The 2nd International Sociohydrology Conference, 19-21 July, 2025, University of Tokyo, Japan
Oral Theme 5: Comparative sociohydrology across places and scales: aiming towards synthesis|
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[42] Inequality, and Water Justice across Regions

[42-04] Endogenous development of farmer-led on-site ground water pump-irrigated Sawah (paddy) rice cultivation in the savanna floodplains and inland deltas in northern Nigeria and Sub-Saharan Africa

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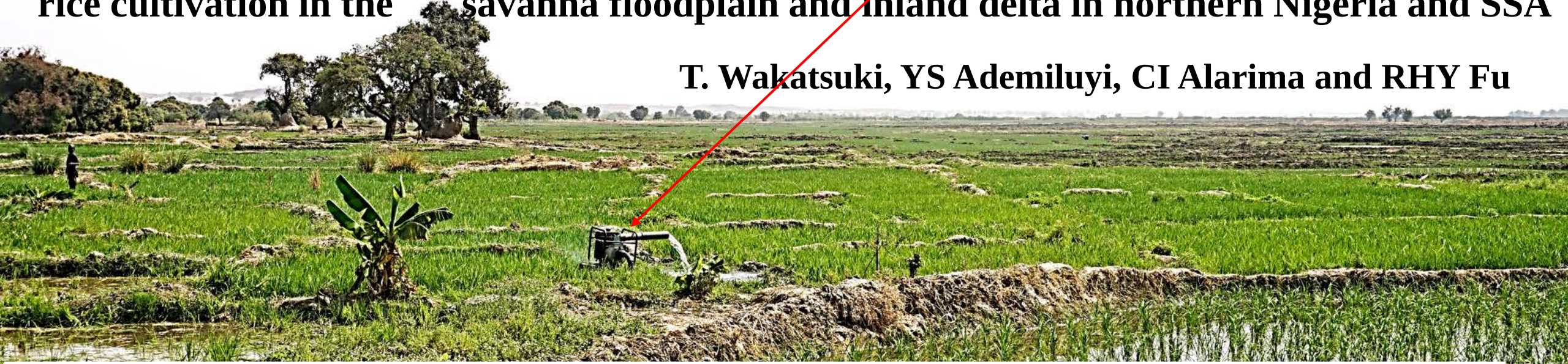
Keywords：On-site pump irrigation、Sawah (Suiden) technology、Farmer lead endogenous development、Ground water、Savanna floodplains and inland deltas、Kebbi rice revolution、Lake Chad Basin

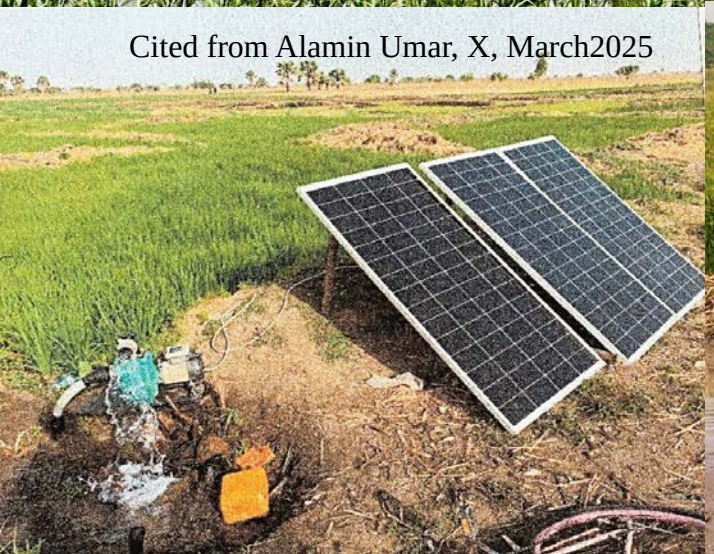
Nigeria increased paddy production 50-fold in1960-2020. It now No.1 ranks in Africa, 10million tons. Northern savannah states have more than half of the suitable land for irrigated *Sawah* (paddy, Suiden in Japanese) platform. This differs from Asia, where coastal rain rich alluvial plains are the centers of rice. Nigeria has a potential of 5 million ha, but currently only one tenth of this, mainly in Kebbi state. In 1990-2020, the World Bank developed on-site ground water pump irrigation system in the floodplains of the Niger River and its tributaries. However, prior to 2010, *rudimentary-Sawah* with poor bunds and no levelling was the norm, thus paddy yield was 1-2.5t/ha. From 2010-17, National Centre for Agricultural Mechanization and the JSPS-Kaken hi team worked with the World Bank to innovate *Sawah* technology: (1) to develop water-managed standard *Sawah* platform with leak-free bunds and with leveling quality of ±5 cm, (2) to be implemented by farmers on their own using power-tiller instead of heavy machinery, and (3)transplanted rice farming. In 2011-12, the *Sawah* team conducted on-the-job training. In2013-14, leading 16 farmers purchased power-tillers and developed 199 ha of *Sawahs*, yielding a total 2100 tons of paddy (6.4 t/ha). Thousands more power tillers were spread in Kebbi State in 2014-17. Thus, Kebbi State produced 2 million tons of paddy in 2017.The Lake Chad Basin and South Sudan have tens of millions of hectares of wetlands, which have socio-hydrological features that allow for Kebbi style on-site farmer lead irrigated Sawah rice cultivation.

Endogenous development of farmer-led on-site ground water pump irrigated Sawah(paddy) rice cultivation in the savanna floodplain and inland delta in northern Nigeria and SSA

T. Wakatsuki, YS Ademiluyi, CI Alarima and RHY Fu



Flood plain, Suru LGA, Kebbi state, Northwest Nigeria, Niger river tributaries, dry season, 31Jan.2019



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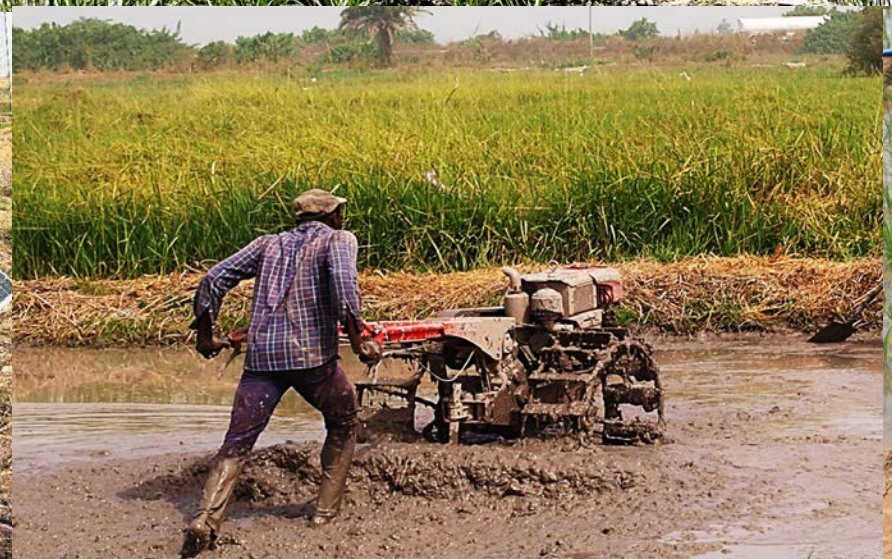


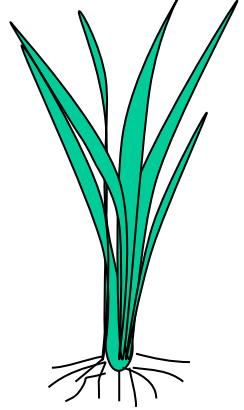
Broken power tiller, Photo taken on the same day 31 January 2019 at the same flood plains, but no on-site irrigation.

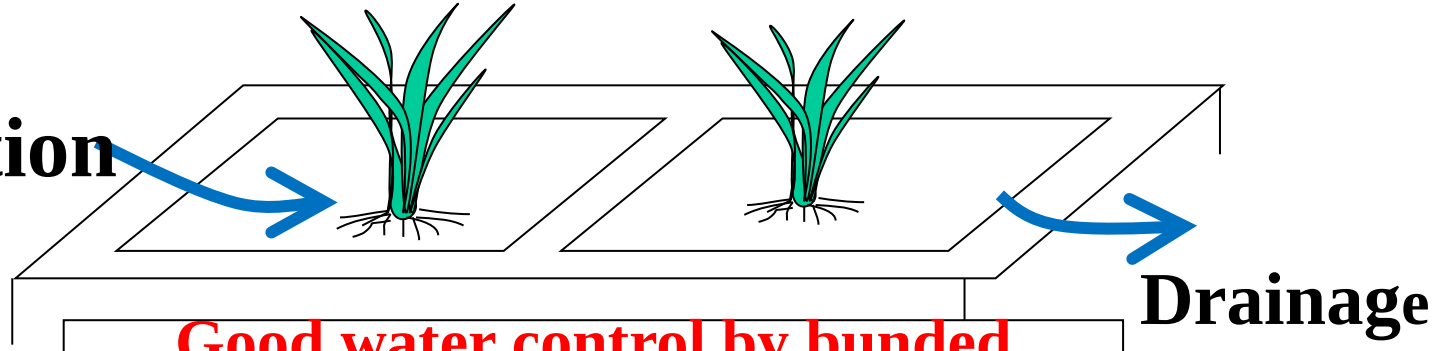
Sawah system, Kebbi, Nigeria

Sawah system, Bali, Indonesia (Lueras and Helmi 1989)

	English	Malay–Indonesian	Chinese（漢字，日本語、韓国語）
Grain and Food	Rice	Nasi	米，飯
Rice plant, Unhulled rice	Paddy	Padi	稲，籾
Environment Ecotechnology	(Paddy)?	Sawah (Water Control Platform)	水田(Suiden) 畠田

In Sub-Saharan Africa (SSA), with the exception of Madagascar, rice crops, “paddy” and paddy fields, “sawah”, which are water control platforms for rice cultivation by bunding, leveling, water inlet, and outlet, are confused. Although irrigation involves water intake, storage, distribution, drainage, there had been no concept and technology for sawah (SUIDEBN in Japanese) platform that enable rice cultivation while managing and control water before liberation from colonial rule by Western countries.





Good water control by bunded and leveled good sawah platform

Biotechnology Options

Weed and pest control: Rapid growth and various resistance genes

Draught and Flood: Deep rooting, C4 gene, Osmo-tolerance and Submergence-tolerance genes

Nutrition, acidity/alkalinity : N-fixation gene, P, Si other nutrition transporter genes

Global warming :ultra high yield gene, aerobic rice gene

Food quality improvement Vitamins, Golden rice

Bio-diversity conservation

Integration By Good Agronomy Practices

Eco-technology Options

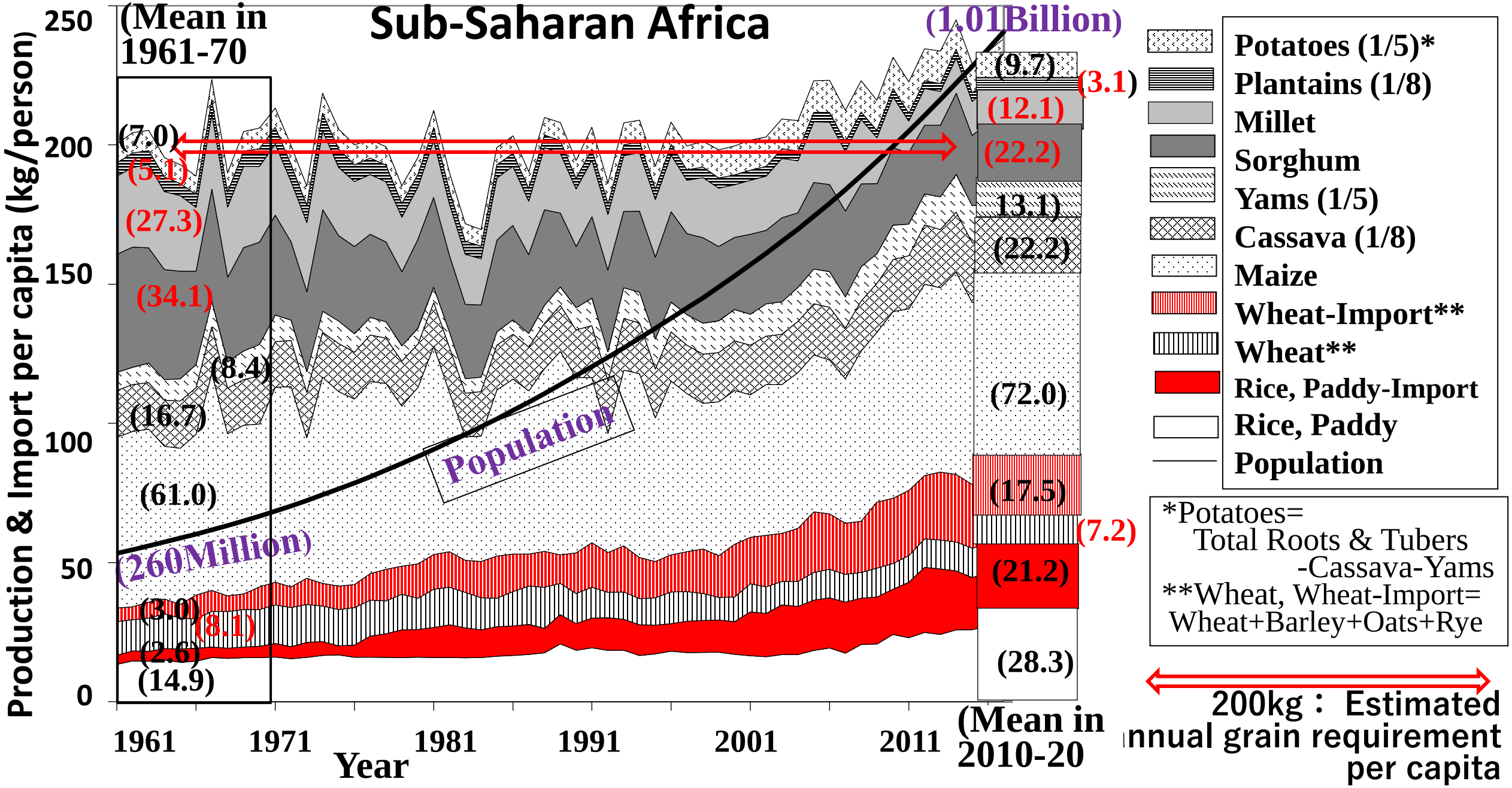
Weed and pest control :Transplanting, water control and nutrient supply by good sawah systems with good water, sawah leveling,puddling, and bunding

Water shortage/Flood control: by Irrigation/drainage, canals, Sawah dam/ground water recharge,

Nutrition, acidity and alkalinity: Sawah based enhancement on N-fixation, P, Si, K and Zn availabilities. Geological fertilization

Global warming: Watershed agroforestry, Carbon sequestration by high yield, oxygen control and sedimentation

Food quality and bio-diversity : Fish, duck and rice in sawah systems



PerCapita growth rate: Rice 1.90, Yam 1.56, Potatoes 1.39, Cassava 1.32, Maize 1.18, Others <1

Table. Changes of grain production of Sub-Saharan Africa and Nigeria in 1961-2020

	Sub-Saharan Africa			Nigeria		
Years	1961-65 mean	2016-20 mean	Increase ratio	1961-65 mean	2016-20 mean	Increase ratio
Population	250 Million	1.09 Billion	4.4	48 Million	196 Million	4.1
Paddy	3.5 Million ton	30 Million ton	8.6	0.21 Million ton	9.8 Million ton	47
Paddy import	0.96 Million ton	22 Million ton	23	0.002 Million ton	0.07 Million ton	35
Maize	15 Million ton	79 Million ton	5.3	1.1 Million ton	11 Million ton	10
Yam*	21 Million ton	144 Million ton	6.9	6.7 Million ton	51 Million ton	7.6
Cassava**	33 Million ton	194 Million ton	5.9	8.4 Million ton	58 Million ton	6.9
Potatoes*	8.8 Million ton	53 Million ton	6.0	1.7 Million ton	12 Million ton	7.1
Plantains**	10 Million ton	27 Million ton	2.7	0.89 Million ton	3.0 Million ton	3.4
Sorghum	8.5 Million ton	24 Million ton	2.8	3.9 Million ton	6.0 Million ton	1.5
Millet	6.8 Million ton	13 Million ton	1.9	2.6 Million ton	1.8 Million ton	0.7
Wheat	2.0 Million ton	7.9 Million ton	4.0	0.02 Million ton	0.08 Million ton	4.0
Wheat import	0.75 Million ton	19 Million ton	25	0.04 Million ton	5.1 Million ton	128

Since gaining independence from colonial rule in 1960, rice production has increased dramatically compared to other crops, which has accelerated to increase in recent years.

***, **Grain equivalent amounts are 1/5 (Yam and Potatoes) to 1/8(Cassava and Plantain)**

Table 3. Paddy production (x1,000 t) in Sub-Saharan African countries and Egypt during 1961-2023. The rankings are based on average annual paddy production in 2011-23 (FAOSTAT 2025). The country colour coding is based on (2011-2023) divided by (1961-70). Blue indicate >20-fold, green of 20~10 fold, black of 10~5 fold, and red <5-fold increase. Asian sawah equivalent areas were calculated 2011-23 paddy divided by mean Asian yield 4.8t/ha.

Countries	Rank 2011-23 in SSA	1961-70	t/ha	1971-80	t/ha	1981-90	t/ha	1991-2000	t/ha	2001-2010	t/ha	2011-23	t/ha	Sawah potential (x1000 ha)	*Asian Sawah equivalent 2011-23 (x1000ha)	Evolutional level of sawah platform
Egypt		2094	5.2	2396	5.4	2333	6	4756	8.2	6072	9.7	4980	9.2	745	1038	5~6
Nigeria	1	264	1.3	533	1.7	1758	2.1	3114	1.7	3512	1.5	7425	2.0	5486	1547	2~5
Madagascar	2	1671	1.8	1990	1.8	2179	1.9	2471	2.1	3477	2.8	4178	3.0	1560	870	4~5
UR Tanzania	3	120	1.1	275	1.4	492	1.6	661	1.6	1313	1.9	3147	2.8	4570	656	3~5
Mali	4	165	1	183	1	220	1.2	563	1.9	1091	2.5	2574	3.2	2544	536	4~5
Guinea	5	258	1.7	398	1.7	614	1.7	946	1.7	1310	1.7	2372	1.3	709	495	1
Coted'Ivoire	6	271	1	434	1.2	536	1.2	649	1.3	722	2	1807	2.7	1140	376	3~5
Sierra Leone	7	397	1.3	533	1.4	493	1.3	381	1.3	470	1.3	1159	1.6	341	241	1
DR Congo	8	104	0.8	209	0.8	312	0.8	374	0.8	317	0.8	1200	0.9	7692	250	1
Senegal	9	107	1.3	93	1.2	141	2	187	2.4	299	2.8	982	3.7	814	204	3~5
Ghana	10	44	1.1	79	0.9	72	1.1	187	1.9	294	2.2	825	3.1	1020	172	3~5
Cameroon	15	13	1.0	35	1.5	71	4.2	45	3.3	76	1.5	267	1.8	2330	56	2~3
Chad	16	33	1.1	38	0.9	39	1.2	98	1.5	132	1.2	257	1.4	5658	54	1
Uganda	17	5	1.1	19	1.1	26	1.3	81	1.4	156	1.6	240	1.8	773	50	2~3
Mozambique	20	90	1.3	86	1.1	88	0.9	125	0.8	126	0.5	183	0.6	1648	38	1
Ethiopia	21	~	~	~	~	~	~	12	1.8	35	1.9	166	3.0	3338	35	1
Zambia	28	~	~	1.5	0.7	8.8	1.0	12	1.0	21	1.4	44	1.4	3925	9	1
Sudan	29	2	1.0	8	1.0	3	1.0	3	0.9	28	3.3	39	4.5	10117	8	4
South Sudan	32	~	~	~	~	~	~	~	~	~	~	22	0.9	6575	5	1
SSA total		3930	1.3	5480	1.4	7780	1.6	10650	1.66	14740	1.75	29400	2.0	50000	6125	1~5
Asia total		243000	2.1	3E+05	2.5	427000	3.5	512000	3.8	577000	4.2	680000	4.8	100000	142000	3~6

*Mean Paddy prodcution/(mean Asian yield of 4.8t/ha in 2011-2023) Sawah Evolutional level 1:Upland rice, 2:Rige planting, 3: Micro & small sawah with poor bunding& levelling, 4: within ± 5cm leveling for good transplanting, 5: Mechanized, 6: Advanced ± 2.5cm & other

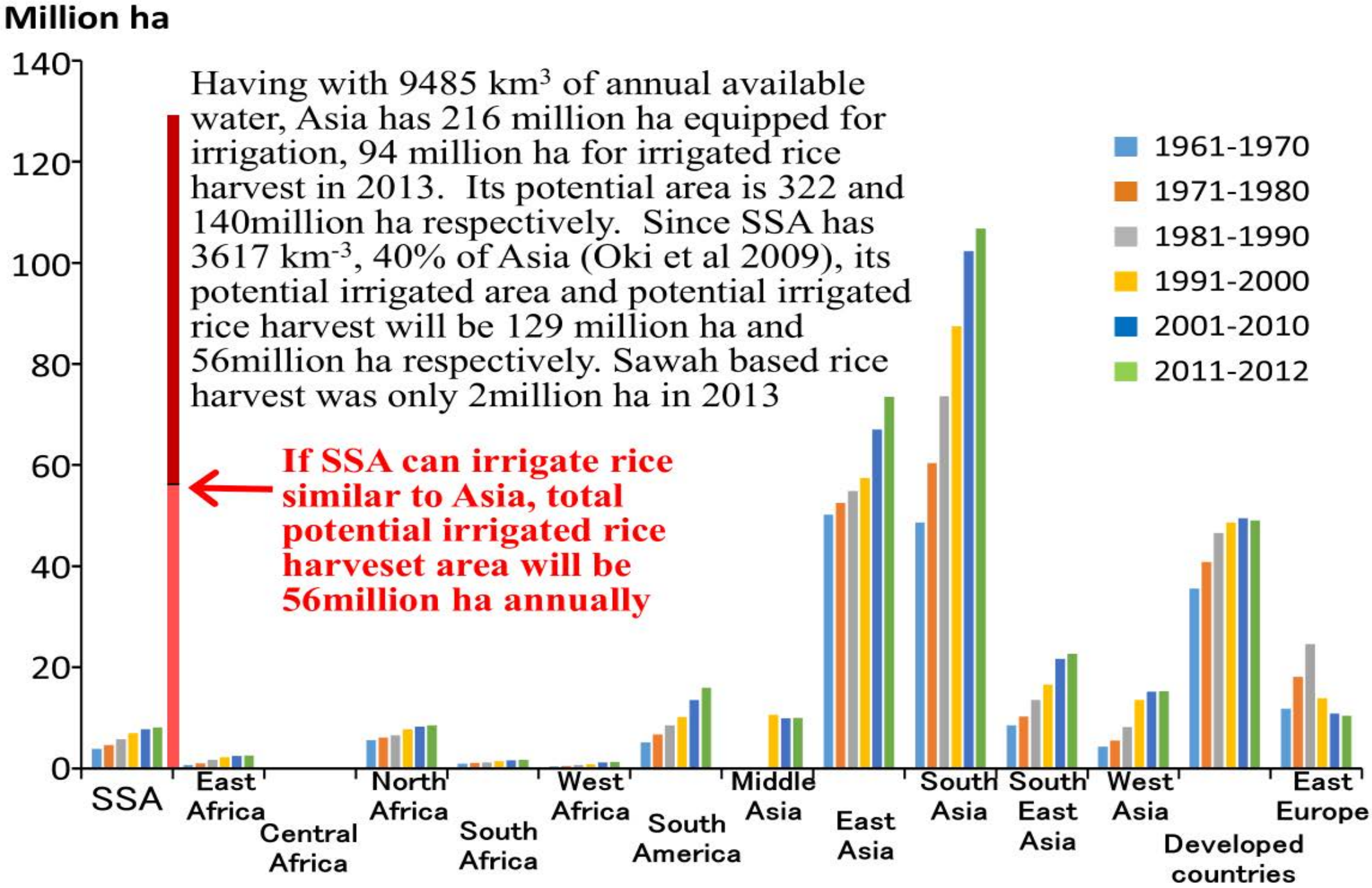

Million ha
140
120
100
80
60
40
20
0
Having with 9485 km3 of annual available water, Asia has 216 million ha equipped for irrigation, 94 million ha for irrigated rice harvest in 2013. Its potential area is 322 and 140million ha respectively. Since SSA has 3617 km-3, 40% of Asia (Oki et al 2009), its potential irrigated area and potential irrigated rice harvest will be 129 million ha and 56million ha respectively. Sawah based rice harvest was only 2million ha in 2013
If SSA can irrigate rice similar to Asia, total potential irrigated rice harveset area will be 56million ha annually
1961-1970
1971-1980
1981-1990
1991-2000
2001-2010
2011-2012
SSA
East Africa
Central Africa
North Africa
South Africa
West Africa
South America
Middle Asia
East Asia
South Asia
South East Asia
West Asia
Developed countries
East Europe

Table 1. Distribution of wetlands and potential irrigated sawah area in Sub Saharan Africa(SSA). (Andriesse 1986, Windmeijer & Andriesse 1993, Potential Sawah area estimate by Wakatsuki 2002 & 2013, Wakatsuki et al. 2012)

Classification	Area (million ha)	Area for potential irrigated sawah development
Coastal swamps	17	4-9 million ha (25-50%)
Inland basins(deltas)	108	5-20 million ha (5-20%)
Flood plains	30	8-23 million ha (25-75%)
Inland valleys	85	9-21 million ha (10-25%)
	Total: 240	**26-73**

Note 1. Although initial priority was small inland valleys because of easier water control, flood plains and inland basins (delta) in Sahel, Sudan and Guinea Savanna zones should be given priority, such as Kebbi, Jigawa, and Borno in Nigeria as well as Chad, South Sudan and Sudan where wide distribution of shallow ground water (Gleeson et al. 2012, Fan et al. 2013) makes small pump, solar pump soon, irrigated sawah efficient and soil fertility is high.

Note 2. Estimated potential sawah area and paddy production are 5-6 million ha and 20-30 million tons of paddy in Nigeria, and 26-73 million ha and 104-292 million tons in SSA. Asia has 140million ha of potential (94 million ha of sawah rice harvest in 2013) with 9485 km^3 of available water, whereas SSA has 3617 km^3 of water availability (40% of Asia) gives 56 million ha potential harvest area (only 2 million ha sawah rice harvest in 2013) (Oki et al. 2009, AQUASTAT 2016, FAOSTAT 2016)

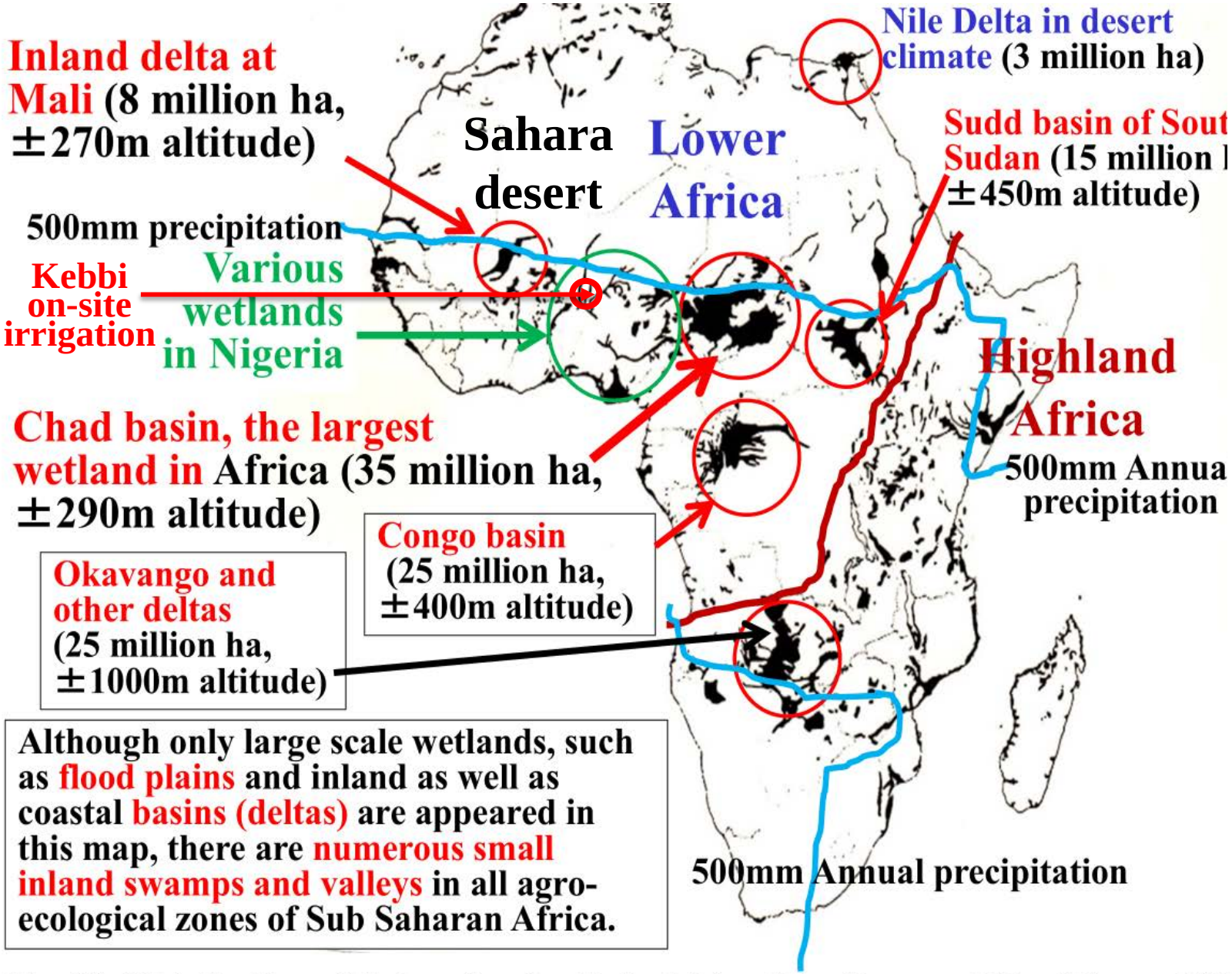
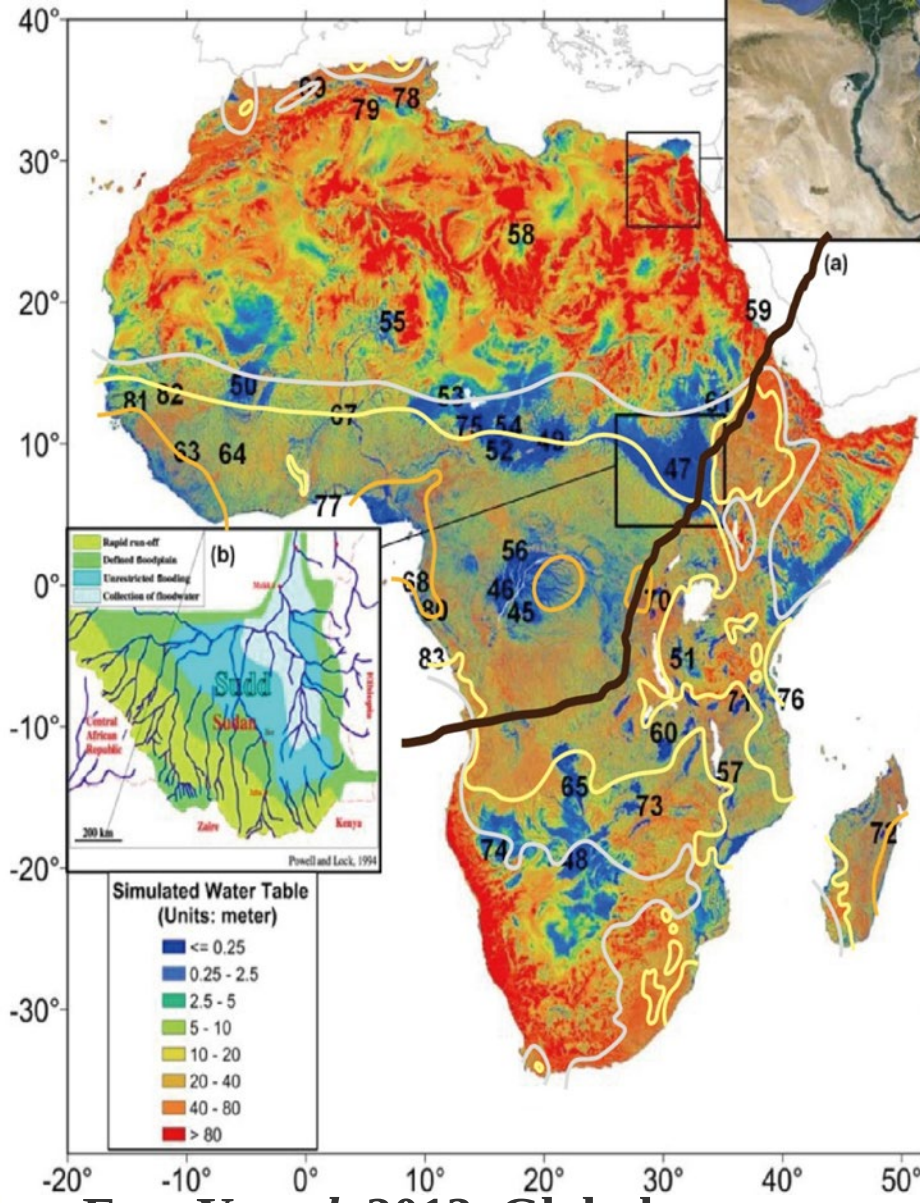
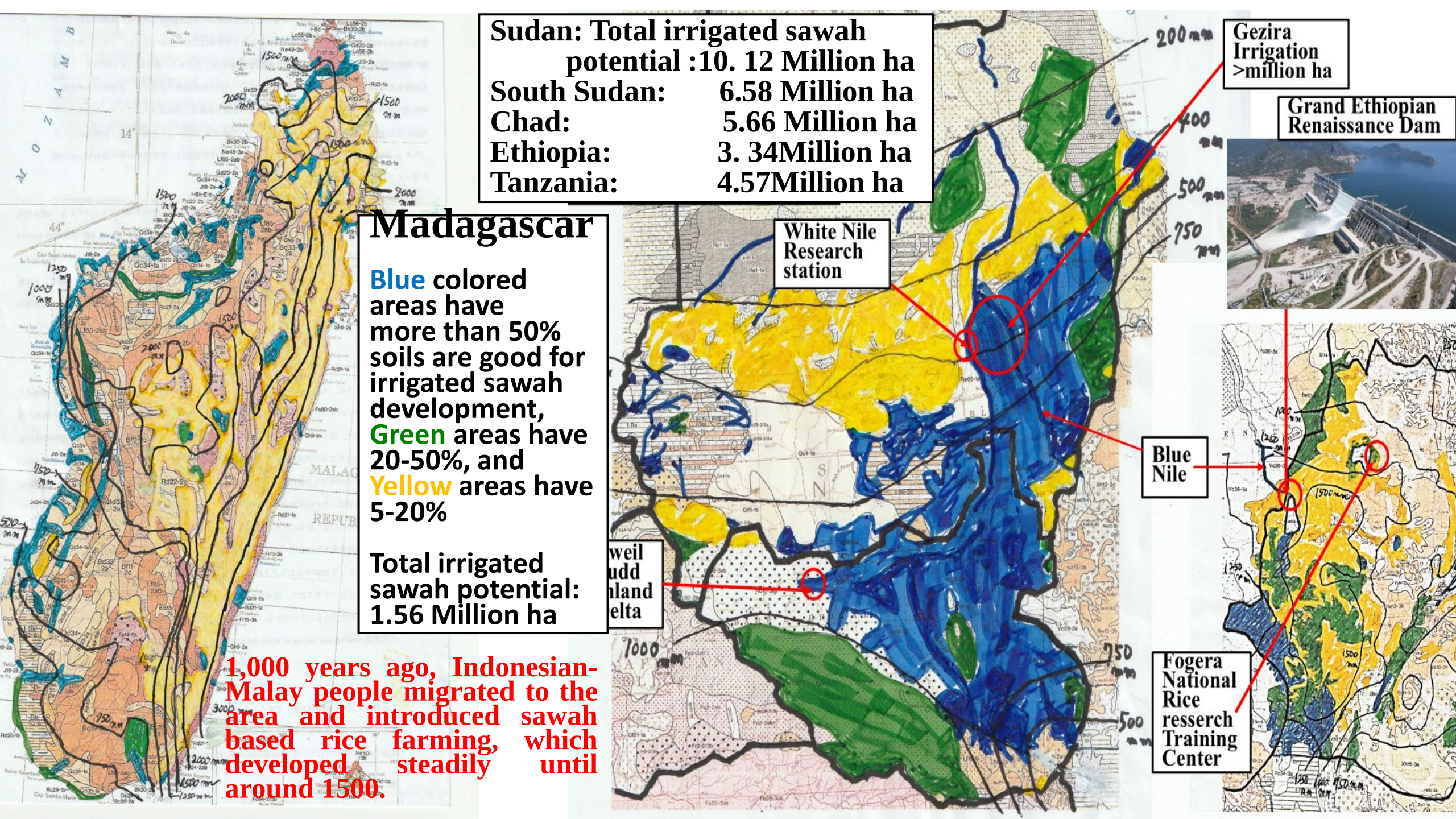
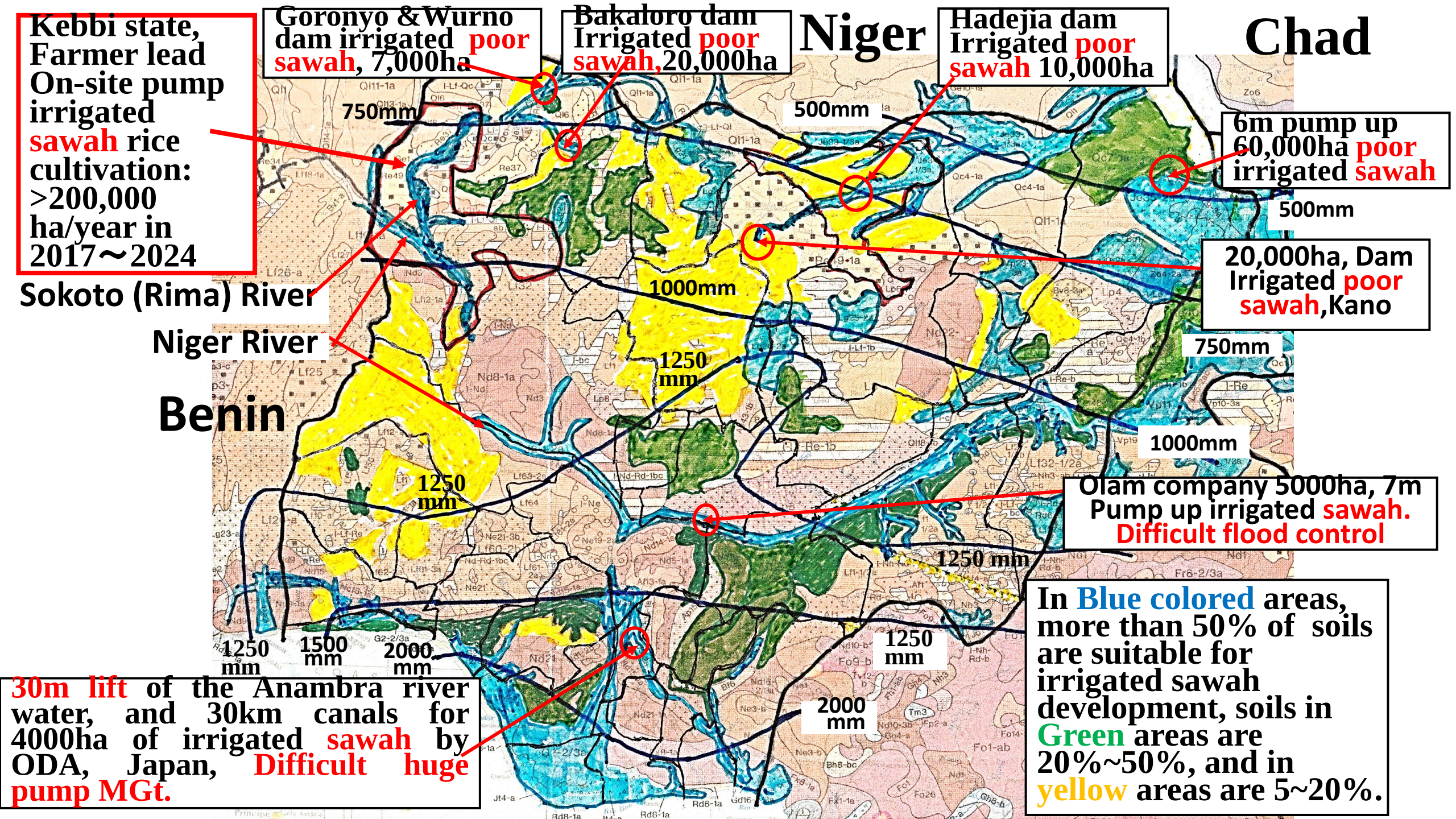


Fig. 18. Distribution of flat wetland soils in Africa (Van Dam and Van Diepen 1982)



Fan, Y *et al.* 2013. Global patterns of groundwater table depth. *Science*, vol. 339, p. 940-943


Sudan: Total irrigated sawah potential :10. 12 Million ha
South Sudan: 6.58 Million ha
Chad: 5.66 Million ha
Ethiopia: 3. 34Million ha
Tanzania: 4.57Million ha
Madagascar
Blue colored areas have more than 50% soils are good for irrigated sawah development, Green areas have 20-50%, and Yellow areas have 5-20%
Total irrigated sawah potential: 1.56 Million ha
1,000 years ago, Indonesian-Malay people migrated to the area and introduced sawah based rice farming, which developed steadily until around 1500.
Gezira Irrigation >million ha
Grand Ethiopian Renaissance Dam
White Nile Research station
Blue Nile
Fogera National Rice resserch Training Center


Kebbi state, Farmer lead On-site pump irrigated sawah rice cultivation: >200,000 ha/year in 2017～2024
Goronyo &Wurno dam irrigated poor sawah, 7,000ha
Bakaloro dam Irrigated poor sawah,20,000ha
Niger
Hadejia dam Irrigated poor sawah 10,000ha
Chad
6m pump up 60,000ha poor irrigated sawah
20,000ha, Dam Irrigated poor sawah,Kano
Sokoto (Rima) River
Niger River
Benin
750mm
500mm
1000mm
1250 mm
1500 mm
2000 mm
Olam company 5000ha, 7m Pump up irrigated sawah. Difficult flood control
30m lift of the Anambra river water, and 30km canals for 4000ha of irrigated sawah by ODA, Japan, Difficult huge pump MGt.
In Blue colored areas, more than 50% of soils are suitable for irrigated sawah development, soils in Green areas are 20%~50%, and in yellow areas are 5~20%.

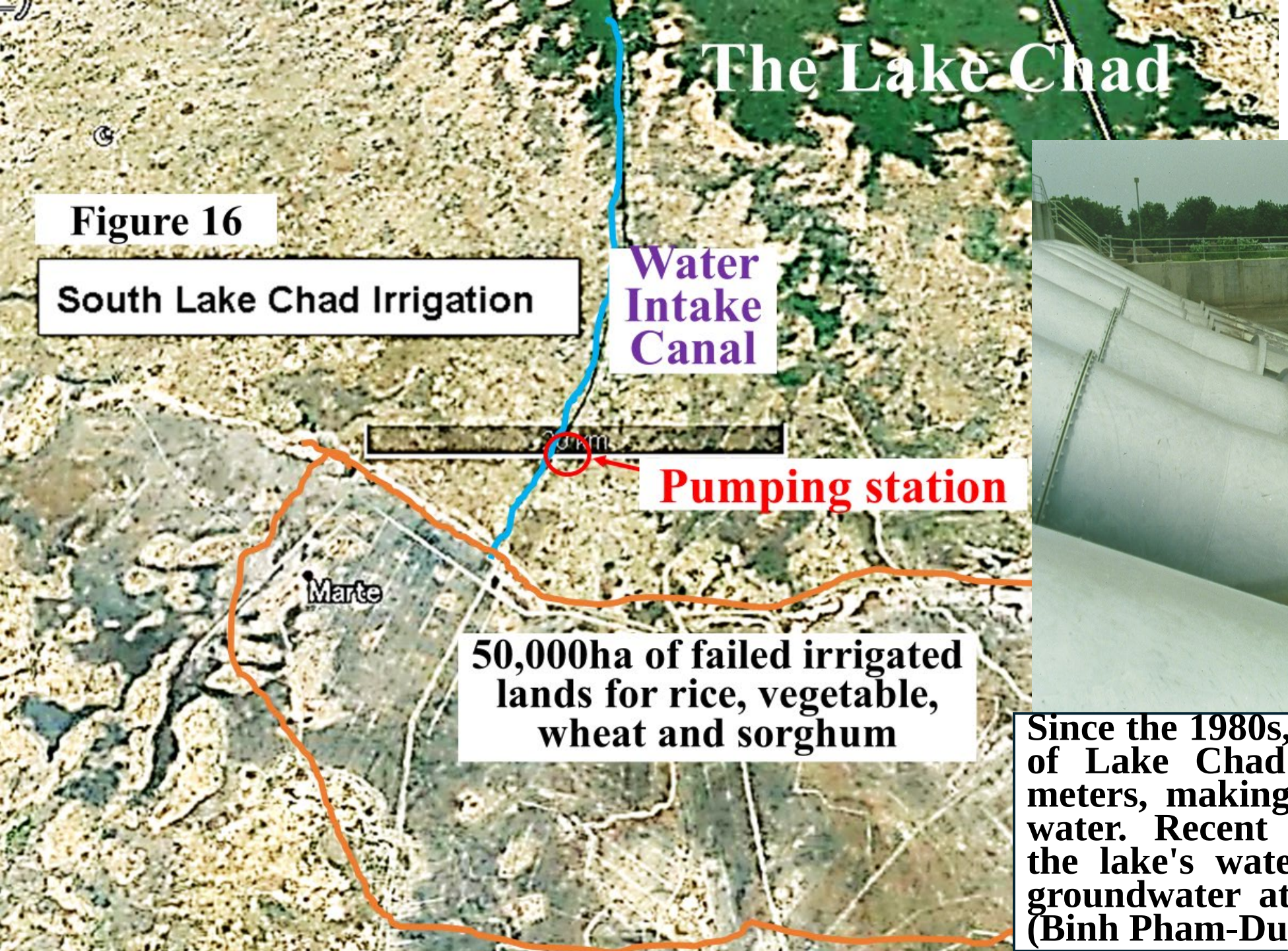
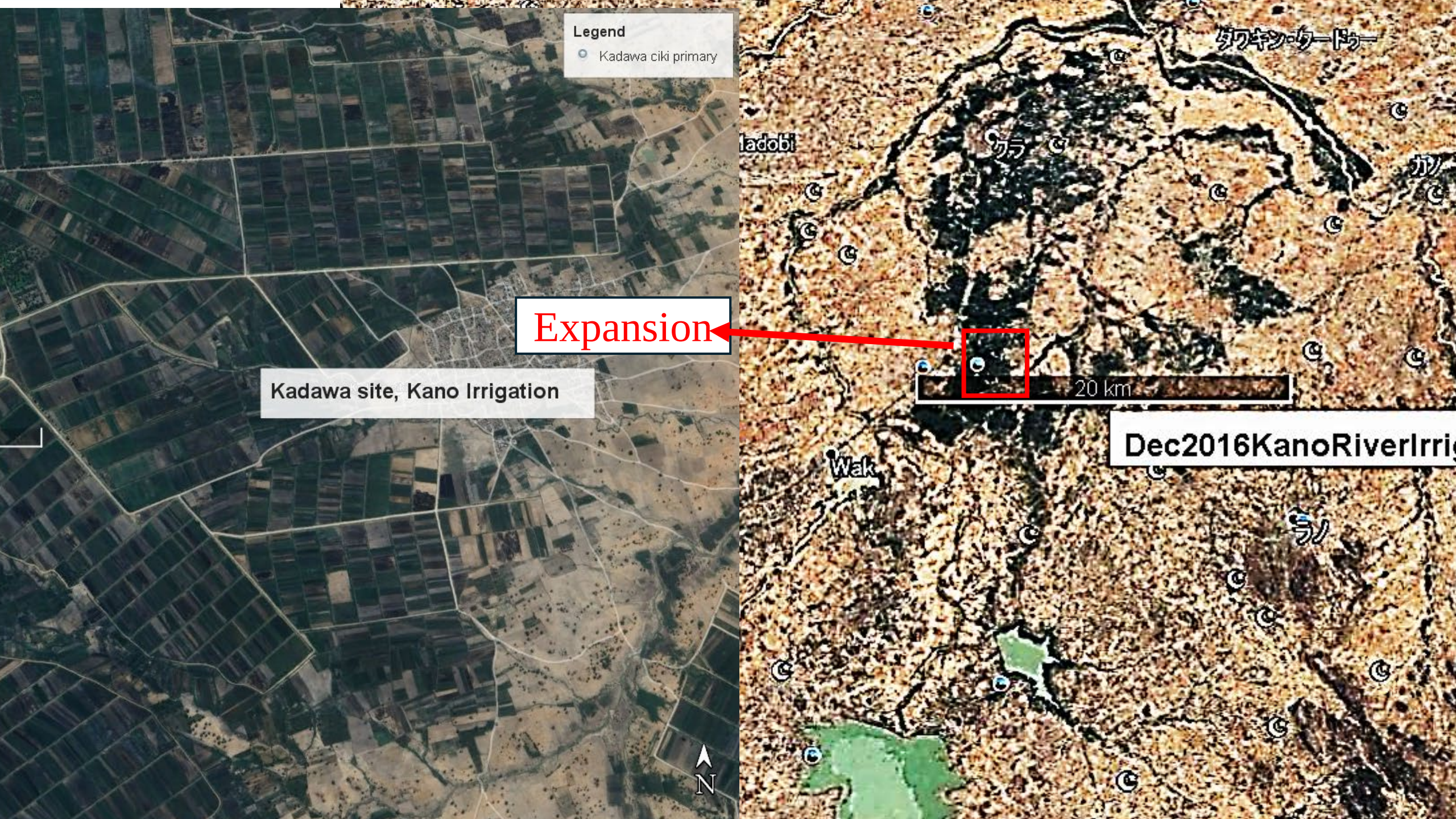


Figure 16

South Lake Chad Irrigation

Since the 1980s, the surface water level of Lake Chad has dropped by 3-4 meters, making it impossible to draw water. Recent research showed that the lake's water amount is stable as groundwater at a depth of 70 meters (Binh Pham-Duc et al 2020).

Mobile pump on-site irrigated vegetable and poor sawah rice cultivation sites, Antul village area along Yazarem river, about 20km West from Dikwa. This site is almost the same original South Chad irrigation site. Photo was May 2011.


Legend
Kadawa ciki primary
Expansion
Kadawa site, Kano Irrigation
N
20 km
Dec2016KanoRiverIrri

(3) Micro Rudimentary Sawah Plots at Kadawa Irrigation, June 2017 by NCAM team

4/2025Kadwa,Kano

11.669N 8.

100 m

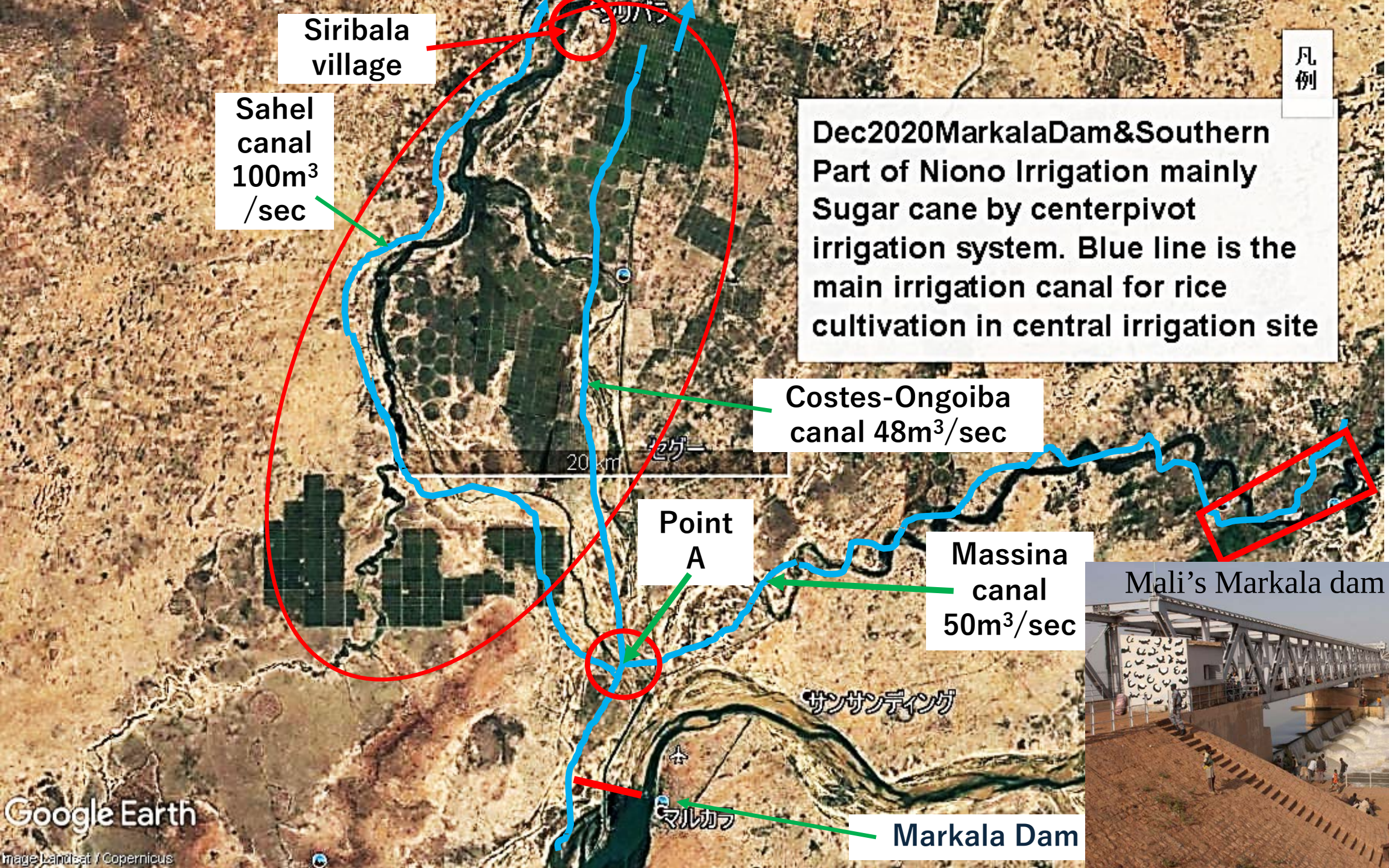
Google Earth

Image © 2025 Airbus

Irrigated ridge rice cultivation

Micro sawah plots (Evolutionary Stage 3) at Archaeological site of early period of Yayoi era, about 2400-2500 years ago, Nakanishi, Nara, Japan, One plot size is 10-25m^2. (Photo by T. Komori, 2011, http://tsu-com515.my.co ocan.jp/H23.11.12.Naka nishiIseki.html).

wooden weir to intake river water for



Mali's Markala dam (Alamy)

Upper: Niono irrigation site (Jan. 1989): Irrigation & drainage canal system available but no bunded leveled sawahs

Lower: The same site above (Aug. 1998): Farmers are busy to make no leaking bund and trans plating after leveling

Table 1. History of irrigation and Sawah platform evolution based on the trends of paddy yield and transplanted and standard sawah (Evolutional stage 4) area in Niono Irrigation sites, Office du Niger in 1935/1973-2002

Year	Total Farm Land Area (ha)	Wet Season Trans-planted Ares(ha)*	Standard Sawah Plots Area (ha)*	Rehabili-tated Area (ha)**	Paddy Yield (t/ha)	Dry Season Vegetable (ha)	Dry season Rice & Maize Area(ha)	Orchards (ha)	Total Cropped Area (ha)	Cropping Intensity (%)	Total Land developed (ha)
1935-65											53,260
1973/74	40,139	0	0	0	2.1						
1979/80	35,104	0	0	0	1.8						
1982/83	35,182	0	0	450	1.6						
1983/84	36,920	5	5	1,773	1.8						
1984/85	38,154	37	37	3,778	1.7						
1985/86	39,433	529	529	5,886	2.1						
1986/87	39,910	869	869	7,898	2.2						
1987/88	42,125	1857	1857	9,617	2.3						
1988/89	43,352	2,721	2,721	9,880	2,3						
1989/90	44,251	4,166	4,166	10,872	2,4						
1990/91	43,872	6,766	6,766	12,452	3,3						
1991/92	44,435	21,462	21,462	14,637	4,1						
1992/93	44,843	22,797	22,797	16,870	4,7						
1993/94	45,442	25,893	25,893	18,455	4,9						
1994/95	44,950	29,487	29,487	19,190	4,6						53,260
1995/96	47,591	35,869	35,869	21,301	5,0	1,880	1,877	563	50,730	107	
1996/97	47,991	45,222	45,222	23,085	5,1	2,519	1,175	601	52,279	109	
1997/98	48,431	48,058	48,058	30,457	5,4	3,095	1,976	603	54,988	114	
1998/99	48,991	48,741	48,741	31,651	6,0	3,752	2,046	908	56,386	115	
1999/00	50,093	50,333	50,333	33,053	6,0	3,807	862	1,000	56,709	113	56,573
2000/2001	55,006	52,060	52,060	38,366	6,1	3,687	5,751	1,012	63,445	115	
2001/2002	56,506	54,093	54,093	40,166	6,1	4,592	7,072	1,012	67,080	119	64,301

*Successful transplanting operation needs the standard sawah platform (Stage 4), i.e., good bunding, ±5cm leveling, irrigation/drainage and puddling, thus the transplanting area and standards sawah area should be the same. **Rehabilitated area is the estimation based on the “irrigation management viewpoint” by the Office du Niger. The data are from Djibril Aw and Geert Diemer “Making a Large Irrigation Scheme Work, A case study from Mali”, The world Bank, 2005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凡例
14.255N 5.943W
300 m
Google Earth
Image © 2021 CNES / Airbus
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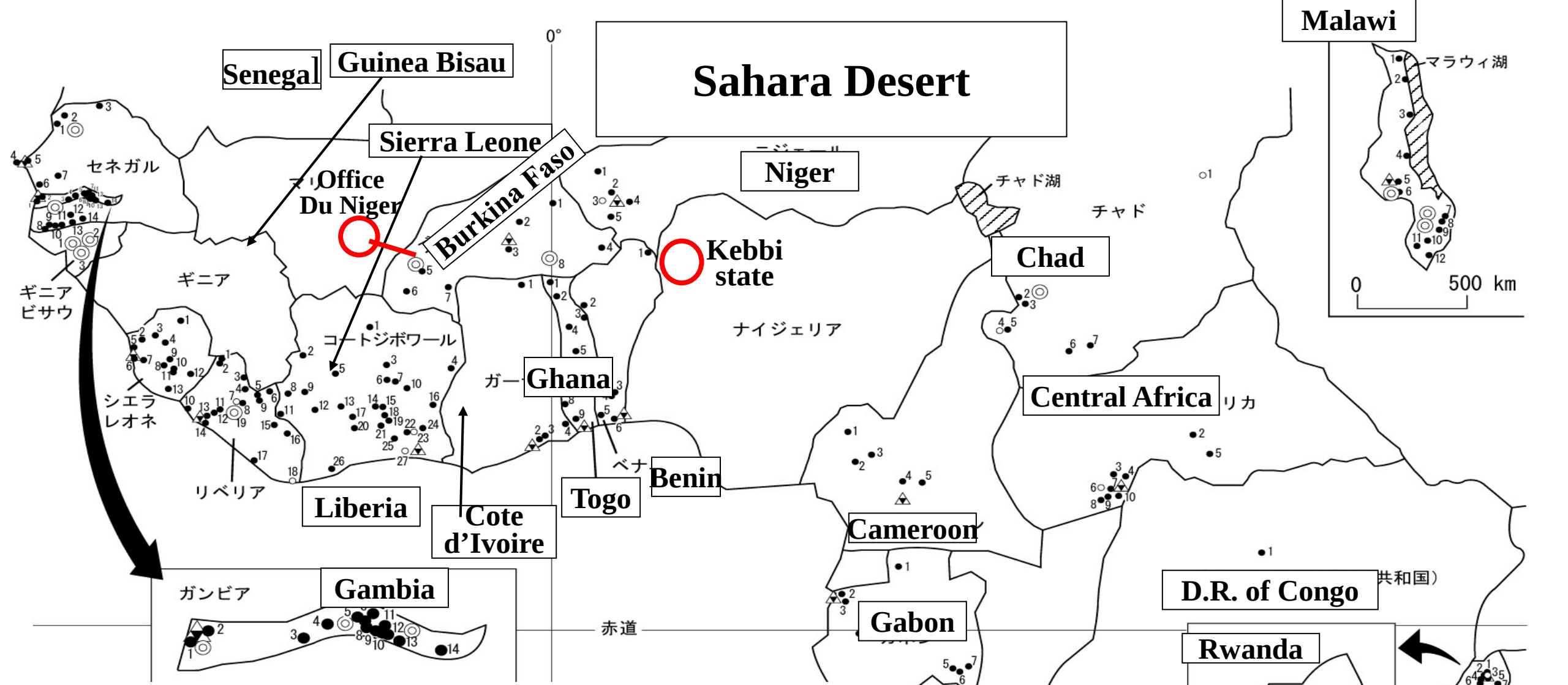
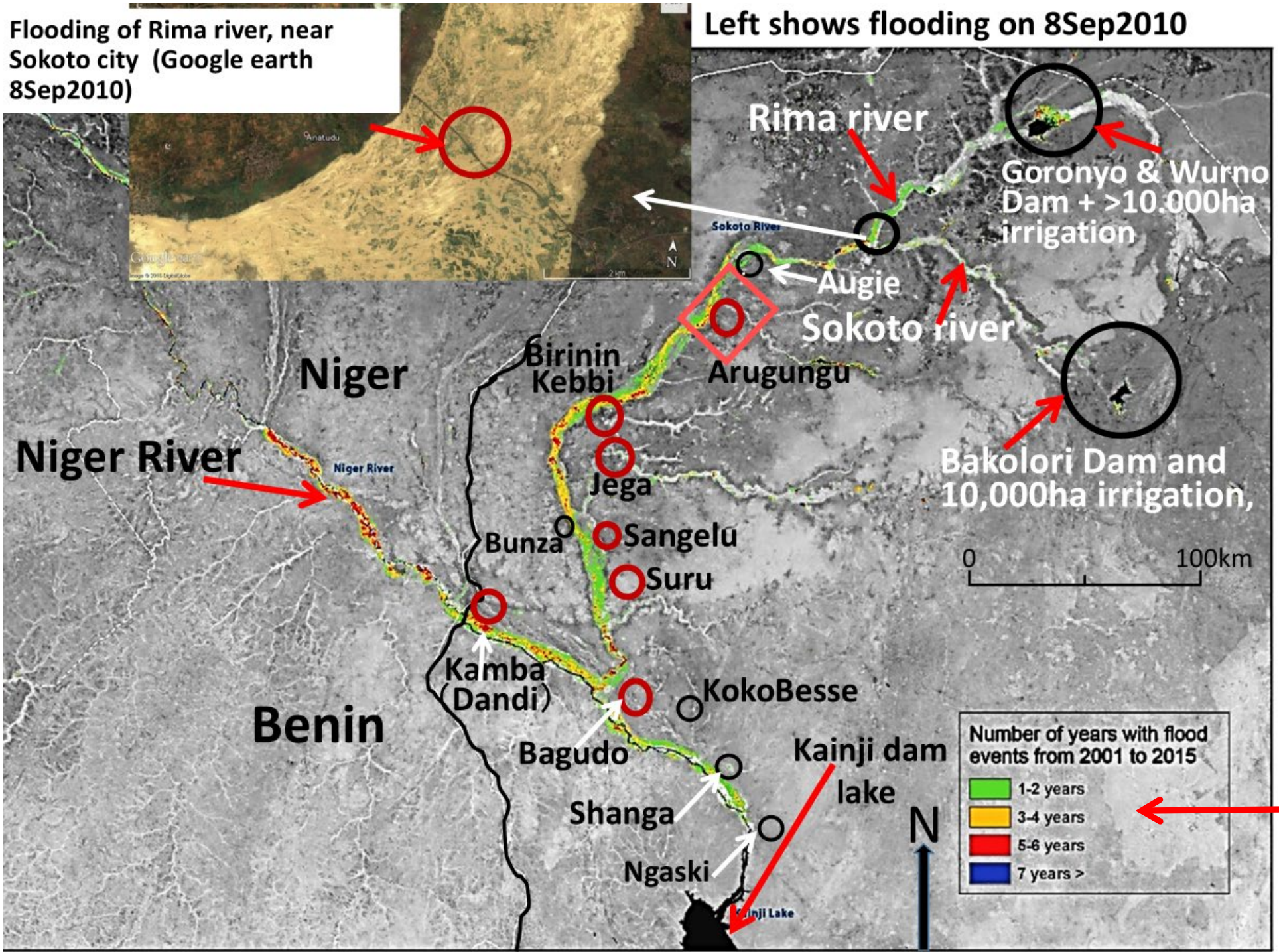


The Taiwanese team transferred sawah based irrigated rice cultivation technology on a large scale in 22 countries of SSA from 1961 to 1975 and from 1990 to 2003. They dispatched young experts to numerous locations showing the map, developing a total of 30,000 hectares good sawah platform and trained 80,000 farmers.



Endogenous development of farmer-led on-site ground water pump irrigated Sawah(paddy) rice cultivation in the savanna floodplain and inland delta in Kebbi state Nigeria

Original flood frequency map cited from Zwart et al 2016

Evolutional stage 1 Sawah cultivation of African rice (*Oryza Glaberrima*) in the floodplain of the Lima (Sokoto) River in Kebbi State. Right: Arugungu, left: Birinin Kebbi, photographed in December 1987.

On-site (no dam, no canal) pump irrigated small sawah (evolutional stage 3) in the floodplain of a tributary of the Niger River near Jega. Photographed in May 2011.

Sawah technology training and demonstration: Powertiller expands the area of each plot, followed by puddling, leveling to within ±5 cm, and then planting in straight rows at the appropriate water depth. Sawah platform, evolutional stage 4 and 5. Photo May 2011.

Africa's undeveloped floodplains and inland deltas have flat terrain, so small cultivators, water power tillers are more suitable than heavy machinery such as bulldozers and backhoes for rice sawah (paddy, Suiden) development, which is carried out by farmers themselves endogenously.

1ha of on-the-job training and demonstration plot (dry season crops are Egyptian-type ultra-high yields, >7 tons/ha), 15 May 2011, The 1st year sawah technology dessemination

Table 5. Training, Demonstration and Extension of Sawah Technology in Major Rice Centers, Kebbi State during March 2011 to May 2014

1. Kinki University/NCAM/Fadama III Demonstration and Training, March 2011-April 2012

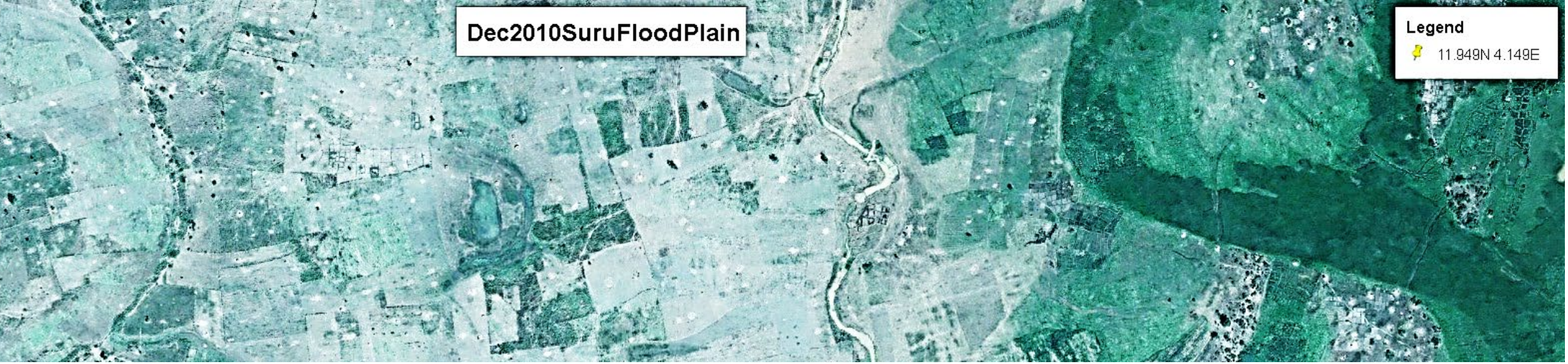
Local Government	Farmers	Powertillers No. supplied	Total Sawah developed (ha)	No. of 100kg Paddy bag	Paddy yield (ton/ha)
Arugungu*	Shared	2 shared	6.5	487.5	7.5
Birinin Kebbi*	Shared	2 shared	3.5	227.5	6.5
Jega*	Shared	2 shared	8	560	7
Total		shared	18	1275	7.1**

*The 1st Demonstration and Training , 2nd Extension and 3rd Dry season areas are shown in Figure 2.
Yield data by Fadama III
**Mean

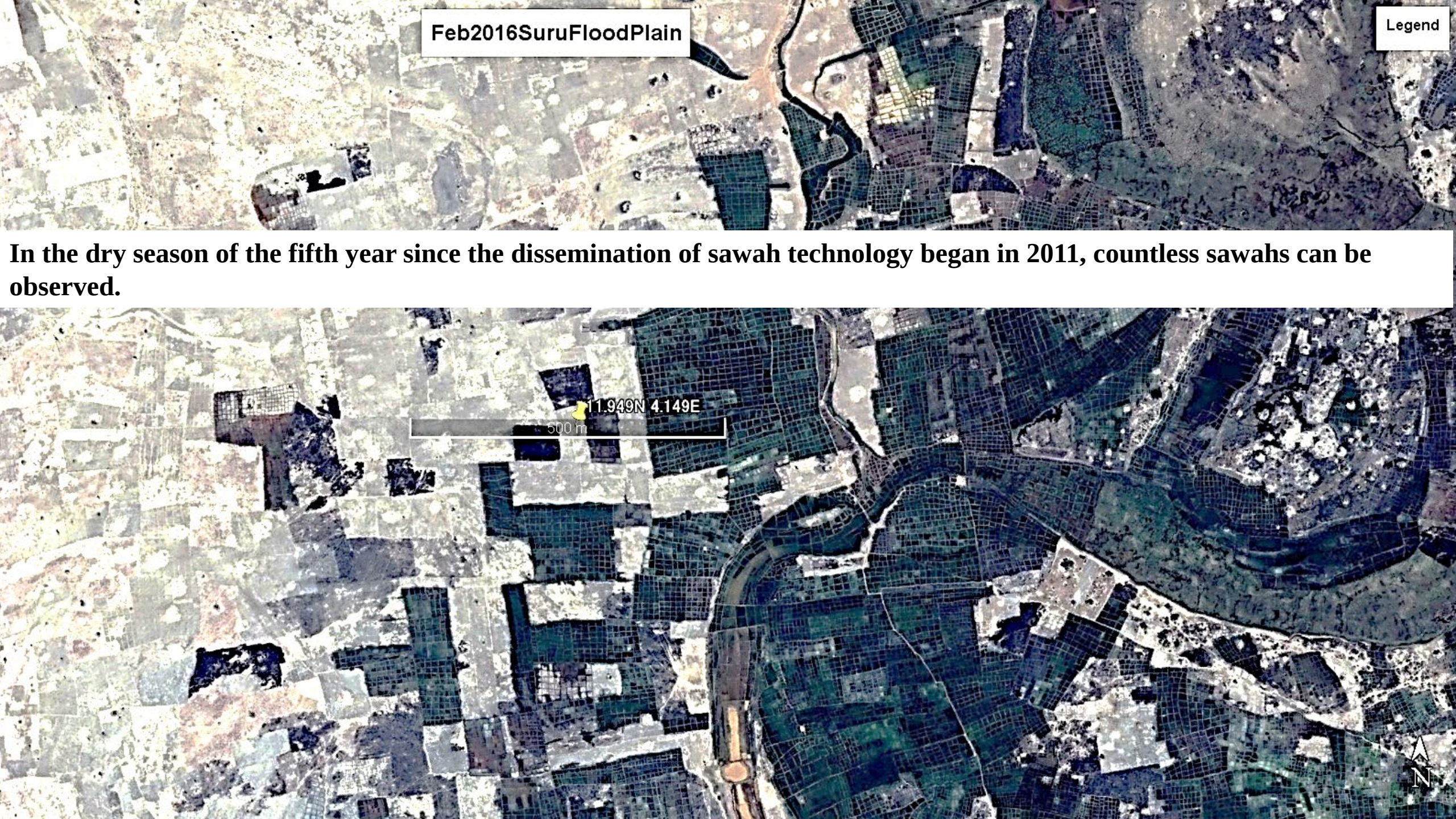
2. Endogenous Extension, April 2012-October 2013

3. Dry season, Nov. 2012-May 2014

Local Governm. Area (LGA)	Farmers	No. of powertiller bought	Sawah area developed (ha)	No. of 100kg paddy bag	Paddy yield (ton/ha)	No. of powertiller bought	sawah area developed (ha)	No. of 100kg Paddy bags	Paddy yield (ton/ha)
Arugungu*	MGD farm*	2	15	975	6.5	2	20	1400	7
	JUM farm	1	10	650	6.5	1	10	650	6.5
	ABK farm	1	4	260	6.5	1	8	480	6
	AK farm	1	3	180	6	1	6	360	6
	AMB farm	1	4	240	6	1	5	300	6
	Dr YA farm	1	4	240	6	1	5	300	6
	ANL farm	1	3	180	6	1	5	325	6.5
	AMI farm	1	6	390	6	1	10	650	6.5
	ASD farm	1	5	300	6	1	5	300	6
Birnin Kebbi*	ABA farm*	1	4	260	6.5	1	4	—	—
	BB farm	1	3	180	6	1	6	360	6
	AS farm	1	3	180	6	1	6	360	6
Bagudo*	ABB farm*	5	35	2450	7	5	50	3500	7
Jega*	HHJ farm*	1	7	455	6.5	1	14	910	6.5
	AUA farm	1	20	1200	6	1	40	2400	6
Suru*	Dr.UD farm	1	5	300	6	1	5	300	6
Total		22	131	8440	6.4**	22	199	12595	6.3**

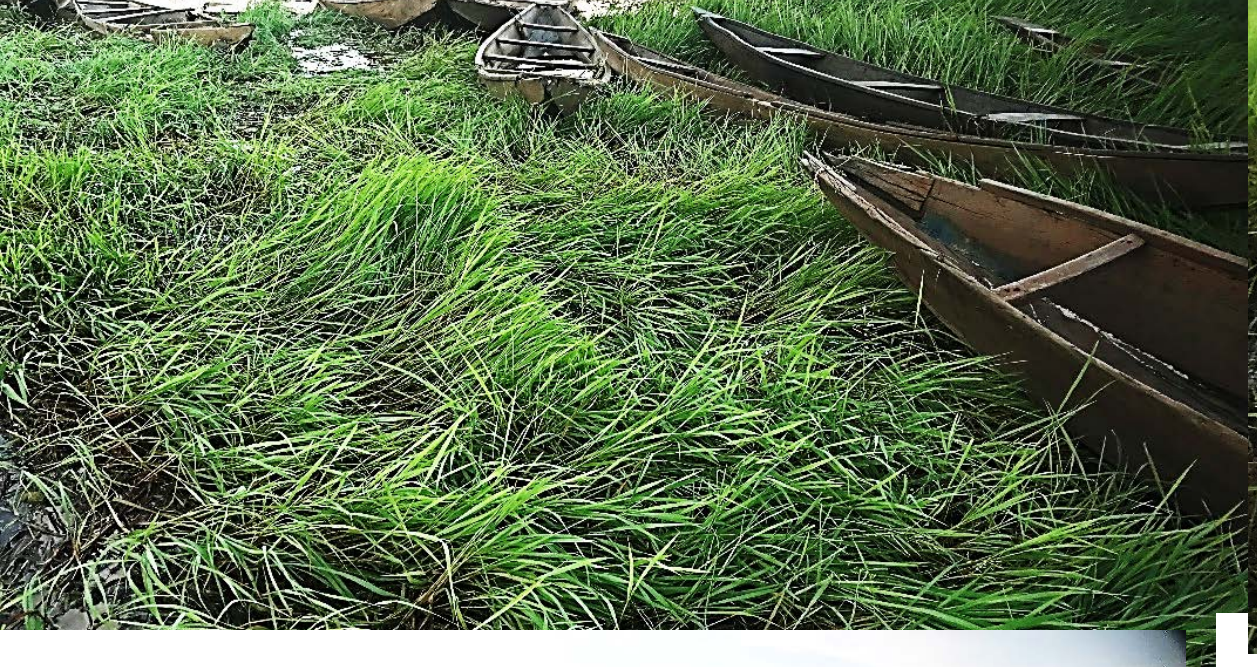


No rice sawahs (paddies). The beginning of the dry season. The meandering Zamfara River, a tributary of the Niger River.

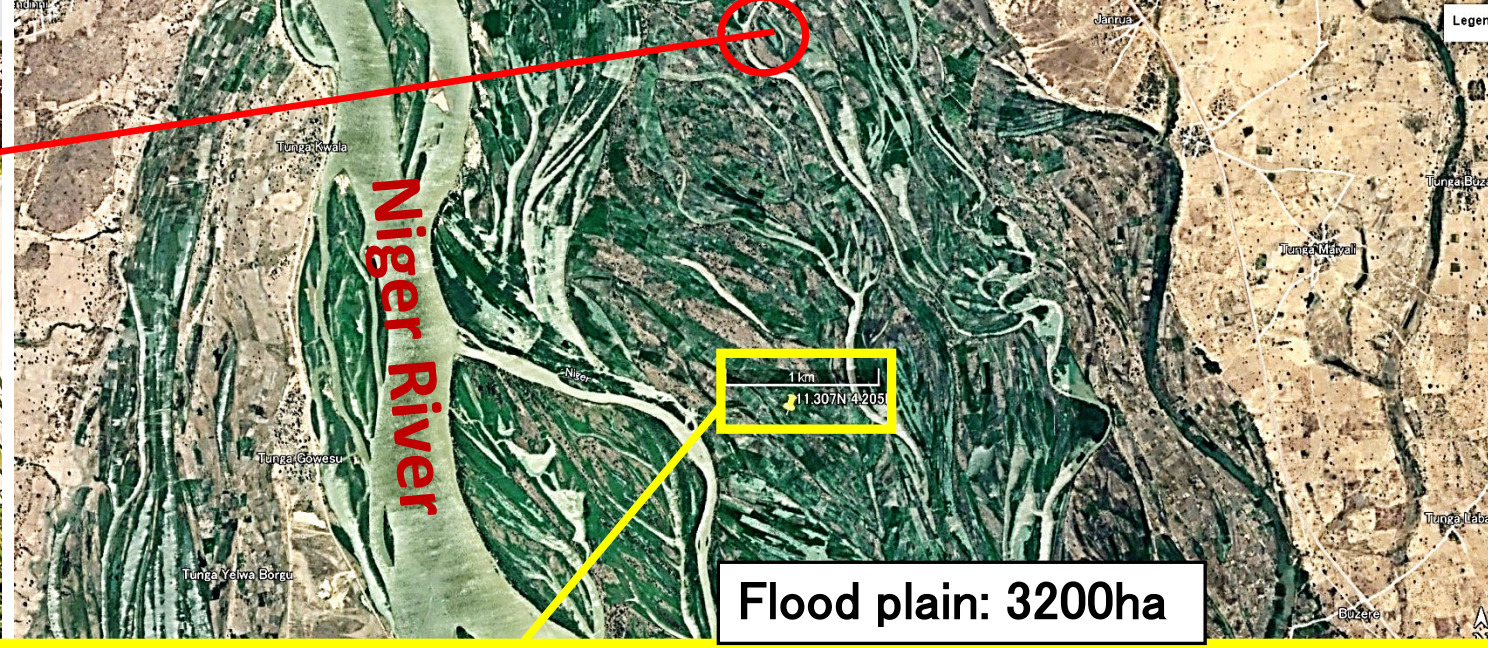


In the dry season of the fifth year since the dissemination of sawah technology began in 2011, countless sawahs can be observed.

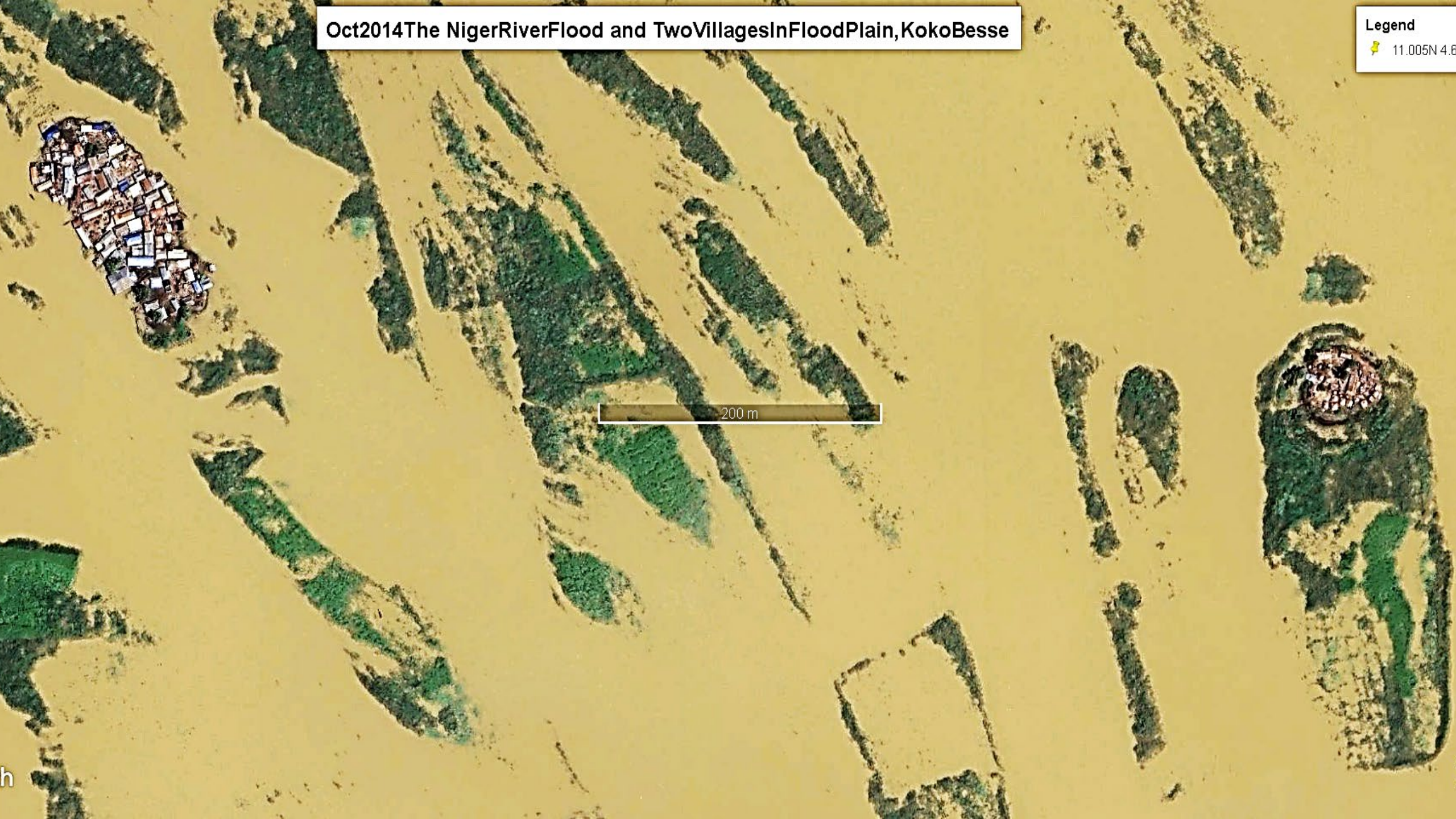
In 2020 farmers developed everywhere. In Suru LGA alone, more than 50,000 ha, in Kebbi State as a whole, more than 200,000 ha, achieving a total paddy production of more than 2 million tons per year with 1-3 crops per year (GEMS4, 2017).



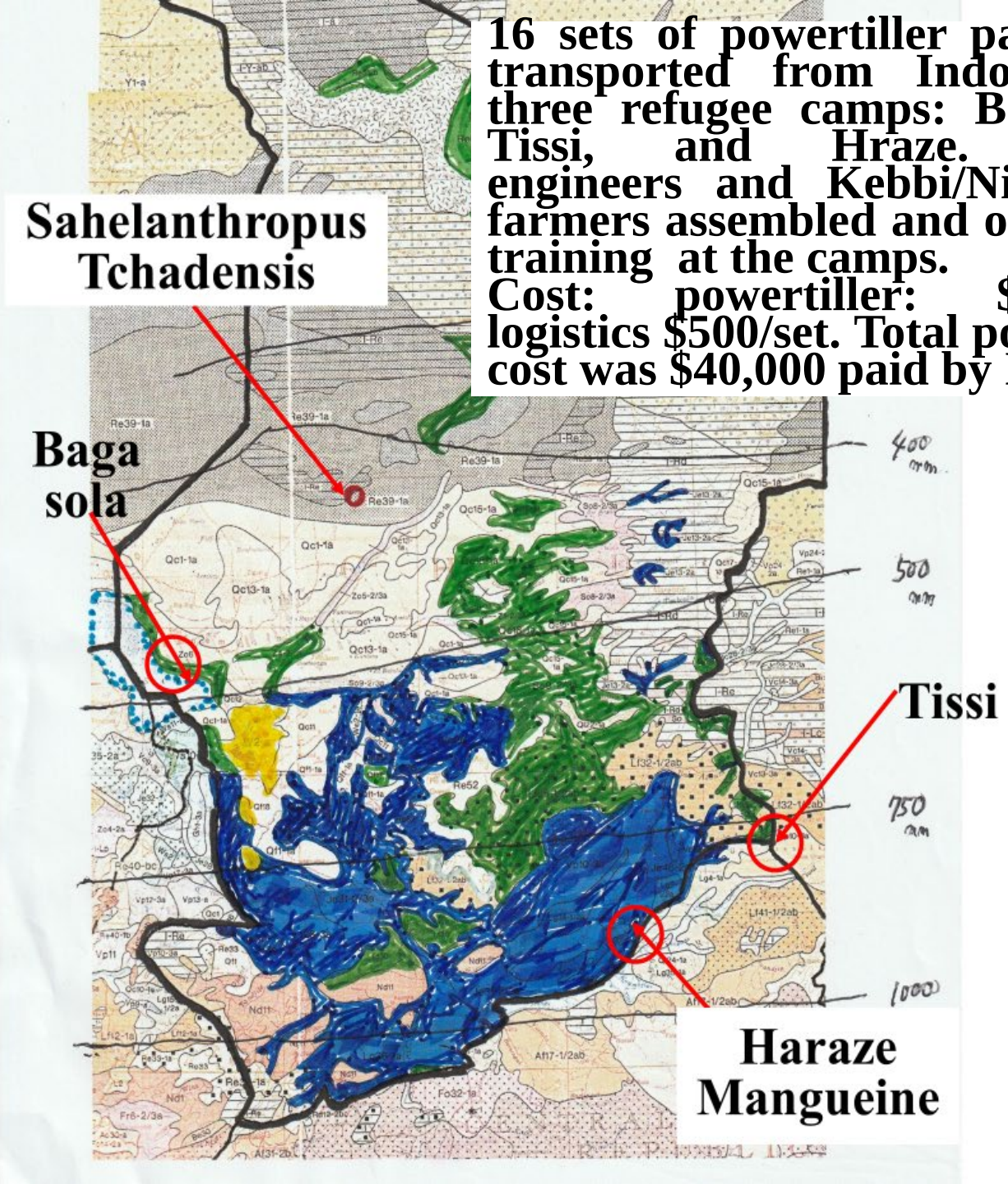
Photos taken on wet season September 2019, A position, Suru Flood plain.


Niger River
Tunga Kwala
Tunga Gowesu
Tunga Yelwa Borgu
Tunga Malwali
Jantua
Buzere
1 km
11.307N 4.205
Flood plain: 3200ha


Legend
11.307N 4.205E
200 m


Oct2014The NigerRiverFlood and TwoVillagesInFloodPlain,KokoBesse
Legend
11.005N 4.6
200 m

16 sets of powertiller parts were transported from Indonesia to three refugee camps: Baga sola, Tissi, and Hraze. NCAM engineers and Kebbi/Niger lead farmers assembled and on-the-job training at the camps.
Cost: powertiller: $2000/set, logistics $500/set. Total powertiller cost was $40,000 paid by IOM.



Between March and May 2017, staff from NCAM in Nigeria, together with 20 members of lead farmers' team—selected from Kebbi and Niger States and trained in Sawah (Eco-)technology—were dispatched to three locations in Chad (Baga sola-Boko Haram, Sudan and the Central African refugee camps). They carried out training on the development of 2 ha of sawah platform for rice cultivation at each site using power-tillers, as well as on rice cultivation.

Although no subsequent follow-up was carried out, Google Earth imagery from March 2024 (showing Tiss, where the Sudanese refugee camp is located) confirms that the sawah fields have been expanded by refugees and local residents, resulting in two areas circled in red (each 4–5 hectares, totaling 10 hectares).