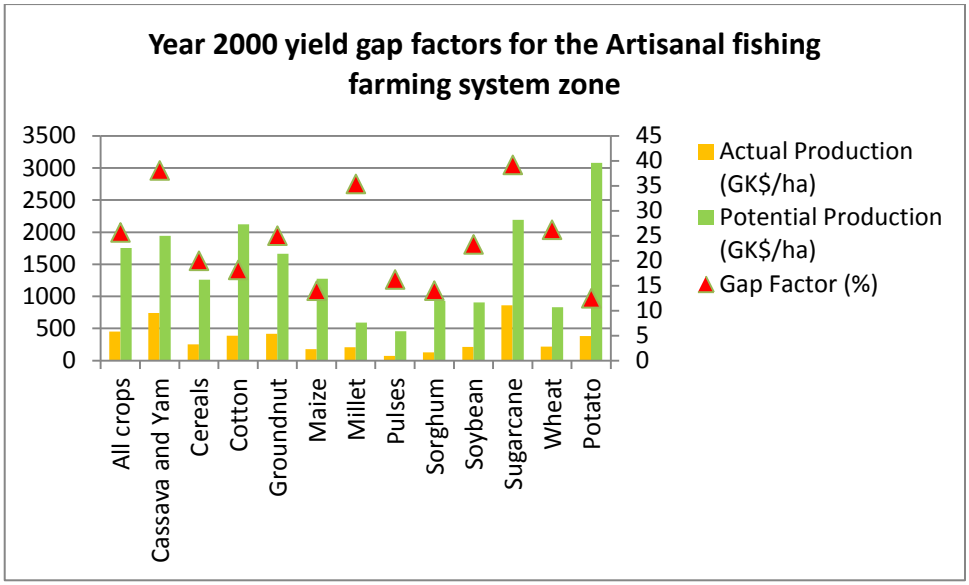

Year 2000 yield gap factors for the Cereal-root crop mixed farming system zone
3000
2500
2000
1500
1000
500
0
70
60
50
40
30
20
10
0
All crops
Cassava and Yam
Cereals
Cotton
Groundnut
Maize
Millet
Pulses
Sorghum
Soybean
Sugarcane
Wheat
Potato
Actual Production (GK$/ha)
Potential Production (GK$/ha)
Gap Factor (%)

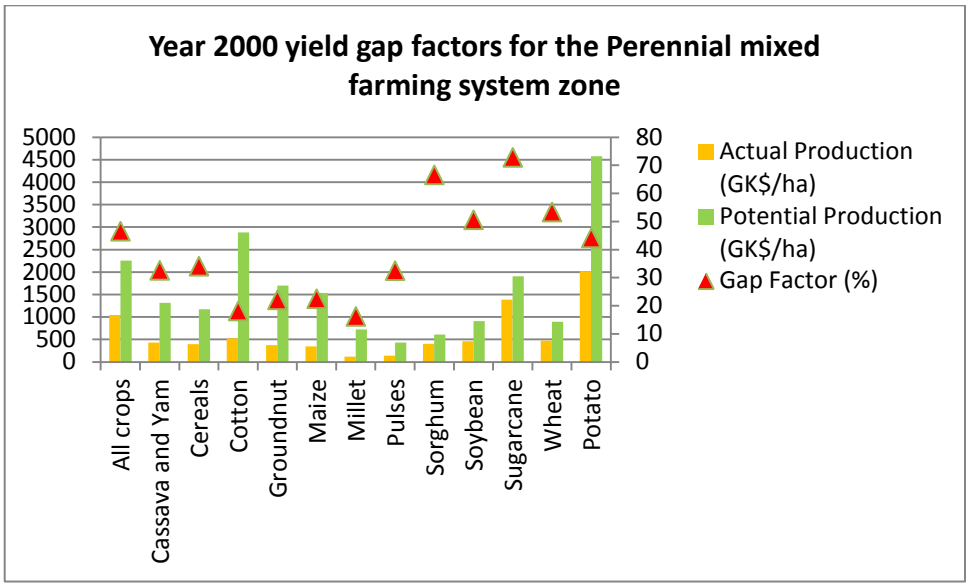

Year 2000 yield gap factors for the Maize mixed farming system zone
4000
3500
3000
2500
2000
1500
1000
500
0
60
50
40
30
20
10
0
All crops
Cassava and Yam
Cereals
Cotton
Groundnut
Maize
Millet
Pulses
Sorghum
Soybean
Sugarcane
Wheat
Potato
Actual Production (GK$/ha)
Potential Production (GK$/ha)
Gap Factor (%)


Year 2000 yield gap factors for the Agro-pastoral farming system zone
3000
2500
2000
1500
1000
500
0
70
60
50
40
30
20
10
0
All crops
Cassava and Yam
Cereals
Cotton
Groundnut
Maize
Millet
Pulses
Sorghum
Soybean
Sugarcane
Wheat
Potato
Actual Production (GK$/ha)
Potential Production (GK$/ha)
Gap Factor (%)


Year 2000 yield gap factors for the Pastoral farming system zone
4000
3500
3000
2500
2000
1500
1000
500
0
70
60
50
40
30
20
10
0
All crops
Cassava and Yam
Cereals
Cotton
Groundnut
Maize
Millet
Pulses
Sorghum
Soybean
Sugarcane
Wheat
Potato
Actual Production (GK$/ha)
Potential Production (GK$/ha)
Gap Factor (%)


Year 2000 yield gap factors for the Arid pastoral-oases farming system zone
4000
3500
3000
2500
2000
1500
1000
500
0
90
80
70
60
50
40
30
20
10
0
All crops
Cassava and Yam
Cereals
Cotton
Groundnut
Maize
Millet
Pulses
Sorghum
Soybean
Sugarcane
Wheat
Potato
Actual Production (GK$/ha)
Potential Production (GK$/ha)
Gap Factor (%)


Year 2000 yield gap factors for the Artisanal fishing farming system zone
3500
3000
2500
2000
1500
1000
500
0
45
40
35
30
25
20
15
10
5
0
All crops
Cassava and Yam
Cereals
Cotton
Groundnut
Maize
Millet
Pulses
Sorghum
Soybean
Sugarcane
Wheat
Potato
Actual Production (GK$/ha)
Potential Production (GK$/ha)
Gap Factor (%)


Year 2000 yield gap factors for the Perennial mixed farming system zone
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
80
70
60
50
40
30
20
10
0
All crops
Cassava and Yam
Cereals
Cotton
Groundnut
Maize
Millet
Pulses
Sorghum
Soybean
Sugarcane
Wheat
Potato
Actual Production (GK$/ha)
Potential Production (GK$/ha)
Gap Factor (%)

Appendix 6 Data provided via ftp

21 November 2012 on ftp <ftp.iiasa.ac.at/outgoing/luc/FS>

(i) Agro-ecological zones reflecting in general terms climatic regimes and soil quality. In the read me file you will find details of filter options (by FS zone, by country by land cover, by protected area and by accessibility class). Tables are available by country, by rg1 (= Central Africa, Southern Africa, Sudano-Sahelian Africa and Gulf of Guinea), rg2 (= Sub-Saharan Africa) and rg3 (= WB 2010 income levels)
(ii) LGD (Length of growing period statistics with continuous day values)
(iii) LGP (Length of growing period statistics by zones of 30 days intervals)
(iv) RID (Aridity index= P/PET*100)
(v) sst (Soil and terrain suitability for traditional low input farming)
(vi) Crop summary table (for rain-fed maize high inputs) describing suitability, potential yield and production, production constraints (moisture, temperature agro-climatic and soil and terrain constraints), fallow land requirements (cultivation factor), water deficits, and area potential yield and production by suitability class combinations.
(vii) Your "Hchoice Area stats" extended with GAEZ land cover classes (cultivated land, built-up land, forest land, grass land/wood land, non-vegetated land, Inland water, rain-fed cultivated land, Irrigated cultivated land.

3 April 2013 on ftp <ftp.iiasa.ac.at/outgoing/luc/FS-Chris>

(i) Reduced crop summary tables for 16 crops/commodities each at high level inputs, advanced management and low inputs, traditional management.
(ii) Year 2000 production and yield gap for: all crops, cereals, cotton, groundnut, millet, maize, pulses, root and tuber I (sweet potato and white potato), root and tuber II (cassava and yam), soybean, sorghum, sugarcane and wheat.
(iii) Year 2000 Population and livestock density (cattle, sheep goat, pig, poultry).

24 April 2013 on ftp <ftp.iiasa.ac.at/outgoing/luc/FS-Chris2>

(i) Coefficients of variation (1961-2000) of precipitation (P), aridity index (P/PET) and reference total LGP
(ii) Coefficients of variation of agro-climatically attainable rain-fed yields (high level inputs) for maize, sorghum, pearl millet, groundnut, cassava, phaseolus bean, soybean and sweet potato LUTs.

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