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Sawah Technology「アフリカ水田農法」 (1) Rice Green Revolution Statistics of Sub Saharan Africa (SSA) and Asia during 1961-2021

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Content

1. Summary of 6 evolutionary stages of sawah platforms for rice cultivation of major rice producing countries in SSA

The current level of national mean paddy yield corresponds to the evolutionary stage (Figure 1) of Sawah (*SUIDEN* in Japanese and "*paddy*" in English) platform in each country. The following is a brief summary of the current evolutionary stages of the sawah system platform in major rice-growing countries of SSA. Details are described in Sawah Technology (2): The background on co-evolution of genetic and ecological technology of sawah rice farming, Sawah Technology (3-1): Overview of the evolutional stages of various sawah platforms based on the ease of water control in SSA countries, especially in Nigeria. Sawah Technology (3-2): Various evolutional stages of sawah platform in Madagascar, UR Tanzania, Uganda, Kenya, Rwanda, Burundi, Malawi and Zambia. Sawah Technology (3-3): Mali, Burkina Faso, Cote D'Ivoire, Senegal, Guinea Bissau, and Gambia. Sawah Technology (3-4): Ghana, Togo, Benin and Niger (forthcoming).

Madagascar: As shown in Sawah Technology (2) and (3-2), Google Earth images show that the evolutionary stage of the sawah (*SUIDEN*) platform for rice cultivation are almost similar stages of Asian countries, such as Indonesia, India and Thailand, which have mainly stages of 4-5. Madagascar has mainly 4 stage.
Mali: Approximately 100,000 ha of Niono irrigation project site, office du Niger, is the major production area, which started in the 1920s. During 1920s-1990 the evolutionary stages were 1 and 2 even under irrigation. During 1980-2000, Sawah platforms improved to stage 4-5, which details are described in Sawah Technology (3-3). The inland delta at the Mopti area and numerous small inland valleys in the Sikasso region have also increased the area of rice cultivation under the Sawah (paddy, *SUIDEN)* platform stages is 1–4.

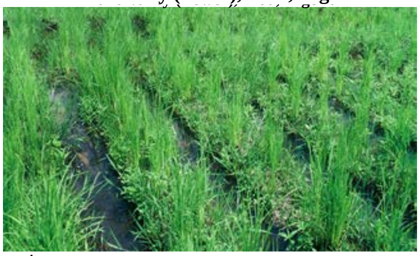
Evolutional stage 1: Lowland non sawah rice cultivation, Inland Valley, Sierra Leone, 1987

Evolutional stage 0: Upland rice and Fonio cultivation at Guinea

Evolutional stage 3: Irrigated micro (rudimentary) sawah. Evolutional stage 2: ridge planted rice in Inland valley, Nupe, Nigeria

Irrigated Rudimentary Micro Sawah plots at Nakanishi, archaelogical site, Nara, Japan at 2400-2500 years ago
http://www.bell.jp/pancho/k_diary-6/images/image-3/1112-202.jpg

Stage 2: Irrigated ridge rice cultivation at the Edozhigi flood plain (upper) and Gadza inland valley (lower), Bida, Nigeria



Stage 1-3 mixture: Tidal irrigation with no sawah, ridge rice cultivation, and micro sawah plots on mangrove swamps in Guinea (upper) and Rokupr Mangrove RiceStation, Sierra Leone (lower)

4th Stage: Standard sawah plots with leveling quality of ±5cm using animal plowing, Indonesia. This has the longest history in Asia

6th Stage: Advanced and larger sawah plot of ca.1ha with leveling quality of ±2.5cm using laser leveler tractor (Kubota Co)

5th stage : Standard sawah plots with leveling quality of ±5cm. Bush inland valley was developed by farmer using powertiller

Transplanting on the 6th stage sawah. Direct sawing is possible with high performance

Fig.1.The six stages of Sawah system platform evolution. Green revolution technology can apply effectively only the evolutional stage 4, 5, 6 and beyond as explained in Sawah Technology (3-1).

Tanzania: Sukuma people at the Mwanza on the shores of Lake Victoria have more than 100 years of Asian origin Sawah based rice farming following Madagascar, which has a history of 1,000 years. Although much shorter than the history of Sawah based rice farming in Madagascar, the Sukuma people in Tanzania appear to have the longest historical experience of Sawah based rice cultivation among other SSA countries. In this region, the Sukuma people have developed a sawah platform that has various evolution stages between 2 and 5. For example, there are various evolutionary stages (1–3) of sawah platforms in the Morogoro area.

Cote d'Ivoire: From 1963 to 73, Taiwan conducted large-scale technology transfer activities for Asian-style irrigated sawah-based rice cultivation throughout Côte d'Ivoire, that is, more than 3,000 extension officers, engineers, and farmers were trained and a total of 5,475 ha of irrigated sawah fields were developed (Hsieh 2001and 2003, Wakatsuki and Hsieh 2003) in more than 20 locations. These irrigated sawah fields developed in numerous small inland valleys can still be observed on Google Earth images. The Mbe rice experimental fields of the AfricanRice's headquarters in the Bouake region and the irrigated sawah fields in the northern Korhogo region are based on Taiwan's activities in the 1960s–70s. The evolutionary level of the sawah platform is 2–5. Since 2003, the evolution of rice cultivation has stalled due to socio-political instability.

Sierra Leone: Taiwan also sent 47 engineers during 1961–1977 to train 1,300 engineers/farmers and developed a total of 120 ha of irrigated sawah fields at 12 locations, including Bo and Kennema. However, the subsequent endogenous sawah development has been slow until 2015 when AfricanRice's SMART-IV (Sawah, Market Access and Rice Technology in inland valley) programme started. However endogenous sawah development is very slow, thus, in general, the evolutionary stage of the sawah platform is 0–3.

Nigeria: The country has a wide range of evolutionary stages in the sawah platform for rice cultivation. Olam Co., Ltd. Has developed 5,000 ha of high-quality sawah field on the flood plain of the Benue River (6th stage); farmers in the Kebbi state are developing more than 100,000 ha of mobile pump-irrigated sawah platform (5th and 4th stages) on the flood plains of the Niger and Rima rivers by farmers' self-help (endogenous) efforts, which is described in the Sawah Technology (6):Kebbi Rice Revolution. Northern states, such as Kano, Jigawa, Sokoto, and Zamfara, have large-scale ODA or government-based irrigated rice fields. However, the quality of their sawah platform is poor because of the ridge (2nd stage) and micro sawah (3rd stage) systems. Japanese experts developed 4,000 ha of irrigated sawah rice fields in the Anambra state in the 1980s; however, because of the inability of sustainable management of huge water pumps, irrigation systems are no more functional. The wide distribution of non-sawah upland and lowland rice cultivation (stages 0, 1, 2, and 3) can be observed throughout the country using Google Earth. The evolutionary levels of the sawah platform are mainly 1-3.

Guinea: North Korea helped the development and training in sawah-based rice farming (Asian type rice cultivation) on a small scale (approximately 10 ha) near Kindia. French team tried similar project at Kissidougou in 1980s. However, there was almost no expansion to other regions. Overall, the evolutionary level of the sawah rice platform is in the 0–3 stage. Taiwan dispatched approximately 200 experts in 1961–71 and 1998–2003 to neighboring countries of **Liberia** for the training of 5,000 farmers and extension workers and developed a total of approximately 1,000 ha of irrigated sawah fields. The evolutionary level of the sawah platform for rice cultivation in **Liberia** is somewhat more advanced (evolutional stage 0–4) than that of **Guinea** and **Sierra Leone.** These three countries are very similar in terms of the ecological environment for rice cultivation. There is a difference in the evolutionary stage of sawah rice cultivation: Liberia, which is influenced the most by the Taiwanese team, followed by Sierra Leone, and Guinea, which was not affected. Guckwdou area in Guinea is special, which borders Liberia and Sierra Leone, sawah fields in stage 4 can be seen, although only small acreage, maybe due to technology transfer by farmers.

DR Congo: Taiwan also made developments while working in small-scale irrigated sawah platform fields in Kinshasa, Kikwit, and Bumba during 1964–72. Although the training was conducted in a small and short period, subsequent development was not possible due to the country's turmoil. The stage of the sawah rice platform evolution is 0–3. However, in Uganda, Rwanda and Burundi border areas, irrigated sawah platform of evolution stage 2-5 similar to those in these three countries can be seen on Google earth. FAOSTAT 2023 reported 1.3 Mt mean annual paddy production in 2016–2020 while USDA 2020 reported only 0.4 Mt during the same period. In such a case, **Senegal** is the no. 8 country, which produced 1.2 Mt during 2016–2020. The evolutionary level of the sawah platform in Senegal is **3-6**. **Ghana:** The Vertisols areas in the south-eastern and northern savannah belt of Ghana have 100-5000 ha of official irrigated sawah platforms stage 4-6, while the majority of rice farmers are cultivating rice on the sawah platform of stage 1-3 in numerous small inland valleys.

Mozambique: Big potential aera of wetlands as well as relatively long history for rice cultivation. No significant development can observe in 1961-2020 (Table 3, FAOSTAT 2022). Developments of various irrigated sawah platforms have just recently started. Evolutionary level of sawah platform is 0–6, mainly 0-3.

2. Remarkable increase of rice cultivation in Sub-Saharan Africa (SSA) in 1961-2020. Asian countries have achieved a sustainable rice green revolution.

Figure 2 shows the trends of paddy production in the top eight countries of SSA and Egypt from 1961 to 2018 (FAOSTA2020). It goes without saying that this ranking will change before and after 2017-18. Figure 2 (USDA) shows the data up to 2019. Except for Madagascar and Sierra Leone, the increase in paddy production was notable in all countries. As shown in Table 3, the most recent production ratio of 2016-20/1961-65 was from 2.5(Madagascar) and 2.8 (Sierra Leone) to 24 (Tanzania) and 47 (Nigeria) reported by FAOSTAT (FAOSTA 2023), while based on the USDA2020, the ratio of 2015-19/1961-65 was from 2.4 (Madagascar) and 3.6 (Sierra Leone) to 20.4 (Nigeria) and 25.7 (Tanzania). In particular, the production accelerated in 2005. The increase of paddy production in Nigeria and Tanzania was remarkable. Figure 3 shows the trends of the top 10 Asian paddy productizing countries during the same period. The most recent production ratios of 2016-2020/1961-65 (Tabel 4) were between 0.65 (Japan), 2.9(China) and 3.3(India) to 4.5 (Indonesia) and 4.6(Viet Nam). The reliability of some statistical data below questionable as manipulation of data was observed in the figures of Guinea and the Democratic Republic of the Congo.

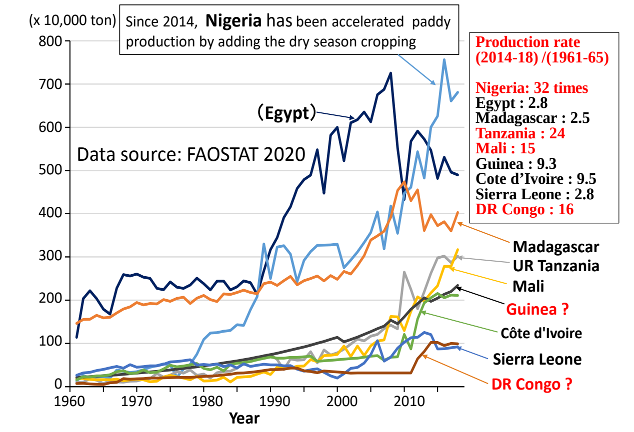


Fig.2. Paddy production during 1961-2018 (Egypt and Sub Saharan Africa rank 1-8 of paddy producing countries)

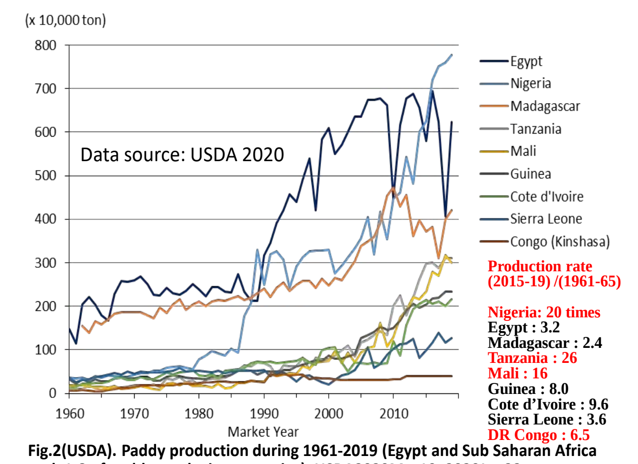


Fig.2(USDA). Paddy production during 1961-2019 (Egypt and Sub Saharan Africa rank 1-8 of paddy producing countries), USDA2020Mar10_2020Jun22

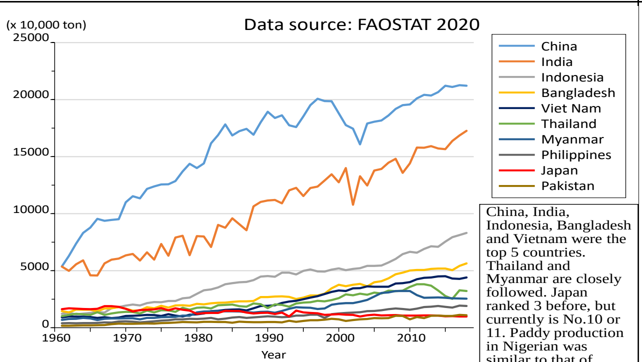


Fig.3. Paddy production during 1961-2018.
（Asian countries ranked 1-10 in rice production)

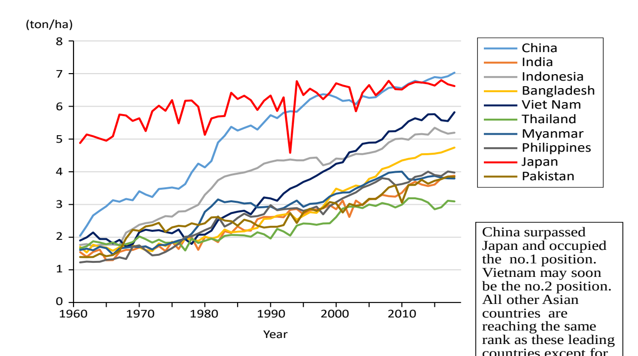


Fig.4. Paddy yield during 1961-2018
（Asian countries ranked 1-10 in rice production)
Data source: FAOSTAT 2020

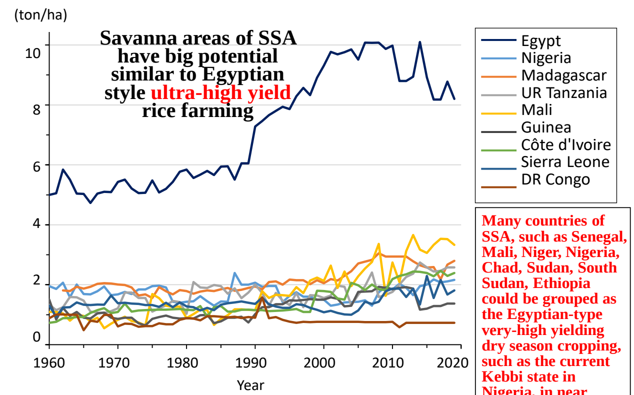


Fig.5a. Paddy yield during 1960-2019
（Egypt and countries in the SSA ranked 1-8 rice production)
Data source: USDA, PS&D Online, 2020

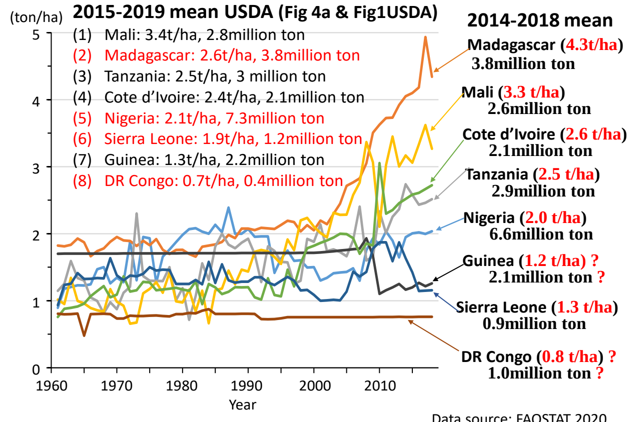


Fig.5b. Paddy yield during 1961-2018
（Countries in the SSA Rank 1-8 of rice production)
Data source: FAOSTAT 2020
USDA 2020

Figure 4 shows that Japan's paddy yield increase was very small during 1971-2017. This is relate to 50 years continued acreage reduction political program (so-called *GENTAN* in Japanese, Arahata 2014), which started in 1970 and ended in 2018. As a result, Japan's national mean paddy yield has been overtaken by China since 2000. In recent years, productivity in Vietnam (5.7t/ha in 2016-20 mean), Indonesia (5.1t/ha in 2016-20 mean), and Bangladesh (4.7 t/ha in 2016-20 mean) has significantly improved. The increase in paddy yield in countries such as Thailand (3.0 t/ha in 2016-20 mean), India (4.0 t/ha in 2016-20 mean), the Philippines (4.0 t/ha in 2016-20 mean) and Pakistan (3.5 t/ha in 2016-20 mean) is relatively low, and productivity in these countries has been close to overtaken by countries of SSA such as Madagascar, Tanzani (2.8 t/ha in 2016-20 mean) and Mali since 2015 (Please see Figure 5b). However we must be cautious regarding the reliability of these statistical data. USDA and FAOSTAT have considerable differences in the statistical data of Madagascar, Nigeria, Sierra Leone Guinea and DR Congo.

Figure 5a and 5b show the progress of national mean paddy yields of SSA's top eight countries and Egypt during 1961-2018/2019. Egypt is the world top level of paddy productivity. The amount of mean solar radiation during rice cultivation in Egypt (28MJ/m^2) is 1.6 times that during the rice season in Niigata, a rice center in Japan (18 MJ / m^{2}day). Other high yielding areas also have strong solar radiation, such as the Senegal river flood plain and the inland delta in Mali (20-30MJ/m^{2}day). The mean solar radiation of Ibadan, which is the transitional region between the coast and the northern savanna zones in Nigeria, is 15MJ/m^{2}day with the lowest values of 6 MJ/m^{2}day in the wet rice season and 25 MJ/m^{2}day in the dry season (Graham-Acquaah et al 2018, Oguntunde et al 2018). Egypt has a dry climate but has the Nile river. Thus diseases and weed damage encountered during paddy cultivation were minimal even under water-saving intermittent irrigation. Rice fields receive sufficient irrigation because of the Nile river water and sawah platform. In addition, the fertile nature of the Nile delta; the paddy yield became the top class in the world. The environmental conditions of rice farming are the same in Australia and the rice states in the United States. Agro-ecosystems that enable high-yield rice cultivation similar to Egypt are also widely distributed in the Sudan Savannah and Sahel belts in West and Central Africa, such as the flood plains of the Senegal river, the inland delta of Mali, Northern Nigeria, such as the Kebbi state, the Lake Chad and the Sudd basin of South Sudan. Egyptian-like dry season rice farming is becoming popular. The Kebbi rice revolution will be described in details in Sawah technology (6). Figure 5b shows the recent improvement in paddy yields of SSA's top eight countries.

As shown in Figures 6 and 7 as well as in Tables 1a, 1b, 2a, and 2b below, SSA showed a dramatic increase in paddy production over the last 60 years (1961–2018/2020). Annual paddy production increased 8.7 times, from 3.5 to 30.3 Mt, of which 66% came from Western Africa in 2016-20; during 1961–65, it was 44%. During this period, the yield also increased, but the main factor for the increase was the expansion of the rice cultivation area. In particular, the expansion of rice cultivation area in West Africa was remarkable.

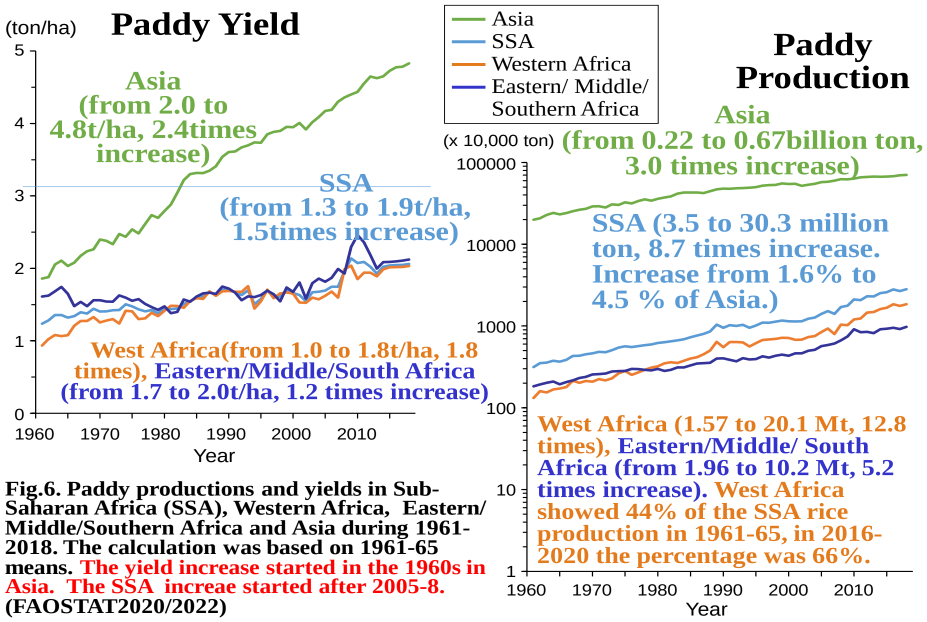


Fig.6. Paddy productions and yields in Sub-Saharan Africa (SSA), Western Africa, Eastern/ Middle/Southern Africa and Asia during 1961-2018. The calculation was based on 1961-65 means. The yield increase started in the 1960s in Asia. The SSA increae started after 2005-8. (FAOSTAT2020/2022)

The main factor for the increase was the synergistic effect of both rice acreage and paddy yield in West Africa. That is, the average yield and acreage of 1961-65 were 1.04 t / ha and 1.52 Mha, respectively, but increased to

1.81 t / ha and 11.1 Mha in 2016-20, respectively. That is, the increase in yield was 1.74 times and the increase in acreage was 7.3 times, thus the amount of paddy production was 12.7 times increase. In Eastern, Middle and Southern Africa, the average yield and acreage of 1961-65 were 1.66 t / ha and 1.18 Mha, respectively, each of which increased to 2.02 t / ha and 5.03 Mha in 2016-20, respectively. That is, the increase in yield was 1.22 times and the increase in acreage was 4.26 times, thus 5.2 times increase in paddy production. The increase in paddy production in West Africa was more prominent than that in Eastern/Middle/Southern Africa where the highland topography/climate is outstanding.

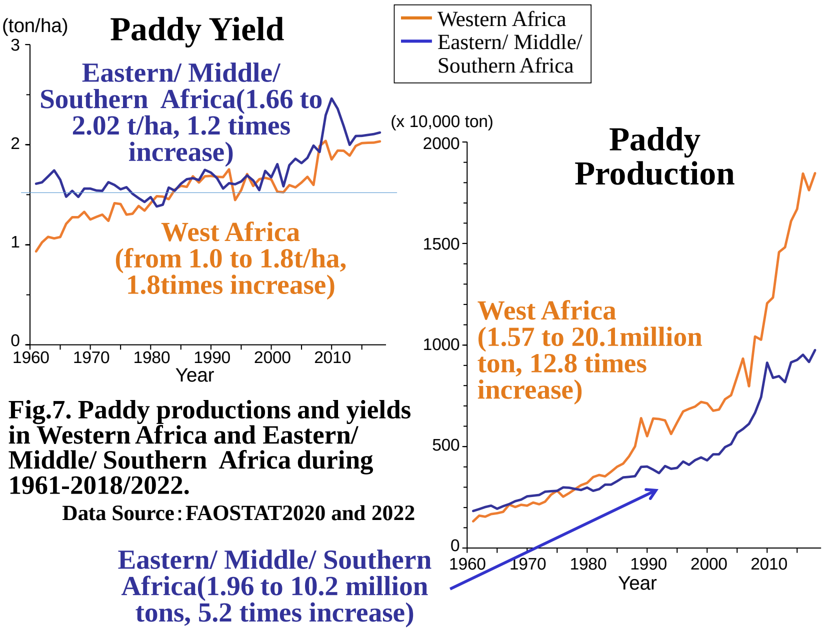


Fig.7. Paddy productions and yields in Western Africa and Eastern/ Middle/ Southern Africa during 1961-2018/2022.
Data Source: FAOSTAT2020 and 2022

Table1a. Rice value trends in Sub-Saharan Africa during 1961-2020. Data source: FAOSTAT 2020 and 2022; Conversion ratio: paddy x 0.625 = milled rice amount; The data are mean of 5 years except for 2008, 2016, and 2017.

	1961 -1965	1966 -1970	1971 -1975	1976 -1980	1981 -1985	1986 -1990	1991 -1995	1996 -2000	2001 -2005	2008	2006 -2010	2011 -2015	2016	2017	2016 -2020
Population (million)	246	279	318	366	423	487	560	639	728	831	832	952	1032	1059	1088+
Area harvested (1,000 ha)	2694	3110	3556	4114	4469	5292	6222	6813	7521	8705	8792	11689	14873	15538	16146
Index (%) of area harvested (100 for mean of 1971-1980)	70.2	81.1	92.7	107	117	138	162	178	196	227	229	305			
Irrigated rice area harvested (1,000 ha)	947	1034	1128	1255	1381	1559	1715	1862	1919	1980	1982	2097	2125	2125	
Index (%) of irrigated area (100 for mean of 1971-1980)	79.5	86.8	94.7	105	116	131	144	156	161	166	166	176	178	178	
Percent of Irrigated rice area harvested (%)	35.2	33.2	31.7	30.5	30.9	29.5	27.6	27.3	25.5	22.8	22.5	17.9	15.5	16.3	
Paddy production (1,000 ton)	3531	4330	5149	5835	6735	8830	10058	11271	12378	17084	17052	23596	27525	27849	30282
Index (%) of paddy production (100 for mean of 1971-1980)	64.3	78.8	93.8	106	123	161	183	205	225	311	310	430	501	507	551
Production (1,000 ton, milled rice)	2207	2706	3218	3647	4210	5519	6286	7045	7737	10678	10657	14748	18360	18575	20199
Paddy yield (ton/ha)	1.31	1.39	1.45	1.42	1.51	1.67	1.62	1.65	1.64	1.96	1.93	2.02	1.85	1.79	1.88
Index (%) of paddy yield (100 for mean of 1971-1980)	91.4	97.1	101	99.0	105	116	113	116	115	137	135	141	129	125	131
Yield (ton/ha, milled rice)	0.82	0.87	0.90	0.89	0.94	1.04	1.01	1.03	1.03	1.23	1.21	1.26	1.23	1.20	1.25
Imported quantity (1,000 ton, milled rice)	600	696	904	1866	2847	3057	3838	4470	7707	8654	8954	12668	12501	14631	
Self-Sufficiency ratio (%)	78.8	79.5	78.1	66.9	59.6	64.2	62.1	61.3	50.1	55.2	54.1	53.8	58.3	53.4	
Imported rice price ($/ton, milled rice)	135	156	267	356	343	276	294	303	242	556	428	506	416	453	
Consumption per capita (kg/person, milled rice)	11.4	12.2	12.9	15.0	16.7	17.6	18.1	18.0	21.2	23.3	23.5	28.8	29.1	29.6	

Table1b. Rice value trends in Asia during 1961-2020. Data source: FAOSTAT 2020 and 2020; : FAOSTAT 2022; Conversion ratio: paddy x 0.625 = milled rice amount; The data are mean of 5 years except for 2008, 2016, and 2017

	1961 -1965	1966 -1970	1971 -1975	1976 -1980	1981 -1985	1986 -1990	1991 -1995	1996 -2000	2001 -2005	2008	2006 -2010	2011 -2015	2016	2017	2016 -2020
Population (million)	1777	1997	2250	2497	2751	3040	3376	3643	3884	4118	4117	4345	4477	4519	4561+
Area harvested (million ha)	111	118	124	128	129	130	132	137	135	143	141	144	139	141	140
Index (%) of area harvested (100 for mean of 1971-1980)	88.4	93.7	98.3	102	102	103	105	109	107	113	112	114	110	112	111
Irrigated rice area harvested (million ha)	70.2	75.0	80.7	86.6	84.4	85.2	94.3	89.2	87.4	91.6	91.9	95.6	97.4	97.7	
Index (%) of irrigated area (100 for mean of 1971-1980)	84.0	89.7	96.5	104	101	102	113	107	105	110	110	114	116	117	
Percent of Irrigated rice area harvested (%)	63.0	63.5	65.0	67.5	65.6	65.5	71.5	65.0	65.0	64.0	65.2	66.4	68.7	67.1	
Paddy production (million ton)	222	264	302	342	406	448	487	536	544	624	612	668	660	673	673
Index (%) of paddy production (100 for mean of 1971-1980)	68.9	82.0	93.8	106	126	139	151	167	169	194	190	208	205	209	209
Production (million ton, milled rice)	139	165	189	213	254	280	304	335	340	390	382	417	440	449	449
Paddy yield (ton/ha)	1.99	2.23	2.43	2.66	3.15	3.44	3.69	3.91	4.04	4.36	4.34	4.64	4.75	4.77	4.81
Index (%) of paddy yield (100 for mean of 1971-1980)	77.9	87.5	95.5	105	124	135	145	153	159	171	170	182	187	187	189
Yield (ton/ha, milled rice)	1.24	1.39	1.52	1.66	1.97	2.15	2.31	2.44	2.53	2.72	2.71	2.90	3.17	3.18	3.21
Imported quantity (1,000 ton, milled rice)	5343	5527	5445	5675	5546	5208	6783	11719	11578	14006	13410	16261	15478	18151	
Self-Sufficiency ratio (%)	96.3	96.7	97.2	97.4	97.8	98.2	97.8	96.6	96.7	96.5	96.6	96.3	96.5	96.0	
Imported rice price ($/ton, milled rice)	125	162	270	366	379	324	372	365	312	770	623	709	600	625	
Consumption per capita (kg/person, milled rice)	80.9	85.2	86.3	87.7	94.1	93.8	92.2	95.2	90.5	98.1	96.1	99.8	98.1	100	

Table2a. Rice value trends in Western Africa during 1961-2020. Data source: FAOSTAT 2020 and 2022; Conversion ratio: Paddy x 0.625 = milled rice amount; All data are mean of five years except for 2008, 2016, and 2017

·	1961 -1965	1966 -1970	1971 -1975	1976 -1980	1981 -1985	1986 -1990	1991 -1995	1996 -2000	2001 -2005	2008	2006 -2010	2011 -2015	2016	2017	2016 -2020
Population (million)	90.6	101	114	131	150	171	195	223	254	291	291	333	361	371	381+
Area harvested (1,000 ha)	1515	1603	1826	2137	2434	3095	3814	4220	4697	5249	5469	7620	10408	11144	11112
Index (%) of area harvested (100 for mean of 1971-1980)	76.4	80.9	92.1	108	123	156	192	213	237	265	276	385	525	562	561
Irrigated rice area harvested (1,000 ha)	55.2	58.2	65.3	143	221	309	483	623	563	616	617	654	656	656	
Index (%) of irrigated area (100 for mean of 1971-1980)	53.1	55.9	62.8	137	213	297	465	599	541	592	593	628	630	630	
Percent of Irrigated rice area harvested (%)	3.64	3.63	3.58	6.68	9.09	9.97	12.7	14.8	12.0	11.7	11.3	8.58	7.18	7.52	
Paddy production (1,000 ton)	1571	2035	2430	2890	3683	5119	6167	6977	7377	10423	10010	14908	18730	19083	20096
Index (%) of paddy production (100 for mean of 1971-1980)	59.1	76.5	91.4	109	138	192	232	262	277	392	376	560	704	717	755
Production (1,000 ton, milled rice)	982	1272	1519	1807	2302	3199	3854	4360	4611	6514	6256	9317	12493	12728	13404
Paddy yield (ton/ha)	1.04	1.27	1.33	1.35	1.51	1.65	1.62	1.65	1.57	1.99	1.83	1.95	1.80	1.71	1.81
Index (%) of paddy yield (100 for mean of 1971-1980)	77.3	94.7	99.2	101	113	123	121	123	117	148	137	146	134	128	135
Yield (ton/ha, milled rice)	0.65	0.79	0.83	0.84	0.95	1.03	1.01	1.03	0.98	1.24	1.14	1.22	1.20	1.14	1.21
Imported quantity (1,000 ton, milled rice)	333	403	477	1188	1809	1852	2401	2801	4996	5496	5574	7820	7164	8304	
Self-Sufficiency ratio (%)	74.9	75.9	76.1	61.9	56.0	63.0	61.6	60.9	48.0	54.2	52.7	54.3	61.7	57.0	
Imported rice price ($/ton, milled rice)	133	148	253	362	342	261	274	291	234	545	413	494	396	435	
Consumption per capita (kg/person, milled rice)	14.5	16.5	17.5	22.8	27.5	29.4	32.1	32.1	37.8	41.3	40.6	51.4	51.7	52.1	

Table2b. Rice value trends in Eastern, Middle & Southern Africa during 1961-2020. Data source: FAOSTAT 2020 and 2022; Conversion ratio: paddy x 0.625 = milled rice amount; The data are mean of 5 years except for 2008, 2016, and 2017.

·	1961 -1965	1966 -1970	1971 -1975	1976 -1980	1981 -1985	1986 -1990	1991 -1995	1996 -2000	2001 -2005	2008	2006 -2010	2011 -2015	2016	2017	2016 -2020
Population (million)	156	178	204	236	273	316	364	416	474	541	541	619	670	688	706+
Area harvested (1,000 ha)	1179	1506	1730	1976	2035	2197	2408	2593	2825	3456	3323	4069	4465	4394	5034
Index (%) of area harvested (100 for mean of 1971-1980)	63.6	81.3	93.4	107	110	119	130	140	152	187	179	220	241	237	272
Irrigated rice area harvested (1,000 ha)	892	976	1063	1112	1160	1251	1231	1238	1356	1364	1365	1443	1469	1469	
Index (%) of irrigated area (100 for mean of 1971-1980)	82.0	89.7	97.7	102	107	115	113	114	125	125	126	133	135	135	
Percent of Irrigated rice area harvested (%)	75.7	64.8	61.4	56.3	57.0	56.9	51.1	47.8	48.0	39.5	41.1	35.5	32.4	33.8	
Paddy production (1,000 ton)	1960	2296	2719	2944	3053	3711	3891	4295	5001	6661	7041	8689	8795	8766	10186
Index (%) of paddy production (100 for mean of 1971-1980)	69.2	81.1	96.0	104	108	131	137	152	177	235	249	307	311	310	360
Production (1,000 ton, milled rice)	1225	1435	1699	1840	1908	2319	2432	2684	3126	4163	4401	5430	5867	5847	6795
Paddy yield (ton/ha)	1.66	1.52	1.57	1.49	1.50	1.69	1.62	1.66	1.77	1.93	2.11	2.14	1.97	1.99	2.02
Index (%) of paddy yield (100 for mean of 1971-1980)	109	99.5	103	97.4	98.0	110	106	108	116	126	138	140	129	130	132
Yield (ton/ha, milled rice)	1.04	0.95	0.98	0.93	0.94	1.05	1.01	1.04	1.11	1.20	1.32	1.34	1.31	1.33	1.35
Imported quantity (1,000 ton, milled rice)	267	292	426	678	1037	1205	1437	1669	2711	3158	3379	4848	5336	6326	
Self-Sufficiency ratio (%)	82.2	83.0	80.0	73.2	64.9	65.9	62.9	61.8	53.9	56.9	56.2	52.9	52.7	47.5	
Imported rice price ($/ton, milled rice)	138	167	280	342	344	298	328	324	258	576	456	525	444	477	
Consumption per capita (kg/person, milled rice)	9.58	9.72	10.4	10.7	10.8	11.1	10.6	10.5	12.3	13.5	14.4	16.6	16.8	17.5	

Other rice related characteristics and trends in Western Africa from 1961 to 2018/2020 are, (1) per capita rice consumption, 3.6 times increase, from 14.5 to 52.1 kg/person/year; (2) population, 4.2 times, from 90.6 to 381 million people; (3) self-sufficiency ratio was 75% in 1961–65, 48% in 2001–5 and 52% in 2017. While comparative data on Eastern/Middle/Southern Africa are, (1) per capita rice consumption, 1.8 times increase, from 9.6 to 17.5 kg/person/year; (2) population, 4.5 times, from 156 to 706 million people; (3) self-sufficiency ratio was 82% in 1961–65, 54% in 2001–5, 54% in 2011–15 and 47.5% in 2017.

During 1961–2020, in Asia, the annual paddy production increased 3.0 times, from 220 to 670 Mt. Major factor was the increase of paddy yield, 2.4 times, from 2.0 to 4.8 t/ha. The acreage of rice increased slightly for 40 years from 1961 to 2000, i.e., 111Mha in 1961-65 and 137Mha in 1996-2000, but there has been almost no change since then till 2020. During the same period, the Asian population increased 2.56 times, from 1.78 to 4.56 billion people; their per capita rice consumption increased 1.24 times, from 80.6 to 100 kg/person/year.

Focusing on the irrigated rice area in the total cultivated area, we compared this data from SSA with that from Asia (Tables 1a, 1b, 2a, and 2b: data source FAOSTAT 2020, AQUASTAT 2017 and 2018). In Asia, the cultivated area slightly increased from 1.1 to 1.4 Bha and the irrigated rice area harvested increased from 0.70 to 0.98 Bha during 1961–65 to 2011–17. The irrigated planting areas were 63–67% of the total cultivated area during this period. It has not changed much for over 50 years. However, the mean yield during 2016–2020 was 2.4 times higher than the average in 1961–65, indicating that most of the rice production increase is due to the increase in yield. However, in Western Africa (Table 2a), the cultivated area has increased from 1.52 to 11.1 million(M)ha (7.4 times increase) in 2016-20 and the irrigated rice area has increased from 55,200 to 654,000 ha (11.8 times increase). Yet, the irrigated area is only 8.7% of the total acreage area harvested in 2011–15. The data on irrigated areas harvest were estimated based mainly on AQUASTA and FAOSTAT 2016–2018. Additional sources have been used for syntheses (Andriesse 1986, Juo and Lowe 1986, Windmeijer and Andriesse 1993, Tabuchi and Hasegawa 1995, Mizutani et al. 1999, Hirose and Wakatsuki 2002, Molden et al. 2007, Oki et al. 2009, Wopereis et al. 2013, Kitamura and Oweis 2018). as the yield increase was 1.74 times, more than half of the 12.8 times increase in paddy production was due to the expansion of the planting area until 2001–05 (Figures 6 and 7). However, after 2006–18, the yield increase was also gradually evident (Figure

6). The explosive increase in production is due to the synergistic effect of the increase in area harvested and yield increase mainly through the expansion of the irrigated sawah platform area. The reliable survey on the increase in irrigated sawah platform area since 2010 is currently insufficient, as described in Sawah Technology (6): Kebbi Rice Revolution.

It should be noted that the reliability of these statistical data of SSA countries varies widely from country to country and cannot be said to be very high. The following is a brief discussion on the assumption that the reliability of the data is not so high. Yield increase started around 2005–08. During the same period, the amount of rice importation has also increased from 0.6 Mt (milled rice; 0.96 Mt as paddy equivalent, assuming a conversion ratio of paddy × 0.625 = milled rice) to 14.6 Mt (milled rice). The Western African population increased 4.4 times, from 246 to 1,088 million people. SSA's per capita rice (milled rice base) consumption increased 2.6 times, from 11.4 to 29.6 kg/person/year, but the self-sufficiency rate of rice dropped from 79% in 1961–65 to 53% in 2011–15. However, the decline in the rice self-sufficiency rate stopped recently, and it seems to have improved after 2016.

3. Ranking trends of paddy production, yield, rice harvest area, irrigated rice area, importation, self-sufficiency, and per capita milled rice consumption in major countries of SSA and Asian during 1961-2021.

Table 3. Paddy production (x1,000 t) in Sub-Saharan African countries and Egypt during 1961-2021. The rankings in the table are based on average annual paddy production in 2011-15 (data source: FAOSTAT 2023). The country colour coding is based on (2016-2020) divided by (1961-1965). That is, blue indicate more than 20-fold, green of 20-10-fold, black of 10-5-fold and red a decrease or less than 5-fold increase.

Country	Rank 2011-15	1961 -65	1966 -70	1971 -75	1976 -80	1981 -85	1986 -90	1991 -95	1996 -2000	2001 -05	2006 -10	2011 -15	2016 -20	2019	2020	2021
Egypt		1845	2342	2396	2363	2333	2566	4178	5333	5997	6147	5519	4618	4804	4804	4841
Nigeria	1	207	321	470	596	1300	2216	2980	3248	3139	3885	5426	9774	8435	8172	8342
Madagascar	2	1563	1779	1943	2037	2087	2271	2430	2511	2898	4055	4032	3917	4231	4228	4391
UR Tanzania	3	120	121	229	320	330	653	579	743	1035	1591	2369	2922	3475	3038	2688
Mali	4	172	158	174	191	165	274	447	678	847	1334	2059	2972	3196	3010	2420
Guinea	5	230	286	355	441	548	680	844	1048	1150	1469	1957	2304	2599	2459	2475
Côte d'Ivoire	6	220	321	388	479	451	621	673	624	665	779	1715	1909	1884	1481	1659
Sierra Leone	7	336	457	502	563	484	501	446	316	490	849	1120	938	947	1050	1979
DR Congo	8	62	146	198	220	273	351	404	344	317	317	763	1291	1379	1476	1581
Senegal	9	100	114	88	97	127	155	172	202	218	380	555	1135	1156	1350	1382
Ghana	10	34	53	66	92	64	80	161	213	264	324	552	818	925	987	1231
Burkina Faso	11	32	38	35	42	44	38	57	98	92	172	308	377	377	451	451
Liberia	12	125	158	222	247	286	271	76	170	124	256	275	279	269	279	256
Chad	13	29	36	42	33	21	56	84	112	122	142	258	270	291	278	243
Benin	14	1.0	2.4	8.7	13	7.4	9.3	12	34	63	104	247	367	406	412	520
Uganda	15	3.2	6.6	15	22	19	33	71	91	128	184	227	228	255	373	303
Mauritania	16	0.6	0.7	2.7	6.2	20	49	51	82	75	85	212	276	383	291	428
Cameroon	17	10	16	18	52	77	65	38	51	52	99	196	326	311	340	362
Guinea-Bissau	18	48	40	38	52	96	109	127	99	90	155	177	182	187	198	214
Mozambique	19	94	86	110	62	82	93	74	175	107	145	174	152	180	137	189
Togo	20	21	19	16	15	15	25	40	79	67	94	164	146	147	160	150
Kenya	21	14	20	33	40	42	48	47	48	48	52	121	127	161	181	186
Malawi	22	5.8	14	56	70	34	37	49	74	73	113	119	119	133	145	147
Ethiopia	23							10	13	13	57	115	164	171	190	200
Rwanda	24	0.0	0.7	2.1	3.4	6.1	7.8	11	9.0	35	71	86	116	132	117	132
Niger	25	11	33	33	28	46	68	63	63	68	73	85	124	122	179	224
Burundi	26	2.7	3.3	5.4	7.9	13	33	37	52	63	74	61	143	241	150	120
Gambia	27	33	34	30	27	30	23	18	23	25	52	55	36	22	40	42
Zambia	28		0.4	0.8	2.3	7.6	10	11	12	14	30	43	31	30	35	66
Sudan (former)	32	1.2	2.4	6.3	9.8	4.5	1.1	1.3	5.0	18	25	25	31	32	34	25

Madagascar, where Malay-Indonesian immigrants spread Asian style irrigated sawah platforms (evolutionary stage 4) throughout the country more than 1000 years ago, was the leader for rice production in Sub-Saharan African countries (SSAs) in 1961-2010. However, rice production has stagnated since 2010. This is thought to be due to mainly political and partly climatic change rather than technical factors. It is clear from the data in Table 3, which shows the remarkable development of rice cultivation in SSAs since African independence in 1961, that SSA, like Asia, has an extremely high potential of rice production based on irrigated sawah platform in terms of climate, soils and hydrology. The reason why irrigated sawah based rice cultivation did not develop

outside Madagascar seems to prove that the historical impact of the slave trade and colonial rule by the West was significant, starting 500 years ago. Western rulers have been never understood the potential of Asian style irrigated sawah based rice culture in SSA. Even in 2023, majority of Western agricultural scientists are likely to have a good understanding of Western-style field agriculture only, but little understanding of the importance of the Asian style irrigated sawah platform for water control and management in SSA in sustainable agriculture and global warming control.
Table 3 shows the ranking trend of paddy production of major countries of SSA and Egypt during 1961–2021. The rank is based on the mean annual paddy production during 2014–18 (FAOSTAT 2020). Even during 2018-2021, paddy production in different countries have been vary widely, and moreover, some countries have increased rapidly, while others decreased. Therefore, it is a little different from the ranking based on the average value of 2014-18 in Table 3. The country rankings are only for convenience to present the data. As the paddy production almost of all SSA countries is increasing rapidly, the ranking is expected to fluctuate significantly in the future. Table 4 shows Asia's major rice-producing countries. General trends between Asia and SSA have been discussed in a previous section. Here, we focused on the characteristics of the countries of SSA. Many countries, especially in Western Africa, increased paddy production more than 10-20 times during the period. Currently, Nigeria is SSA's no. 1 rice-producing country. As shown in Tables 2a and 2b, even with the large increase in production, the synergistic effect of SSA population explosion and annual rise in rice consumption, especially in West Africa, has lowered the self-sufficiency rate from 80% in 1961–65 to 50% in 2011–2015. Table 1a and 1b as well as Table 5 shows comparative rice related data of the top 20 countries of both Asia and SSA. Comparing the data of rice productivity and rice consumption shown in Table 5, it can be summarized that the general technology level of rice cultivation in the top 20 countries of SSA in 2010–15 has reached the same level as that of the top 20 countries of Asia in the 1960s–70s.

As shown in Table 3, the ratio of mean annual paddy production during 2016–20 and 1961–65, 14 of the top 30 (29 countries from SSA and Egypt) have increased by more than 20 times, which are shown in blue color, that is, Nigeria 47 times, from 0.2 Mt in 1961–65 to 9.8 Mt in 2016–20 (USDA data in 2016–19 mean was 7.5 Mt); UR Tanzania 24 times; DR Congo 21 times (USDA data 6.5 times only); Ghana 24 times; Benin more than 100 times; Uganda 71 times; Mauritania more than 100 times; Cameroun 33 times; Malawi 21 times; Ethiopia more than 100 times; Rwanda more than 100 times; Burundi 53 times; Zambia more than 100 times; Sudan (former) 26 times. Green colour countries includes Mali 17 times; Senegal 11 times; Guinea 10 times; Burkina Faso 12 times and Niger 11 times. Other four countries show 10–5 times increase in production, which are shown in black color, that is, Côte d'Ivoire 8.7 times; Chad 9.2 times; Togo 7.0 times; and Kenya 9.1 times. Only seven countries shown in red have increased between 1.1–3.8 times, that is, Egypt 2.5 times; Madagascar 2.5 times; Sierra Leone 2.8 times; Liberia 2.2 times; Guinea-Bissau 3.8 times; Mozambique 1.6 times; and Gambia 1.1 times. For both Egypt and Madagascar, this may be because the agro-ecological limit of increasing rice production has been reached. Egypt may have a shortage of available water; Madagascar may have a shortage of new lowlands, a lack of available water or some socio-political reason. The other five countries experienced severe socio-economic crises/conflicts during 1970– 2000.

Nigeria (Table 3) presented a significant increase in production from 5.4 Mt in 2011–2015 to 8.1 Mt in 2016-2020. As per the USDA 2020 data, it produced 7.2, 7.5, 7.6, and 7.8 Mt during 2016–2019, respectively. Detailed annual paddy productions in Mt (FAOSTAT 2022) are as follows: 3.6 in 2005, 4.0 in 2006, 3.2 in 2007, 4.2 in 2008, 3.5 in 2009, 4.5 in 2010, 4.6 in 2011, 5.4 in 2012, 4.8 in 2013, 6.0 in 2014, 6.3 in 2015, 7.6 in 2016, 7.8 in2017, 8.4 in 2018, 8.4 in 2019, and 8.2 in 2020. Official agricultural statistics of the government of Nigeria (NAERLS and FDAE 2014) published only rice production data for the rainy season up to 2015. FAOSTAT relies on data from NAERLS and FDAE. In Nigeria, full-scale dry season rice cultivation began only after 2013 with a government initiative, with an estimated additional paddy production of 1 Mt in 2013 and 2 to 3 Mt in 2014–2015. Recently, FAOSTAT 2020 revised the Nigerian data to include dry season paddy production in 2016. However, the reliability of these statistical data must be examined.

Meanwhile, in Asia, only five countries showed an increased production by more than 5 times during this period (Tables 4 and 5 below). Annual paddy production in Asia was 60 times in 1960s, is currently 22 times, and will be less than 20 times in future that of SSA. The trend of Asian paddy production since 1960, when the Green Revolution began, shows mature changes. In contrast to Asia, the explosive rise in paddy production in SSA is very evident. However, these statistical data often have poor reliability, which requires attention. Some countries of SSA such as Sierra Leone, Liberia, Mozambique, Guinea-Bissau, and Gambia had steep

Table 4. Paddy production (x10,000 t) of Asian countries during 1961-2021. This rank is based on the mean annual paddy production during 2011-15 (Data source: FAOSTAT 2023). The country colour coding is based on (2016-2020) divided by (1961-1965). That is, green indicate more than 4 fold, black of 4-2 fold, and red a decrease or less than 2-fold increase.

Country1053	Rank 2011-15	1961 -65	1966 -70	1971 -75	1976 -80	1981 -85	1986 -90	1991 -95	1996 -2000	2001 -05	2006 -10	2011 -15	2016 -20	2019	2020	2021
China, mainland	1	**7222**	**9773**	**11995**	**13499**	**16425**	**17701**	**18174**	**19619**	**17449**	**19010**	**20550**	**21300**	**21100**	**21400**	**21400**
India	2	**5273**	**5714**	**6451**	**7329**	**8481**	**10086**	**11590**	**12744**	**12856**	**14228**	**15773**	**17400**	**17800**	**18700**	**19500**
Indonesia	3	**1239**	**1628**	**2118**	**2567**	**3577**	**4228**	**4750**	**5050**	**5247**	**6055**	**7047**	**5555**	**5460**	**5465**	**5442**
Bangladesh	4	**1503**	**1657**	**1679**	**1932**	**2160**	**2462**	**2661**	**3162**	**3765**	**4578**	**5125**	**5370**	**5459**	**5491**	**5694**
Viet Nam	5	**949**	**900**	**1073**	**1104**	**1459**	**1727**	**2251**	**2945**	**3462**	**3790**	**4405**	**4324**	**4350**	**4277**	**4386**
Thailand	6	**1127**	**1287**	**1395**	**1592**	**1887**	**1927**	**2038**	**2379**	**2935**	**3252**	**3466**	**3119**	**2862**	**3023**	**3358**
Myanmar	7	**777**	**772**	**838**	**1061**	**1428**	**1374**	**1593**	**1834**	**2348**	**3154**	**2675**	**2641**	**2627**	**2599**	**2491**
Philippines	8	**396**	**483**	**536**	**727**	**807**	**922**	**986**	**1106**	**1377**	**1608**	**1805**	**1882**	**1881**	**1929**	**1996**
Japan	9	**1644**	**1776**	**1569**	**1502**	**1361**	**1326**	**1269**	**1200**	**1089**	**1076**	**1049**	**1067**	**1054**	**1047**	**1053**
Pakistan	10	**182**	**285**	**359**	**459**	**493**	**492**	**533**	**698**	**713**	**890**	**974**	**1048**	**1112**	**1263**	**1398**
Cambodia	11	**246**	**288**	**148**	**107**	**171**	**232**	**254**	**368**	**456**	**720**	**922**	**1070**	**1089**	**1125**	**1141**
RepublicKorea	12	**481**	**521**	**591**	**746**	**758**	**791**	**683**	**710**	**668**	**621**	**561**	**623**	**502**	**471**	**711**
Nepal	13	**215**	**217**	**237**	**231**	**253**	**311**	**316**	**382**	**424**	**415**	**477**	**517**	**561**	**555**	**562**
Sri Lanka	15	**97**	**130**	**136**	**177**	**239**	**236**	**256**	**254**	**290**	**366**	**391**	**409**	**459**	**512**	**515**
Lao PDR	14	**61**	**83**	**87**	**80**	**121**	**131**	**139**	**181**	**244**	**291**	**361**	**377**	**353**	**352**	**387**
DPR Korea	16	**197**	**214**	**257**	**292**	**228**	**214**	**372**	**186**	**229**	**239**	**276**	**238**	**280**	**211**	**185**
Malaysia	17	**115**	**143**	**195**	**191**	**179**	**173**	**206**	**209**	**223**	**238**	**247**	**253**	**235**	**236**	**242**
Iran	18	**85**	**102**	**126**	**141**	**154**	**177**	**231**	**243**	**262**	**239**	**228**	**226**	**249**	**182**	**160**
Taiwan	19	**274**	**304**	**302**	**319**	**298**	**237**	**215**	**193**	**162**	**148**	**165**	**177**	**179**	**175**	**156**
Turkiye	20	**22**	**23**	**25**	**29**	**31**	**27**	**22**	**31**	**44**	**74**	**89**	**95**	**100**	**98**	**101**
Afghanistan	21	34	38	41	43	35	33	33	35	40	60	53	37	38	44	46
Kazakhstan	22							33	23	25	30	37	51	56	56	50
Uzbekistan	23							51	35	20	20	31	34	31	29	33
Iraq	24	14	27	17	17	14	19	25	21	21	27	31	30	57	46	42
Turkmenistan	25							8.1	2.8	9.2	5.1	11	11	8.5	8.6	8.3
Timor-Leste	27	1.4	1.5	1.9	2.7	3.7	4.1	5.2	4.2	5.3	8.6	9.3	5.5	4.8	5.0	4.5
Tajikistan	26							2.1	4.7	5.3	5.9	8.1	9.8	10.6	9.9	6.7
Bhutan	28	3.9	4.4	4.9	5.4	6.1	5.4	4.3	4.8	4.9	7.2	7.8	6.8	5.0	5.4	4.1
Kyrgyzstan	29							0.4	1.3	1.8	1.9	2.6	4.0	4.1	4.4	4.6
Azerbaijan	30							0.2	1.4	1.4	0.4	0.4	1.1	1.1	0.9	1.0

Table 5. Ranking trend of paddy production of African (x10,000 t) and Asian(x M t) countries during 1961-2017. (This rank is based on the mean annual paddy production during 2011-15; Data source: FAOSTAT 2020)

Rank	Asian Countries	Mean paddy production [million ton] **(Paddy yield [t/ha],** Milled rice consumption per capita [kg/person]) 1961-1970	1981-1990	2008-2017	SSA Countries	Mean paddy production [10,000 ton] (**Paddy yield [t/ha]**, Milled rice consumption per capita [kg/person]) 1961-1970	1981-1990	2008-2017
1	**China**	85 (**2.9**, 71)	171 (**5.2** 98)	203 (**6.7**, 93)	Egypt	209 (**5.2**, 42)	245 (**6.0**, 31)	550 (**9.5**, 40)
2	India	55 (**1.5**, 70)	93 (**2.3** 73)	155 (**3.6**, 76)	Nigeria	26 (**1.3**, 3)	176 (**2.1**, 17)	535 (**1.9**, 28)
3	Indonesia	14 (**1.9**, 94)	39 (**4.0** 148)	70 (**5.1**, 179)	Madagascar	167 (**1.8**, 181)	218 (**1.9**, 149)	408 (**3.9**, 125)
4	Bangladesh	16 (**1.7**, 181)	23 (**2.2** 160)	51 (**4.4**, 213)	Tanzania	12 (**1.1**, 8)	49 (**1.6**, 17)	231 (**2.2**, 31)
5	Viet Nam	9.2 (**1.9**, 169)	16 (**2.8** 164)	42 (**5.5**, 293)	Mali	16 (**1.0**, 19)	22 (**1.2**, 26)	204 (**3.1**, 88)
6	Thailand	12 (**1.8**, 233)	19 (**2.0** 227)	33 (**3.0**, 305)	Guinea	26 (**1.7**, 49)	61 (**1.7**, 87)	187 (**1.3**, 146)
7	Myanmar	7.7 (**1.6**, 197)	14 (**3.0** 230)	28 (**3.9**, 342)	Côte d'Ivoire	27 (**1.0**, 51)	54 (**1.2**, 68)	153 (**2.4**, 94)
8	Philippines	4.4 (**1.4**, 93)	8.6 (**2.6** 101)	18 (**3.8**, 125)	Sierra Leone	40 (**1.3**, 106)	49 (**1.3**, 100)	100 (**1.6**, 125)
9	Japan	17 (**5.3**, 112)	13 (**6.1** 69)	10 (**6.7**, 56)	DR Congo	10 (**0.8**, 5)	31 (**0.8**, 8)	67 (**0.8**, 7)
10	Pakistan	2.3 (**1.6**, 28)	4.9 (**2.5** 33)	9.8 (**3.6**, 32)	Senegal	11 (**1.3**, 56)	14 (**2.0**, 67)	56 (**3.9**, 98)
11	**Cambodia**	2.7 (**1.2**, 257)	2.0 (**1.3** 171)	8.9 (**3.1**, 376)	Ghana	4.3 (**1.1**, 8)	7.2 (**1.1**, 8)	54 (**2.6**, 30)
12	South Korea	5.0 (**4.2**, 113)	7.7 (**6.3** 126)	5.8 (**6.9**, 79)	Burkina Faso	3.5 (**0.9**, 5)	4.1 (**1.7**, 11)	29 (**2.2**, 31)
13	Nepal	2.2 (**1.9**, 122)	2.8 (**2.0** 104)	4.6 (**3.1**, 119)	Liberia	14 (**0.8**, 98)	28 (**1.2**, 128)	28 (**1.2**, 103)
14	Sri Lanka	1.1 (**2.1**, 104)	2.4 (**3.0** 100)	3.8 (**3.7**, 126)	Chad	3.2 (**1.1**, 6)	3.9 (**1.2**, 7)	23 (**1.4**, 11)
15	Lao PDR	0.7 (**1.0**, 221)	1.3 (**2.0** 215)	3.5 (**3.9**, 350)	Benin	0.2 (**0.7**, 2)	0.8 (**1.2**, 12)	22 (**3.3**, 119*)
16	**DPR Korea**	2.1 (**4.3**, 100)	2.2 (**3.4** 74)	2.6 (**5.0**, 70)	Uganda	0.5 (**1.1**, 1)	2.6 (**1.3**, 1)	22 (**2.4**, 7)
17	Malaysia	1.3 (**2.2**, 124)	1.8 (**2.6** 91)	2.5 (**3.8**, 87)	Mauritania	0.1 (**1.5**, 12)	3.5 (**4.5**, 48)	18 (**5.0**, 62)
18	Iran	0.9 (**2.7**, 24)	1.7 (**3.4** 32)	2.3 (**4.2**, 35)	Cameroon	1.3 (**1.0**, 3)	7.1 (**4.2**, 9)	21 (**1.4**, 31)
19	Taiwan	2.9 (**3.7**, 139)	2.7 (**4.8** 87)	1.6 (**6.2**, 48)	Guinea-Bissau	4.4 (**1.0**, 55)	10 (**1.5**, 107)	18 (**1.7** 112)
20	Turkey	0.2 (**4.0**, 5)	0.3 (**4.8** 6)	0.9 (**8.0**, 11)	Mozambique	9.0 (**1.3**, 7)	8.8 (**0.9**, 11)	16 (**0.6**, 23)

Paddy production (Yield, Consumption)

*including smugglingout to Nigeria?

declines in paddy production and their population declined over the past 50 years. This was due to social conflicts caused by civil war. Similarly some countries in Asia socio-political crises such as Cambodia in 1970s-1990s, China in 1996-2005 and North Korea in 1990s to the present, might relate the decline in paddy production. Some countries of rapid industrial development, such as Japan, Korea, and Taiwan showed a decline in paddy production and consumption in recent years. China, however, maintains sustainable paddy production. In other countries such as Indonesia, Bangladesh, and the Philippines, the green revolution indicates that agricultural production has entered the maturity stage and the stage of industrial development. These countries may follow trends similar to those of Japan, Korea, Taiwan, and China. This indicates that food imports will increase in the future in some Asian countries, indicating that there is a high possibility of a global food crisis during the world population peak period of 2030–2050.

Very fortunately, however, as described in Sawah Technology (2)-(6), SSA as a whole has an irrigated sawah platform development potential of about 40% of Asia, or 50 million ha. If the current average paddy yield of 4.8 t / ha in Asia is achieved in SSA by 2050, the increase in paddy production will reach to 240 million tons. Thus the food problem that is currently worried will able to solve. It can be seen from the development of rice cultivation over the past 60 years as shown in Figures 1-7 and Tables 1-17, this issue is not impossible for SSA.

v As shown in Table 5, annual per capita milled rice consumption in kg of Vietnam, Thailand, Myanmar, Cambodia, and Lao PDR was higher than 200kg/person, which means that these countries have enough rice to export. However, all the countries in SSA consumed far less than 200 kg/person. Thus, many countries of SSA are rice importers, if other cereals such as maize and wheat have insufficient production.

Table 6. Rice value trends in Nigeria (No.1 rice producing country in SSA during 2011-2015) during 1961-2020. Data source: FAOSTAT 2020 and 2022; Conversion ratio: Paddy x 0.625 = Milled rice amount; All data are mean of five years except for 2008, 2016, and 2017.

	1961-1965	1966-1970	1971-1975	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000	2001-2005	2008	2006-2010	2011-2015	2016	2017	2016-2020
Population (million)	48.1	53.6	60.2	69.3	79.5	90.4	103	116	132	150	150	172	186	191	196+
Area harvested (1,000 ha)	179	234	289	332	630	1069	1678	2053	2271	2382	2366	2854	4936	5628	5409
Index (%) of area harvested (100 for mean of 1971-1980)	57.7	75.4	93.0	107	203	344	541	661	732	767	762	919	1587	1810	1739
Irrigated rice area harvested (1,000 ha)	98.0	98.0	98.0	98.0	98.0	171	261	315	313	266	266	219			
Index (%) of irrigated area (100 for mean of 1971-1980)	100	100	100	100	100	175	266	322	319	272	272	223			
Percent of Irrigated rice area harvested (%)	54.7	41.9	33.9	29.5	15.6	16.0	15.5	15.4	13.8	11.2	11.3	7.67			
Paddy production (1,000 ton)	207	321	470	596	1300	2216	2980	3248	3139	4179	3885	5426	7564	7826	8080
Index (%) of paddy production (100 for mean of 1971-1980)	38.9	60.2	88.2	112	244	416	559	609	589	784	729	1018	1419	1468	1516
Production (1,000 ton, milled rice)	130	201	294	373	813	1385	1862	2030	1962	2612	2428	3391	5045	5220	5389
Paddy yield (ton/ha)	1.15	1.36	1.67	1.71	2.06	2.10	1.78	1.59	1.38	1.75	1.66	1.91	1.53	1.39	1.49
Index (%) of paddy yield (100 for mean of 1971-1980)	67.9	80.7	98.8	101	122	124	106	94.0	81.7	104	98	113	0.91	0.82	0.88
Yield (ton/ha, milled rice)	0.72	0.85	1.04	1.07	1.29	1.31	1.11	0.99	0.86	1.10	1.04	1.19	1.02	0.93	1.00
Imported quantity (1,000 ton, milled rice)	1.28	1.09	3.73	408	492	289	329	647	1436	971	1241	1851	91.5	65.1	
Self-Sufficiency ratio (%)	99.0	99.4	98.8	51.0	62.7	81.7	84.8	76.2	57.8	72.9	66.5	65.1	98.1	98.4	
Imported rice price ($/ton, milled rice)	220	197	404	565	463	258	275	337	222	795	512	550	437	575	
Consumption per capita (kg/person, milled rice)	2.71	3.76	4.93	11.1	16.5	18.4	21.4	23.0	25.8	23.8	24.3	30.6	27.7	27.7	

Table 7. Rice Value Trends in Madagascar (No.2 rice producing country in SSA during 2011-2015) during 1961-2020. Data source: FAOSTAT 2020 and 2022 ; Conversion ratio: Paddy x 0.625 = Milled rice amount; All data are mean of five years except for 2008, 2016, and 2017.

	1961-1965	1966-1970	1971-1975	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000	2001-2005	2008	2006-2010	2011-2015	2016	2017	2016-2020
Population (million)	5.49	6.24	7.15	8.24	9.51	11.0	12.7	14.8	17.3	20.0	20.0	23.0	24.9	25.6	26.3+
Area harvested (1,000 ha)	843	986	1042	1147	1183	1142	1166	1187	1227	1284	1284	1037	862	730	1269
Index (%) of area harvested (100 for mean of 1971-1980)	77.0	90.1	95.2	105	108	104	107	108	112	117	117	94.8	77	67	116
Irrigated rice area harvested (1,000 ha)	375	438	463	510	526	507	675	793	909	1044	1044	806	709	567	
Index (%) of irrigated area (100 for mean of 1971-1980)	77.0	90.1	95.2	105	108	104	139	163	187	215	215	166	146	117	
Percent of Irrigated rice area harvested (%)	44.4	44.4	44.4	44.4	44.4	44.4	57.9	66.8	74.1	81.3	81.3	77.7	77.7	77.7	
Paddy production (1,000 ton)	1563	1779	1943	2037	2087	2271	2430	2511	2898	3914	4055	4032	3816	3601	3982
Index (%) of paddy production (100 for mean of 1971-1980)	78.5	89.4	97.6	102	105	114	122	126	146	197	204	203	191	181	200
Production (1,000 ton, milled rice)	977	1112	1214	1273	1305	1420	1519	1569	1811	2446	2535	2520	2546	2402	2656
Paddy yield (ton/ha)	1.85	1.80	1.87	1.78	1.76	1.99	2.08	2.12	2.36	3.05	3.15	3.90	4.43	4.92	3.13
Index (%) of paddy yield (100 for mean of 1971-1980)	102	99.0	102	97.6	96.8	109	114	116	129	167	173	214	243	270	172
Yield (ton/ha, milled rice)	1.16	1.13	1.17	1.11	1.10	1.24	1.30	1.32	1.47	1.91	1.97	2.44	2.95	3.29	2.09
Imported quantity (1,000 ton, milled rice)	17.0	15.1	67.1	104	214	94.8	46.2	87.5	190	169	151	282	233	595	
Self-Sufficiency ratio (%)	98.4	98.7	94.8	92.5	86.1	93.8	97.1	94.9	90.8	93.6	94.2	89.8	91.1	79.1	
Imported rice price ($/ton, milled rice)	76	78	236	293	263	302	315	288	198	473	387	438	385	421	
Consumption per capita (kg/person, milled rice)	181	180	179	167	160	138	123	112	115	131	134	122	105	111	

Table 8. Rice Value Trends in United Republic of Tanzania (No.3 rice producing country in SSA during 2011-2015) during 1961-2020. Data source: FAOSTAT 2020 and 2022; Conversion ratio: Paddy x 0.625 = Milled rice amount; All data are mean of five years except for 2008, 2016, and 2017.

	1961 -1965	1966 -1970	1971 -1975	1976 -1980	1981 -1985	1986 -1990	1991 -1995	1996 -2000	2001 -2005	2008	2006 -2010	2011 -2015	2016	2017	2016 -2020
Population (million)	11.0	12.7	14.9	17.4	20.4	23.7	27.9	31.9	36.4	41.9	41.9	48.5	53.0	54.7	56.3+
Area harvested (1,000 ha)	89.2	129	161	255	262	348	355	480	581	888	804	992	1039	1097	1162
Index (%) of area harvested (100 for mean of 1971-1980)	42.9	62.1	77.5	122	126	167	171	231	280	427	387	477	500	527	559
Irrigated rice area harvested (1,000 ha)	3.72	5.27	7.26	14.6	20.0	34.8	15.6	49.8	104	367	369	442	446	446	
Index (%) of irrigated area (100 for mean of 1971-1980)	34.1	48.3	66.5	134	183	319	143	456	952	3365	3377	4051	4083	4083	
Percent of Irrigated rice area harvested (%)	4.17	4.09	4.50	5.72	7.62	10.0	4.40	10.4	17.9	41.4	45.8	44.6	35.9	38.2	
Paddy production (1,000 ton)	120	121	229	320	330	653	579	743	1035	1421	1591	2369	2229	2452	3220
Index (%) of paddy production (100 for mean of 1971-1980)	43.8	44.0	83.5	116	120	238	211	271	377	517	579	862	812	893	1173
Production (1,000 ton, milled rice)	75.2	75.6	143	200	207	408	362	464	647	888	994	1481	1487	1635	2148
Paddy yield (ton/ha)	1.33	0.94	1.46	1.26	1.29	1.88	1.62	1.58	1.81	1.60	1.98	2.39	2.15	2.24	2.77
Index (%) of paddy yield (100 for mean of 1971-1980)	97.7	69.4	107	92.6	95.1	139	119	117	133	118	146	176	1.58	165	204
Yield (ton/ha, milled rice)	0.83	0.59	0.91	0.79	0.81	1.18	1.01	0.99	1.13	1.00	1.24	1.49	1.43	1.49	1.85
Imported quantity (1,000 ton, milled rice)	13.2	14.7	31.8	47.4	70.6	66.1	69.7	121	135	64.2	64.3	114	0.91	0.94	
Self-Sufficiency ratio (%)	83.6	83.9	84.2	81.8	74.6	86.1	83.5	79.9	83.0	93.3	93.6	92.5	100.0	99.9	
Imported rice price ($/ton, milled rice)	150	171	303	364	446	304	296	341	203	255	270	409	791	572	
Consumption per capita (kg/person, milled rice)	8.06	7.11	11.6	14.2	13.6	20.0	15.5	18.3	21.5	22.7	25.1	32.8	35.6	32.8	

Table 9. Rice Value Trends in Mali (No.4 rice producing country in SSA during 2011-2015) during 1961-2020. Data source: FAOSTAT 2020 and 2022; Conversion ratio: Paddy x 0.625 = Milled rice amount; All data are mean of five years except for 2008, 2016, and 2017.

	1961 -1965	1966 -1970	1971 -1975	1976 -1980	1981 -1985	1986 -1990	1991 -1995	1996 -2000	2001 -2005	2008	2006 -2010	2011 -2015	2016	2017	2016 -2020
Population (million)	5.44	5.79	6.26	6.84	7.54	8.19	9.10	10.4	12.0	14.1	14.1	16.5	18.0	18.5	19.1+
Area harvested (1,000 ha)	167	169	188	169	167	202	267	332	392	483	485	657	835	768	879
Index (%) of area harvested (100 for mean of 1971-1980)	93.3	94.4	105	94.7	93.6	113	149	186	220	270	272	368	468	430	492
Irrigated rice area harvested (1,000 ha)	57.8	58.0	57.8	57.8	57.8	50.6	64.2	125	187	224	225	256	258	258	
Index (%) of irrigated area (100 for mean of 1971-1980)	100	100	100	100	100	87.6	111	216	323	387	390	443	446	446	
Percent of Irrigated rice area harvested (%)	34.7	34.4	30.8	34.2	34.6	25.0	24.1	37.6	47.6	46.4	46.5	39.0	30.9	33.6	
Paddy production (1,000 ton)	172	158	174	191	165	274	447	678	847	1624	1334	2059	2781	2708	2972
Index (%) of paddy production (100 for mean of 1971-1980)	94.1	86.4	95.3	105	90.5	150	245	371	464	889	730	1127	1524	1484	1628
Production (1,000 ton, milled rice)	107	98.6	109	119	103	171	280	424	530	1015	834	1287	1855	1806	1983
Paddy yield (ton/ha)	1.05	0.95	0.91	1.15	0.99	1.35	1.68	2.04	2.17	3.37	2.78	3.14	3.33	3.53	3.38
Index (%) of paddy yield (100 for mean of 1971-1980)	102	91.9	88.1	112	96.4	131	163	198	210	326	269	304	323	343	328
Yield (ton/ha, milled rice)	0.66	0.59	0.57	0.72	0.62	0.85	1.05	1.28	1.35	2.10	1.73	1.96	2.22	235	226
Imported quantity (1,000 ton, milled rice)	0.03	6.95	36.4	19.1	75.2	64.0	28.4	68.2	169	172	132	169	250	277	
Self-Sufficiency ratio (%)	100	94.1	74.8	86.1	59.2	73.9	90.9	86.3	76.3	85.5	86.0	88.9	87.4	86.2	
Imported rice price ($/ton, milled rice)	120	108	329	377	367	285	342	222	194	384	369	391	347	328	
Consumption per capita (kg/person, milled rice)	19.8	18.2	23.1	20.3	23.6	28.8	33.9	47.4	58.2	84.1	68.4	88.4	111	109	

Table 10. Rice Value Trends in Guinea (No.5 rice producing country in SSA during 2011-2015) during 1961-2020. Data source: FAOSTAT 2020 and 2022; Conversion ratio: Paddy x 0.625 = Milled rice amount; All data are mean of five years except for 2008, 2016, and 2017.

	1961 -1965	1966 -1970	1971 -1975	1976 -1980	1981 -1985	1986 -1990	1991 -1995	1996 -2000	2001 -2005	2008	2006 -2010	2011 -2015	2016	2017	2016 -2020
Population (million)	3.67	4.01	4.36	4.71	5.21	5.99	6.90	7.86	8.76	9.74	9.74	10.9	11.7	12.1	12.4+
Area harvested (1,000 ha)	135	168	208	258	321	398	493	612	661	795	936	1638	1688	1806	1850
Index (%) of area harvested (100 for mean of 1971-1980)	58.0	72.0	89.3	111	137	170	211	262	283	340	401	702	723	775	794
Irrigated rice area harvested (1,000 ha)	6.00	7.80	15.0	22.2	27.0	25.8	27.0	15.2	15.1	40.9	40.9	40.9	40.9	40.9	
Index (%) of irrigated area (100 for mean of 1971-1980)	32.3	41.9	80.6	119	145	139	145	81.7	81.2	220	220	220	220	220	
Percent of Irrigated rice area harvested (%)	4.43	4.64	7.20	8.59	8.42	6.50	5.47	2.48	2.28	5.15	4.37	2.50	2.42	2.26	
Paddy production (1,000 ton)	230	286	355	441	548	680	844	1048	1150	1534	1469	1957	2136	2198	2438
Index (%) of paddy production (100 for mean of 1971-1980)	57.9	71.9	89.2	111	138	171	212	263	289	385	369	491	537	552	613
Production (1,000 ton, milled rice)	144	179	222	276	342	425	528	655	719	959	918	1223	1425	1466	1626
Paddy yield (ton/ha)	1.70	1.70	1.71	1.71	1.71	1.71	1.71	1.71	1.74	1.93	1.65	1.19	1.27	1.22	1.32
Index (%) of paddy yield (100 for mean of 1971-1980)	99.8	99.9	100	100	100	100	100	100	102	113	96.7	70.0	74.2	71.3	77.2
Yield (ton/ha, milled rice)	1.06	1.06	1.07	1.07	1.07	1.07	1.07	1.07	1.09	1.21	1.03	0.75	0.84	0.81	0.88
Imported quantity (1,000 ton, milled rice)	32.9	24.7	25.6	60.9	70.2	148	242	190	230	339	280	439	654	557	
Self-Sufficiency ratio (%)	81.7	88.0	89.9	83.1	83.0	74.9	68.7	77.5	76.2	73.9	76.7	74.9	67.1	71.1	
Imported rice price ($/ton, milled rice)	160	162	288	318	300	199	220	216	189	451	357	448	374	417	
Consumption per capita (kg/person, milled rice)	48.1	50.7	56.8	71.3	79.1	95.4	111	108	108	133	123	152	169	160	

Table 11. Rice Value Trends in Côte d'Ivoire (No.6 rice producing country in SSA during 2011-2015) during 1961-2020. Data source: FAOSTAT 2020 and 2022; Conversion ratio: Paddy x 0.625 = Milled rice amount; All data are mean of five years except for 2008, 2016, and 2017.

	1961 -1965	1966 -1970	1971 -1975	1976 -1980	1981 -1985	1986 -1990	1991 -1995	1996 -2000	2001 -2005	2008	2006 -2010	2011 -2015	2016	2017	2016 -2020
Population (million)	3.92	4.73	5.86	7.36	9.15	11.1	13.3	15.6	17.6	19.6	19.6	22.1	23.8	24.4	25.1+
Area harvested (1,000 ha)	249	287	312	409	386	531	611	406	343	367	373	696	781	781	698
Index (%) of area harvested (100 for mean of 1971-1980)	69.0	79.7	86.6	113	107	147	169	113	95.2	102	104	193	217	2i7	194
Irrigated rice area harvested (1,000 ha)	2.12	6.35	12.3	17.6	22.0	31.9	34.4	29.7	23.1	16.5	16.5	16.5	16.5	16.5	
Index (%) of irrigated area (100 for mean of 1971-1980)	14.2	42.5	82.0	118	147	213	230	199	155	110	110	110	110	110	
Percent of Irrigated rice area harvested (%)	0.85	2.21	3.92	4.31	5.71	6.00	5.63	7.32	6.73	4.49	4.42	2.37	2.09	2.07	
Paddy production (1,000 ton)	220	321	388	479	451	621	673	624	665	680	779	1715	2055	2120	1909
Index (%) of paddy production (100 for mean of 1971-1980)	50.8	74.0	89.6	110	104	143	155	144	153	157	180	395	474	489	440
Production (1,000 ton, milled rice)	138	201	243	299	282	388	420	390	416	425	487	1072	1371	1414	1274
Paddy yield (ton/ha)	0.88	1.11	1.24	1.17	1.17	1.17	1.11	1.57	1.94	1.85	2.07	2.44	2.63	2.71	2.74
Index (%) of paddy yield (100 for mean of 1971-1980)	73.0	92.4	103	97.1	96.6	96.7	92.1	130	161	154	172	202	218	225	227
Yield (ton/ha, milled rice)	0.55	0.70	0.78	0.73	0.73	0.73	0.69	0.98	1.21	1.16	1.30	1.53	1.76	1.81	1.83
Imported quantity (1,000 ton, milled rice)	49.4	57.8	78.6	138	348	353	350	429	723	762	891	1181	1282	1347	
Self-Sufficiency ratio (%)	74.1	77.8	76.0	71.4	44.6	52.7	54.8	48.0	36.6	35.8	35.1	47.5	50.1	49.6	
Imported rice price ($/ton, milled rice)	126	137	314	418	269	269	304	268	244	619	490	569	413	426	
Consumption per capita (kg/person, milled rice)	47.4	54.7	55.1	59.0	68.8	66.9	58.1	52.6	64.7	60.6	70.1	102	108	109	

Table 12. Rice Value Trends in Sierra Leone (No.7 rice producing country in SSA during 2011-2015) during 1961-2020. Data source: FAOSTAT 2020 and 2022 ; Conversion ratio: Paddy x 0.625 = Milled rice amount; All data are mean of five years except for 2008, 2016, and 2017.

	1961 -1965	1966 -1970	1971 -1975	1976 -1980	1981 -1985	1986 -1990	1991 -1995	1996 -2000	2001 -2005	2008	2006 -2010	2011 -2015	2016	2017	2016 -2020
Population (million)	2.43	2.65	2.92	3.24	3.63	4.14	4.33	4.42	5.20	6.13	6.13	6.87	7.33	7.49	7.65
Area harvested (1,000 ha)	273	327	361	409	366	376	342	257	470	476	540	668	765	781	784
Index (%) of area harvested (100 for mean of 1971-1980)	71.0	84.9	93.8	106	95.0	97.7	88.9	66.8	122	124	140	174	199	203	204
Irrigated rice area harvested (1,000 ha)	0.00	0.00	0.00	0.00	0.00	1.88	0.00	5.78	2.97						
Index (%) of irrigated area (100 for mean of 1986-1995)	0.00	0.00	0.00	0.00	0.00	200	0.00	614	316						
Percent of Irrigated rice area harvested (%)	0.00	0.00	0.00	0.00	0.00	0.50	0.00	2.24	0.63						
Paddy production (1,000 ton)	336	457	502	563	484	501	446	316	490	680	849	1120	875	897	937
Index (%) of paddy production (100 for mean of 1971-1980)	63.2	85.8	94.3	106	90.8	94.1	83.7	59.3	91.9	128	159	210	164	168	176
Production (1,000 ton, milled rice)	210	286	314	352	302	313	279	197	306	425	531	700	534	598	625
Paddy yield (ton/ha)	1.23	1.40	1.39	1.37	1.33	1.34	1.30	1.21	1.03	1.43	1.57	1.68	1.14	1.15	1.20
Index (%) of paddy yield (100 for mean of 1971-1980)	89.1	101	101	99.5	96.2	96.8	94.1	87.6	74.6	103	114	121	82.6	83.3	87.0
Yield (ton/ha, milled rice)	0.77	0.88	0.87	0.86	0.83	0.84	0.81	0.76	0.64	0.89	0.98	1.05	0.70	0.77	0.80
Imported quantity (1,000 ton, milled rice)	12.5	31.1	22.4	36.9	58.0	102	167	152	99.0	196	126	255	218	357	
Self-Sufficiency ratio (%)	94.6	90.2	93.4	90.7	84.3	75.5	63.2	56.2	74.7	68.4	80.1	73.3	71.5	61.1	
Imported rice price ($/ton, milled rice)	153	138	433	316	330	339	305	471	441	435	372	412	362	403	
Consumption per capita (kg/person, milled rice)	91.5	120	115	120	99.5	100	103	79.5	77.5	101	107	139	104	123	

Table 13. Rice Value Trends in the Democratic Republic of the Congo (No.8 rice producing country in SSA during 2011-2015) during 1961-2020. Data source: FAOSTAT 2020 and 2022; Conversion ratio: Paddy x 0.625 = Milled rice amount; All data are mean of five years except for 2008, 2016, and 2017.

	1961 -1965	1966 -1970	1971 -1975	1976 -1980	1981 -1985	1986 -1990	1991 -1995	1996 -2000	2001 -2005	2008	2006 -2010	2011 -2015	2016	2017	2016 -2020
Population (million)	16.5	18.9	21.7	25.0	28.4	32.5	38.8	44.9	51.5	60.4	60.5	71.4	78.8	81.4	84.1+
Area harvested (1,000 ha)	85.2	185	258	281	329	437	545	456	420	419	419	1007	1388	1475	1459
Index (%) of area harvested (100 for mean of 1971-1980)	31.6	68.8	95.7	104	122	162	202	169	156	156	156	374	515	547	541
Irrigated rice area harvested (1,000 ha)				1.41	2.69	3.23	3.57	4.56	3.43	2.30	2.30	2.30	2.30	2.30	
Index (%) of irrigated area (100 for mean of 1976-1985)				68.9	131	157	174	222	167	112	112	112	112	112	
Percent of Irrigated rice area harvested (%)				0.50	0.82	0.74	0.65	1.00	0.82	0.55	0.55	0.23	0.18	0.18	
Paddy production (1,000 ton)	61.8	146	198	220	273	351	404	344	317	317	317	763	1104	1213	1272
Index (%) of paddy production (100 for mean of 1971-1980)	29.6	69.6	94.6	105	131	168	193	165	152	151	152	365	528	580	609
Production (1,000 ton, milled rice)	38.6	90.9	124	138	171	220	252	215	198	198	198	477	736	809	849
Paddy yield (ton/ha)	0.74	0.79	0.77	0.78	0.83	0.80	0.74	0.75	0.75	0.76	0.76	0.76	0.80	0.82	0.87
Index (%) of paddy yield (100 for mean of 1971-1980)	95.2	102	98.9	101	107	104	95.8	97.4	97.4	97.4	97.5	97.8	103	106	112
Yield (ton/ha, milled rice)	0.46	0.49	0.48	0.49	0.52	0.50	0.46	0.47	0.47	0.47	0.47	0.47	0.53	0.55	0.58
Imported quantity (1,000 ton, milled rice)	25.6	24.1	26.7	37.0	33.4	80.3	66.0	64.6	139	98.2	127	68.9	41.7	74.6	
Self-Sufficiency ratio (%)	61.0	77.6	82.6	79.0	83.7	73.2	79.5	77.2	60.4	66.8	64.8	85.7	93.4	89.3	
Imported rice price ($/ton, milled rice)	138	174	249	266	233	315	411	375	374	181	319	487	463	563	
Consumption per capita (kg/person, milled rice)	3.91	6.05	6.94	7.02	7.16	9.21	8.24	6.24	6.51	4.90	5.44	7.56	8.07	8.58	

Table 14. Rice Value Trends in Senegal (No.9 rice producing country in SSA during 2011-2015) during 1961-2020. Data source: FAOSTAT 2020 and 2022; Conversion ratio: Paddy x 0.625 = Milled rice amount; All data are mean of five years except for 2008, 2016, and 2017.

	1961 -1965	1966 -1970	1971 -1975	1976 -1980	1981 -1985	1986 -1990	1991 -1995	1996 -2000	2001 -2005	2008	2006 -2010	2011 -2015	2016	2017	2016 -2020
Population (million)	3.49	4.02	4.66	5.31	6.10	7.09	8.22	9.35	10.6	12.0	12.0	13.8	15.0	15.4	15.9+
Area harvested (1,000 ha)	76.3	88.9	74.6	76.2	67.8	75.4	74.1	82.0	86.1	125	115	142	261	306	328
Index (%) of area harvested (100 for mean of 1971-1980)	101	118	99.0	101	90.0	100	98.3	109	114	166	153	188	346	406	435
Irrigated rice area harvested (1,000 ha)	20.7	20.3	19.3	18.3	17.5	18.8	30.3	41.6	80.7	71.6	71.6	71.6	71.6	71.6	
Index (%) of irrigated area (100 for mean of 1971-1980)	110	108	103	97.5	93.0	100	161	221	429	381	381	381	381	381	
Percent of Irrigated rice area harvested (%)	27.1	22.8	25.8	24.0	25.8	25.0	40.9	50.7	93.7	57.1	62.0	50.6	44.1	42.8	
Paddy production (1,000 ton)	99.7	114	88.4	97.3	127	155	172	202	218	408	380	555	946	1011	1134
Index (%) of paddy production (100 for mean of 1971-1980)	107	122	95.2	105	137	167	185	218	235	440	409	598	1018	1088	1221
Production (1,000 ton, milled rice)	62.3	70.9	55.2	60.8	79.6	96.8	107	127	137	255	237	347	631	675	756
Paddy yield (ton/ha)	1.30	1.25	1.14	1.25	1.89	2.06	2.31	2.44	2.52	3.26	3.12	3.94	3.62	3.30	3.46
Index (%) of paddy yield (100 for mean of 1971-1980)	109	105	95.5	104	159	173	194	205	212	273	262	330	303	276	290
Yield (ton/ha, milled rice)	0.81	0.78	0.71	0.78	1.18	1.29	1.45	1.53	1.58	2.04	1.95	2.46	2.41	2.21	2.30
Imported quantity (1,000 ton, milled rice)	137	151	170	276	349	356	390	536	808	1012	854	1049	974	1181	
Self-Sufficiency ratio (%)	31.8	31.7	24.8	18.2	18.5	21.4	21.7	18.7	14.4	20.1	21.7	24.4	28.9	27.3	
Imported rice price ($/ton, milled rice)	105	127	211	217	232	219	209	256	250	637	420	402	334	363	
Consumption per capita (kg/person, milled rice)	56.8	55.6	48.5	63.3	70.4	63.8	60.5	70.8	89.4	106	90.7	101	91.4	105	

Table 15. Rice Value Trends in Ghana (No.10 rice producing country in SSA during 2011-2015) during 1961-2020. Data source: FAOSTAT 2020 and 2022; Conversion ratio: Paddy x 0.625 = Milled rice amount; All data are mean of five years except for 2008, 2016, and 2017.

	1961 -1965	1966 -1970	1971 -1975	1976 -1980	1981 -1985	1986 -1990	1991 -1995	1996 -2000	2001 -2005	2008	2006 -2010	2011 -2015	2016	2017	2016 -2020
Population (million)	7.30	8.33	9.49	10.6	12.0	14.0	16.1	18.4	20.8	23.6	23.6	26.6	28.5	29.1	29.8+
Area harvested (1,000 ha)	32.6	45.3	68.4	106.6	70.8	64.1	86.5	115	123	133	142	212	244	258	285
Index (%) of area harvested (100 for mean of 1971-1980)	37.2	51.8	78.2	122	80.9	73.3	98.9	131	141	152	162	242	279	295	326
Irrigated rice area harvested (1,000 ha)	4.99	4.99	4.99	4.99	4.99	15.4	11.9	14.9	23.4	21.3	21.1	21.8	22.5	22.5	
Index (%) of irrigated area (100 for mean of 1971-1980)	100	100	100	100	100	309	239	299	469	426	424	436	452	452	
Percent of Irrigated rice area harvested (%)	15.3	11.0	7.29	4.68	7.04	24.0	13.8	13.0	19.0	16.0	14.9	10.3	9.23	8.71	
Paddy production (1,000 ton)	33.9	53.1	66.3	91.6	63.6	80.0	161	213	264	302	324	552	688	722	815
Index (%) of paddy production (100 for mean of 1971-1980)	42.9	67.3	84.0	116	80.6	101	204	270	335	383	411	700	871	915	1033
Production (1,000 ton, milled rice)	21.2	33.2	41.4	57.2	39.8	50.0	100	133	165	189	203	345	459	482	544
Paddy yield (ton/ha)	1.05	1.18	0.97	0.86	0.91	1.31	1.86	1.87	2.15	2.27	2.22	2.59	2.82	2.80	2.86
Index (%) of paddy yield (100 for mean of 1971-1980)	114	129	106	94.1	99.3	143	203	205	235	248	243	284	308	305	312
Yield (ton/ha, milled rice)	0.65	0.74	0.61	0.54	0.57	0.82	1.16	1.17	1.34	1.42	1.39	1.62	1.88	1.87	1.91
Imported quantity (1,000 ton, milled rice)	30.0	40.1	30.4	32.1	38.3	77.8	180	77.3	543	395	386	404	698	820	
Self-Sufficiency ratio (%)	42.7	45.8	61.8	68.8	51.4	39.8	37.6	66.1	25.4	32.3	33.9	48.6	38.1	35.5	
Imported rice price ($/ton, milled rice)	215	196	288	382	372	296	234	356	240	547	486	661	411	490	
Consumption per capita (kg/person, milled rice)	7.03	8.80	7.60	8.37	6.44	9.12	17.5	11.4	34.0	24.8	25.0	28.3	39.6	43.6	

As we described in Sawah Technology (2) background and Sawah system evolution, Madagascar (Table 7), in Eastern Africa is a unique country among the other countries of SSA, with a long history of more than 1,000 years of Asian-style sawah-based rice cultivation. In 1961–65, it had 0.38 million ha, 40% of SSA's total irrigated rice area of 0.95 million ha (Table 1a), which produced 1.56 Mt of paddy, 44% of the total production of SSA. From 1961 to 2015, Madagascar appeared to be achieving similar results to Asian countries, i.e. sustained production growth was being achieved through increases in irrigated rice area and yields. However, it then stagnated in 2010-2020, with production growth not matching population growth (Table 3 and Fig. 25a), largely due to the failure of rice production support policies, including ODA. Madagascar also experienced severe droughts in 2016-17 and 2021, resulting in a sharp decline in paddy rice production. This is thought to be due to the effects of global warming, which has become increasingly severe in recent years.

Since the rice crisis of 2008 and the price soaring, the increase in rice production in Africa has accelerated further, and in the 10 years from 2006-2010 to 2016-2020, 5 years mean rice production increased 17Mt to 30Mt (76%). The policy from Japan International cooperation Agency (JICA) for increasing rice production (CARD 2008) was timely, except for Madagascar. As shown in Tables 3 and 5, the national paddy yields of Madagascar, Senegal, Benin, Mauritania, Kenya, Niger, andRwanda have reached a level of 3 t/ha or higher. All of these are the countries with higher irrigated rice with higher evolutionary sawah platform systems (see Sawah Technology (2) and (3) background and sawah platform evolution) among the countries of SSA. Mali, Senegal, and Mauritania have additional yield increase factors, such as high solar radiation. Table 3 shows the ranking of the average amount of paddy production in 2016–20, with Nigeria as no. 1, which achieved a 47 fold increase in mean production based on 1961–65 (Essiet 2016, Yombe 2016, Johnson and Masias 2017, Shehu and Lolo 2017, Tene 2017).

Rice cultivation in other SSA countries, led by Nigeria and Tanzania, follows a different development path from Madagascar and Asian countries. That is, two factors, (1) rapid expansion of rice cultivation area and (2) steady increase in yield due to the evolution of irrigated sawah platform based rice cultivation by farmers' own power and government supports, act synergistically to rapidly increase paddy production. There is a possibility that full scale of irrigated sawah based rice cultivation, which was realized by Asia and Madagascar over 1000 years of historical time, will be realized in half a century (2000-2050).

Meanwhile, the percentage of irrigated rice area has been steadily decreasing, 35% in 1961–65 and 19% in 2011–15. This is because the relative status of Madagascar in SSA has declined, and rice cultivation in other countries of SSA has expanded rapidly. The current irrigated rice area percentage (19%) is lower than that of the irrigated rice area ratio at the beginning of the Asian Green Revolution (Table 1b, average of 63% in 1961–65). However, the absolute irrigated rice area of SSA has been increased from 0.95 million ha in 1961–65 to 2.1 Mha in 2011–15. Thus, the synergistic effect of paddy production has increased significantly.

SSA rice farmers have been rapidly expanding the irrigated sawah platform area, especially since 2010, to improve the evolutionary level of irrigated sawah platform. Official data on the area of both official and private irrigated sawah platform since 2015 has not been obtained currently. However, for example, as described in Sawah Technology (3), (3-2) and (6), expansion of evolutional stage 4-5 of sawah platform by farmers' self-support efforts are remarkable in Kebbi state in Nigeria and Sukuma farmers in Tanzania, of which total area expansion may reach to half million ha in 2010-2020. Therefore, it is highly possible that as of 2021, it has more than doubled in SSA altogether as of 2015. Thus the synergistic effect of paddy production has been explosively increased.

Table 16 summarizes the latest paddy production data of the top 32 countries of SSA in 1961–2018 by FAOSTAT 2020. As shown in Figure 4b, USDA 2020 presented a significant difference in paddy productions of Nigeria (7.3 Mt), Madagascar (3.8Mt), and DR Congo (0.4 Mt) during 2015–2019. As shown in Table 16, during 1961–2018, Nigeria and other countries shown in green colour achieved more than a 10-fold increase, countries shown in white showed an increase of 5–10 times, and countries in red showed an increase of less than 5 times during this period. Table 17 shows the difference between the average annual paddy production for the last 10 years, that is, between 2007–08 and 2017–18 as reported by FAOSAT 2020. The ranking of the table is based on the 2014–18 average. During those periods, the SSA increased paddy production from 15.5 to 27.5 Mt. Annual paddy production increased by 11.9 Mt. Nigeria showed the biggest increase in contribution, 3 Mt (with USDA 2020 source, 4.12 Mt), which is equivalent to 25% (if USDA 2020, more than 30%) of overall SSA increase, corresponding to 11.9 Mt. Mali ranked the second, with 1.62 Mt increase (13.6% contribution); no. 3 was Tanzania, with 1.56 Mt (13.1% contribution); 4^{th} was Côte d'Ivore, with 1.47 Mt (12.3% contribution); 5^{th} was Guinea, 0.80 Mt (6.7% contribution); 6^{th} was DR Congo with 680,000 t (5.7%

contribution); 7th was Ghana with 640,000 t (3.8% contribution); 8th was Senegal, with 440,000 t (3.7% contribution); 9th was Benin, with 280,000 t (2.3% contribution); 10th was Cameroun, with 280,000 t (2.3% contribution); 11th was Sierra Leone 270,000 t (2.3% contribution); 12th was Mauritania, with 160,000 t (1.3% contribution); 13th was Chad 120,000 t (1.0% contribution); 14th was Burkina Faso, with 110,000 t (0.9%contribution); and 15th was Ethiopia with 100,000 t (0.8% contribution). These 15 countries contributed to a 10 Mt increase in paddy production, which is 85% of the overall increase in SSA in the past 10 years. The Western countries contributed to 77.4% in total.

Table 16. Top 32 countries of SSA based on the average paddy production (× 1,000 t) in 2014–18. The ranking numbers in 1961–65 and paddy yield data (t/ha) in 2014–18 are also shown. The countries where the production rate between 2014–18/1961–65 was more than 10 times are shown in green, 5–10 times in white, and less than 5 in red (FAOSTAT 2020)

Rank by 2014-18 data	Countries	Mean paddy Production in 1961-65 (x1000tons)	Mean paddy Production in 2014-18 (x1000tons)	Average growth rate for 2014-18 and 1961-65	Paddy yield in t/ha	Rank by 1961-65 data	Rank by 2014-18 data	Countries	Mean paddy Production in 1961-65 (x1000tons)	Mean paddy Production in 2014-18 (x1000tons)	Average growth rate for 2014-18 and 1961-65	Paddy yield in t/ha	Rank by 1961-65 data
1	Nigeria	207	6648	32	2.00	5	17	Mauritania	0.6	244	414	5.22	29
2	Madagascar	1563	3829	2.5	4.32	1	18	Guinea-Bissau	48	169	3.5	1.47	12
3	UR Tanzania	120	2901	24	2.55	8	19	Togo	21	142	6.9	1.70	18
4	Mali	172	2645	15	3.29	6	20	Ethiopia	-	137	>100	2.92	31
5	Guinea	230	2138	9.3	1.22	3	21	Mozambique	94	130	1.4	0.52	10
6	Côte d'Ivoire	220	2098	9.5	2.62	4	22	Malawi	5.8	112	19	1.77	23
7	DR Congo	62	996	16	0.76	11	23	Kenya	14	108	7.7	3.86	19
8	Sierra Leone	336	954	2.8	1.30	2	24	Niger	11	103	9.5	4.19	20
9	Senegal	100	715	7.2	4.10	9	25	Rwanda	0.01	102	16986	3.31	30
10	Ghana	34	685	20	2.78	13	26	Burundi	2.7	73	27	1.77	26
11	Burkina Faso	32	309	9.7	1.97	15	27	Angola	27	54	2.0	1.08	17
12	Cameroon	10	297	29	1.24	22	28	Gambia	33	52	1.6	0.79	14
13	Benin	1.0	292	300	3.32	28	29	Zambia	-	37	>50	1.37	32
14	Liberia	125	273	2.2	1.11	7	30	Comoros	10	31	3.0	1.27	21
15	Chad	29	266	9.3	1.43	16	31	Sudan (former)	1.2	28	23	3.23	27
16	Uganda	3.2	249	78	2.60	25	32	Central African R.	4.6	11	2.5	1.54	24

Table 17. Increase in annual paddy production over the past 10 years in the top 32 countries of SSA. The overall average difference was 11.9 Mt (27.5–15.5) between 2007/8 and 2017–18. The relative% contribution of the top 32 countries of SSA are also shown (FAOSTAT 2020). *Note values 780 of Nigeria and 40 in DR Congo were sourced from USDA 2020.

Rank by 2014-18 mean paddy production	Countries	Mean annual paddy Production in 2007-08 (x10,000tons)	Mean annual paddy Production in 2017-18 (x10,000tons)	Differences between (2017-18)-(2007-08)	Percentage to the total increment in SSA	Rank by 2014-18 mean paddy production	Countries	Mean annual paddy Production in 2007-08 (x10,000tons)	Mean annual paddy Production in 2017-18 (x10,000tons)	Differences between (2017-18)-(2007-08)	Percentage to the total increment in SSA
1	Nigeria	368	671(780*)	303(412*)	25(33)	17	Mauritania	8	24	16	1.3
2	Madagascar	375	382	6	0.51	18	Guinea-Bissau	14	18	4	0.3
3	UR Tanzania	138	294	156	13.1	19	Togo	8	14	6	0.5
4	Mali	135	297	162	13.6	20	Ethiopia	4	14	10	0.8
5	Guinea	147	227	80	6.7	21	Mozambiq	10	12	3	0.2
6	Côte d'Ivoire	64	211	147	12.3	22	Malawi	11	12	0	0.02
7	DR Congo	32	99(40*)	68(12*)	5.7(1*)	23	Kenya	3	11	7	0.6
8	Sierra Leone	63	91	27	2.3	24	Niger	6	11	5	0.4
9	Senegal	30	74	44	3.7	25	Rwanda	7	11	4	0.4
10	Ghana	24	75	50	4.2	26	Burundi	7	6	-2	decrease
11	Burkina Fas	13	24	11	0.9	27	Angola	1	6	5	0.4
12	Cameroon	7	35	28	2.3	28	Gambia	2	5	3	0.2
13	Benin	9	37	28	2.3	29	Zambia	2	4	2	0.2
14	Liberia	26	25	-1	decrease	30	Comoros	2	3	1	0.1
15	Chad	14	26	12	1.0	31	Sudan (form)	3	3	0	0.04
16	Uganda	17	26	9	0.8	32	Central African.	4	1	-3	decrease

The dramatic increase in Nigerian paddy production after 2013 was due to the promotion of dry season cultivation in the northern states of the Sudan and Sahel Savanna zones, such as Kebbi, Jigawa, Sokoto, Zamfara, and Kano. In particular, the Kebbi state has dramatically increased production where there is no large-scale irrigation scheme. Kebbi state alone is estimated to have contributed to an increase in paddy production more than Tanzania, Mali, and Corte d'Ivoire in the past 10 years. In Nigeria, this is called the Kebbi Rice Revolution (Sawah Technology) (6).

4. Trends of world market prices of rice, soybean, wheat and maize during 1971-2023 (MAFF, 2023, Japan, http://www.maff.go.jp/j/zyukyu/jki/j_zyukyu_kakaku/)

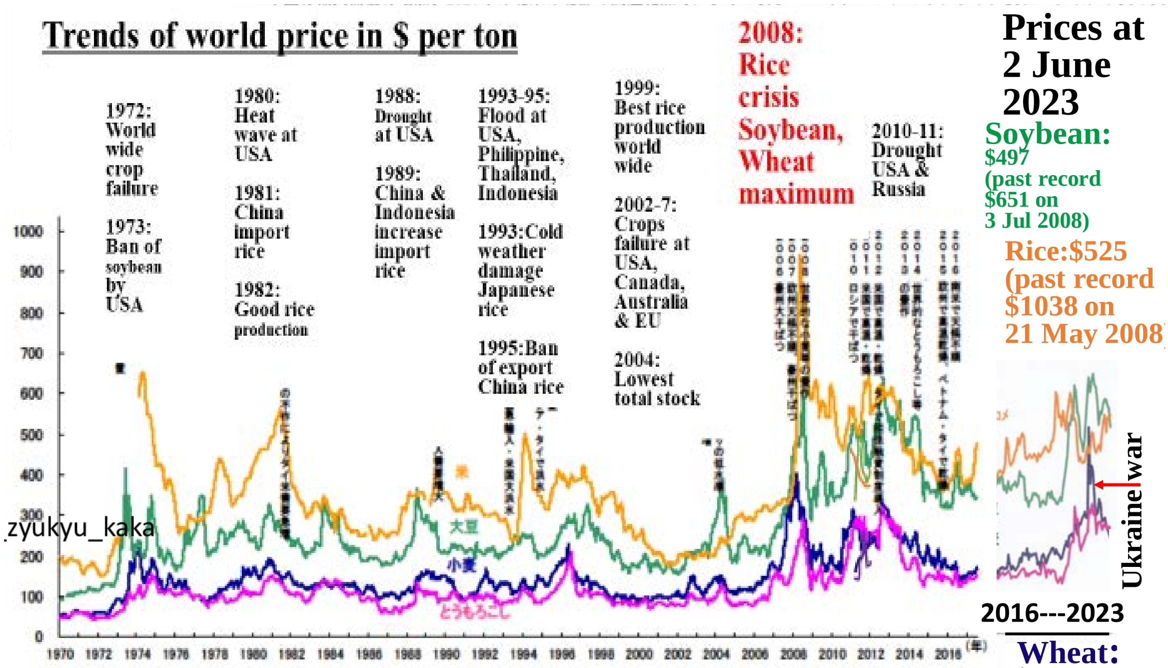


Fig.8. Trends of world trading prices of rice at Thai (milled 2nd class FOB) , soybean, wheat and maize at Chicago commodity exchange during 1972-2023 (Ministry of Agriculture, Forestry and Fishery, MAFF, Japan, 2023, https://www.maff.go.jp/j/zyukyu/jki/j_zyukyu_kakaku/attach/pdf/index-5.pdf).
Note : Prices of wheat, maize, and soybean are prices at both the first and the last Friday of each month. Rice price is at both the first and the last Wednesday of each month. Note FOB, Free On Board at Bangkok port.

The reason for the rise in rice production can be explained in part by the trends in grain prices of rice compared to other crops, such as maize (corn) and wheat, in the past 50 years, as shown in Figure 8 (Ministry of Agriculture, Forestry and Fisheries (2019, 2023). Although SSA has the ecological environment suitable for irrigated sawah rice cultivation is widely distributed in SSA as in Asia, the spread of Asian style irrigated rice farming was very restricted, probably, by 500 years of slave trade and colonial rule of the western countries before independence in 1960s. After the independent, such restrictions were over. However, recovering from this 500-year historical damage will require a considerable investment of resource and money in long time.
The four cereal prices in Figure 8, including soybean, fluctuate significantly. However, the price of rice is constantly maintained at higher rates of approximately 2–3 times higher per ton compared to wheat and maize.

The total production cost of the main producing regions of corn worldwide (South Africa, the USA, and Romania) and the main producing regions of wheat (Argentina, Australia, Canada, the USA, EU, Russia, and Ukraine) is about US$100–200 /t. In the case of rice, it was in the range of US$100-150 /t(paddy) under irrigated sawah platform (evolutional stage 4-5) for Vietnam and US$150–300 /t (paddy) under irrigated sawah platform (evolutional stage 2-4) for Nigeria and Tanzania (Zimmer et al. 2015, Ben-Chendo et al 2017, Sawah technology 5). In addition to poor production infrastructure and immature technology, due to the high labour costs, the production costs of SSA were almost to double that of Asian rice exporters in Vietnam, Thailand, India, etc.
However, since the production cost of corn has also been similarly high and paddy price has been 2-3 times

higher than corn, rice production has an economic advantage in SSA. If the evolutional stage of irrigated sawah platform reach to 4-5, SSA rice will have more economic competitiveness in the world. The suitable area of wheat is not large from the view point of the ecological environment in SSA. But suitable area of rice is huge in SSA. As shown in the many statistical data in this paper, the rapid rise in rice productivity since 2005–08 has accelerated the economic advantage of rice production in SSA.

In addition to this economy, rice consumption is rapidly increasing because of the taste of rice, its value as healthy food, ease of cooking, and high preservability even in the tropical climate.Those characteristics of rice as a staple food are remarkable compared with yam, cassava, sorghum, millet, corn, and wheat. In addition, rice is consumed almost 100% of the production amount by humans, followed by wheat (approximately 80%). However, corn is produced mainly for livestock feed and bioethanol, 70–80%, except for SSA (National Agriculture and Livestock Industry Promotion Organization, Japan, 2008, Agriculture, Forestry and Fisheries Policy Research Institute, Japan, 2019).

Table 18. Summary of the the fluctuations in international prices from 1971 to 2022 for rice, soybeans, wheat and maize.

1. **General price fluctuation trends of the four crops were very volatile and somewhat similar. This may be affected by climate fluctuation and cycling.**
2. **In the last 50 years, rice prices have been approximately 3 times more expensive than maize and wheat. It has been even 50% more expensive than beans. Since the resources required to produce per tonne are similar, although SSA has the highest production cost because of the lowest productivity worldwide, rice production has the highest benefit for African farmers.**
3. **Reasons: (1) Rice can be easily converted into direct income, with high redeemability; (2) easy distribution, preservation, cooking, and post-harvest; (3) excellent nutrient quality; (4) sustainable high productivity under the improved irrigated sawah platform; (5) the 1st step for mechanisation.**
4. **No devaluation compared to national currency, such as Naira (N) in Nigeria (US$1= ₦0.66 in 1970, = ₦0.55 in 1980, = ₦7.4 in 1990, = ₦86 in 2000, = ₦160 in 2010, =₦160 in 2015, = ₦370 in 2017, = ₦357 in November 2019)**

We also noticed that the characteristics of rice mentioned above provided additional value to the farmers in remote border areas in SSA. As described in Sawah Technology (5): practices and potential, from October 2015 to April 2017, Chad's International Migration Organization (IOM) implemented a settlement project for immigrant refugees using Sawah Technology. The Nigerian Sawah team of the National Centre for Agricultural Mechanization (NCAM) has coordinated the project. As part of this, the NCAM sawah team sent five lead sawah farmers in their sawah village near the city of Bida in central Nigeria to refugee villages for 2 to 3 months in the refugees' villages of Chad. The project sites were near the border of the Central African Republic, Sudan, and the Lake Chad side of Nigeria. The five Nigerian lead sawah farmers trained the refugee farmers. They performed on-site training for the development of irrigated sawah platform using power tillers, both manual and engine-driven techniques for digging and installing tube wells to pump up shallow (shallower than 20 m) groundwater and mobile pump-irrigated sawah-based rice cultivation by refugee farmers' self-help efforts were performed.

Most of the accommodation and staying expenses in the refugee villages were paid by dispatched farmers at first, then farmers prepaid expenses were reimbursed after the completion of the field works and training. Because it was an entrusted business. Therefore, at that time, five rice farmers in Bida, Nigeria, brought 30 kg of milled parboiled rice to refugee villages in Chad. If one person can eat 400 g of polished rice per day, resulting in 1,500 kcal, which is enough to the basal metabolic rate of adults, thus 30 kg would correspond to 75 days of staple food. The important point is that the rice brought to the project site was able to be exchanged for local foods at a very good exchange rate. The rice could be converted or bartered in any village at a price more than 3 times that of corn or cassava. Meat and vegetables were also exchangeable or purchasable. It was worth per unit weight compared with any other staple cereals in SSA. Moreover, it is easy to preserve and rice is cook-able anywhere. The authors recalled the KOKU-DAKA system. KOKU,「石」, means unit volume of rice grains, which is equivalent to approximately 150 kg of milled rice and equivalent to sustaining one adult person's staple food for one year and DAKA,「高」means the amount in Japanese. Rice can also play a role similar to a money in remote villages. Moreover, storing rice is more advantageous in terms of sustain the value than the unstable currency, such as the Nigerian Naira (varying more than twice as much as US$1 = ₦160–420 in just two years in 2015–2017.

5. Comparative trends of population, annual per capita output and import amount (kg), daily average intake (kcal), and yields of major staple food crops in SSA and Asia for last 50 years

Figures 9a and 9b show the changes in production and import volume over the past 50 years of the main staple crop per capita per year in SSA and the population change over the past 50 years. Countries in SSA eat a wide variety of grains and foods. The data for Asia, West Africa, and other countries are shown in the same manner below. Figure 9a shows the FAOSTAT 2020 production or import weight (kg) data divided by population. All data were calculated per capita. The black line shows the trends in the population of the entire country, which corresponds to if the country is or not experiencing population growth. White represents rice production based on paddy; red represents the import volume of rice (also displayed on a paddy basis, the conversion rate of milled rice and paddy is 0.625 × paddy = milled rice). All data were calculated per capita. First, it was wheat on top of rice, then corn, cassava, yam, sorghum, millet, plantains, and potatoes; data on paddy, wheat, corn, sorghum, and millet were reported by FAOSTAT only, but those data on cassava, plantain, and banana were used with a coefficient of one-eighth of the original FAOSTAT data, and yam and potatoes were one-fifth. We used those coefficients of cereals or grain equivalent to making an integrated figure that enables comparison with all food crops. It may be necessary to further study the suitability of grain equivalence counting.
The grain equivalent of the line indicated by the purple horizontal arrow in Figure 9a is 200 kg/person. This figure shows the total amount of grains, including the amount of grain equivalent of various foods, such as cassava, yam, potatoes, and plantains (which have high water content) on the same basis. The per capita grain production and imports of each country of SSA and the breakdown are shown using the same standard. So the purple horizontal arrows of 200kg/person or 1200kcal/day/person show the critical food production level of a region or a country. Thus, if a region and a country produce approximately 200 kg /person of total of various grains, they will not starve. Taking into account the water content, post-harvest losses, etc., one-fifth of the FAO data for potatoes and yams, and one-eighth for plantains and cassava are plotted as conversion factors for the amount of grain production, including paddy, corn, and wheat. This makes it possible to make a unified comparison of the importance of various foods in different countries of SSA.

Figure 9b is a calorie-based calculation using FAO published data to check the validity of the grain equivalent factors of one-fifth and one-eighth in Figure 8a. The 1,200 kcal/person/day line in this figure corresponds to the grain equivalent of the 200 kg/person/year line in Figure 9a. The amount of food production (basal metabolic rate) required for per capita survival. The exact amount may differ by country, depending on the population composition. Because the trends in Figures 9a and 9b are almost equivalent, the grain equivalent factors of one-fifth and one-eighth are scientifically acceptable. This is the supporting evidence for the validity of the grain equivalence coefficients where we used in this paper. We can improve the more practical grain equivalent factors. In contrast, it can be seen that the calorie consumption of each food can be revised to calculate a scientifically more reasonable amount of grain consumption, such as potatoes, yams, plantains, and cassavas if necessary in future.

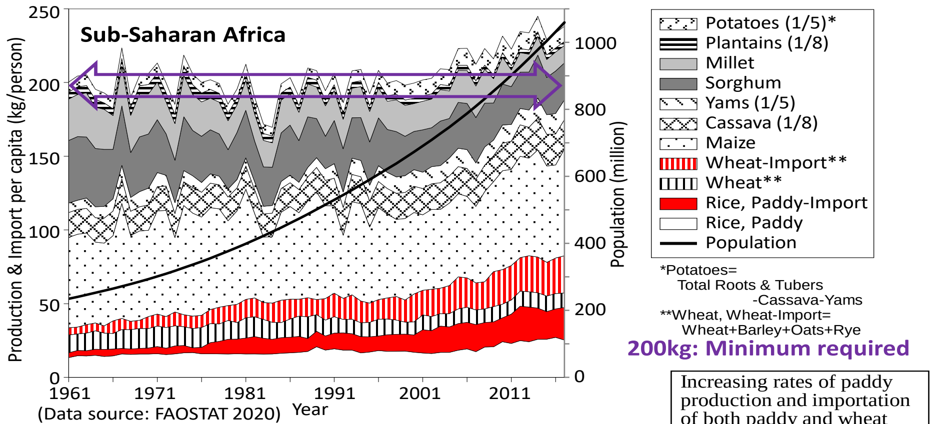
As shown in Figures 9a, 9b, 10a, and 10b, during 1961–2018, the SSA population increased by 4.4 times, the Asian population increased 2.6 times (Tables 1a and 1b). The average annual cereal production per capita and the average calorie intake per day were 200 kg/person (5 kg was wheat and rice imports) in SSA in the 1960s and 1,300 kcal/day (50 kcal was imported, of which two-thirds was wheat). In the 2010s, the average annual cereal production per capita and the average calorie intake per day increased to 220 kg/person and 1,540 kcal/person, but the increase was due to importation, 23 kg/person for wheat, and 21 kg/person for rice, totaling 44 kg/person. The production volume in SSA was 180 kg/person, and the self-sufficiency rate declined. Furthermore, in Asia during the same period, the average annual cereal production per capita increased from 240 to 350 kg/person. No. 1 food was rice, and no. 2 was wheat. Maize has been mainly used as animal feed. The imported amount has been less than half compared with SSA; in particular, rice imports have been very low. The benefits of the green revolution during 1961–2017 are clearly seen in Asia

Note: Tentative verification of cereals' equivalent coefficients of one-eighth for cassava and plantains, and one-fifth for yam and potatoes

As shown in Figures 9a, 9b, 10a, and 10b, while Asian staple foods are concentrated in rice and wheat, SSA has diverse staple food crops, such as maize, sorghum, millet, cassava, yam, wheat, rice, plantain, potatoes, sweet potatoes, and rice. The original weight database of FAOSTAT for these diverse crops includes various water contents. The difference in water content between cereals, roots, and tubers is large. The post-harvest losses are also diverse. Protein and other nutrients are also different. Thus, in order to compare the importance of staple crops uniformly with FAOSTAT's weight-based data, the crop or grain equivalent coefficients of root and tubers, as well as plantains, were tentatively estimated as follows: (1) The original kg weight data of FAOSTAT were divided by 5 for yam and potatoes, while cassava and plantains were divided by 8 to estimate their cereals' equivalent amount for comparison. The reasons are as follows: (1) cassava and yam food energy supply in kcal per g of potatoes and plantain are one-fifth, and a quarter for yam and cassava, resulting in cassava 132 kcal/100 g, potatoes 82 kcal/100 g, yam 100 kcal/100 g, plantain 122 kcal/100 g, milled rice 368 kcal/100 g, maize 365 kcal/100 g, wheat 327 kcal/100 g. (2) The post-harvest losses of cassava and yam are estimated to be 2 times, plantain 1.6 times, and potatoes 1 times of cereals. These conversion factors, one-eighth and one-fifth, respectively, can be supported through the comparison between Figures 9a/9b and many other similar Figures (Figures 10a/10b, 11a/11b, and 12a/12b) on food supply (kcal/capita/day) and those of kg per person in this report. All calculations were performed similarly. In Figures 9a/9b and 10a/10b, for example, the grain equivalent coefficient of one-eighth was applied for cassava, that is, multiplied by one-eighth, and it was made into a figure of 1 t/ha and 2.6 t/ha, respectively. Similarly, the figure was drawn using the coefficient of one-eighth for plantain bananas, but a grain equivalent coefficient of one-fifth was used for potatoes and yam. The plantain was from 6.8 t/ha to 12.3 t/ha (1.8 times), the potatoes from 8.3 t/ha to 19 t/ha (2.3 times), the sorghum from 0.64 t/ha to 1.2 t/ha (1.9 times), and yam from 9.7 t/ha to 18 t/ha (1.9 times). Thus, the yields of almost all staple crops increased more than double during 1961–2015.Note: Tentative verification of cereals' equivalent coefficients of 1/8 for Cassava and Plantains, and 1/5 for Yam and Potatoes

As seen in Fig. 9a and 9b as well as 10a and 10b, while Asian's staple foods are rather simple, i.e., rice and wheat, SSA has very diverse staple food crops, i.e., maize, sorghum, millet, cassava, yam, wheat, rice, plantain, potatoes, sweet potatoes, and rice. Since original weight data base of FAOSTAT for those diverse crops including various water contents. The difference of water contents between cereals and root and tubers are big. Post-harvest losses are also diverse. Protein and other nutrients are also different. Thus in order to compare the importance as staple crops uniformly with FAOSTAT's weight - based data, the crop or grain equivalent coefficients of root and tubers as well as plantain were tentatively estimated as follows, i.e., (1) The original kg weight data of FAOSTAT were divided 5 for yam and potatoes, while cassava and plantains were divided by 8 to estimate their cereals' equivalent amount for comparison. The reasons are as follows, i.e., (1) Cassava and yam Food energy supply, kcal per g of potatoes and plantain are one fifth, a quarter for Yam and cassava, i.e., cassava 132kcal/100g, potatoes 82kcal/100g, yam 100kcal/100g, plantain 122kcal/100g, while milled rice 368kcal/100g, maize 365kca/100g, wheat 327kcal/100g. (2) The postharvest loss of cassava and Yam are estimated 2 times, plantain for 1.6 times, and potatoes for 1.0 of cereals. These conversion factors, 1/8 and 1/5 respectively, can be supported through the comparison between Fig. 9a/9b and many other similar figures (Fig.10a/10b, 11a/11b, and 12a/12b) on food supply (kcal/capita/day) and those of kg per person in this report. All calculations below were carried out in the same way. In figures 9a/9b and 10a/10b, for examples, the grain equivalent coefficient of 1/8 was applied for cassava, i.e., multiplied by one eighth, and it was made into a figure of 1 t/ha and 2.6 t/ha, respectively. Similarly the figure was drawn using the coefficient of 1/8 for plantain bananas, but the grain equivalent coefficient 1/5 was used for potatoes and yam. The plantain was from 6.8 t/ha to 12.3 t/ha (1.8 times), the potatoes from 8.3 t/ha to 19 t/ha (2.3 times), the sorghum 0.64 t/ha is 1.2 t/ha (1.9 times), and yam from 9.7 t/ha to 18 t/ha (1.9 times). Thus the yields of almost all staple crops have increased more than double during 1961-2015.

Figure 9b is a calorie-based calculation using FAO published data to check the validity of the grain equivalent factors of one-fifth and one-eighth in Figure 8a. The 1,200 kcal/person/day line in this figure corresponds to the grain equivalent of the 200 kg/person/year line in Figure 8a. The mean amount of food production, 200kg/person/year is the one to cover the basal metabolic rate required for per capita survival. The exact amount may differ by country, depending on the population composition. Because the trends in Figures 9a and 9b are almost equivalent, the grain equivalent factors of one-fifth and one-eighth are scientifically acceptable for sufficient scientific basis for our purpose of making a unified comparison across regions and countries of diverse staple food crops. We can improve the more practical grain equivalent factors if necessary in future.

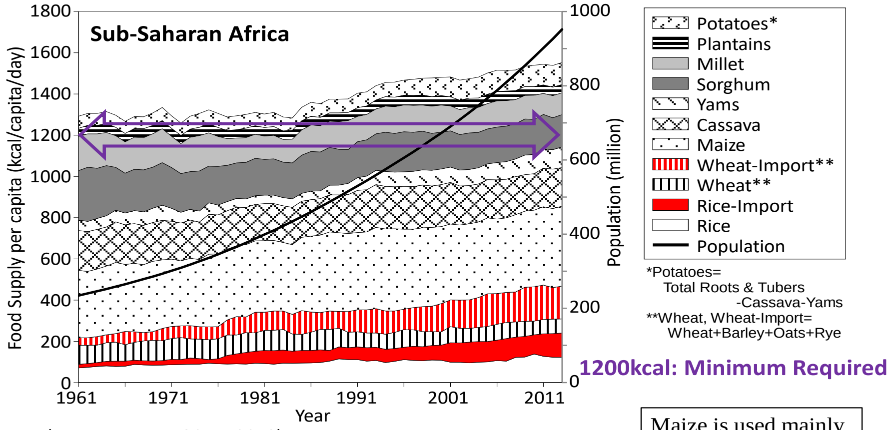


(Data source: FAOSTAT 2020)

Fig.9a. Per capita various food production and import (kg/person) in Sub-Saharan Africa during 1961-2017.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

Increasing rates of paddy production and importation of both paddy and wheat exceeded population growth. Per capita production of both potatoes and yam slightly increased. Per capita, rice consumption became no. 2 in the 2000s. Per capita food production, however, has stagnated over the last 50 years.

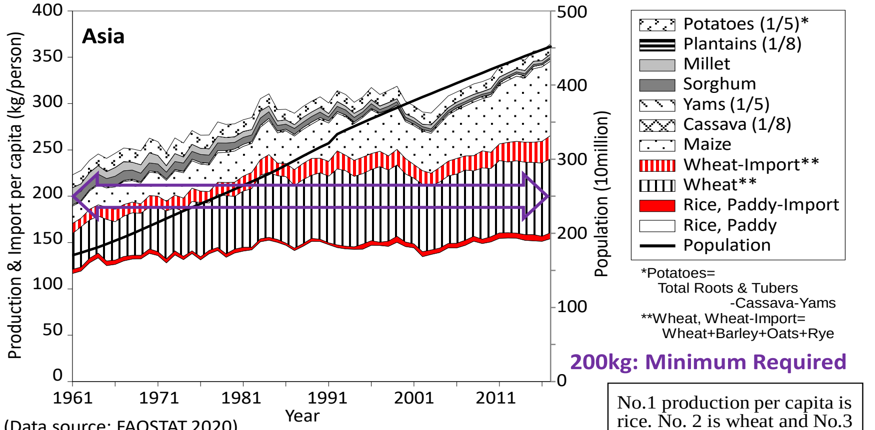


(Data source: FAOSTAT 2019)

Maize is used mainly for food in SSA

Fig.9b. Per capita various food supply (kcal/capita/day) in Sub-Saharan Africa during 1961-2013.

We used the cereals' equivalent coefficients of one-eighth for cassava and plantains and one -fifth for yam and potatoes. These conversion factors can be tentatively verified by comparing values on per capita production and importation amounts in kg and per capita consumption in kcal.



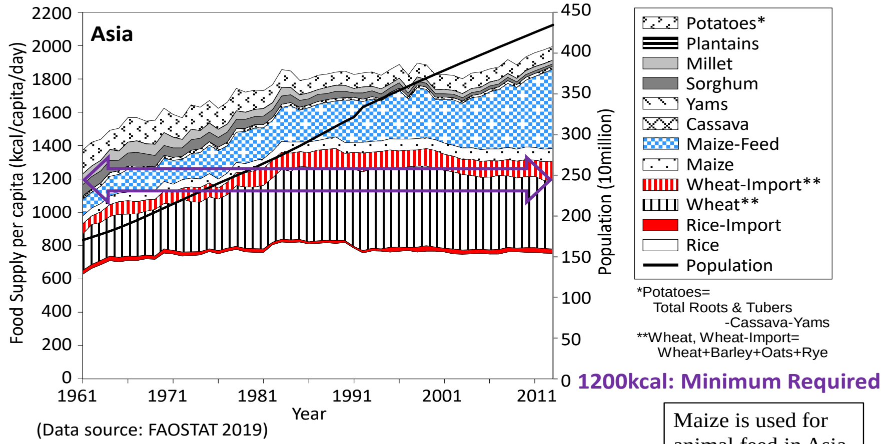
(Data source: FAOSTAT 2020)

Fig.10a. Per capita various food production and import (kg/person) in Asia during 1961-2017.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

No.1 production per capita is rice. No. 2 is wheat and No.3 is maize. All these three grains increased significantly per capita production thanks to the Green Revolution during last 50 years. This is the basic foundation of sustainable and rapid economic growth of Asian counties.

Feed（FAOSTAT, Production-Food Supply Quantity）追加

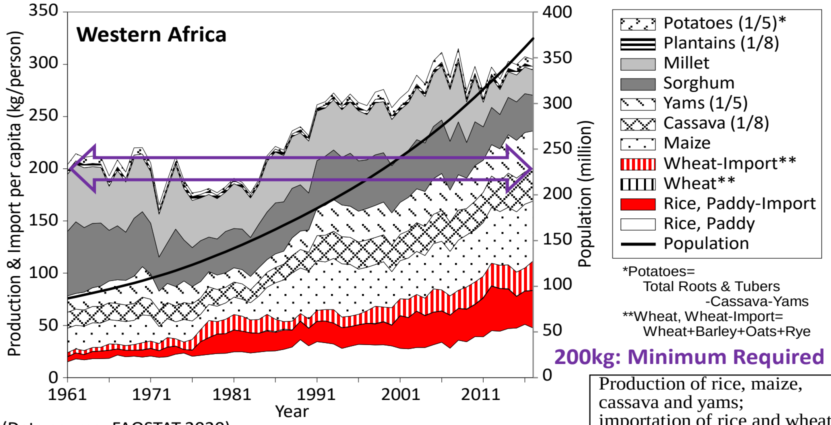


(Data source: FAOSTAT 2019)

Maize is used for animal feed in Asia

Fig.10b. Per capita various food supply (kcal/capita/day) in Asia during 1961-2013.

We used the cereals' equivalent coefficients of one-eighth for cassava and plantains and one -fifth for yam and potatoes. These conversion factors can be tentatively verified by comparing values on per capita production and importation amounts in kg and per capita consumption in kcal.

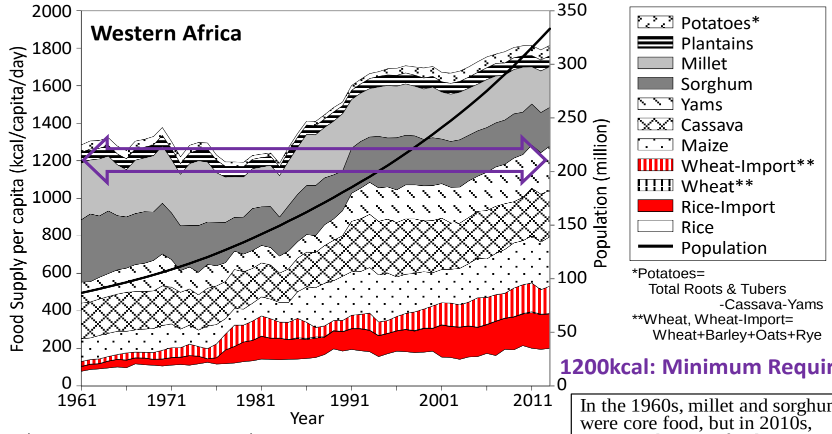


(Data source: FAOSTAT 2020)

Fig.11a. Per capita various food production and import (kg/person) in Western Africa during 1961-2017.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

Production of rice, maize, cassava and yams; importation of rice and wheat increased compare to the population growth. Rice production increased to a level of competition for maize production. Rice consumption ranked No.1 including importation. Overall food production per capita has increased slightly during the last 50 years.

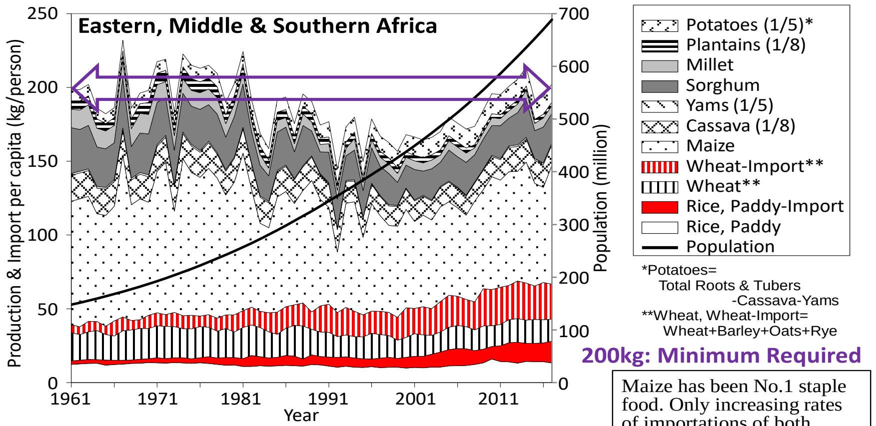


(Data source: FAOSTAT 2019)

Fig.11b. Per capita various food supply (kcal/capita/day) in Western Africa during 1961-2013.

In the 1960s, millet and sorghum were core food, but in 2010s, rice was the No.1 food in Western Africa. However importation has been expanding rapidly even though there has been suitable rice production ecology.

We used the cereals' equivalent coefficients of one-eighth for cassava and plantains and one -fifth for yam and potatoes. These conversion factors can be tentatively verified by comparing values on per capita production and importation amounts in kg and per capita consumption in kcal.

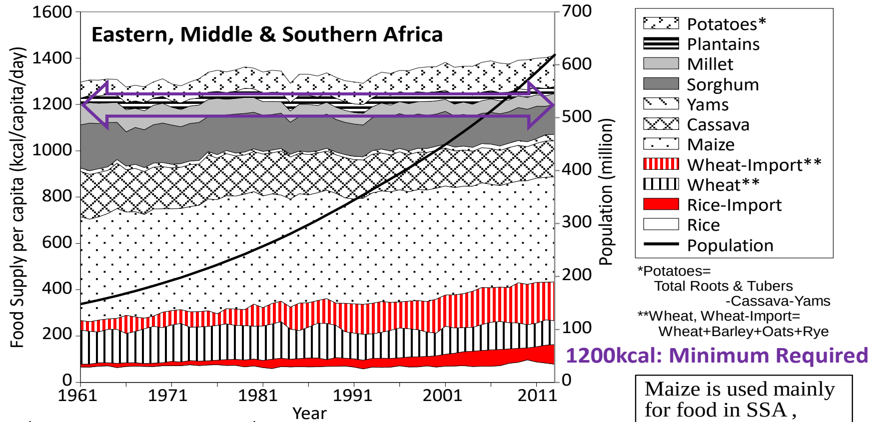


(Data source: FAOSTAT 2020)

Fig.12a. Per capita food production and import (kg/person) in Eastern, Middle & Southern Africa during 1961-2017.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

Maize has been No.1 staple food. Only increasing rates of importations of both paddy and wheat exceeded to population growth. Per capita productions of both potatoes and yam increased slightly. Per capita rice consumption became No.3 in 2000s. No.2 is wheat. Per capita food productions, however, have been stagnated last 50 years.



(Data source: FAOSTAT 2019)

Fig.12b. Per capita various food supply (kcal/capita/day) in Eastern, Middle & Southern Africa during 1961-2013.

Maize is used mainly for food in SSA , Especially in Eastern, Middle & Southern Africa.

We used the cereals' equivalent coefficients of one-eighth for cassava and plantains and one -fifth for yam and potatoes. These conversion factors can be tentatively verified by comparing values on per capita production and importation amounts in kg and per capita consumption in kcal.

Figures 11a and 11b, as well as 12a and 12b, compare the various staple food statuses between Western Africa and other countries of SSA, such as Eastern, Middle, and Southern Africa. The differences between West Africa and East Africa are clear. In East Africa, maize has been the core staple food, but the consumption of wheat has been the second-largest. However, the proportion of wheat self-sufficiency production has declined over the past 50 years. Sorghum was the no. 2 staple food in the 1960s but became no. 4 in the 2010s. Rice has become no. 3 since 2000. However, most of the increase has been covered by imports. The self-sufficiency of food production in this area has declined from the level of 190 kg/person 50 years ago to the level of 154 kg/person in the 2010s, resulting in serious food crises. On the other hand, in West Africa, sorghum and millet that were stapled core foods 50 years ago have been decreasing, and the production of rice, maize, cassava, and yam have increased from 1960 to 2017. However, the importation of rice is increasing rapidly. The total per capita rice consumption was no. 1, and maize was no. 2 in Western Africa in the 2010s. The importation of wheat is also rising. Food self-sufficiency in West Africa increased slightly from a level of 200 kg/person 50 years ago to 230 kg/person in the 2010s.

Figure 11b shows the relative contribution as food calories in Western Africa, basically low lying areas of African continent, which are in the following order: sorghum (No. 1), millet, cassava, maize, rice, yam, wheat, plantains, and potatoes before 1961; and then the order changed to rice (No. 1), cassava, maize, yam, sorghum, millet, wheat, plantains, and potatoes after 2010 to date. In contrast, as shown in Figure 12b, in Eastern/Middle/Southern Africa, basically highland areas of African continent, maize continued to be the No. 1 contribution as food calories, followed by wheat, cassava, sorghum, millet, potatoes, rice, plantains and yam before 1961; and the order changed to maize (still No. 1), wheat, rice, potatoes, cassava, sorghum, millet, plantains, and yam. In SSA, the consumption of rice has increased to No. 1, especially in Western Africa among the nine staple food crops in the last 57 years.

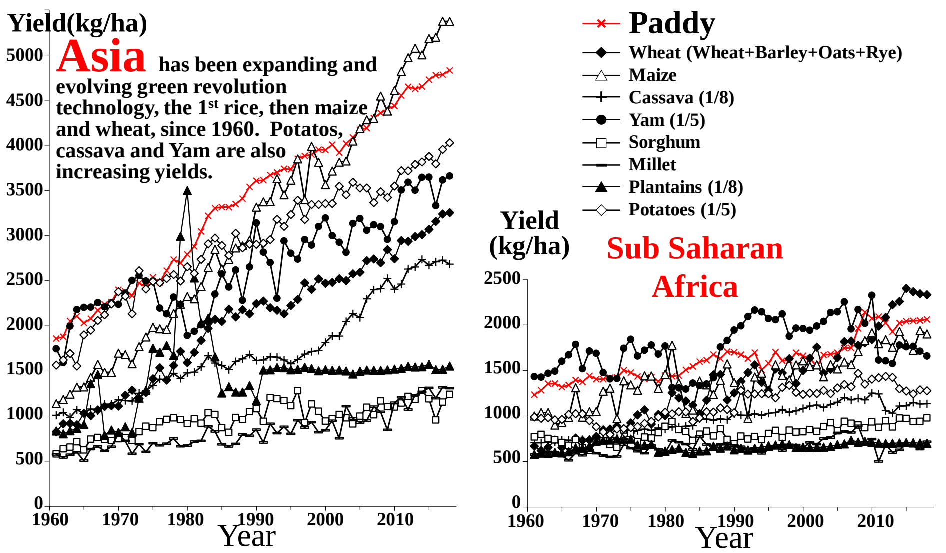


Fig.13. Yield trends of five major cereals, as well as yam and cassava between Asia and Sub Saharan Africa (SSA) during 1961-2018, show that SSA has no clear indication of green revolution except for paddy (FAOSTA 2020).

Figure 13 and Table 19 show the comparison between Asia and SSA for the yield trends of five major cereals, yam, and cassava from 1961 to 2018 (FAOSTAT 2020). Figure 14 and Table 20 show similar comparative yield trends of five major cereals, yam, and cassava between Western Africa and Eastern/Middle/Southern Africa during 1961–2018 (FAOSTAT 2020). In Asia, in the past 50 years, the paddy yield increased from 2.0 to 4.6 t/ha (2.3 times), wheat from 0.92 to 3.0 t/ha (3.3 times), maize from 1.24 to 5.0 t/ha (4.0 times), and potato from 1.7 to 3.8 t/ha (2.3 times). Calculations were based on the 1961–65 and 2011–15 (five year mean averages). These four crops are the major food crops in Asia. The others are minor. However, as shown in Figures 9a and 9b, in SSA, all nine food crops are important foods as calorie sources.

In SSA, the **paddy** yield stagnated from 1.3 to 1.6 t/ha during 1961–2005; however, it increased rather sharply from 1.6 to 2.1 t/ha during 2005–2017. The yields of **wheat and maize** show a somewhat similar trend to that of the paddy during 2005-2017. During 1961–2005, wheat yield increased from 0.67 to 1.6 t/ha and maize yield from 0.98 to 1.5 t/ha; and further increased from 1.6 to 2.2t/ha for wheat and from 1.5 to 1.9 t/ha for maize. **Cassava** increased from 0.72 to 1.1 t/ha in 1961–2005 and 1.1 t/ha in 2017; **plantain** from 0.59 to 0.70 t/ha in 1961–2005 and 0.72

Table 19. Yield(kg/ha) trends of five major cereals as well as yam and cassava between Asia and Sub Saharan Africa (SSA) during 1961-2018. All data are mean of 5 years except for 2016, 2017 and 2018. Data source: FAOSTAT, 2020.

		1961-1965	1966-1970	1971-1975	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000	2001-2005	2006-2010	2011-2015	2016	2017	2018
Asia	Rice, Paddy	1986	2231	2433	2664	3153	3444	3691	3907	4041	4337	4640	4777	4784	4829
	Wheat	918	1081	1277	1560	1927	2168	2201	2433	2535	2749	2990	3156	3238	3255
	Maize	1241	1533	1777	2125	2572	2951	3489	3722	3918	4422	5010	5199	5375	5373
	Cassava (1/8)	1027	1115	1242	1434	1570	1610	1627	1714	2010	2409	2631	2708	2728	2684
	Yams (1/5)	1943	2233	2483	2155	2184	2624	2713	2977	3012	3077	3578	3332	3616	3661
	Sorghum	643	744	815	950	962	978	1125	1068	975	1096	1203	956	1154	1240
	Millet	559	675	660	691	769	756	823	885	943	1019	1219	1199	1318	1311
	Plantains (1/8)	848	1054	1187	2331	1911	1273	1521	1520	1496	1511	1548	1514	1518	1555
	Potatoes (1/5)	1666	2151	2394	2544	2817	2896	3077	3323	3494	3470	3783	3794	3956	4027
SSA	Rice, Paddy	1310	1392	1447	1419	1507	1666	1617	1655	1644	1934	2021	2044	2049	2062
	Wheat	668	733	877	1003	1153	1303	1414	1496	1603	1813	2191	2366	2343	2333
	Maize	982	1077	1256	1385	1324	1382	1296	1514	1524	1722	1822	1722	1938	1902
	Cassava (1/8)	717	746	768	853	904	975	1016	1058	1122	1202	1112	1151	1134	1135
	Yams (1/5)	1485	1676	1577	1722	1323	1661	2092	1996	2050	2145	1667	1763	1713	1658
	Sorghum	755	681	745	790	831	783	770	821	867	915	931	939	943	979
	Millet	585	579	603	624	711	685	633	661	748	798	624	669	638	718
	Plantains (1/8)	592	661	741	655	618	647	650	675	665	715	704	708	703	701
	Potatoes (1/5)	975	981	844	956	1007	1058	1252	1271	1267	1379	1371	1244	1288	1277

t/ha in 2017; **potatoes** from 1.0 to 1.4 t/ha in 1961–2005 and 1.2 t/ha in 2017; **sorghum** from 0.75 to 0.93 t/ha in 1961–2005 and 0.98 t/ha in 2017; **yam** from 1.5 to 1.7 t/ha in 1961–2005 and 1.7 t/ha in 2017; **millet** from 0.59 to 0.6 t/ha in 1961–2005 and 0.66 t/ha in 2017. In general, SSA has no clear indication of the green revolution, except for paddy and wheat, as well as for maize in recent years (FAOSTAT 2019). In 1961–5, paddy yield of Asia was 2.0 t/ha and that of SSA was 1.3 t/ha, with a ratio of 1.5, but in 2011–15 the ratio was 2.3; for maize, this ratio was 1.3 in 1961–5 and 2.7 in 2011; for -potatoes, the ratio was 1.7 in 1961–5 and 2.7 in 2011–15.

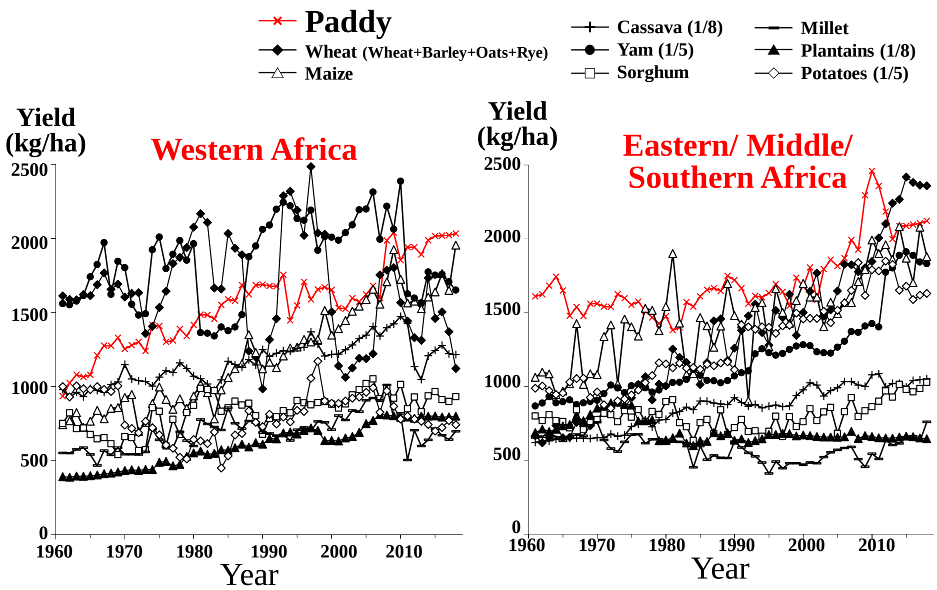


Fig.14. Yield trends of five major cereals as well as yam and cassava between Western Africa and Eastern/ Middle/ Southern Africa during 1961-2018 (FAOSTA 2020).

Table 20. Yield(kg/ha) trends of five major cereals as well as yam and cassava between Western Africa and Eastern/ Middle/ Southern Africa during 1961-2018. All data are mean of five years except for 2016, 2017 and 2018. Data source: FAOSTAT, 2020.

		1961-1965	1966-1970	1971-1975	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000	2001-2005	2006-2010	2011-2015	2016	2017	2018
Western Africa	Rice, Paddy	1036	1268	1328	1351	1512	1651	1620	1654	1569	1830	1955	2019	2021	2032
	Wheat	1603	1680	1511	1871	1925	1448	1913	2014	1140	1625	1454	1503	1369	1120
	Maize	764	851	856	892	958	1194	1204	1358	1494	1713	1581	1761	1649	1954
	Cassava (1/8)	956	1024	1038	1110	1050	1170	1232	1268	1283	1407	1211	1277	1220	1215
	Yams (1/5)	1607	1812	1691	1897	1368	1754	2176	2050	2101	2194	1662	1757	1706	1650
	Sorghum	736	623	696	749	925	828	827	886	935	979	901	912	899	930
	Millet	560	539	598	620	762	736	673	730	830	888	632	671	641	697
	Plantains (1/8)	393	416	447	502	559	603	670	679	677	796	795	793	793	799
	Potatoes (1/5)	979	937	712	572	583	735	790	969	919	886	757	722	769	742
Eastern/ Middle/ Southern Africa	Rice, Paddy	1662	1523	1571	1491	1501	1687	1616	1658	1772	2109	2143	2096	2106	2122
	Wheat	665	730	875	1001	1148	1300	1412	1491	1610	1816	2207	2381	2363	2359
	Maize	1031	1125	1326	1461	1393	1452	1340	1574	1536	1726	1935	1703	2079	1879
	Cassava (1/8)	635	649	678	759	850	894	871	904	986	1031	1024	1040	1046	1051
	Yams (1/5)	894	896	982	989	1058	1043	1180	1248	1246	1376	1756	1888	1843	1832
	Sorghum	781	759	803	829	756	738	706	749	797	849	958	963	987	1028
	Millet	659	698	615	638	583	539	512	473	522	536	603	664	630	760
	Plantains (1/8)	707	794	880	716	637	661	643	675	660	666	654	659	650	645
	Potatoes (1/5)	973	1005	898	1077	1130	1145	1403	1427	1476	1692	1758	1589	1618	1631

Figure 14 and Table 20 show the comparison of yield trends between Western Africa and Eastern/Middle/Southern Africa over the last 57 years. In Eastern/Middle/Southern Africa, maize yield has improved from 1.0 t/ha in 1961–5, 1.5t/ha in 2001–5, 1.9 t/ha in 2011–5, and 1.7–2.1 in 2016–7. Comparative data for wheat are 0.67, 1.6, 2.2, and 2.4–2.5 t/ha; for paddy 1.7, 1.8, 2.1, and 2.1 t/ha. Although wheat productivity has improved, paddy yield stagnated from 1961 to 2017. For potatoes, the comparative data are 0.97, 1.5, 1.8, and 1.6–1.5t/ha. For cassava, the comparative data are 0.64, 0.99, 1.0, and 1,0 t/ha; for sorghum 0.78, 0.80, 0.97, and 0.99–1.1t/ha; for millet 0.66. 0.52, 0.60, 0.67–69 t/ha; for plantains 0.71, 0.66, 0.65, and 0.67–66 t/ha; and for yam 0.89, 1.2, 1.8, and 1.9t/ha. Except for yam, there was no clear improvement in productivity. In Western Africa, although the original yield was very low, the paddy yield has increased constantly, that is, from 1.0 to 1.6 t/ha during 1961–2005, and has accelerated from 1.6 t/ha to 2.0 t/ha during 2011–5, and 2.1 t/ha in 2016–17. Comparative data for cassava are 0.96, 1.3, 1.2, 1.3–1.2 t/ha, for maize 0.76, 1.5, 1.6, 1.8–1.6t/ha, for yam 1.7, 2.1, 1.7, 1.7t/ha, for sorghum 0.74, 0.94, 0.9, 0.9
t/ha, for millet 0.56, 0.83, 0.63, 0.68–0.64 t/ha, for wheat 1.6, 1.1,1.5, 1.5–1.4t/ha, for plantains 0.39, 0.68, 0.8, 0.81–0.83 t/ha, for potatoes 0.98, 0.92, 0.76, -.72–74t/ha. Except for maize and plantains, all the others had no clear indication of productivity improvement. The productivity of paddy in Western Africa and maize in Eastern/Middle/Southern Africa has improved with clear respective regional advantages. Wheat productivity in the
Eastern/Middle/Southern region is improving. These trends reflect the agro-ecological characteristics of both regions. However, the productivity level is still low, and there seems to be great potential for improvement in the future.

6. Data Crosscheck of FAOSTAT and USDA including maize production data of SSA's top 8 countries and Egypt

Some paddy production data of Nigeria from 2015 to 2017 described in FAOSTAT 2018 were revised considerably in FAOSTAT 2019 and the recent production of rice grain and yield data of Côte d'Ivoire was revised by FAOSTAT 2018. The paddy yield data of Guinea presented a constant value of 1.7 t/ha in 1961–2000 and DR Congo 0.74–0.80 t/ha in 1961–2017 (Figure 4b and Table 21b). This does not mean the data was obtained in the field but as "data arbitrarily written" in the office. Data on paddy production in Nigeria and Egypt from 2011 to 2014 showed a difference of over 1 Mt between FAOSTAT and USDA (Tables 21a and 22a). In addition, data on dry season paddy production that started in Nigeria in 2013 had not been properly quantified in FAOSTAT 2018 or USDA2019. At this stage, it is unclear which dataset, FAOSTAT or USDA, is more reliable. It seems more suitable to refer to both data as needed. This is equivalent to Sawah Hypothesis 1 in Sawah Technology and Enclosure in the British Agricultural Revolution. It is very difficult to obtain reliable primary production and area data if farmers' fields are not scientifically demarcated, that is, using eco-technologically. The poor statistical data of majority of the countries of SSA are because the majority of the countries of SSA have poor agricultural platforms, such as sawah system platforms for rice cultivation. That is the reason why the reliability of published SSA statistical data is poor, including the irrigated area and irrigated rice cultivation area.

Table 21a. Paddy production (x 1,000 t) during 1961-2018 (Egypt and Sub Saharan Africa Rank 1-8 of rice producing countries. The rank is based on mean annual paddy production during 2011-15). All data are mean of 5 years except for 2016, 2017, and 2018 as well as missing annual data. Data source: FAOSTAT, 2020.

	1961-1965	1966-1970	1971-1975	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000	2001-2005	2006-2010	2011-2015	2016	2017	2018
Egypt	1845	2342	2396	2363	2333	2566	4178	5333	5997	6147	5519	5309	4961	4900
Nigeria	207	321	470	596	1300	2216	2980	3248	3139	3885	5426	7564	6608	6809
Madagascar	1563	1779	1943	2037	2087	2271	2430	2511	2898	4055	4032	3816	3601	4030
Tanzania	120	121	229	320	330	653	579	743	1035	1591	2369	3019	2868	3017
Mali	172	158	174	191	165	274	447	678	847	1334	2059	2781	2781	3168
Guinea	230	286	355	441	548	680	844	1048	1150	1469	1957	2136	2198	2340
Côte d'Ivoire	220	321	388	479	451	621	673	624	665	779	1715	2055	2120	2109
Sierra Leone	336	457	502	563	484	501	446	316	490	849	1120	875	897	920
DR Congo	62	146	198	220	273	351	404	344	317	317	763	951	998	990

Table 21b. Paddy yield (t/ha) during 1961-2018 (Egypt and Sub Saharan Africa Rank 1-8 of rice producing countries. The rank is based on mean annual paddy production during 2011-15). All data are mean of 5 years except for 2016, 2017, and 2018 as well as missing annual data. Data source: FAOSTAT, 2020.

	1961-1965	1966-1970	1971-1975	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000	2001-2005	2006-2010	2011-2015	2016	2017	2018
Egypt	5.29	5.08	5.30	5.45	5.67	6.28	7.77	8.67	9.65	9.72	9.53	9.34	9.02	8.83
Nigeria	1.15	1.36	1.67	1.71	2.06	2.10	1.78	1.59	1.38	1.66	1.91	2.02	2.00	2.04
Madagascar	1.85	1.80	1.87	1.78	1.76	1.99	2.08	2.12	2.36	3.15	3.90	4.18	4.93	4.34
Tanzania	1.33	0.94	1.46	1.26	1.29	1.88	1.62	1.58	1.81	1.98	2.39	2.43	2.46	2.51
Mali	1.05	0.95	0.91	1.15	0.99	1.35	1.68	2.04	2.17	2.78	3.14	3.33	3.62	3.27
Guinea	1.70	1.70	1.71	1.71	1.71	1.71	1.71	1.71	1.74	1.65	1.19	1.27	1.22	1.26
Côte d'Ivoire	0.88	1.11	1.24	1.17	1.17	1.17	1.11	1.57	1.94	2.07	2.44	2.61	2.67	2.72
Sierra Leone	1.23	1.40	1.39	1.37	1.33	1.34	1.30	1.21	1.03	1.57	1.68	1.14	1.15	1.15
DR Congo	0.74	0.79	0.77	0.78	0.83	0.80	0.74	0.75	0.75	0.76	0.76	0.76	0.76	0.76

Table 22a. Paddy production (x 1,000 t) during 1961-2019 (Egypt and Sub Saharan Africa Rank 1-8 of rice producing countries). All data are mean of 5 years except for 2016 and 2017 as well as missing annual data. Data source: USDA, PS&D Online, 2020.

	1961-1965	1966-1970	1971-1975	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000	2001-2005	2006-2010	2011-2015	2016	2017	2018	2019
Egypt	1845	2341	2426	2363	2351	2498	4103	5285	5983	6274	6436	6957	6232	4058	6232
Nigeria	356	397	510	634	930	2122	2971	3248	3139	3885	5425	7200	7500	7600	7778
Madagascar	1544	1826	1842	2053	2114	2258	2408	2540	2896	4055	4033	3816	3100	4000	4200
Tanzania	117	143	214	288	358	641	580	746	994	1467	2370	3006	2873	3100	3100
Mali	170	131	141	200	155	264	440	674	854	1225	2074	2782	2708	3168	3000
Guinea	278	344	347	374	393	495	541	753	921	1446	1932	2174	2198	2339	2339
Cote d'Ivoire	218	321	384	472	451	659	718	839	735	793	1715	2054	2118	2006	2154
Sierra Leone	336	459	489	531	495	529	411	317	491	849	1068	1160	1400	1170	1270
DR Congo	62	121	187	223	262	267	437	361	317	315	384	400	400	400	400

Table 22b. Paddy yield (t/ha) during 1961-2019 (Egypt and Sub Saharan Africa Rank 1-8 of rice producing countries). All data are mean of 5 years except for 2016 and 2017 as well as missing annual data. Data source: USDA, PS&D Online, 2020.

	1961-1965	1966-1970	1971-1975	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000	2001-2005	2006-2010	2011-2015	2016	2017	2018	2019
Egypt	5.29	5.08	5.27	5.46	5.73	6.17	7.74	8.68	9.72	10.02	9.11	8.18	8.18	8.78	8.20
Nigeria	1.84	1.75	1.82	1.63	1.45	1.98	1.78	1.59	1.38	1.66	1.91	2.18	2.08	2.11	2.16
Madagascar	1.85	2.01	1.76	1.80	1.78	1.87	2.04	2.10	2.36	2.91	2.78	2.59	2.18	2.67	2.80
Tanzania	1.41	1.11	1.54	1.29	1.97	1.78	1.51	1.56	1.70	1.87	2.39	2.44	2.46	2.58	2.58
Mali	0.98	0.75	0.96	1.25	0.97	1.13	1.66	2.03	2.24	2.61	3.02	3.33	3.53	3.52	3.33
Guinea	1.00	0.95	0.80	0.91	0.87	0.90	1.34	1.50	1.49	1.85	1.61	1.29	1.29	1.37	1.37
Cote d'Ivoire	0.87	1.11	1.18	1.17	1.18	1.14	1.14	1.39	1.77	1.94	2.38	2.28	2.46	2.29	2.39
Sierra Leone	1.23	1.40	1.35	1.32	1.22	1.40	1.33	1.23	1.07	1.57	1.79	1.56	2.16	1.67	1.81
DR Congo	0.90	0.83	0.65	0.76	0.90	0.91	1.00	0.75	0.76	0.75	0.70	0.73	0.73	0.73	0.73

Table 23a. Maize production (x 1,000 t) during 1961-2018 (Egypt and Sub Saharan Africa Rank 1-8 of maize producing countries. The rank is based on mean annual maize production during 2011-15). All data are mean of 5 years except for 2016, 2017 and 2018 as well as missing annual data. Data source: FAOSTAT, 2020.

	1961-1965	1966-1970	1971-1975	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000	2001-2005	2006-2010	2011-2015	2016	2017	2018
South Africa	5272	6376	8519	9406	8259	9164	8006	9475	9796	10325	11699	7779	16820	12510
Nigeria	1109	1150	916	695	1107	4841	6355	5126	5243	7277	9323	11548	10420	10155
Egypt	1913	2322	2539	3012	3510	4129	4975	5985	6475	6949	7758	7818	8543	7300
Ethiopia	743	856	904	1229	1274	1701	1556	2802	3137	4005	6767	7847	8007	7360
Tanzania	702	661	871	1605	1835	2496	2240	2345	3492	4116	5488	5863	5918	5987
Kenya	1164	1490	1780	2139	2084	2599	2536	2264	2684	2889	3612	3339	3688	4014
Malawi	838	1053	1222	1284	1357	1354	1396	1980	1617	3095	3542	2369	3464	2698
Zambia	646	702	1115	1289	937	1435	987	974	929	1737	2875	2873	3607	2395
Uganda	215	336	468	515	368	469	758	914	1202	1913	2689	2670	2992	2964

Table 23b. Maize yield (t/ha) during 1961-2018 (Egypt and Sub Saharan Africa Rank 1-8 of maize producing countries. The rank is based on mean annual maize production during 2011-15). All data are mean of 5 years except for 2016, 2017 and 2018 as well as missing annual data. Data source: FAOSTAT, 2020.

	1961-1965	1966-1970	1971-1975	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000	2001-2005	2006-2010	2011-2015	2016	2017	2018
South Africa	1.23	1.42	1.80	2.04	1.80	2.00	1.91	2.49	2.92	4.08	4.43	4.00	6.40	5.39
Nigeria	0.86	0.92	0.91	1.20	1.26	1.36	1.19	1.36	1.53	1.91	1.55	1.76	1.59	2.09
Egypt	2.89	3.62	3.64	3.83	4.31	5.17	6.04	7.30	7.73	7.88	7.67	7.61	7.79	7.80
Ethiopia	0.96	1.03	1.07	1.53	1.62	1.59	1.39	1.67	1.75	2.30	3.28	3.67	3.74	3.29
Tanzania	0.79	0.64	0.83	1.22	1.35	1.37	1.40	1.74	1.79	1.36	1.41	1.45	1.45	1.46
Kenya	1.19	1.21	1.30	1.44	1.72	1.83	1.81	1.50	1.68	1.59	1.70	1.43	1.76	1.87
Malawi	0.99	1.06	1.13	1.22	1.17	1.09	1.09	1.49	1.06	2.01	2.11	1.42	2.01	1.60
Zambia	0.84	0.83	1.09	1.65	1.81	1.95	1.58	1.59	1.66	2.23	2.75	2.48	2.52	2.21
Uganda	1.11	1.11	1.27	1.34	1.26	1.28	1.51	1.50	1.69	2.01	2.45	2.36	2.56	2.62

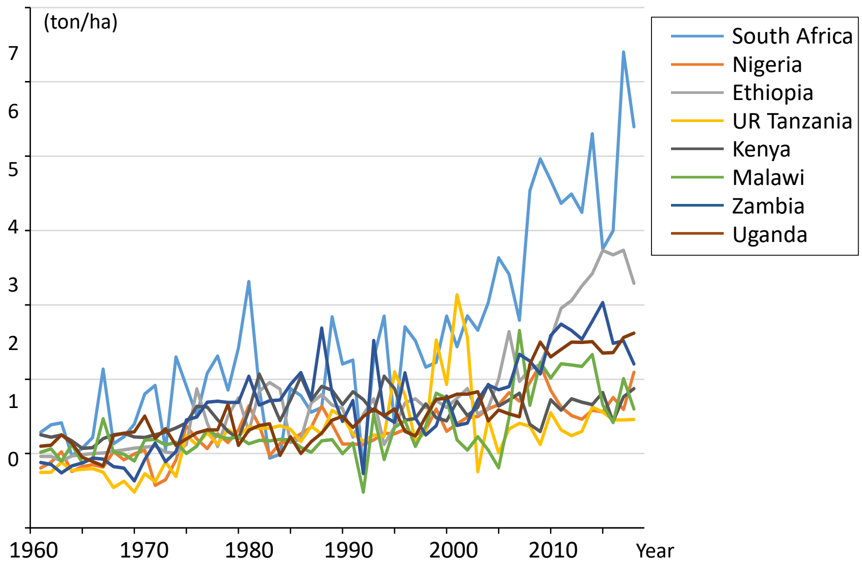


Fig.15. Maize yield during 1961-2018（Sub Saharan Africa Rank 1-8 of rice producing countries) Data source: FAOSTAT 2020

Tables 23a and 23b show maize production data for comparison with paddy production data in SSA, which show the changes in the 5-year average of production and yield of maize in the countries of SSA's no. 1 to no. 8, including Egypt during 1961–2015. Both production volume and yield increased in all nine countries. As already mentioned, except for Nigeria, Eastern/Middle/Southern African countries accounted for no. 2–8. The greatest increase in production in the past 50 years was Nigeria in absolute amount, with 8.2 Mt, 8.4 times increase between 1961–65 and 2011–15. In terms of the ratio increase, no. 1 was Uganda, 12.5 times increase between 1961–65 and 2011–15. In other countries, the production increase ratio was 9.1 times for Ethiopia and 2.2 times for Southern Africa. Although this increased production is remarkable, it is small compared to rice production increase during the same period, 1961–2015. Figure 15 shows the maize yield trends of the top 8 countries in SSA in 1960–2017. South Africa reached a value higher than 6 t/ha in 2017. Ethiopia reached a level of 4 t/ha during 2015–2017. Egypt is still no. 1 in Africa, higher than 7 t/ha in the last 10 years. This is because of the higher solar radiation, irrigation of the Nile River water with more advanced evolutional stage of sawah platform, 4-6, compared to other areas.

7. General ranking trend of paddy production and yields of the countries of SSA ranked 1st-8th, 9th-16th, 17th-24th and below 25th during 1961-2018/2019.

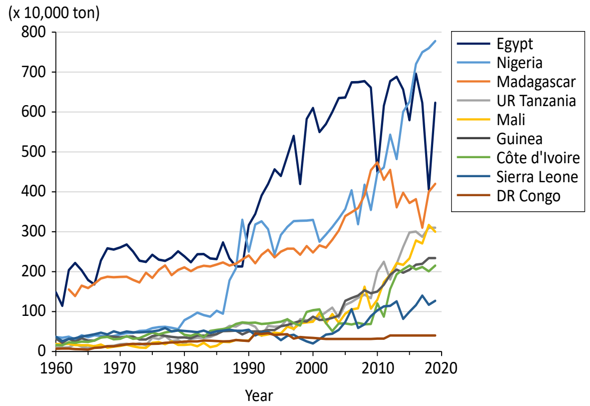


Fig. 16. Paddy production during 1960-2019 (Egypt and Sub-Saharan Africa Rank 1-8 of rice producing countries)

Data source: USDA, PS&D Online, 2020

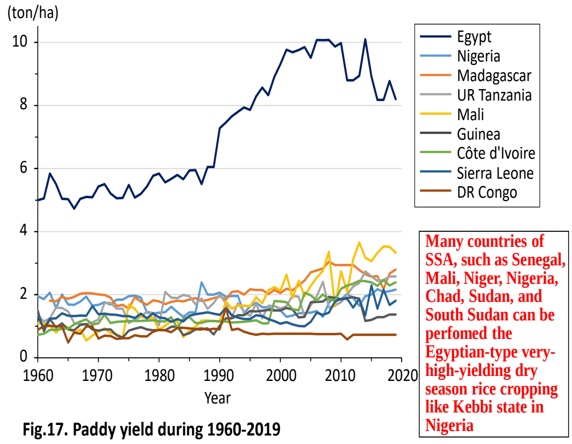


Fig.17. Paddy yield during 1960-2019 (Egypt and Sub-Saharan Africa Rank 1-8 of rice producing countries)

Data source: USDA, PS&D Online, 2020

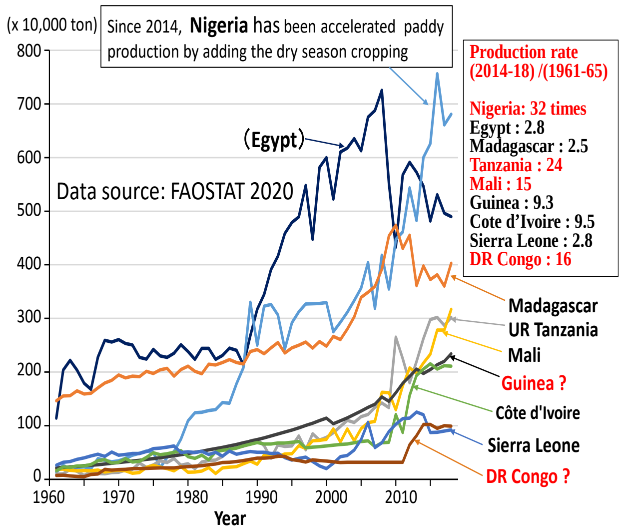
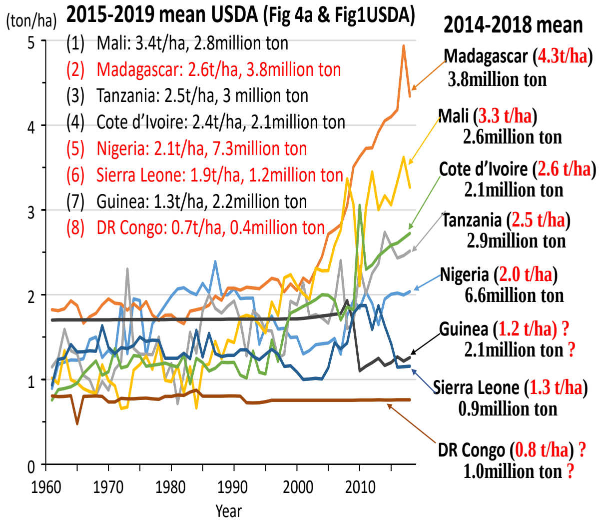


Fig.1. Paddy production during 1961-2018 (Egypt and Sub Saharan Africa rank 1-8 of paddy producing countries)



Data source: FAOSTAT 2020
USDA 2020

Fig.4b. Paddy yield during 1961-2018 (Countries in the SSA Rank 1-8 of rice production)

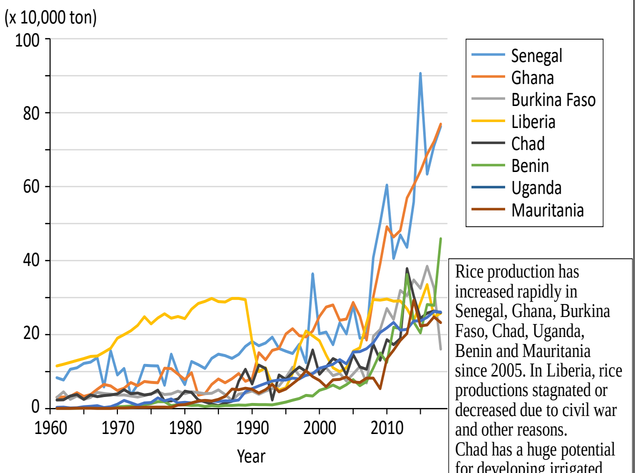


Fig.18. Paddy production during 1961-2018 (Sub-Saharan Africa Rank 9-16 of rice producing countries).

Data source: FAOSTAT 2020

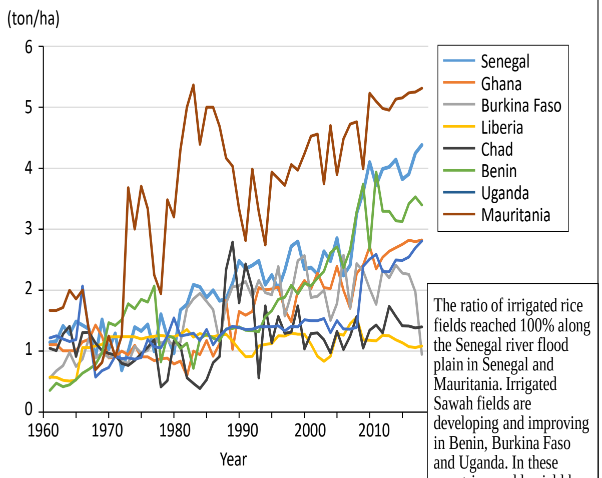
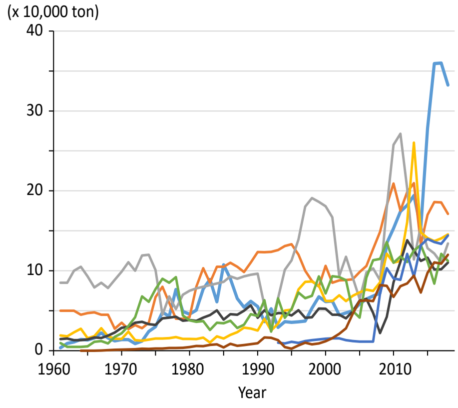


Fig.19. Paddy yield during 1961-2018 (Sub-Saharan Africa Rank 9-16 of rice producing countries).

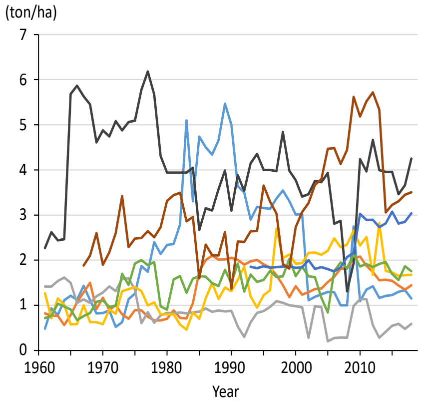
Data source: FAOSTAT 2020



Although paddy production fluctuated widely in Mozambique, Guinea-Bissau, Malawi, and Kenya; paddy production is increasing rapidly in Togo and Ethiopia, in addition to the above countries, since 2011. Although Cameroon had huge SEMRY and other irrigation sites, upland rice cultivation has expanded in recent years, which resulted in lower paddy yield as shown in Figure 21

Fig.20. Paddy production during 1961-2018 (Sub- Saharan Africa Rank 17-24 of rice producing countries).

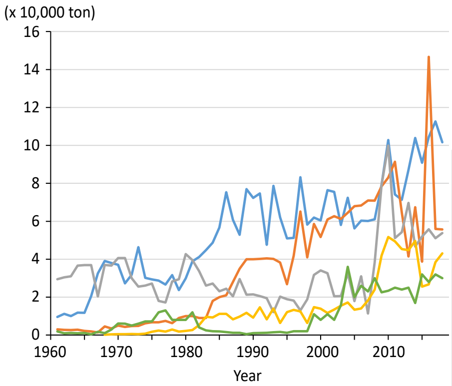
Data source: FAOSTAT 2020



It is necessary to pay attention to the decline of yield in Kenya, where irrigated rice fields are nearly 100%. Countries that have recently started cultivating paddy such as Ethiopia and Rwanda show improved paddy yields.

Fig.21. Paddy yield during 1961-2018 (Sub-Saharan Africa Rank 17-24 of rice producing countries).

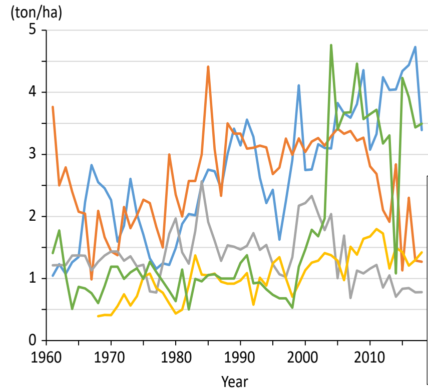
Data source: FAOSTAT 2020



Recent expansion of paddy production in Burundi and Zambia is dramatic. Gambia is a traditional rice-producing country. Paddy production in Gambia and other countries has increased since 2005. Sudan has a huge potential along the Nile River flood plain. The Sudd wetlands in South Sudan have huge potential for developing irrigated Sawah systems that are equal to or higher than Nigeria. However, paddy production is currently low because of political and social conflicts.

Fig.22. Paddy production during 1961-2018 (Sub-Saharan Africa Rank below 25 of rice producing countries)

Data source: FAOSTAT 2020



The recent high value in Sudan may have resulted from the spread of Egyptian-style irrigated rice farming at the huge, 1Mha, Gezira irrigation scheme on Nile flood plains/inland delta in recent years or a statistical data error caused by the independence of South Sudan.

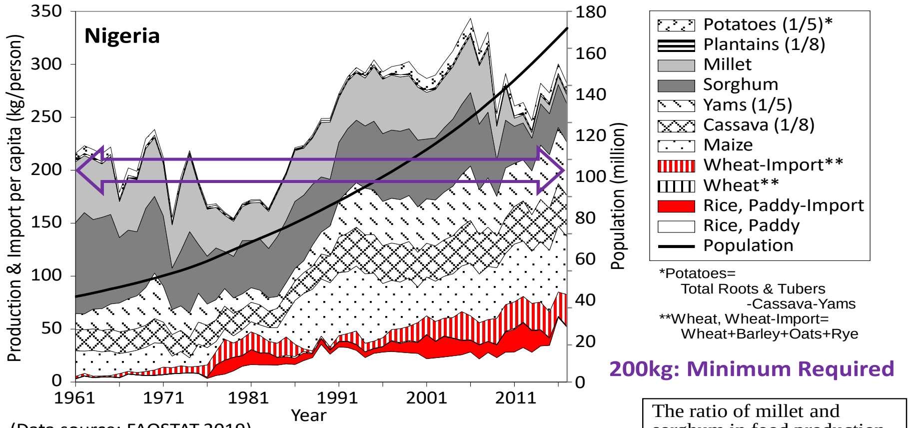
Fig.23. Paddy yield during 1961-2018 (Sub-Saharan Africa Rank below 25 of rice producing countries).

Data source: FAOSTAT 2020

8. Comparative importance and trends of major staple crops of rice, wheat, maize, cassava, yam, sorghum, millet, plantains and potatoes in SSA countries for the past 50 years

Figure 24a shows Nigeria's major crops productions and imported amount in kg/person/year in 1961-2017 and 24b shows calorie based food consumption in kcal/person/day in 1961-2015. Please note violet arrows to show the level of 200kg/person/year and 1200kcal/person/day shows the food security level of Nigeria during the last 50 years. Similar figures are shown in Figure 25 for Madagascar, Figure 26 for UR Tanzania, Figure 27a and 27b for Mali, Figure 28 for Guinea, Figure 29 for Cote d'Ivoire, Figure 30 for Sierra Leone, Figure 31 for DR Congo, Figure 32 for Senegal, Figure 33 for Ghana, Figure 34 for Chad, Figure 35 for Liberia, Figure 36 for Benin, Figure 37 for Cameroun, Figure 38 for Ethiopia, Figure 39 for Malawi, Figure 40 for Kenya and Figure 41 for Rwanda.

As shown in the Figure 24, in Nigeria, basically traditional sorghum and millet have been decreased, and rice production and consumption have increased rapidly. In 2017, rice became the number one food in Nigeria, including imports. Although corn is increasing, rice consumption is the No. 1 food in terms of paddy base. It is likely to increase more and more in the future. Figure 25a shows the changes in food production over the past 60 years in Madagascar, the second largest rice-growing country in SSA, Rice cultivation in Madagascar is rice eater and very similar to Asia. However, per capita production is not increasing. Figure 26 shows Tanzania, which is the No. 3 rice producer in SSA now. Tanzania's number one staple food is maize, but rice production is growing rapidly. The rate of increase over the last 60 years far exceeds that of Maize. In recent years, total food production has finally been exceeded the line of 200 kg / person / year. This means that the food situation has improved. According to Figure 27a, rice production is growing rapidly in Mali. Since 2011, it has been 550 kg / person / year, far exceeding the 200 kg / person / year line. Thus this is probably error data.

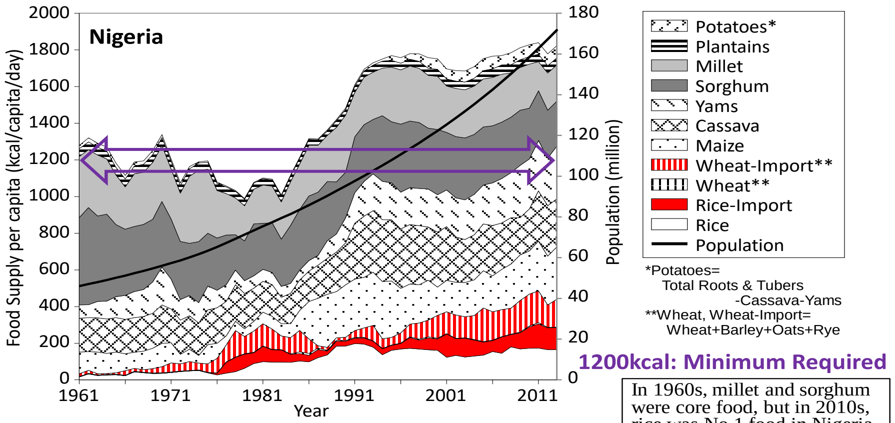


(Data source: FAOSTAT 2019)

Fig.24a. Per capita various food production and import (kg/person) in Nigeria (No.1 rice producing country in SSA) during 1961-2017.

The ratio of millet and sorghum in food production decreased sharply from 70% to less than 20% in the last 50 years. Yams, cassava, maize, rice production and importation increased rapidly. Adding the imported amount to the production, rice has become the No. 1 staple food..

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.



In 1960s, millet and sorghum were core food, but in 2010s, rice was No.1 food in Nigeria. However importation has continuously increased even though under very good and huge rice producing potential.

(Data source: FAOSTAT 2019)

Fig.24b. Per capita various food supply (kcal/capita/day) in Nigeria (No.1 rice producing country in SSA) during 1961-2013.

We used the cereals' equivalent coefficients of one-eighth for cassava and plantains and one -fifth for yam and potatoes. These conversion factors can be tentatively verified by comparing values on per capita production and importation amounts in kg and per capita consumption in kcal.

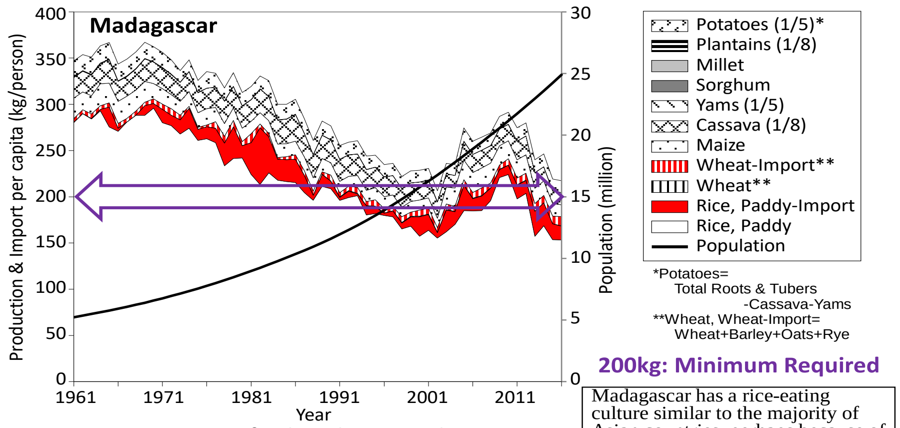
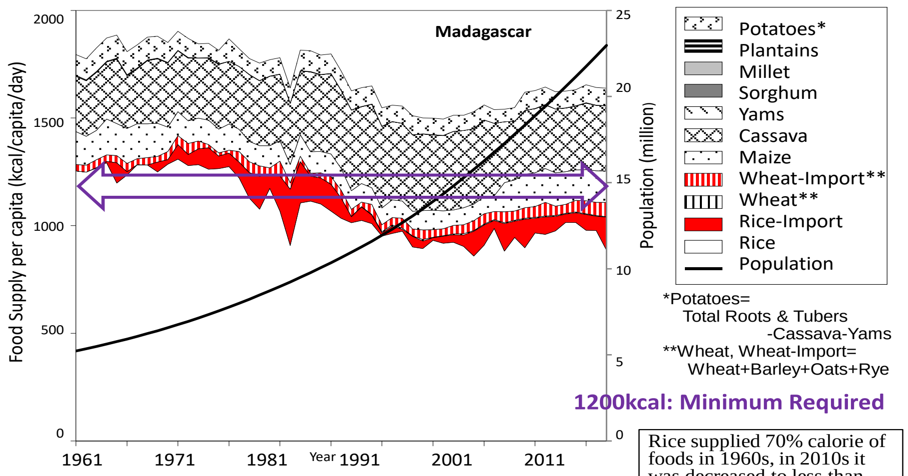


Fig.25a. Per capita various food production and Import (kg/person) in Madagascar (No.2 rice producing country in SSA) during 1961-2017. (Data source: FAOSTAT 2019)

Madagascar has a rice-eating culture similar to the majority of Asian countries, perhaps because of immigrants of Malay–Indonesian origin 1,000–2,000 years ago. More than 80% of Madagascar food is rice. Rice production per capita has been decreasing, especially in the last 20 years. The increase in rice production has not kept up with the population growth. Therefore, in recent years, the food problem has become more serious.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

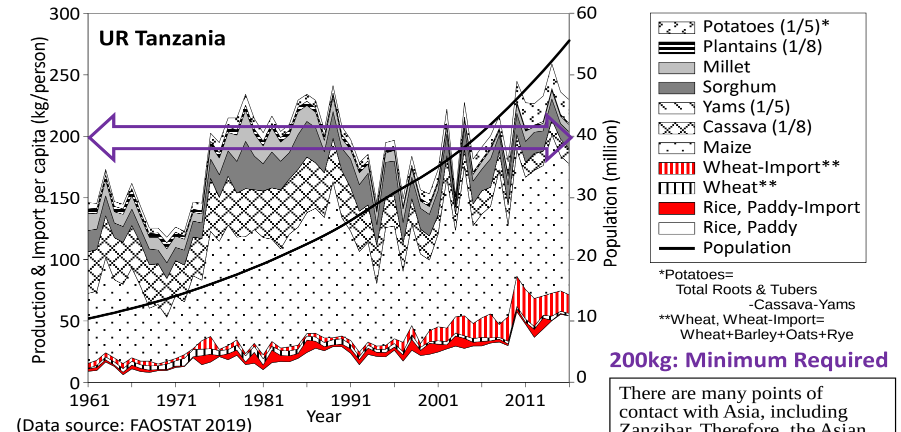


Rice supplied 70% calorie of foods in 1960s, in 2010s it was decreased to less than 60%. Self sufficiency % of rice has been sustaining higher than 90% during 1960-2013. However it had dropped to 85% in 2014.

Fig 25b. Per capita various food supply (kcal/capita/day) in Madagascar (No.2 rice producing country in SSA) during 1961-2013.

We used the cereals' equivalent coefficients of one-eighth for cassava and plantains and one -fifth for yam and potatoes. These conversion factors can be tentatively verified by comparing values on per capita production and importation amounts in kg and per capita consumption in kcal.

(Data source: FAOSTAT 2018)

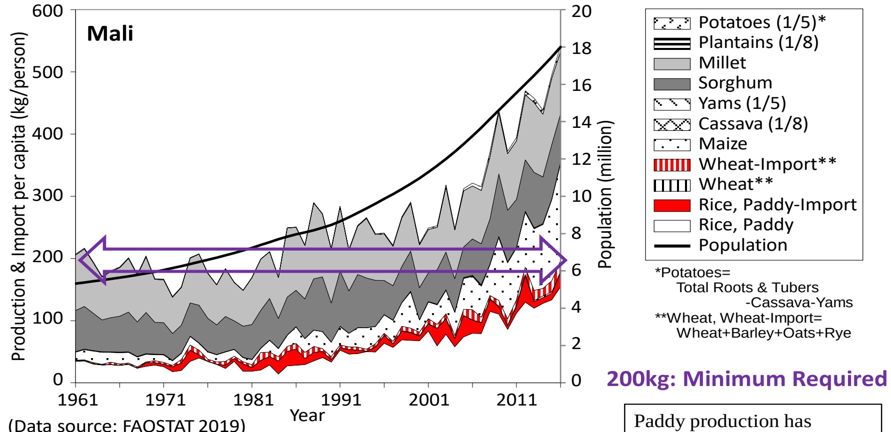


(Data source: FAOSTAT 2019)

Fig.26. Various food production and import (kg/person) in UR Tanzania (No.3 rice producing country in SSA) during 1961-2016.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

There are many points of contact with Asia, including Zanzibar. Therefore, the Asian style irrigated sawah based rice cultivation is progress rapidly. By 2025, paddy production is expected to surpass Madagascar to become SSA's No. 2 paddy-producing country. Although maize is the traditional staple food, the rice diet may become no. 1 before 2050.



(Data source: FAOSTAT 2019)

Fig.27a. Various food production and import (kg/person) in Mali (No.4 rice producing country in SSA) during 1961-2016.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

Paddy production has expanded dramatically over the last 30 years. Currently, rice is the no. 1 food. Recently, the per capita consumption reached more than 100 kg per year, which is similar to that of the Asian countries. The production of maize has recently increased.

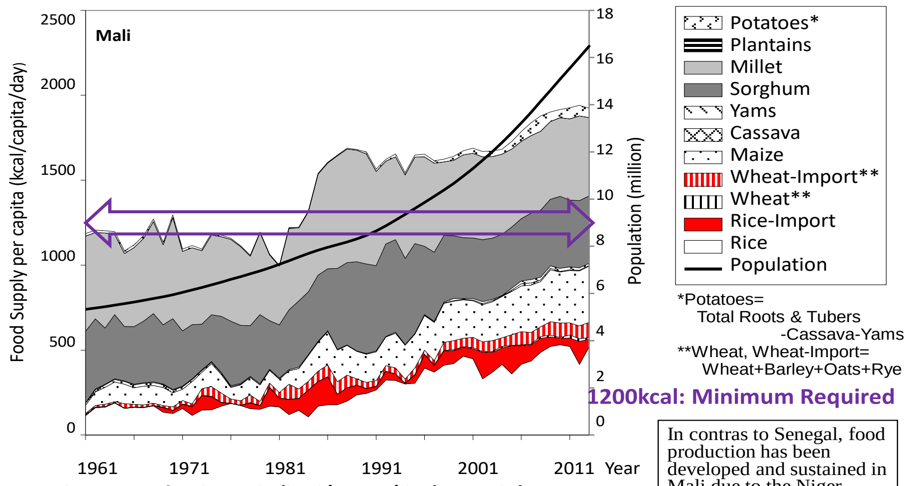
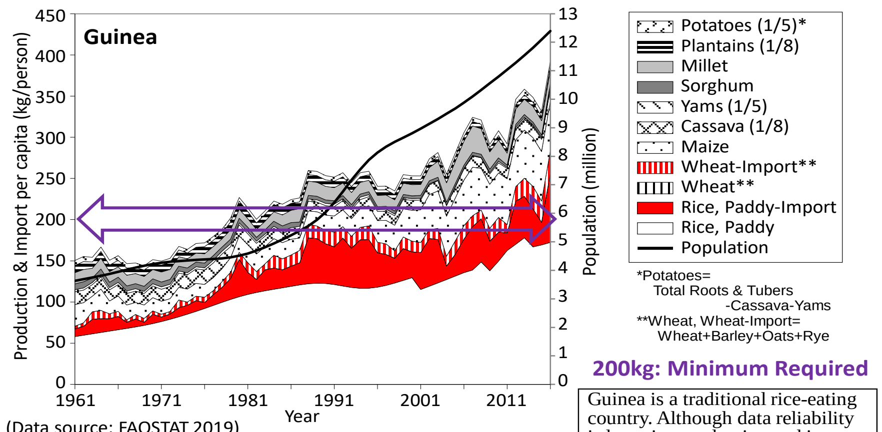


Fig 27b. Various food supply (kcal/capita/day) in Mali (No.4 rice producing country in SSA) during 1961-2013. (Data source: FAOSTAT 2018)

We used the cereals' equivalent coefficients of one-eighth for cassava and plantains and one -fifth for yam and potatoes. These conversion factors can be tentatively verified by comparing values on per capita production and importation amounts in kg and per capita consumption in kcal.

In contras to Senegal, food production has been developed and sustained in Mali due to the Niger River and inland delta. The amount of importation of both wheat and rice is not so visible, which is partly because of the landlocked country.t

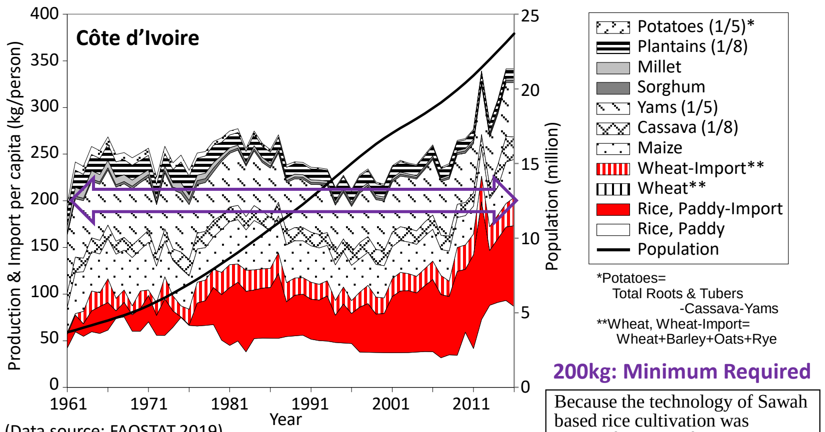


(Data source: FAOSTAT 2019)

Fig.28. Various food production and import (kg/person) in Guinea (No.5 rice producing country in SSA) during 1961-2016.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

Guinea is a traditional rice-eating country. Although data reliability is low, rice production and imports have been increasing from 1960 to 2013. The low credibility of rice data can be confirmed by the straight line of paddy production; the ratio of paddy production to production area (i.e., yield) did not change and it was fixed at 1.7 t/ha in the past 50 years (See Figure 4b).

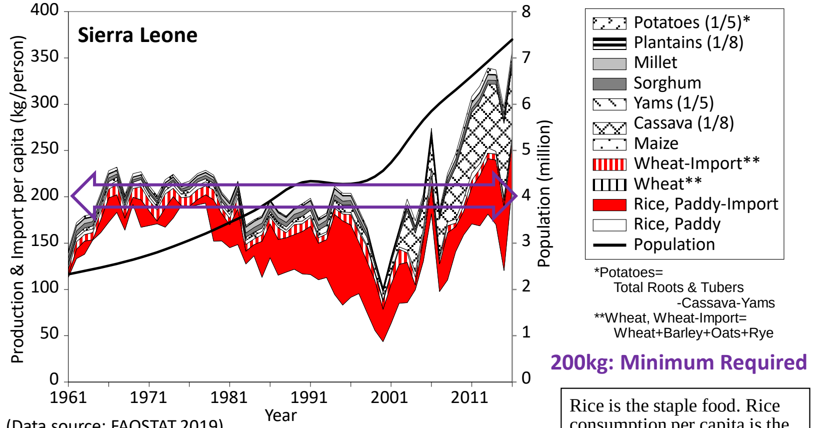


(Data source: FAOSTAT 2019)

Fig.29. Various food production and import (kg/person) in Côte d'Ivoire (No.6 rice producing country in SSA) during 1961-2016.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

Because the technology of Sawah based rice cultivation was successfully transferred by Taiwan team in 1962-1973, per capita rice production was high until 1975. However, it decreased after that. Rice import increased sharply from 2002 by civil war, which ended in 2011. Paddy production has increased since 2011, but the self-sufficiency rate remains at 50%.

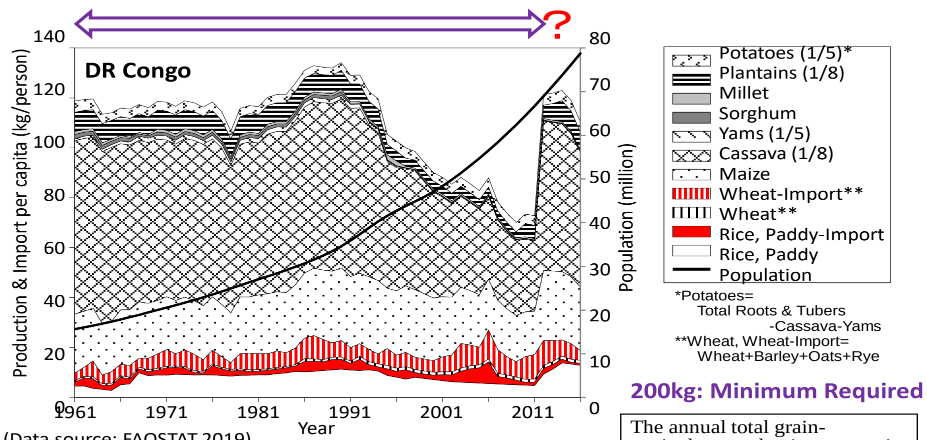


(Data source: FAOSTAT 2019)

Fig.30. Various food production and import (kg/person) in Sierra Leone (No.7 rice producing country in SSA) during 1961-2016.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

Rice is the staple food. Rice consumption per capita is the same as that in Asian countries. Rice production decreased sharply from the 1970s to 2000, particularly during civil war of 1989–1998. The population also decreased during this decade. However, rice production has recovered rapidly in recent years.



(Data source: FAOSTAT 2019)

Fig.31. Various food production and import (kg/person) in DR Congo (No.8 rice producing country in SSA) during 1961-2016.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

The annual total grain-equivalent production per capita is about 100 kg, which is a level at which large-scale hunger occurs. After 1990, the agricultural production decreased including rice by several wars. The credibility of data is extremely low because of the situation typical for failed government.

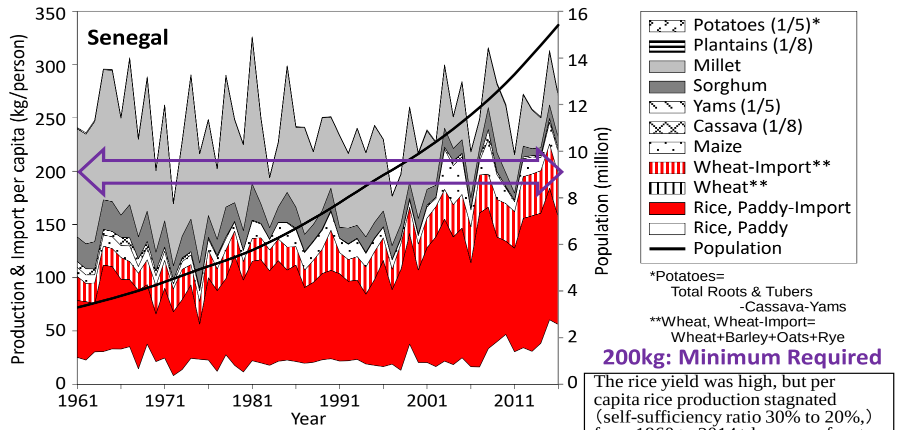


Fig.32. Per capita various food production and import (kg/person) in Senegal (No.9 rice producing country in SSA) during 1961-2016. (Data source: FAOSTAT 2019)

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

The rice yield was high, but per capita rice production stagnated (self-sufficiency ratio 30% to 20%,) from 1960 to 2014+ because of water and lowland shortage along the Senegal river area. Casamance in the south has great potential for rice, but development has been delayed due to political instability. It seems that Senegal's agriculture is in a devastating state. Thus, it is unusual that Senegal is considered to be one of the leading countries in the African Green Revolution.

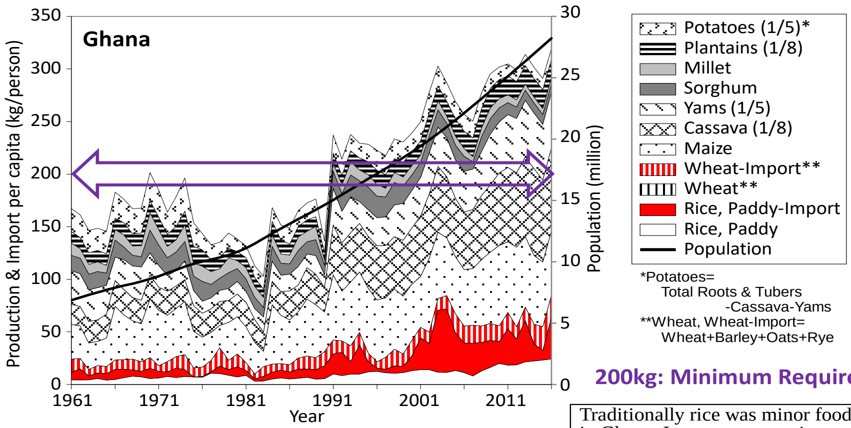
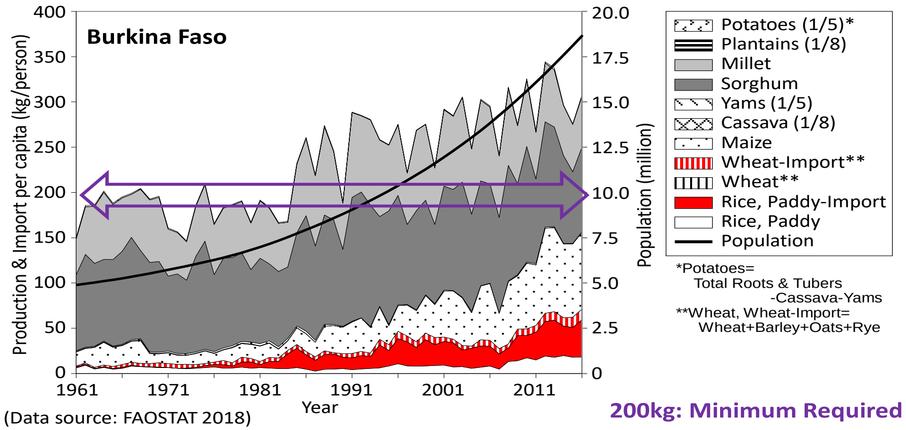


Fig.33. Various food production and import (kg/person) in Ghana (No.10 rice producing country in SSA) during 1961-2016. (Data source: FAOSTAT 2019)

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

Traditionally rice was minor food in Ghana. In recent years, rice both consumption and production has increased, especially rice imports have been increasing more than the increase in its production. The productions of maize, cassava, and yams have also increased. Food production for crops, except for rice, is well developed.

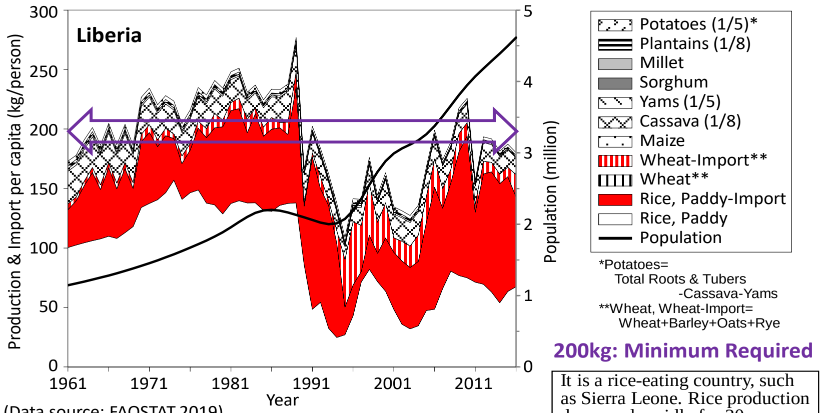


(Data source: FAOSTAT 2018)

Fig. 34. Various Per Capita Food Production & Import (kg/person) in Burkina Faso (No.11 rice producing country in SSA) during 1961-2016.

Cereal equivalent amounts of calories per kg are one fifth for Potato & plantain, one fourth for Yam and cassava (FAO Food composition data). In addition to these, postharvest and storage losses are estimated 2 times bigger than cereals for Cassava, 1.6 times for plantain, 1.3 times for Yam, and 1.0 for potatoes. Thus the cereals conversion ratios of potatoes and Yams are 1/5 and 1/8 for Plantains and Cassava.

Millet and Sorghum production which are traditional food cover population increase. Rice and Maize production increased markedly. Rice import also increased rapidly.

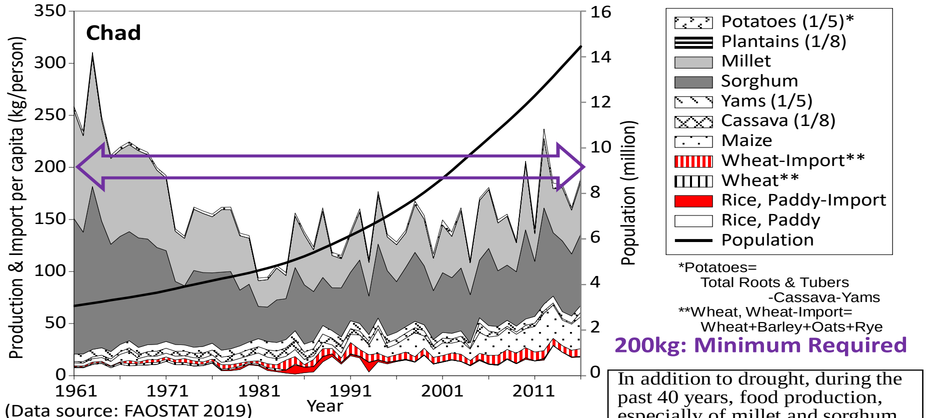


(Data source: FAOSTAT 2019)

Fig.35. Various food production and import (kg/person) in Liberia (No.12 rice producing country in SSA) during 1961-2016.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

It is a rice-eating country, such as Sierra Leone. Rice production decreased rapidly for 20 years from the end of the 1980s to 2003, particularly due to the civil war period for the decade of 1985–95, thereby it experienced a crisis of the continuation as the nation. The population also decreased. Rice production has not recovered even today.

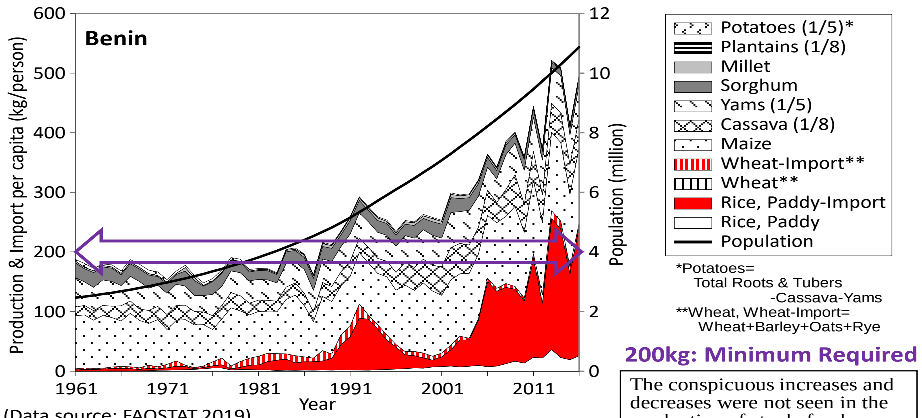


(Data source: FAOSTAT 2019)

Fig.36. Various food production and import (kg/person) in Chad (No.13 rice producing country in SSA) during 1961-2016.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

In addition to drought, during the past 40 years, food production, especially of millet and sorghum, decreased because of wars within Chad and with Sudan and Libya. The production of maize and rice per capita has been increasing rapidly in recent years. The potential for rice production is extremely high because of Africa's main wetlands, that is, the Chad basins.

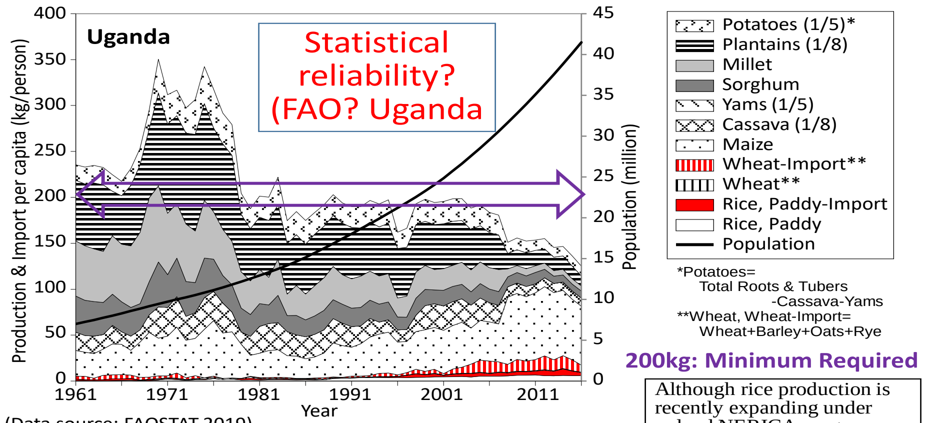


(Data source: FAOSTAT 2019)

Fig.37. Various food production and import (kg/person) in Benin (No.14 rice producing country in SSA) during 1961-2016.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

The conspicuous increases and decreases were not seen in the production of staple food crops in the past 50 years. However, rice imports increased rapidly in 1991 and after 2004. A considerable proportion of this imported rice, which increased rapidly, was suspected to be smuggled into Nigeria. Benin's own rice production has skyrocketed since 2005.

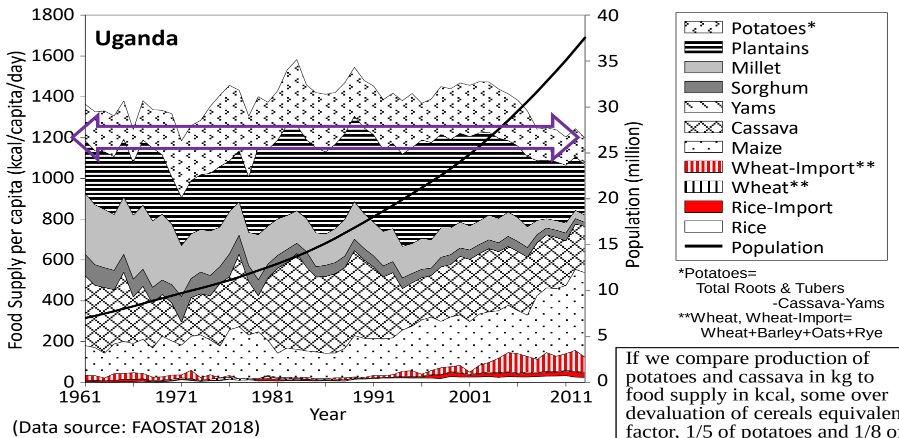


(Data source: FAOSTAT 2019)

Fig.38a. Per Capita Various Food Production & Import (kg/person) in Uganda (No.15 rice producing country in SSA) during 1961-2016.

Cereal equivalent amounts of calories per kg are one fifth for Potato & plantain, one fourth for Yam and cassava (FAO Food composition data). In addition to these, postharvest and storage losses are estimated 2 times bigger than cereals for Cassava, 1.6 times for plantain, 1.3 times for Yam, and 1.0 for potatoes. Thus the cereals conversion ratios of potatoes and Yams are 1/5 and 1/8 for Plantains and Cassava.

Although rice production is recently expanding under upland NERICA program, still it is negligible amount. Traditionally plantain, millet, sorghum and maize are major staples. Food production had decreased after the outbreak of political and social disasters during the late 1970's, especially Millet and Sorghum.

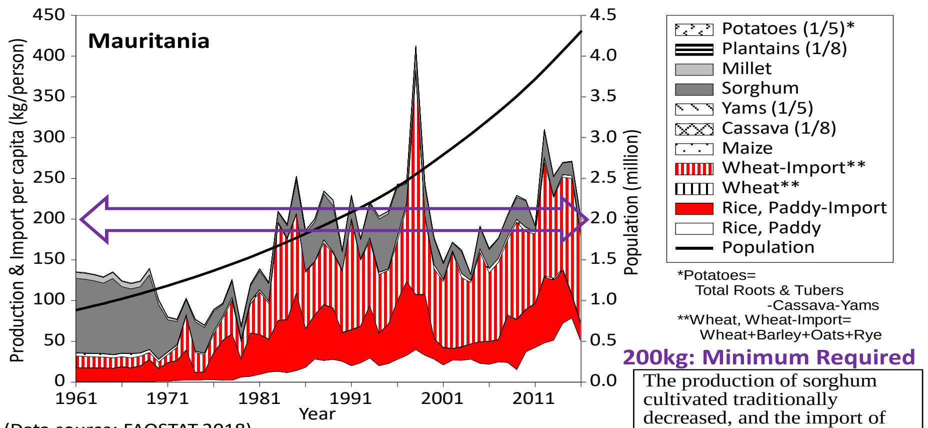


(Data source: FAOSTAT 2018)

Fig.38b, Per Capita Various Food Supply (kcal/capita/day) in Uganda (No.15 rice producing country in SSA) during 1961-2013.

If we compare production of potatoes and cassava in kg to food supply in kcal, some over devaluation of cereals equivalent factor, 1/5 of potatoes and 1/8 of cassava may estimate in Uganda. However, we have to consider the statistical data reliability, too, especially during 1970s.

We used that the cereals' equivalent coefficients of 1/8 for Cassava and Plantains as well as 1/5 for Yam and Potatoes. These conversion factors can be tentatively verified if we compare figure on per capita production and importation amounts in kg and per capita consumption in kcal.

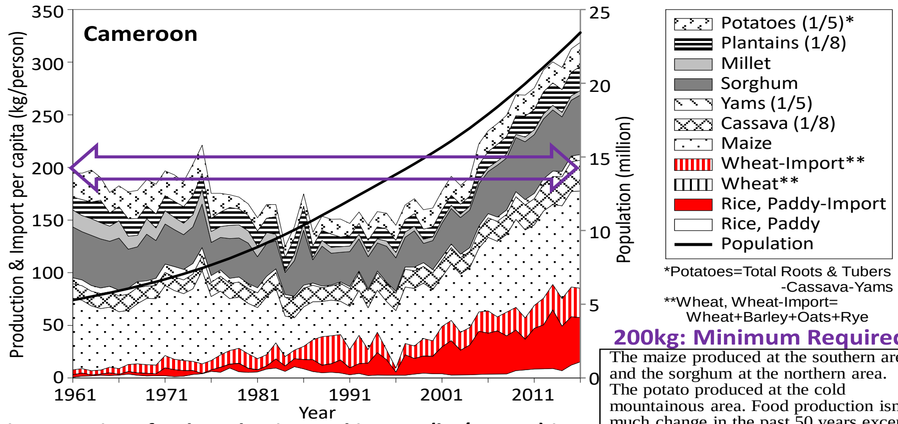


(Data source: FAOSTAT 2018)

Fig 39. Various Food Production & Import (kg/person) in Mauritania (No.16 rice producing country in SSA) during 1961-2016.

Cereal equivalent amounts of calories per kg are one fifth for Potato & plantain, one fourth for Yam and cassava (FAO Food composition data). In addition to these, postharvest and storage losses are estimated 2 times bigger than cereals for Cassava, 1.6 times for plantain, 1.3 times for Yam, and 1.0 for potatoes. Thus the cereals conversion ratios of potatoes and Yams are 1/5 and 1/8 for Plantains and Cassava.

The production of sorghum cultivated traditionally decreased, and the import of rice and wheat increased rapidly. Although the room for production expansion is limited because of the problem of water resources, irrigation rice field is developing at Senegal River flood plain and delta, and the paddy production is increasing with the high yield.

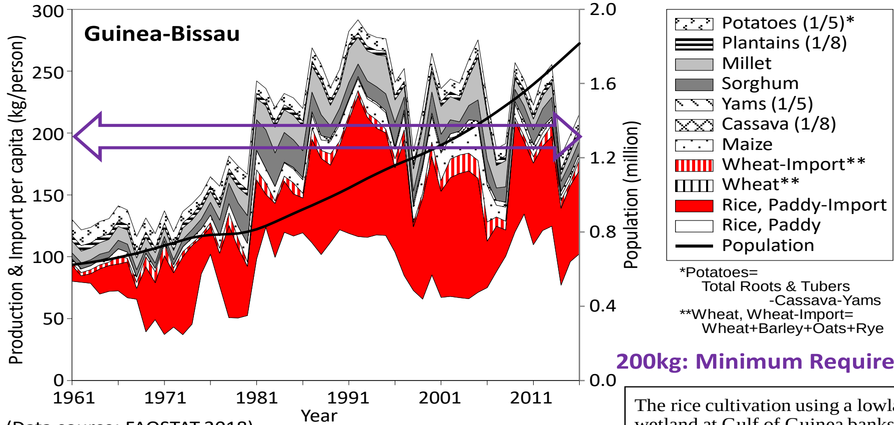


200kg: Minimum Required

Fig.40. Various food production and import (kg/person) in Cameroon (No.17 rice producing country in SSA) during 1961-2016. (Data source: FAOSTAT 2019)

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

The maize produced at the southern area and the sorghum at the northern area. The potato produced at the cold mountainous area. Food production isn't much change in the past 50 years except the decrease of millet. But, the import of wheat and rice is increasing rapidly. Per capita rice production slightly increased in 1980s when management of northern vast irrigated rice field(SEMRY) was carried out, and thereafter decreased. The rice production tend to increase by the CARD support of JICA in late years. Cameroon has huge irrigated sawah potential between the Benue river flood plains and the Lake Chad basin



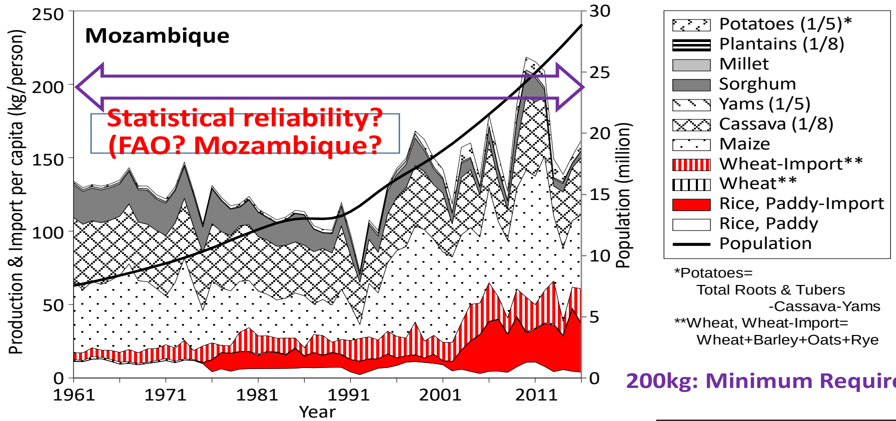
200kg: Minimum Required

(Data source: FAOSTAT 2018)

Fig. 41. Various Food Production & Import (kg/person) in Guinea-Bissau (No.18 rice producing country in SSA) during 1961-2016.

Cereal equivalent amounts of calories per kg are one fifth for Potato & plantain, one fourth for Yam and cassava (FAO Food composition data). In addition to these, postharvest and storage losses are estimated 2 times bigger than cereals for Cassava, 1.6 times for plantain, 1.3 times for Yam, and 1.0 for potatoes. Thus the cereals conversion ratios of potatoes and Yams are 1/5 and 1/8 for Plantains and Cassava.

The rice cultivation using a lowland wetland at Gulf of Guinea banks is traditional agriculture in this country. Although it gained independence from Portugal in 1947, the rice production stagnated because of the continuous internal disturbance after the independence. Rice import is increasing. The rice production tend to increase in late years, and in future?

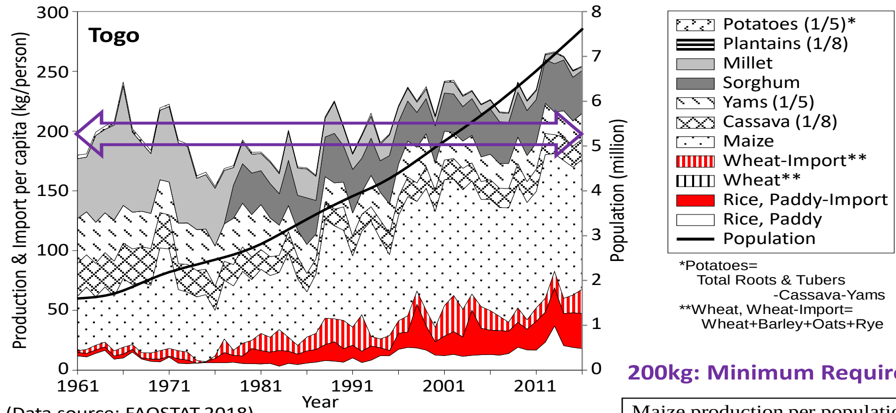


200kg: Minimum Required

Fig. 42. Various Food Production & Import (kg/person) in Mozambique (No.19 rice producing country in SSA) during 1961-2016. (Data source: FAOSTAT 2018)

Cereal equivalent amounts of calories per kg are one fifth for Potato & plantain, one fourth for Yam and cassava (FAO Food composition data). In addition to these, postharvest and storage losses are estimated 2 times bigger than cereals for Cassava, 1.6 times for plantain, 1.3 times for Yam, and 1.0 for potatoes. Thus the cereals conversion ratios of potatoes and Yams are 1/5 and 1/8 for Plantains and Cassava.

Rice production tend to stagnate or decline in the past 50years. The production of other foods are also stagnating at a low level to feed population increase. The import of rice and wheat are increasing rapidly in recent years.



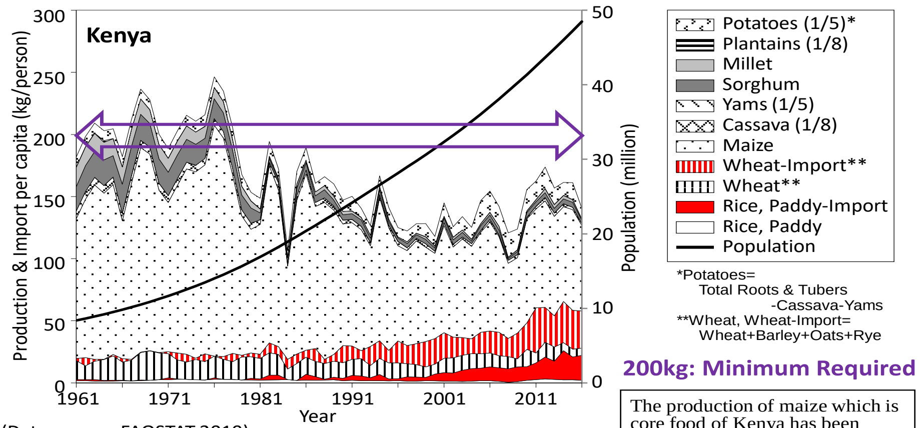
200kg: Minimum Required

(Data source: FAOSTAT 2018)

Fig 43. Various Food Production & Import (kg/person) in Togo (No.20 rice producing country in SSA) during 1961-2016.

Cereal equivalent amounts of calories per kg are one fifth for Potato & plantain, one fourth for Yam and cassava (FAO Food composition data). In addition to these, postharvest and storage losses are estimated 2 times bigger than cereals for Cassava, 1.6 times for plantain, 1.3 times for Yam, and 1.0 for potatoes. Thus the cereals conversion ratios of potatoes and Yams are 1/5 and 1/8 for Plantains and Cassava.

Maize production per population increased markedly. The import of rice and wheat also increased in the past 50 years. Rice production increased in 1960s-1970s when Taiwan supported rice cultivation, but stagnated afterwards. The rice production is getting increase in recent years.



(Data source: FAOSTAT 2019)

Fig.44. Various food production and import (kg/person) in Kenya (No.21 rice producing country in SSA) during 1961-2016.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

The production of maize which is core food of Kenya has been decreased. Wheat production in highlands has been also decreased. These decreases were covered by Potatoes production somewhat and the increase of rice and wheat importation. All together, the agricultural productions are stagnating. Although Kenya attracts a lots of ODA, the effects are not so clear?

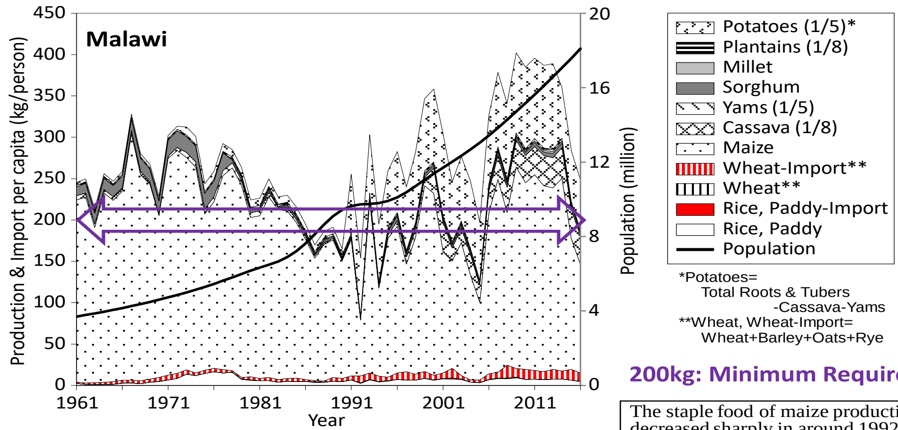


Fig.45. Various food production and import (kg/person) in Malawi (No.22 rice producing country in SSA) during 1961-2016. (Data source: FAOSTAT 2019)

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

The staple food of maize production decreased sharply in around 1992 and around 2004 that were the time of the internal disturbance. The population increase also stopped at the time. The production of potatoes and cassava is increasing in recent years, but agricultural production is on the whole stagnating. Rice production increased in 1970s when Taiwan supported rice cultivation, but stagnated afterwards.

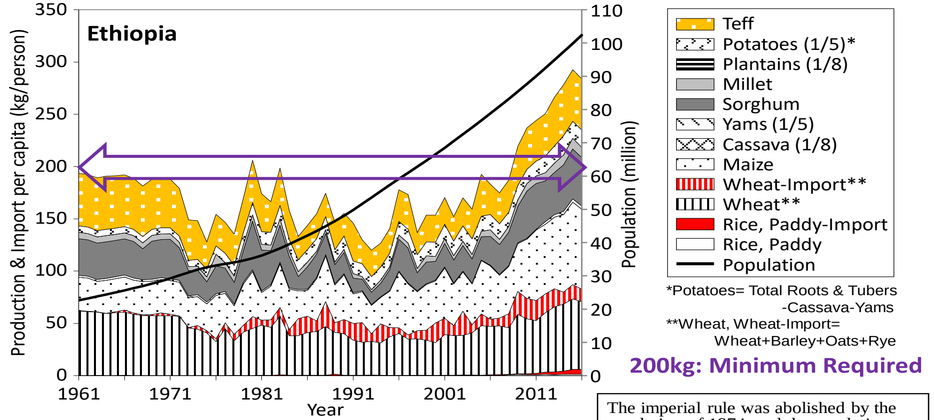


Fig.46. Various food production and import (kg/person) in Ethiopia (No.23 rice producing country in SSA) during 1961-2016. (Data source: FAOSTAT 2019, The World Bank Group 2019)

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

The imperial rule was abolished by the revolution of 1974, and the revolutionary government collapsed in 1991. After that the internal disturbance such as Eritrean disputes continued to 2005, which again started in 2021. Consequently, the agriculture stagnated. In late years it is recovering gradually. The cultivation of wheat, potato and maize at the mountainous area, and sorghum at the arid lowland are main food productions. In late years rice cultivation is started, and the production is increasing rapidly.

テフ (ጤፍ ṭef, teff, *Eragrostis tef*) は、イネ科スズメガヤ属の植物

Teff, *Eragrostis teff*, belongs to *Poaceae* family of plant

https://ja.wikipedia.org/wiki/%E3%83%86%E3%83%95_(%E7%A9%80%E7%89%A9)

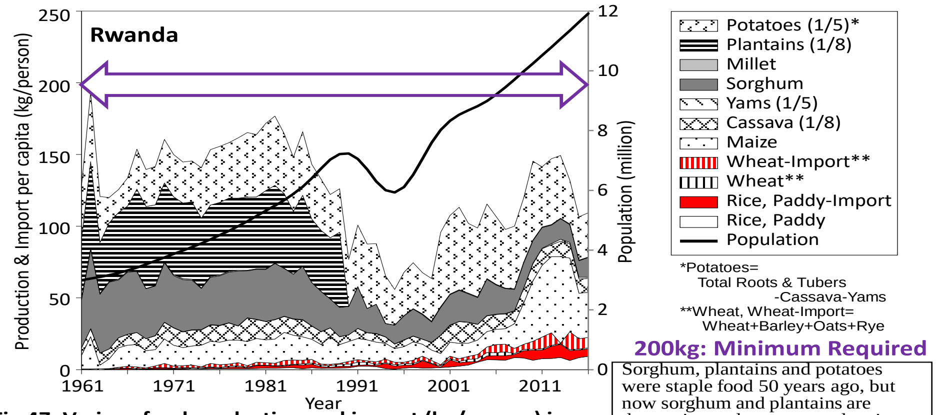
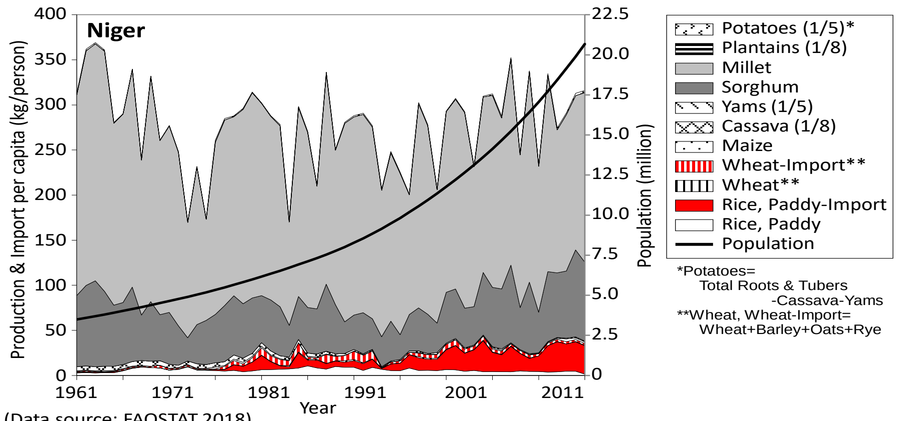


Fig.47. Various food production and import (kg/person) in Rwanda (No.24 rice producing country in SSA) during 1961-2016. (Data source: FAOSTAT 2019)

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

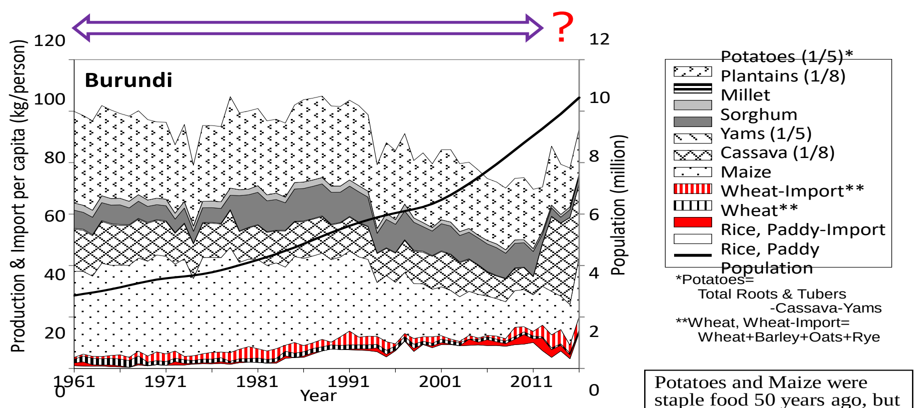
Sorghum, plantains and potatoes were staple food 50 years ago, but now sorghum and plantains are decreasing and potatoes and maize are increasing. The agriculture stagnated from the late 1980s to about 2005. That period was before and after the crisis that 10-20% of the total population were slaughtered in 1994. Rice production was 120,000 t with 3.6 t/ha (2016-2020 mean, FAOSTAT2022). Sawah evolutional stage is 4 -5 by Taiwan's technology transfer in 1960s -1970s.



(Data source: FAOSTAT 2018)

Fig. 48. Various Food Production & Import (kg/person) in Niger (No.25 rice producing country in SSA) during 1961-2016.

Cereal equivalent amounts of calories per kg are one fifth for Potato & plantain, one fourth for Yam and cassava (FAO Food composition data). In addition to these, postharvest and storage losses are estimated 2 times bigger than cereals for Cassava, 1.6 times for plantain, 1.3 times for Yam, and 1.0 for potatoes. Thus the cereals conversion ratios of potatoes and Yams are 1/5 and 1/8 for Plantains and Cassava.

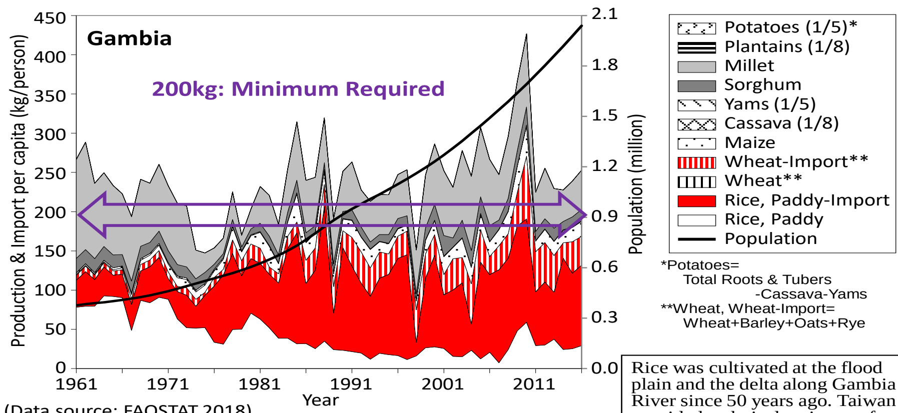


(Data source: FAOSTAT 2018)

Fig. Various Food Production & Import (kg/person) in Burundi (No.26 rice producing country in SSA) during 1961-2016.

Cereal equivalent amounts of calories per kg are one fifth for Potato & plantain, one fourth for Yam and cassava (FAO Food composition data). In addition to these, postharvest and storage losses are estimated 2 times bigger than cereals for Cassava, 1.6 times for plantain, 1.3 times for Yam, and 1.0 for potatoes. Thus the cereals conversion ratios of potatoes and Yams are 1/5 and 1/8 for Plantains and Cassava.

Potatoes and Maize were staple food 50 years ago, but today, Maize is decreasing and Rice is increasing. The agriculture stagnated until around 2010 due to the Rwanda crisis in 1994.

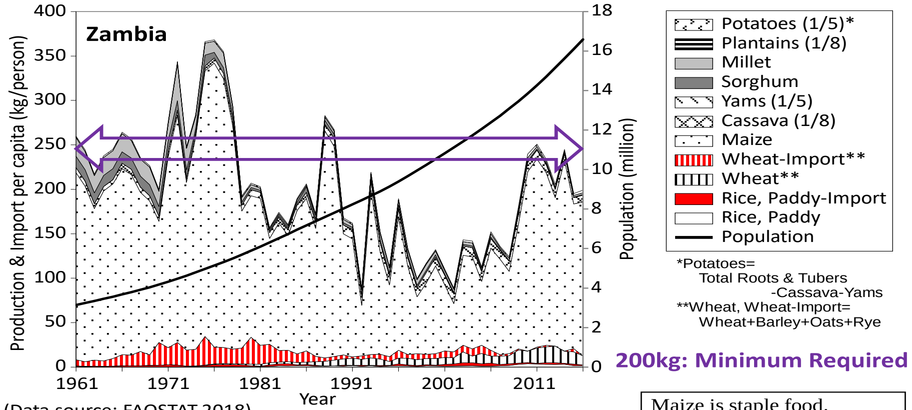


(Data source: FAOSTAT 2018)

Fig. 50. Various Food Production & Import (kg/person) in Gambia (No.27 rice producing country in SSA) during 1961-2016.

Cereal equivalent amounts of calories per kg are one fifth for Potato & plantain, one fourth for Yam and cassava (FAO Food composition data). In addition to these, postharvest and storage losses are estimated 2 times bigger than cereals for Cassava, 1.6 times for plantain, 1.3 times for Yam, and 1.0 for potatoes. Thus the cereals conversion ratios of potatoes and Yams are 1/5 and 1/8 for Plantains and Cassava.

Rice was cultivated at the flood plain and the delta along Gambia River since 50 years ago. Taiwan provided technical assistance for rice cultivation for a long term from the 1960s. However, the rice production stagnated by the collapse of Senegambia confederation formed of former French Senegal and former British Gambia (1989) and the political unrest. Because Gambia is in a agricultural crisis, rice import is increasing rapidly.

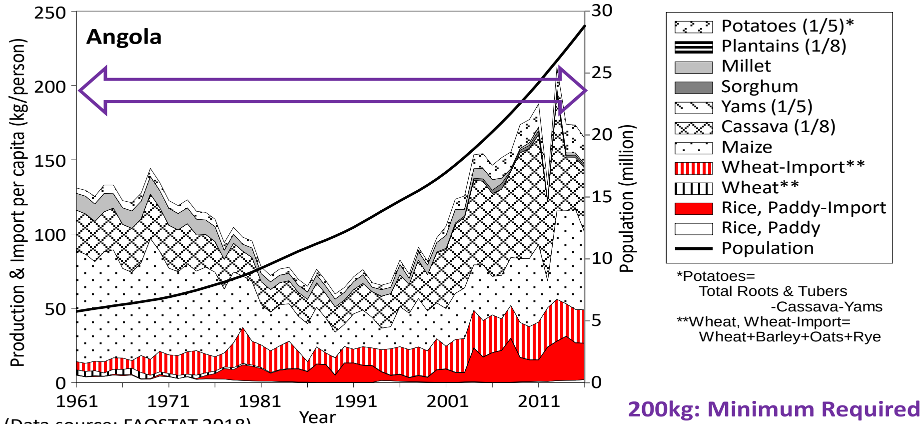


(Data source: FAOSTAT 2018)

Fig. 51. Various Food Production & Import (kg/person) in Zambia (No.28 rice producing country in SSA) during 1961-2016.

Cereal equivalent amounts of calories per kg are one fifth for Potato & plantain, one fourth for Yam and cassava (FAO Food composition data). In addition to these, postharvest and storage losses are estimated 2 times bigger than cereals for Cassava, 1.6 times for plantain, 1.3 times for Yam, and 1.0 for potatoes. Thus the cereals conversion ratios of potatoes and Yams are 1/5 and 1/8 for Plantains and Cassava.

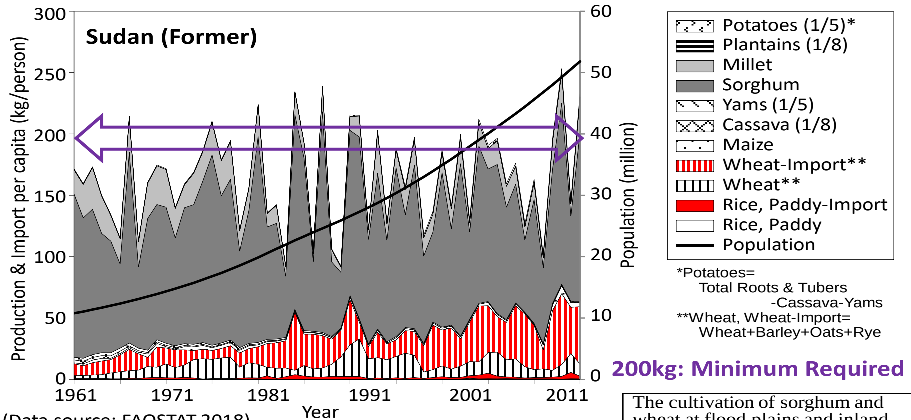
Maize is staple food. However, the production per capita has been unstable and decreased during 1980-2005. Rice production has started quite recently and still very small small. Wheat production has been increasing.



(Data source: FAOSTAT 2018)

Fig. 52. Various Food Production & Import (kg/person) in Angola (No.29 rice producing country in SSA) during 1961-2016.

Cereal equivalent amounts of calories per kg are one fifth for Potato & plantain, one fourth for Yam and cassava (FAO Food composition data). In addition to these, postharvest and storage losses are estimated 2 times bigger than cereals for Cassava, 1.6 times for plantain, 1.3 times for Yam, and 1.0 for potatoes. Thus the cereals conversion ratios of potatoes and Yams are 1/5 and 1/8 for Plantains and Cassava.



(Data source: FAOSTAT 2018)

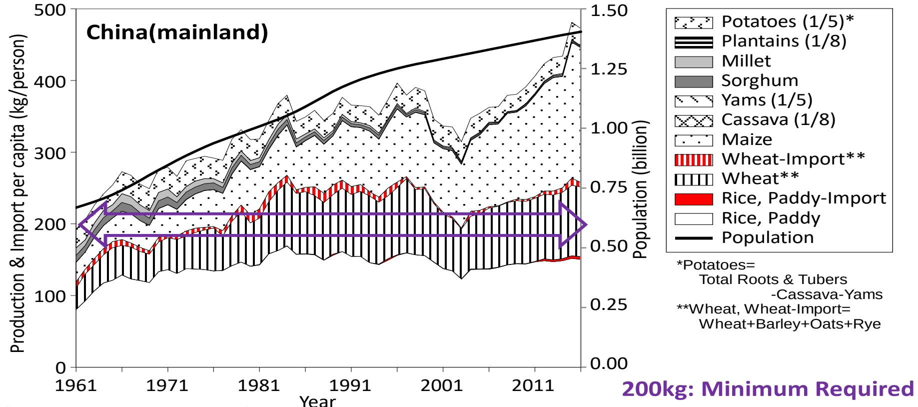
Fig. 53. Food Production & Import (kg/person) in Sudan (Former). (No.32 rice producing country in SSA) during 1961-2016. (Import data of South Sudan in 2012-2013 not available.)

Cereal equivalent amounts of calories per kg are one fifth for Potato & plantain, one fourth for Yam and cassava (FAO Food composition data). In addition to these, postharvest and storage losses are estimated 2 times bigger than cereals for Cassava, 1.6 times for plantain, 1.3 times for Yam, and 1.0 for potatoes. Thus the cereals conversion ratios of potatoes and Yams are 1/5 and 1/8 for Plantains and Cassava.

The cultivation of sorghum and wheat at flood plains and inland deltas are main cereal productions. The agricultural production is stagnant and unstable by war such as recent Darfur conflict and the independence of South Sudan. South Sudan has the vast swamp called "Sudd" and the very large Nile flood plain. The potential of the rice production is extremely high as much as Chad.

9. General ranking trends of paddy production and yields as well as comparative importance and trends of major staple crops in Asian's rank 1st to 10th countries during 1961-2015+2016-2019, including the comparative figures for United Kingdom and USA

Note: Paddy production and Yield figures of Asian countries are shown in Figure 3 and 4



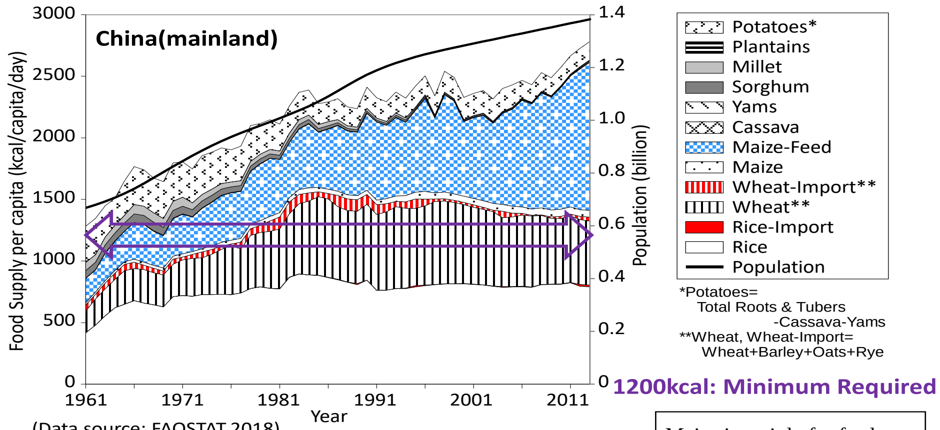
(Data source: FAOSTAT 2019)

Fig.54a. Various food production and import (kg/person) in China (No.1 rice producing country in Asia) during 1961-2016.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

Rice and wheat production is sufficient to cover domestic consumption. Maize is mainly for feed.

Feed = Production - Food Supply Quantity (FAOSTAT)



(Data source: FAOSTAT 2018)

Fig 54b. Various food supply (kcal/capita/day) in China (mainland) (No.1 rice producing country in Asia) during 1961-2013.

Maize is mainly for feed to produce meat in China.

We used the cereals' equivalent coefficients of one-eighth for cassava and plantains and one -fifth for yam and potatoes. These conversion factors can be tentatively verified by comparing values on per capita production and importation amounts in kg and per capita consumption in kcal.

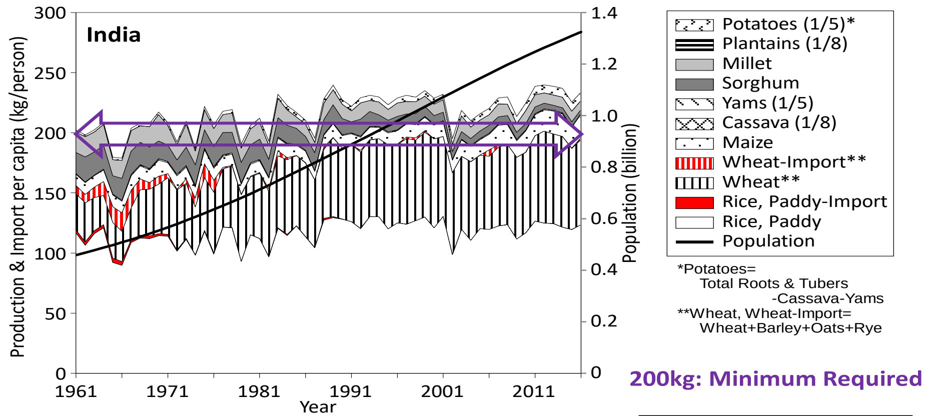
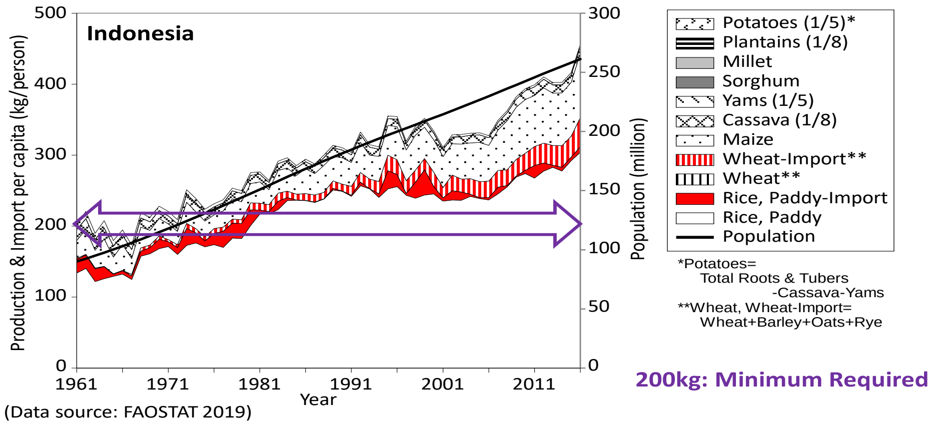


Fig.55 Various food production and import (kg/person) in India (No.2 rice producing country in Asia) during 1961-2016. (Data source: FAOSTAT 2019)

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

Compared with China, there is not enough production to cover domestic consumption.

Although per Capita food production of India has been no surplus during 1961-2013, Gradually improving recently. Thus importation is almost zero.

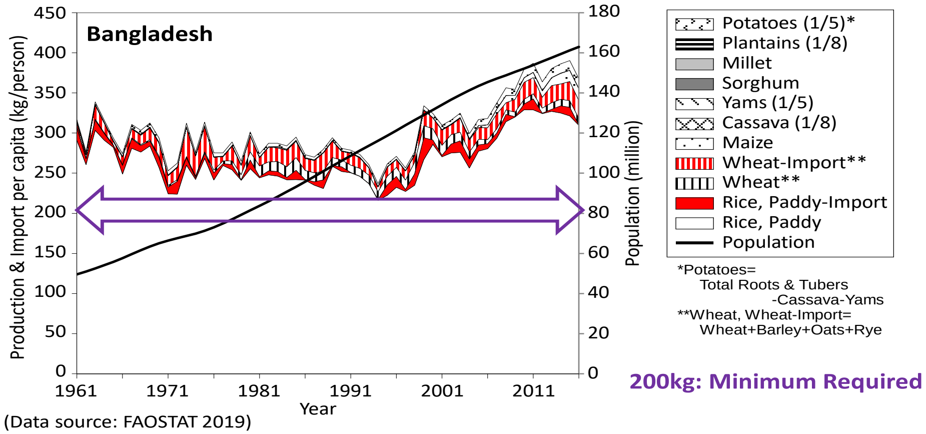


(Data source: FAOSTAT 2019)

Fig.56. Various food production and Import (kg/person) in Indonesia No.3 rice producing country in Asia) during 1961-2016.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

Per Capita rice production of Indonesia has been increasing during 1961-2013.

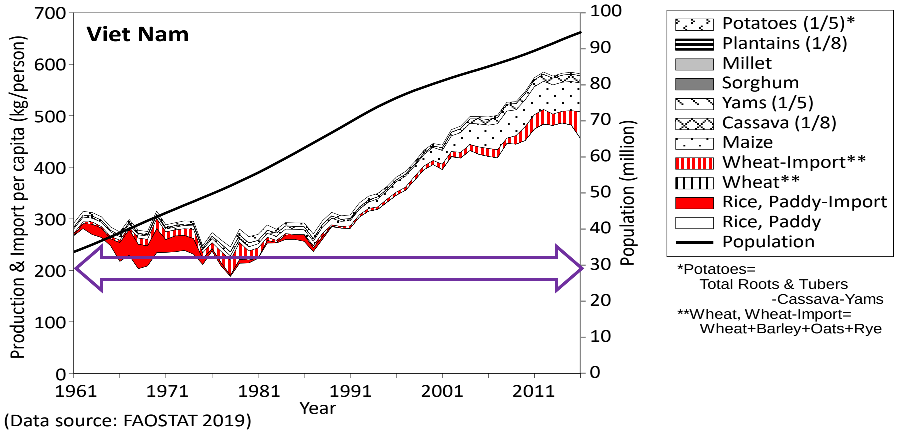


(Data source: FAOSTAT 2019)

Fig.57. Various food production and import (kg/person) in Bangladesh (No.4 rice producing country in Asia) during 1961-2016.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

Per Capita rice production of Bangladesh has been maintaining during 1961-2013.

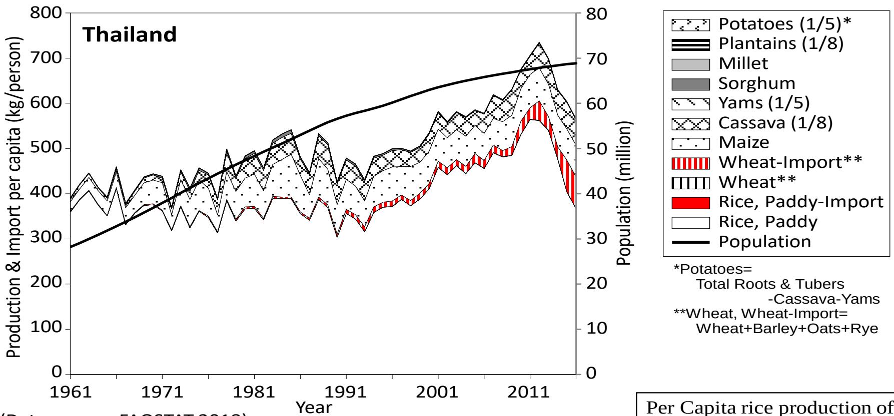


(Data source: FAOSTAT 2019)

Fig.46. Various food production and import (kg/person) in Viet Nam (No.5 rice producing country in Asia) during 1961-2016.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

Per Capita rice production of Viet Nam has been rapidly increasing recently, which makes Viet Nam major rice exporter recently.

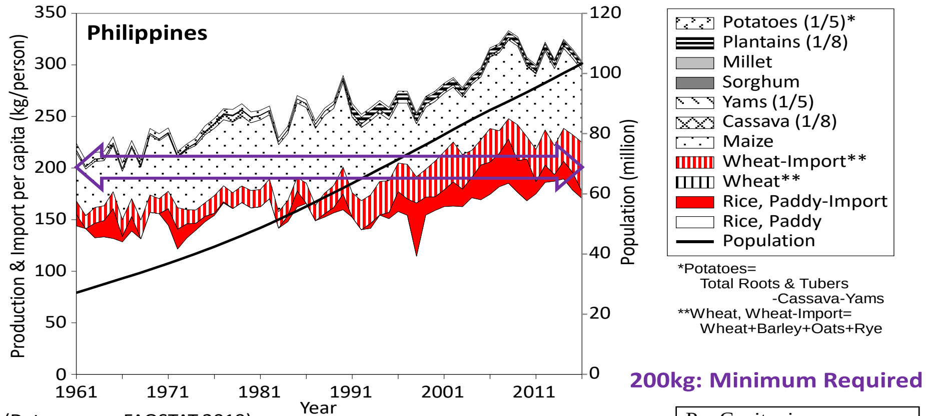


(Data source: FAOSTAT 2018)

Fig. Various Food Production & Import (kg/person) in Thailand (No.6 rice producing country in Asia) during 1961-2016.

Cereal equivalent amounts of calories per kg are one fifth for Potato & plantain, one fourth for Yam and cassava (FAO Food composition data). In addition to these, postharvest and storage losses are estimated 2 times bigger than cereals for Cassava, 1.6 times for plantain, 1.3 times for Yam, and 1.0 for potatoes. Thus the cereals conversion ratios of potatoes and Yams are 1/5 and 1/8 for Plantains and Cassava.

Per Capita rice production of Thailand has been increasing recently, which makes maintain Thailand major rice exporter.

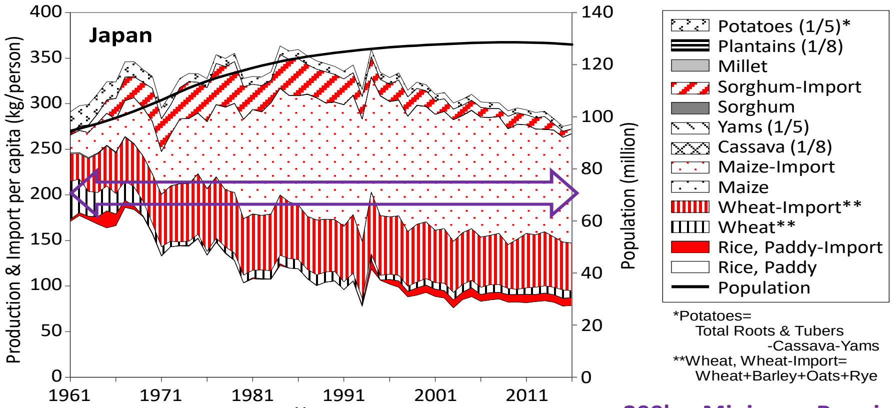


(Data source: FAOSTAT 2019)

Fig.59. Various food production and import (kg/person) in Philippines No.8 rice producing country in Asia) during 1961-2016.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

Per Capita rice production has been stagnating during 1961-2013. That why rice importation is visible. This is somewhat strange among other major Asian countries under IRRI's host country.



(Data source: FAOSTAT 2019)

Fig.60a. Various food production and import (kg/person) in Japan (No.10 rice producing country in Asia) during 1961-2016.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

In 1971 Japan started the strong policy to discourage rice production, which continued by 2018. That why rice production rapidly decreased. So Japanese rice agriculture has been damaged last 40 years.

Feed = Production + Import - Food Supply Quantity (FAOSTAT)

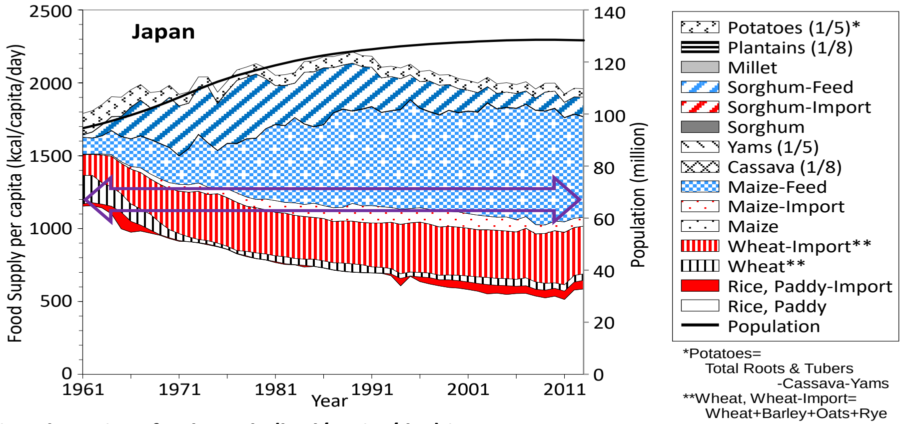


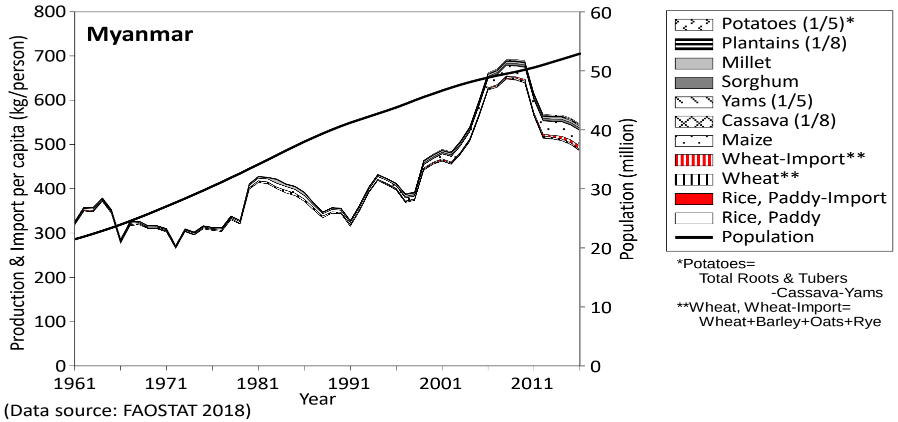
Fig.60b. Various food supply (kcal/capita/day) in Japan (No.9 rice producing country in Asia) during 1961-2013.

1200kcal: Minimum Required

(Data source: FAOSTAT 2019)

We used the cereals' equivalent coefficients of one-eighth for cassava and plantains and one -fifth for yam and potatoes. These conversion factors can be tentatively verified by comparing values on per capita production and importation amounts in kg and per capita consumption in kcal.

The imported maize and sorghum have been used for animal feed to produce meat. The imported wheat for bread and noodle to replace the decrease of rice consumption

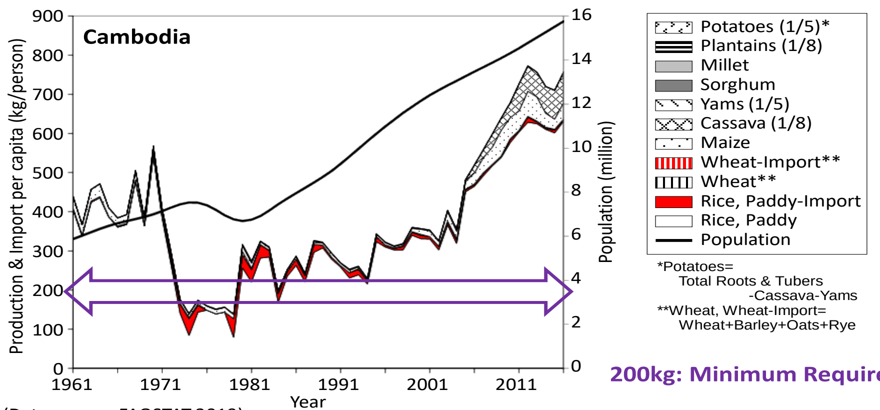


(Data source: FAOSTAT 2018)

Fig. Various Food Production & Import (kg/person) in Myanmar (No.7 rice producing country in Asia) during 1961-2016.

Cereal equivalent amounts of calories per kg are one fifth for Potato & plantain, one fourth for Yam and cassava (FAO Food composition data). In addition to these, postharvest and storage losses are estimated 2 times bigger than cereals for Cassava, 1.6 times for plantain, 1.3 times for Yam, and 1.0 for potatoes. Thus the cereals conversion ratios of potatoes and Yams are 1/5 and 1/8 for Plantains and Cassava.

Per Capita rice production of Myanmar are 400-500kg. This means Myanmar has enough rice to export.

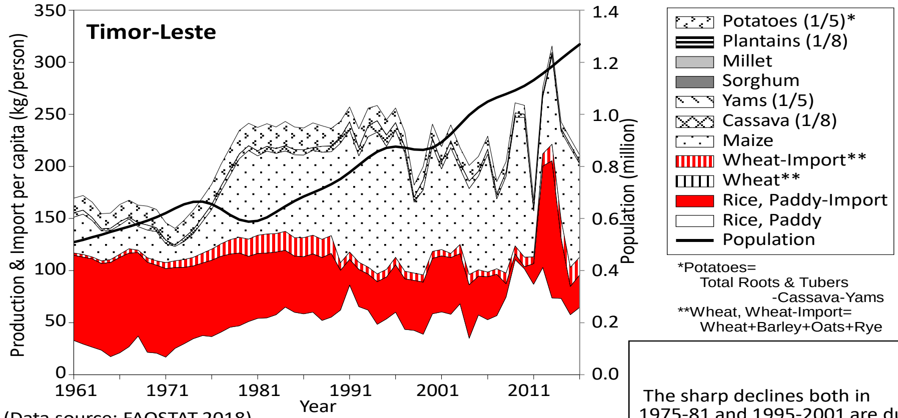


(Data source: FAOSTAT 2019)

Fig.61 Various Food Production & Import (kg/person) in Cambodia (No.11 rice producing country in Asia) during 1961-2016.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

Long very sever civil war continued during 1970s-1990s, which made devastating decrease of paddy production and population as well.

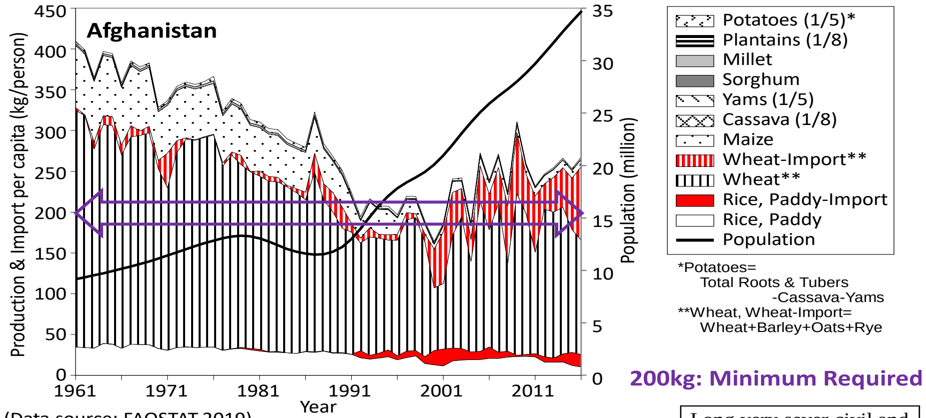


(Data source: FAOSTAT 2018)

Food Production & Import (kg/person) in Timor-Leste (No.26 rice producing country in Asia) during 1961-2016.

Cereal equivalent amounts of calories per kg are one fifth for Potato & plantain, one fourth for Yam and cassava (FAO Food composition data). In addition to these, postharvest and storage losses are estimated 2 times bigger than cereals for Cassava, 1.6 times for plantain, 1.3 times for Yam, and 1.0 for potatoes. Thus the cereals conversion ratios of potatoes and Yams are 1/5 and 1/8 for Plantains and Cassava.

The sharp declines both in 1975-81 and 1995-2001 are due to the social crises in relation to the consolidation by and the independence from Indonesia. Paddy and maize production have been increasing recently. However rice never became to the level of 1960s

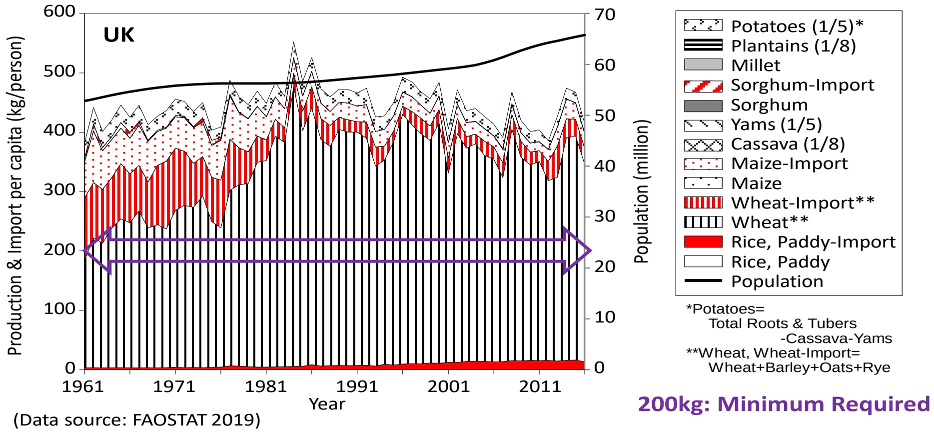


(Data source: FAOSTAT 2019)

Fig.62. Various food production and import (kg/person) in Afghanistan (No.21 rice producing country in Asia) during 1961-2016.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

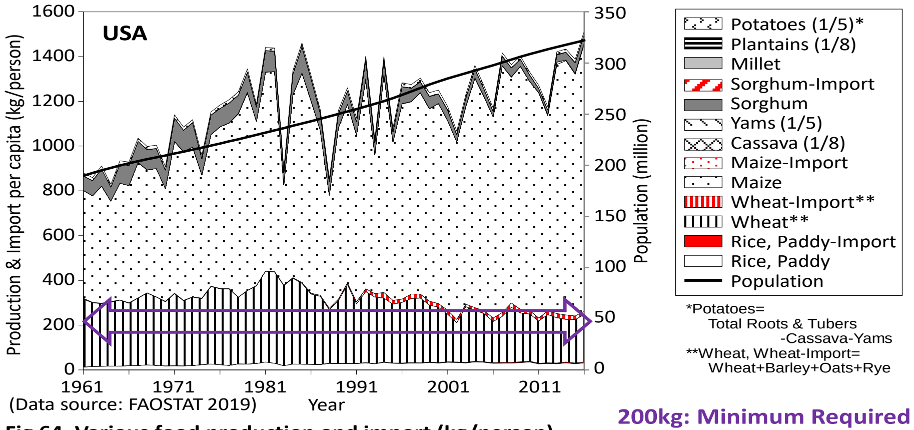
Long very sever civil and international wars has been continued since at the end of 1970s to date, which made devastating decrease of population during 1980 to 1990. Wheat, paddy and maize production never became to the level of 1960s



(Data source: FAOSTAT 2019)

Fig 63. Various Food Production & Import (kg/person) in UK during 1961-2016.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.



(Data source: FAOSTAT 2019)

Fig 64. Various food production and import (kg/person) in USA during 1961-2016.

Cereal equivalent amounts of calories per kilogram are one-fifth for potatoes and plantains, one-fourth for yam and cassava (FAO, Food composition data). In addition, post-harvest and storage losses are estimated to be 2 times bigger than that of cereals and cassava, 1.6 times that of plantain, 1.3 times that of yam, and 1.0 times that of potatoes. Thus, the cereal conversion ratios of potatoes and yams are one-fifth and one-eighth for plantains and cassava.

10. References

Agriculture, Forestry and Fisheries Policy Research Institute, Japan, 2019. Global Food Supply and Demand Trends and Medium- to Long-Term Outlook in 2028 based on the world food supply and demand model, https://www.maff.go.jp/primaff/seika/attach/pdf/190304_2028_02.pdf , March 2019

Alognon A, Bah S, Sow A and Manful JT, 2018. Variations in agronomic and grain quality traits of rice grown under irrigated lowland conditions in West Africa, Food Sci. Nutr. 2018:6:970-982, DOI:10.1002/fsn3.635.

Andriesse W, 1986. Wetlands in SubSaharan Africa, Area and Distribution. In Juo ASR and Low JA edited "The Wetlands and Rice in SubSaharan Africa", pp15-30, Proceedings of an international conference on wetland utilization for rice production in Sub-Saharan Africa, pp.1-318, 4-8 November 1985, Ibadan Nigeria, International Institute of Tropical Agriculture.

AQUASTAT, 2016. http://www.fao.org/nr/aquastat

AQUASTAT, 2017. http://www.fao.org/nr/aquastat

AQUASTAT, 2018. http://www.fao.org/nr/aquastat

Arahata K, 2014. "Japan's Paddy Farming in the 40 Years of the Acreage Reduction Program" In Japanese 「減反 40 年と日本の水田農業」, Association of Agriculture & Forestry Statistics, Tokyo, 817 page

Ben-Chendo GN, Lawal N and Osuji MN, 2017. Cost and return of paddy rice production in Kaduna state, European J. Agric. And Forestry, Vol. 5, No.3:41-48.

Borojevic, K. and Borojevic, K., 2005. The transfer and history of "reduced height genes"(Rht) in wheat from Japan to Europe. Journal of Heredity , 96(4), pp.455-459.

CARD, 2008. Coalition for African Rice Development (CARD), JICA and AGRA, http://www.jica.go.jp/activities/issues/agricul/pdf/card_jp.pdf (accessed on 25th February 2016)

Essiet D, 2016. Concern over N720.2b yearly rice import, The Nation, 21 November 2016, http://thenationonlineng.net/concern-n720-2b-yearly-rice-import/

Evans, LT, 1996. Crop evolution, adaptation and yield. Cambridge university press.

FAOSTAT, 2016. http://www.fao.org/statistics/en/

FAOSTAT, 2017. http://www.fao.org/statistics/en/

FAOSTAT, 2018. http://www.fao.org/statistics/en/

FAO, 2017. Rice Market Monitor, July 2017, http://www.fao.org/fileadmin/templates/est/COMM_MARKETS_MONITORING/Rice/Images/RMM/RMM-Jul17.pdf

Fischer, T, Byerlee, D and Edmeades, G, 2012, October. Crop yields and food security: will yield increases continue to feed the world. In Proceedings of the 12th Australian agronomy conference (pp. 14-18).Graham-Acquaah S, Satoto K, Traore K, Dieng I,

Hirose, S. and Wakatsuki, T. eds., 2002. Restoration of inland valley ecosystems in West Africa. Association of Agriculture & Forestry Statistics, Tokyo, 1-572 pages, Contents and summary, http://www.kinki-ecotech.jp/download/nourinntoukeikyoukaichosho_EN/book_en_contents%20and%20summary_20200212.pdf, Chapter 1-4, http://www.kinki-ecotech.jp/download/nourinntoukeikyoukai-chosho_EN/book_en_chapter1-4ed_20200212.pdf, Chapter 5-7, References and Index, http://www.kinki-ecotech.jp/download/nourinntoukeikyoukai-chosho_EN/book_en_chapter5-7ed_20200212.pdf

Hopper, WD, 1976. The development of agriculture in developing countries. Scientific American, 235(3), pp.196-205. Johnson, M.E. and Masias, I., 2017. Assessing the state of the rice milling sector in Nigeria: The role of policy for growth and modernization (Vol. 40). Intl Food Policy Res Inst.

Hsieh SC, 2001. Agricultural Reform in Africa-With Special Focus on Taiwan Assisted Rice Production in Africa, Past, Present and the Future Perspective-,Tropics, 11 (1): 33–58.

Hsieh SC 2003. Agricultural Technology Transfer to Developing Countries. National Pingtung University of Science and Technology Press, 1–14, 165–232.

IFPRI Research the Future Innovation Lab for Food Security Policy, Research Paper 59, pp.1-35, Feed The Future, USAID, Michigan State University, FMARD, http://ageconsearch.umn.edu/record/259580/files/FSP%20Research%20Paper%2059.pdf

Johnson M and Masias I, 2017. Nigerian Agricultural Policy Project, Assessing the state of the rice milling sector in Nigeria: The role of policy for growth and modernization, IFPRI Research the Future Innovation Lab for Food Security Policy, Research Paper 59, pp.1-35, Feed The Future, USAID, Michigan State University, FMARD, http://ageconsearch.umn.edu/record/259580/files/FSP%20Research%20Paper%2059.pdf

Juo ASR and Lowe JA. 1986. The wetlands and rice in Sub Saharan Africa, Proceedings of an international conference on wetland utilization for rice production in Sub-Saharan Africa, 4th to 8th of November, 1985,

IITA, Ibadan, 318pp.
Kitamura, Y and Oweis, TY, 2018. Agricultural water management in the drylands: New paradigm to cope with scarcity and climate change. *GIHODO SHUPPAN Co., Ltd.:Tokyo, Japan*, pp.179-194.
MAFF 2022. Trends of world trading prices of rice, soybean, wheat, and maize during 1971-2022, http://www.maff.go.jp/j/zyukyu/jki/j_zyukyu_kakaku/
Ministry of Agriculture, Forestry and Fisheries Policy Research Institute, March, 2022.
Global Food Supply and Demand Trends and Medium- to Long-Term Outlook in 2028 based on the world food supply and demand model, https://www.maff.go.jp/primaff/seika/attach/pdf/190304_2028_02.pdf, March 2019.
Mizutani, M, Hasagawa, S, Koga, K, Goto, A and VVN, M, 1999. Advanced paddy field engineering. *The Japanese Society of Irrigation, Drainage and Reclamation Engineering (JSIDRE)*, *170*.
Molden D (ed), 2007. *Water for Food, Water for Life*. Earthscan, London and IWMI, Colombo, 624pp.
NAERLS and FDAE, 2014. Agricultural Performance Survey of 2014 Wet Season in Nigeria, National Report, National Agricultural Extension and Research Liaison Services (NAERLS) and Federal Department of Agricultural Extension (FDAE), Federal Ministry of Agriculture and Rural Development (FMARD), https://naerls.gov.ng/wp-content/uploads/2017/06/Agricultural-Performance-Survey-of-2014-Wet-Season-in-Nigeria.pdf, 1-190pp.
National Agriculture and Livestock Industry Promotion Organization, 2008. Livestock Information, November 2008, Global Feed Grain Supply and Demand Trends, Global Feed Demand and Supply, Moving from High Corn to Cheap Wheat, https://lin.alic.go.jp/alic/month/domefore/2008/nov/jyu-koku.htm
Oguntunde PG, Lischeid G and Dietrich O, 2018. Relationship between yield and climate variables in southwest Nigeria using multiple linear regression and support vector machine analysis, Int J Biometeorol (2018) 62:459-469, https://doi.org/10.1007/s00484-017-1454-6.
Oki T, Agata Y, Kanae S, Saruhashi T, Yang D, and Musiake K, 2009. Global assessment of current water resources using total runoff integrating pathways. Hydrological Sciences Journal, 46(6), 983-995, DOI:10.1080/02626660109492890.
Shehu B and Lolo A, 2017. Promoting Rice Productivity in Kebbi State: Linking Data and Policy, State Policy Note 2, 1-4pp, IFPRI Research the Future Innovation Lab for Food Security Policy, Feed The Future, USAID, Michigan State University, FMARD, http://foodsecuritypolicy.msu.edu/uploads/files/Nigeria/StatePolicyNotes/Kebbi_State_Policy_Note_2.pdf
Tabuchi T and Hasegawa S, 1995. Paddy Fields in the World, Japanese Society of Irrigation, Drainage and Reclamation Engineering, Tokyo, 353pp.
Shehu B and Lolo A, 2017. Promoting Rice Productivity in Kebbi State: Linking Data and Policy, State Policy Note 2, 1-4pp, IFPRI Research the Future Innovation Lab for Food Security Policy, Feed The Future, USAID, Michigan State University, FMARD, http://foodsecuritypolicy.msu.edu/uploads/files/Nigeria/StatePolicyNotes/Kebbi_State_Policy_Note_2.pdf
United Nations Department of Economics and Social Affaires 2017. The World Population Prospects 2017 Revision, https://www.un.org/development/desa/publications/world-population-prospects-the-2017-revision.html
USDA, National Agricultural Statistics Service 2017. Corn Area Planted and Harvested, Yield, Production, Utilization, Price, and Value - United States: 1866-2016. In Crop Production Historical Track Records (April 2017), pp.28-38. https://www.nass.usda.gov/Publications/Todays_Reports/reports/croptr17.pdf
USDA PS&D Online, 2017. https://apps.fas.usda.gov/psdonline/app/index.html#/app/home
Wakatsuki T and Hsieh Sung-Ching, 2003. History of International Cooperation for Development of Rice Culture in Africa. Part 1. Taiwan, International cooperation of agriculture and forestry,「アフリカ稲作開発協力史―その１ 台湾―」国際農林業協力」, Vol. 26(No.3):17-29 (In Japanese), http://www.kinki-ecotech.jp/download/ICAFVol26No32003.pdf
Windmeijer PN and Andriesse W. 1993. *Inland Valley in West Africa: An Agroecological Characterization of Rice-Growing Environment*, ILRI, Wageningen, p. 160.
Wopereis MCS, Johnson DE, Ahmadi N, Tollens E and Jalloh A, 2013. Realizing Africa’s Rice Promise, AfricaRice, CABI, Oxfordshire, UK, 451pp.
Yombe AS, 2016. Kebbi State sets to produce over 1million tons of rice in 2016 Dry season farming, in National Daily News Paper, http://nationaldailyng.com/kebbistate-sets-to-produce-over-1million-tons-of-rice-in-2016-dry-season-farming/
Zimmer Y et al., 2015. Agri benchmark Cash Crop Report 2015, 1-35pp., Tunen Institute, Braunschweig, Germany, Downloaded on 1 August 2017, http://www.agribenchmark.org/fileadmin/Dateiablage/B-Cash-Crop/Reports/F_Cash_Crop_Report_2015_web.pdf