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Sawah Technology「アフリカ水田農法」 (3-3) :Evolution of Sawah Platform in Mali, Burkina Faso, Corte D'Ivoire, Senegal, Mauritania and Gambia

Toshiyuki WAKATSUKI

Life and Environmental Science, Shimane University, Matsue, Japan
Mail: wakatuki@life.shimane-u.ac.jp

Content

1. Mali and Burkina Faso

1.1. Niono and Massina irrigation sies in Mali

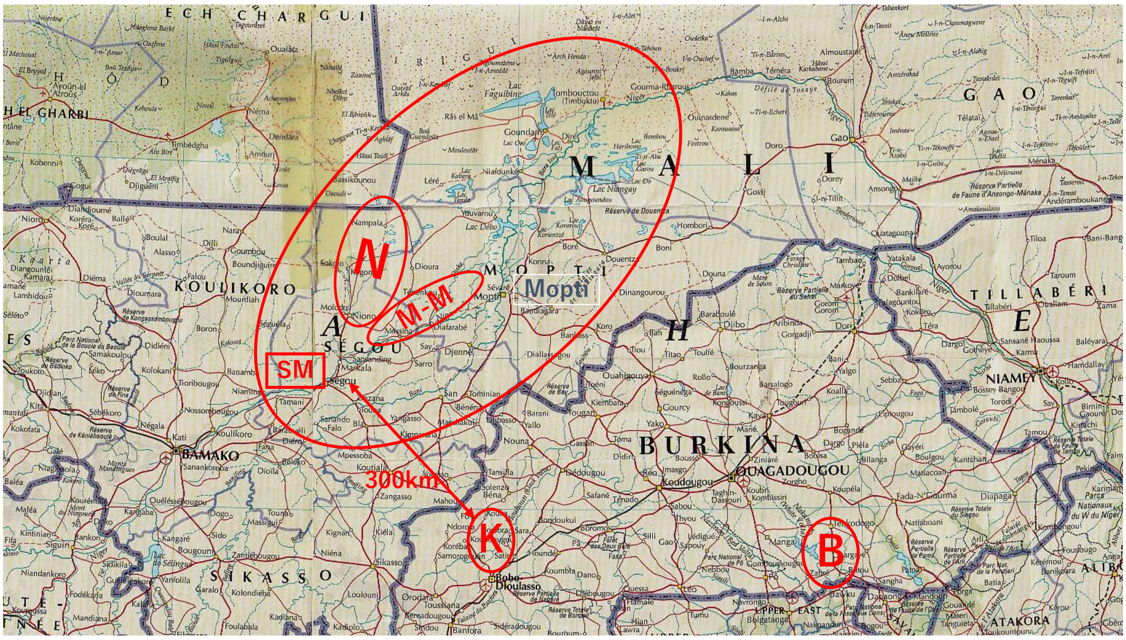


Figure 1. Map Niono(N)/Massina-Malibya(MM) irrigation sites of Mali's Office du Niger and Vallee du Kou(K) and Bagre irrigation site(B), BurkinaFaso (The Times Atlas 2007).

Total Area of Inland Delta and Flood Plains of Mali is about 6-8 million ha. Markala dam/weir at Segu (SM) is using for irrigation at Niono site (N) and Malibya-Massina (M-M). Taiwan team Asian model of 1000ha of standard sawah platform using weir irrigation in 1965 at Vallee du Kou(K), Burkina Faso. This site seems to contribute the dramatic success/rehabilitation of the Niono rice irrigation site in 1982-2002. Taiwan team also developed dam based more than 3000ha of irrigation site at Bagre (B) in 1994-2018.

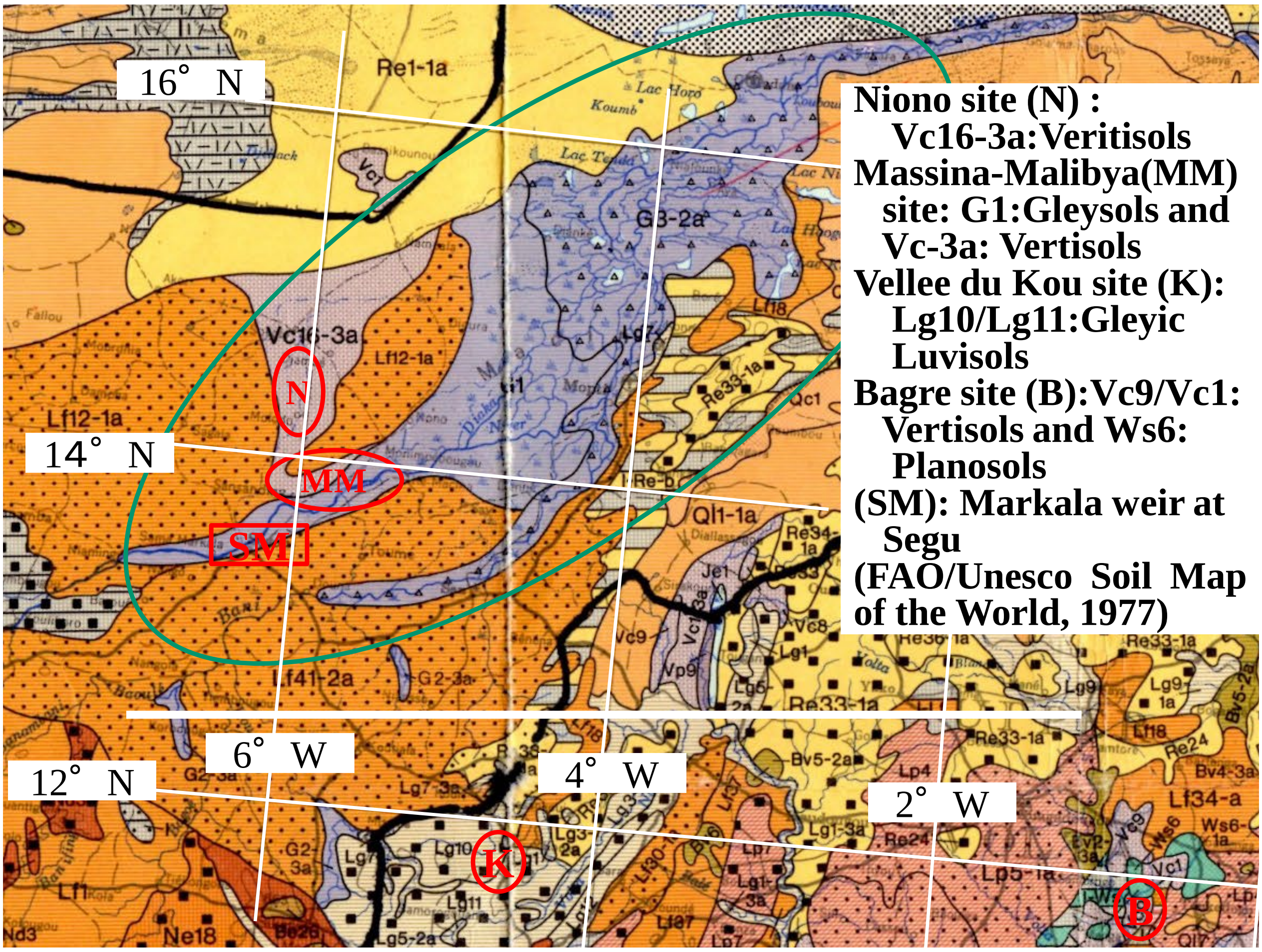
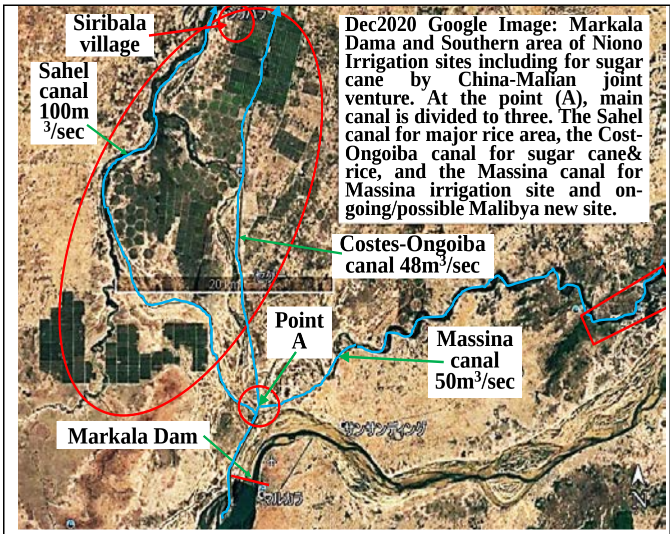


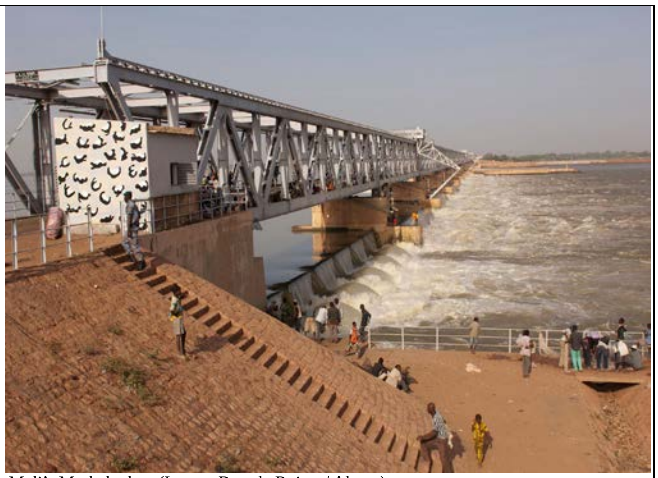
Figure 2. Soil map (FAO-Unesco 1977) of the same areas of Figure 1. Google earth image.

Figure 1 shows Mali's inland delta and the flood plains, of which main areas are surrounded by the green oval line. It is considered to one of the areas where the domestication of African rice, *Oryza Glaberrima*, began about 3000 years ago. The two small red oval parts described (N) and (M-M) on the left side of the Fig. 1 show the Niono irrigation project sites, which have now reached about 100,000 ha in (N) area and 30,000ha in (M-M) area. Development began in the French colonial era of 1932 for irrigated cotton cultivation. It is the largest rice irrigation scheme currently in SSA. As shown in Figure 3A, the irrigation water taken from the Markara Barrage (weir/dam) at Segu built on 1947 is divided into three main irrigation canals at Point A (Figure 3A). The central canal is passing through Niono irrigation area, and finally join to the inland delta of the Niger river, which is main irrigation and drainage canals. The range of water flows at the Markala dam in rainy season 500-2750 t/s in July-December (September is the Maximum) and 100-200 t/s in January-June (March-April is the minimum).

A weir (dam) is built on the Niger River near Markala at the lower left of the Figure 3A. This raises the water level of the Niger River by 5.5 meters draws water from the left side of the weir, and extends the irrigation canals to the north and east. Water intake is about 10% (198 t/ha) of the available water of the Niger River in rainy season. Without additional irrigation using ground water and reservoir ponds, such as Molodo Fala, dry season cropping will be limited. About 100,000 ha at Niono and 30,000ha at Massina sites are mainly for rice cultivation. About 40,000ha sugar cane are also currently growing (Wikipedia 2022). Malibya (Mali-Libya) project started in 2008. The Malian government awarded a 50-year renewable lease for 100,000ha un-irrigated farmland to the Libyan government. Through the Google earth observation on December 2020, about 25,000ha of farmers' rice fields are partly irrigated but majority of farm lands are under construction or stopping construction because of political instability (WikipediaA 2022, Brondeau 2018).

Taiwan team assisted to develop 1000ha of Asian model of standard sawah platform at the first time using weir irrigation in 1965 at Vellee du Kou (K), Burkinafaso (Hsieh 2001 and 2003, Wakatsuki and Hsieh 2003). This platform is possible to transplanting rice cultivation. This model site seems to contribute the dramatic success/rehabilitation of the Niono rice irrigation site in 1982-2002 as shown in Table 1. Taiwan team also played the major role of the Bagre (B)'s 3000ha irrigation project of Burkina Faso in 1995-2002. About 1200ha irrigated standard sawah platform were developed by the help of Taiwan team (Kao and Liu 2010). Very interestingly both Niono site and the Bagre site have similar soil type of Vetisols as shown in the Figure 2 (FAO-Unesco 1977). Massina site and Vellee du Kou have another good sawah soils of Glyesols.



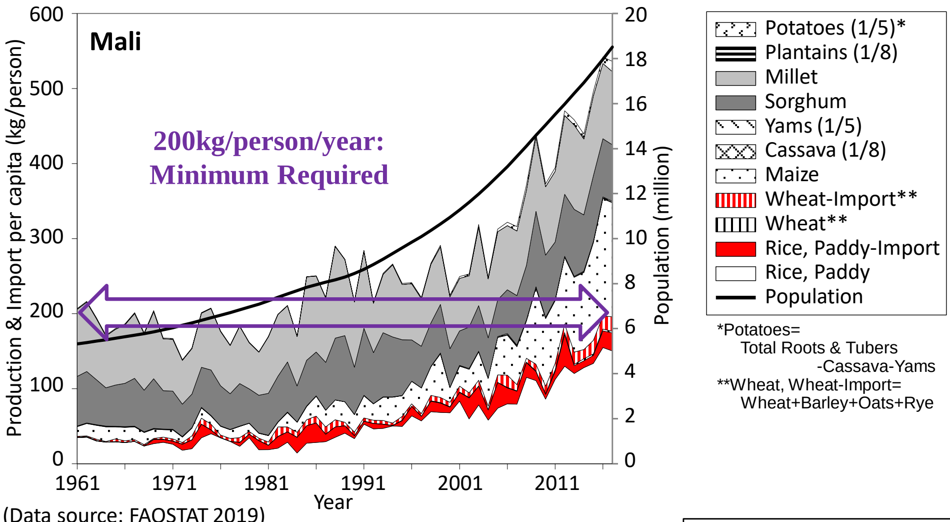


Mali's Markala dam (Image: Bert de Ruiter / Alamy), https://chinadialogue.net/en/nature/is-china-edging-away-from-a-massive-dam-on-the-river-niger/

Figure 3 A (left): The southern part of the Niono irrigation project site where SUKALA (2022), a joint venture between China and Mali, is cultivating sugar cane after expropriating the farmland of a local farmer. Figure 3B (Right): Markala dam to lift the Niger River water to irrigate Niono and Sukula ara (two blue lines of the left side and center) as well as Massina. Malibya (2014) project is located at Massina area (Moseley 2013).

The red circled area at the Fig 3A shows sugar cane plantation about 50,000ha and M'Bewani zone of rice cultivation of Mali's Office du Niger about 100,000ha (Figure 5-①), and the trapezoidal section indicated by red line is a part of the western end of the Massina irrigation, about 30,000ha of the Office du Niger. Around this area, government of Mali leased about 100,000ha to Libya in 2008 (See the Figure 7). China geo-engineering corporation (CGC) had operated the additional construction works for irrigation. The current situation is unknown, as both Libya and Mali have been politically very volatile since 2010. The expropriation of farmers' cultivated land by the Mali government, if happened in such a huge project, seems to be possible causing "neocolonial land grab", which is thought to contribute partly to the current political instability in Mali.
However as shown in Figure 4A, the trend of Mali's grain production per capita, especially rice, is growing rapidly since 1990. National mean paddy yield was 3.4t/ha and mean annual paddy production was 2.7 million tons during 2014-2019 (mean of FAOSTAT and USDA data cited from FAOSTAT 2022 and USDA 2016 as well as 2019), which comparative data were as follows, Nigeria: 2.2t/ha and 7 million tons, Madagascar: 3.5t/ha and 3.8million tons, Tanzania: 2.5t/ha and 3 million tons, Guinea 1.3t/ha and 2.2 million tons, and Cote d'Ivoire: 2.5t/ha and 2.1 million tons, respectively. This means rice productivity and production have increased. This means Mali's various huge irrigation projects have contributed to increase national food production.

As shown in Figure 4A, total grain equivalent amount of 200 kg/year/person indicates sufficient food production. Mali has achieved 400 kg/year/person before 2010 (Fig.4A), which is at a level which grain can export to foreign countries. However, it is unbelievable considering the serious social unrest in Mali in recent years. As shown in the Figure 4A, Rice has been imported even after 2010. According to Figure 4B, the average basal metabolic rate of Mali is only 1800 kcal/person/day including rice and wheat imports after 2011. It is only about half of the 3000 kcal/person/day estimated from the per capita grain production of 500 kg/per/year after 2015 (Figure 4A). If the reliability of these statistical data is acceptable, then a significant portion of Mali's grain production has been taken abroad. Are these data a manifestation of land-grab seizure by foreign companies? (Brondeau 2018, Hertzong et al 2012).



(Data source: FAOSTAT 2019)

Fig.4A. Various Food Production & Import (kg/person) in Mali (No.4 rice producing country in SSA) during 1961-2017.

Paddy production has been expanding dramatically last 30years. Now rice is No.1 food. Per capita consumption is more than 100kg per year now, which is similar level to Asian country. Maize production has increased recently.

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.

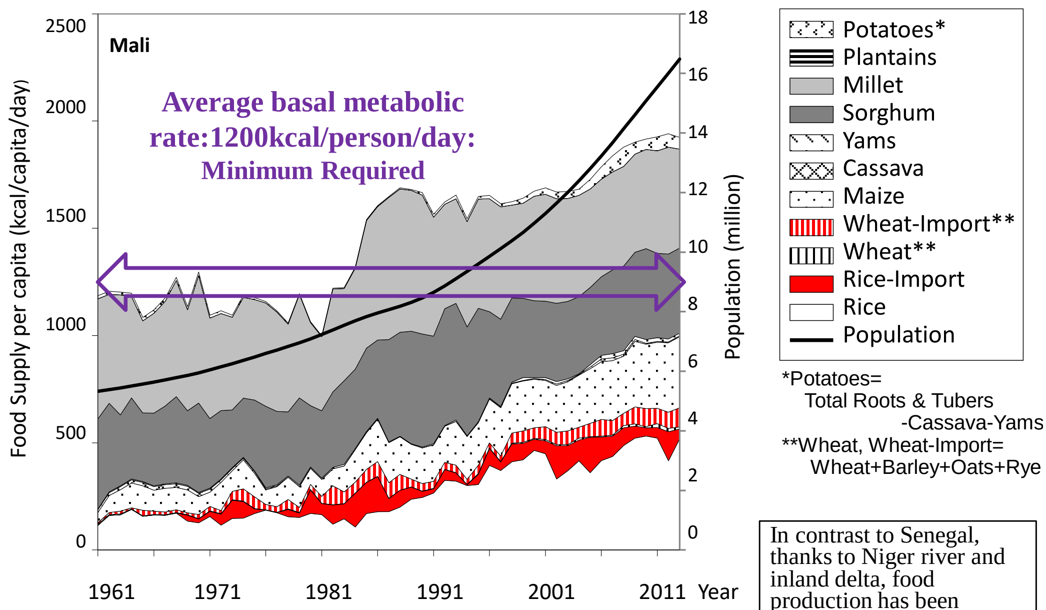


Fig 4B. Various Food Supply (kcal/capita/day) in Mali (No.4 rice producing country in SSA) during 1961-2013. (FAOSTAT 2018)

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.

In contrast to Senegal, thanks to Niger river and inland delta, food production has been developed and sustained in Mali. The amount of importation of both wheat and rice have not been visible, which as partly because of land locked country.

The truth of the land grab issue in Mali is a socio-political issue, not the subject of this report. Based on the data in Table 1 below, the historical development of the Niono Project site managed by Mali 's Office Du Niger in 1932 to 2002 will be discussed. The Niono project uses the Malakara weir as its water source. It is the largest and longest-running SSA irrigated rice project. From 1932 to 1960, it was developed by the French colonial government as a cotton growing area. However, since independence, rice has been cultivated mainly, and sugar cane has also been cultivated.

As shown in Fig. 5 (1), the total irrigated rice cultivation area at the current Niono Project site is estimated to reach 100,000 ha. The irrigated rice cultivated area for about 70 years from 1932 to 2002 was about 50,000 ha. As can be seen from the Table 1, from 1973 to 1990, paddy yield remained at a level of about 2 t/ha despite being an irrigated rice field. However, the paddy yield tripled from the level of 2 t/ha to the level of 6 t/ha in 2000 due to the expansion of the transplanted rice cultivation method that began in 1983. Before 1983 farmers had been practiced direct sawing method on the 12-24ha sized irrigated farmlands with irrigation and drainage canals. The farmlands have no proper bunded compartments and no leveling, i.e., the evolutional stages of the sawah platform were stage 1(no bunds), 2(ridge), and/or 3(micro rudimentary sawah).

In summary, before 1983, the Niono Irrigation scheme had irrigation and drainage facilities, but there was no standard sawah platform in farmer's rice fields. Therefore, the farmers could not manage the water necessary for rice cultivation. Therefore, the yield could not exceed the level of 2t / ha. Also, the efficiency of irrigation water utilization remained low. The basic problem was that neither the farmers nor the staffs of Office du Niger had the concept, technical term and technology for the sawah platform in irrigated rice cultivation.

Transplanting method is not possible without a standard sawah platform (evolution stage 4) or higher. Rice seedlings with a plant height of about 15 cm can be transplanted by leveling the sawah plot surrounded by the standards bunds with leveling quality of less than 10 cm (± 5 cm). This facilitates water and weed control.

1-2. Making Niono irrigation scheme work by sawah platform evolution during 1985-1995

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, ±10cm 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**

According to the World Bank report (Djibril Aw and Geert Diemer 2005), "Dutch supported ARPON (Improvement of Peasant Rice Cultivation at The Office du Niger) operated the improvement of both canals and rice fields in 1982-92 (Brondeau 2018). The canal systems were improved mainly by ARPON (donor) side and the farmers' fields mainly by farmers. The field improvement consisted of land leveling. The donor (ARPON) divided each 12- to 24-ha plot into half-ha compartment. Farmers then divided these compartments into smaller ones by building bunds and leveling a little more land inside them each year. As farmers invested their labor, they gained a greater stakes in the Office du Niger handling of the scheme than befitted their status as tenants”. These evolutional stage 4 sawah platform fields, which were developed by the farmers themselves, made it possible to grow transplanted rice cultivation. Therefore, the Office du Niger's irrigated sawah based rice cultivation (i.e., Asian Style) was not started in 1932, but half a century later in 1982.

The technical guidance for this project by the Dutch team was probably based on the technical cooperation provided by the Taiwanese team in 1962-73 at Vallee du Kou scheme of 1300ha sawah platform good for transplanting method, in neighboring Burkina Faso. The author (Wakatsuki) visited the Vallee du Kou site in April 1987 (Burkina Faso had established diplomatic relations with the continent China from 1973 to 1994) after Taiwan left (Taiwan had diplomatic relation in 1962-1973). At that time, the site's operational support had been done by Dutch technical cooperation team. They had been also working with Mali's Niono project team of ARPON. The distance between Vallee du Kou and Segu in Mali is about 300 km, and it was connected by nice paved national highway, and it seems that there was historically continuous exchange between farmers and the private sectors in both countries.

In addition to the Google earth images shown in Figures 55 to 58 below, the records and photographs of the field surveys conducted by Wakatsuki in 1987, 1989, and 1998, I will discuss on the historical improvement of evolutional stage of the sawah platform through the farmers self-help efforts and technical backstopping by Mali’s Office du Niger, The Netherlands, French and Taiwan, in Niono Project site.

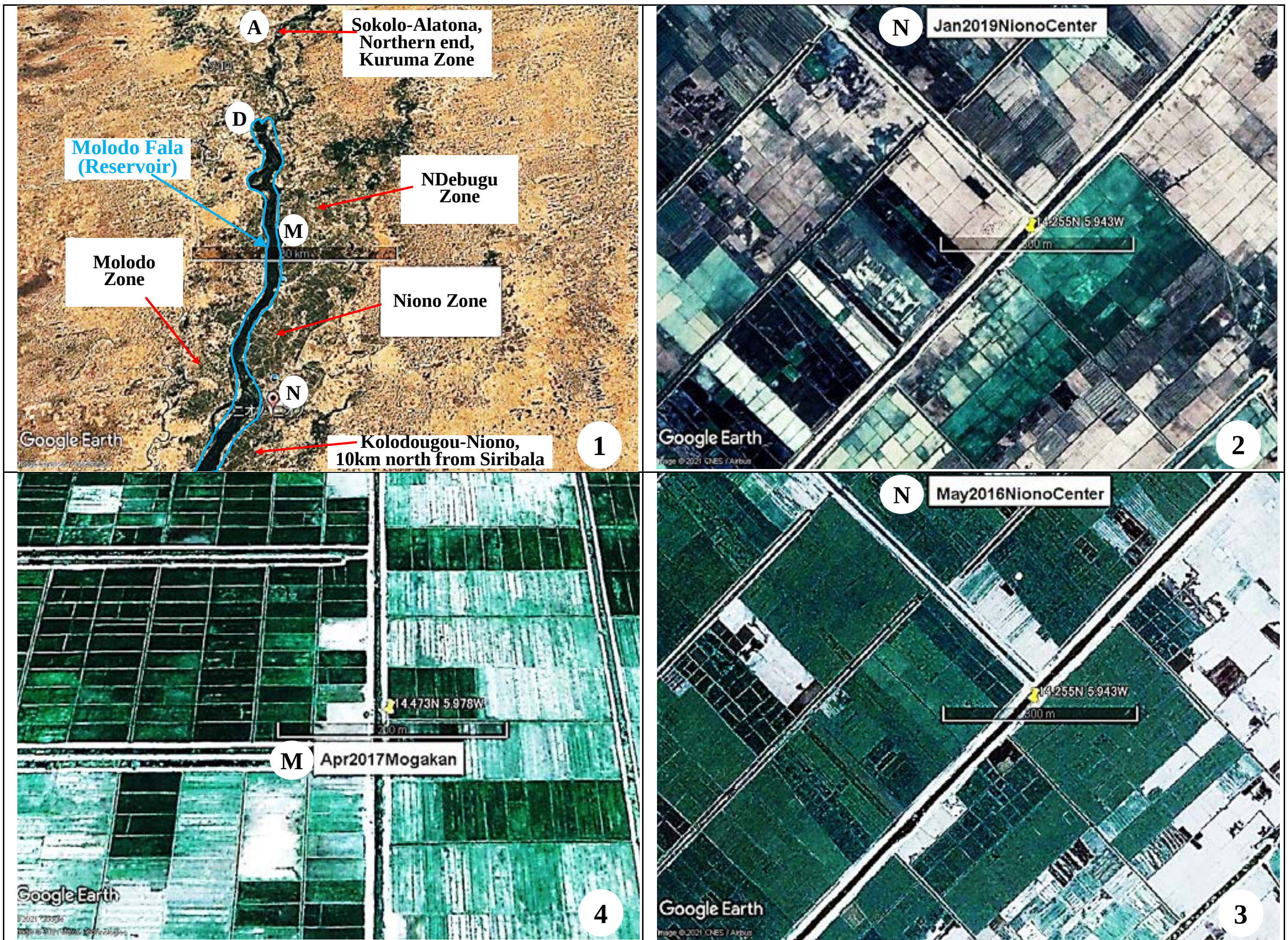


Figure 5① shows the core area of Mali's Office du Niger, which started in 1932 for irrigated cotton cultivation. Figure 5② and ③ are Google earth images at the same area of the centers of the Niono (N) site on January 2019 and May 2016 respectively. Figure 5 ④ shows the sawah platform at the Mogakan area(M) on April 2017. Figure 5 ②-④ are a standard irrigated sawah system platform of evolutional stage 4. Since ② is the beginning of the dry season, the sawah plots that are thought to be just before transplanting, the plots where the ridges of for the upland cultivations such as vegetable, sorghum and or maize can be seen. Since ③ is the beginning of the wet season (May), almost all sawah plots are covered with the young transplanted rice.

The central marker line of the Fig 5 ① has 30 km long, and the central fossil channel Molodo Fala (blue lined area), which flows from north to south, is an oxbow lake and also functions as a water storage for irrigation. The natural levee of this oxbow lake has been raised and stabilized to create a 100km main irrigation canal. This 100km distance gives only 10m elevation difference, i.e., 286m altitude near Point A at the southern end and 276m at the northern end of the Kuruma Zone (Fig 5 ①) at the north. Thus, irrigation water flow is very slow. It takes in a week.
From 1932 to 1990, farmers used direct sowing rice cultivation using plots developed for irrigated cotton fields of 12-24 ha. The evolution level was stage 1-3 sawah platforms, which had not been bunded or leveled as for irrigated sawah based platform. Therefore, the yield remained below 2 t/ha (Table 1, Djibril Aw and Geert Diemer 2005). As shown in Table 1, over the 20 years since 1982, farmers had been continuously improved through trial and error to create and complete the standard sawah platforms equivalent the stage 4, which is appropriate for transplanting rice practices. During the period the guidance of the Dutch and French technical teams and the model sawah platforms of the Vallee du Kou of Burkina Faso were seems to be all important.

As shown in the upper two photos in 1989 and lower two in 1998 of the Figure 6, in 1989 there were no standards sawah plots in the Niono Irrigation project sites. But in 1998 farmers are busy to work to develop and improve standard sawah plots and rice transplanting practices. As shown in the Photo of the Fig 6 ③, it was probable that the leveling of some sawah plots were not sufficient (height difference was 10 cm or more), so weeds were overgrown on the relative higher area in the plot, or some transplanted seedlings were under water because of too low after introducing irrigation water. The 7-8 farmers can be seen in the rear of the photo are doing bund-building and leveling work. Therefore, the development and improvement of sawah platforms for irrigated rice fields through self-help efforts by farmers is a long and time-consuming process of localization of technology.

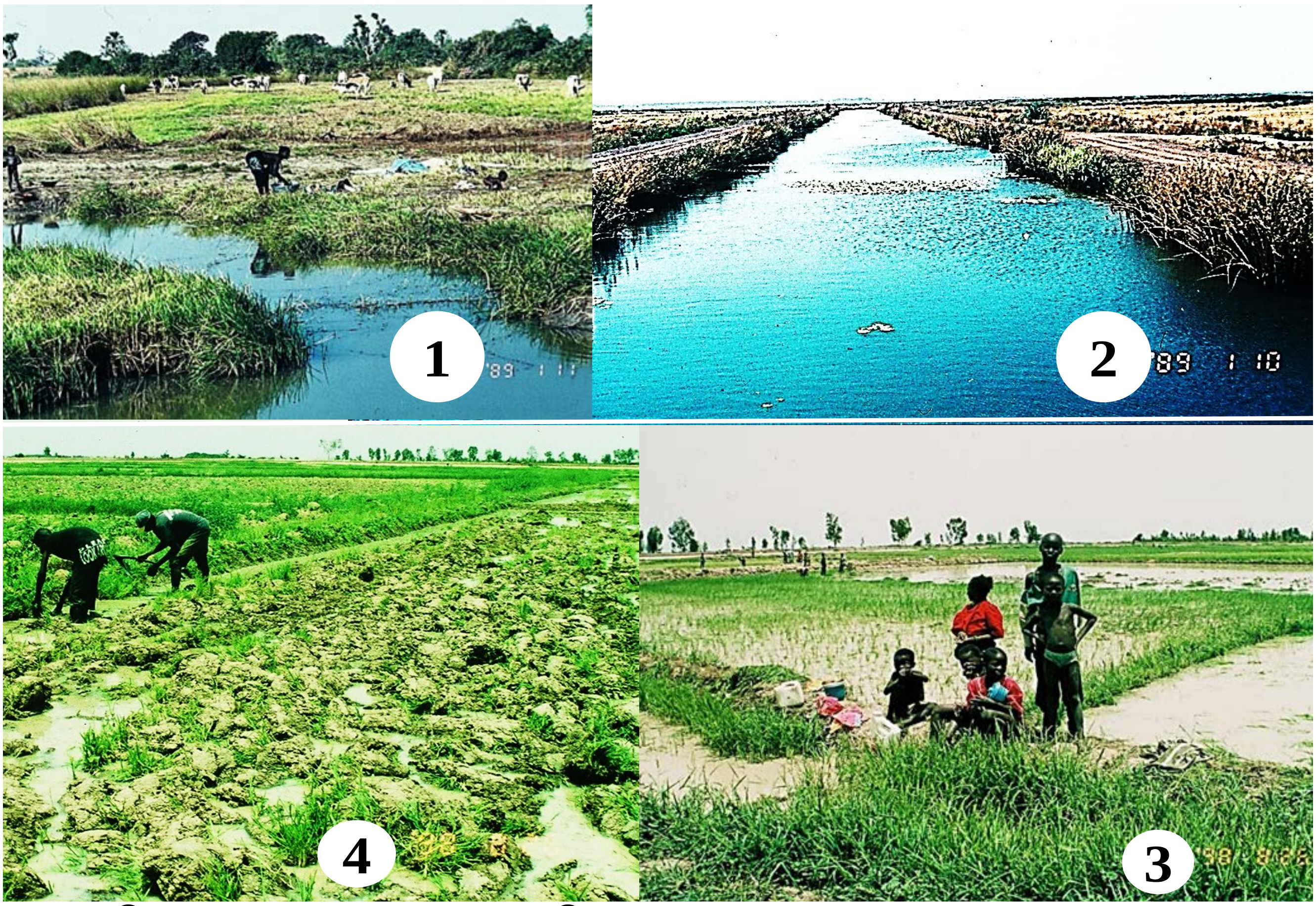


Figure 6 ①Rice cultivation at Massina and ②Rice fields and irrigation canal at Niono area. Both photos were taken on January 1989. Rice platform evolutional stages were 1 to 3. ③ and ④ were taken on August 1998 at Niono central rice area. Sawah platform stage 4 good for transplanting. ④two farmers are practicing for bund clearing to stop water leaking and many soil blocks inverted by oxen plowing are shown.

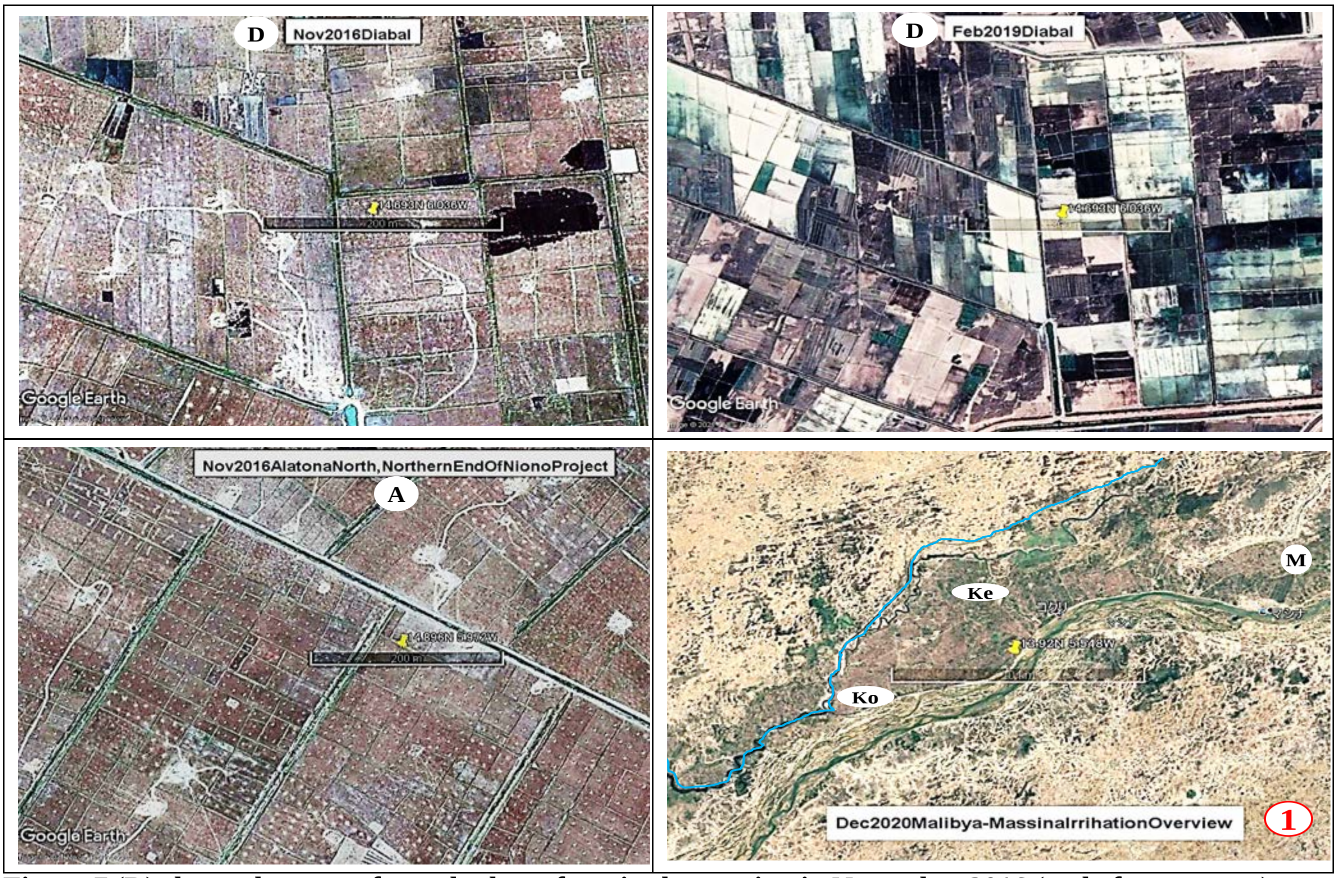
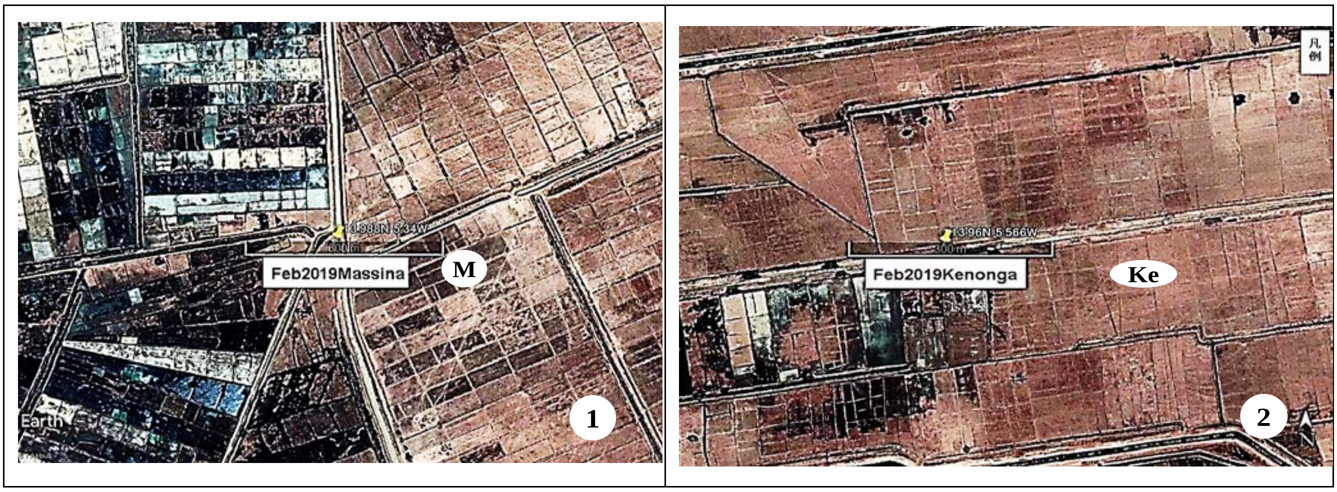


Figure 7 (D) shows the state of sawah plots after rice harvesting in November 2016 (end of wet season) near Diabal town, which location is shown in the Fig. 7 ①. The right side of the Fig. 7 (D) is a Google earth image taken at the dry season on January 2019. Figure 7 (A) shows sawah plots developed by farmers' own-efforts Alatona area, the northernmost part of the Niono project site. Figure 7 ① shows overview of Malibya-Massina area. Blue line is the Massina canal starting from the Point A of Markala weir system as shown in the Figure 3 (A). Sawah plots at (M) Massina, (Ke) Kenongo and (Ko) Kolongo are shown in Figure 5.

As seen of the Fig 7 (D:Diabal) left side: on November 2016, the area of sawah plots developed by farmers on their own is very diverse as 100-4000m^2. This is because the irrigation project made only irrigation canals and drainage canals. Farmers had to set up the undeveloped fields between the irrigation and drainage canals to the transplantable sawah plots according to the height difference of their fields. In 2019, Sawah plots were further subdivided and leveled into the evolutional stage 4 sawah plots improving more suitable for transplanted rice cultivation. Some of the Sawah Plots are also ridged and cultivated with vegetables. The size of the sawah plots in Fig 7 (A) are relatively uniform, and most of them are 400 m^2 in size.



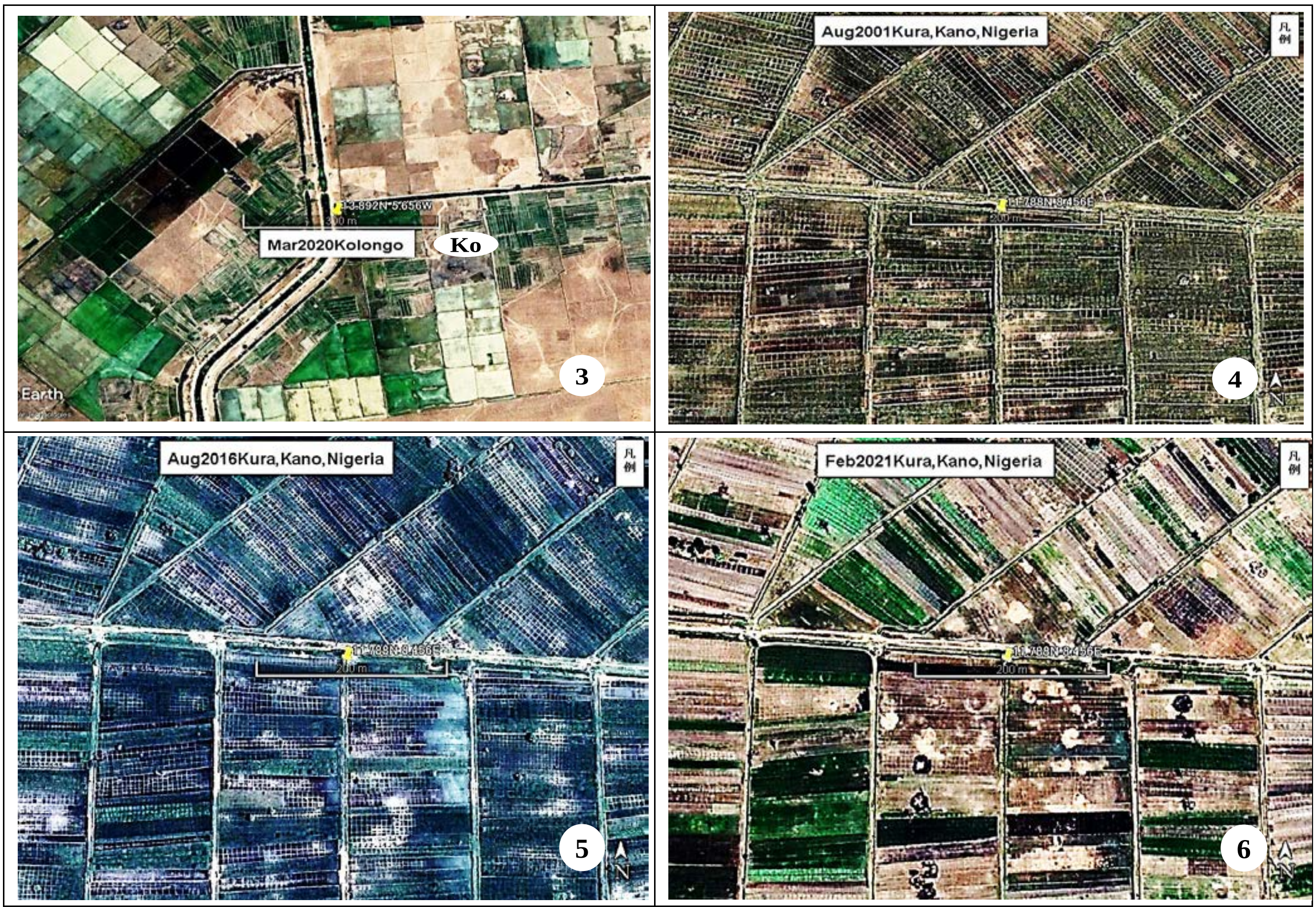


Figure 8 (1)-(3) shows standard sawah platform, evolutional stage 4, at ⑴Massina (13.988N 5.34W), ⑵Kenonga (13.96N 5.566W), and ⑶Kolongo (13.892N 5.656W) are Massina Irrigation sites under the Office du Niger, Mali. The positions of these three locations are shown as (M), (Ke) and (Ko) in the Fig. 8 (1)-(3). Figure 8 (4) and (5) show micro rudimentary sawah platform, evolutional stage 2 and/or 3, at Kura area in Kano Irrigation project site in Nigeria, which location information is 11.788N 8.456E.

The length of the central marker line is 300m for (1) Massina (M), (2) Kenonga (Ke), and (3) Kolongo (Ko). (1) Massina's Sawah plots are surrounded by straight and strong bunds with little leakage, which size is 400-2500m^2. (3) Kolongo site has orderly sawah plots of 2500m^2 in size. It seems that sawah platform development was carried out using heavy machinery. Sawah development at Kenonga, Fig. 8(2), are thought to have been done by farmers themselves. Bunds are not clear and weak. There are also some irrigated agricultural lands that has not been developed or improved (Evolutional stage 1 or 2). According to Wakatsuki’s field survey records, the Figure 6 ① photo was taken in January 1989 near Figure the 8 ①. As of 1989, no irrigated sawah plots were found.

Figure 8 ④-⑥ are Google earth images taken in 2021 at the Kura area, location information 11.788N 8.456E, of the Kano Irrigation project site in Nigeria. Similar to the sawah platform description (one plot size was 5mx5m) in the survey record when the author (T.W.) visited on August 1986, three Google earth images on 2001, 2016 and 2021 are all irrigated micro (rudimentary) sawah, evolutional stage 2-3. As mentioned in the chapter of “Sawah Technology (2) Background”, total Kano Irrigation area has 15000ha, which is the oldest and the biggest in Nigeria. Thus both current Kano irrigation project sites and Niono irrigation site before 2000 can not accommodate the green revolution technology (see Table 1).

1-3. First standard sawah platform in Vallee du Kou in Burkina Faso by Taiwan team in 1965-1973 (Hsieh 2001, 2003, Wakatsuki and Hsieh 2003)

The Vallee du Kou system (Figures 9-12) seems to have become a model for the development of transplanted rice cultivation platform (sawah stage 4) at the Niono site through ARPON (Amelioration de la riziculture paysanne a l'Office du Niger) of the Dutch team in the 1980s-90s (Djibril Aw.and Geert Diemer 2005).

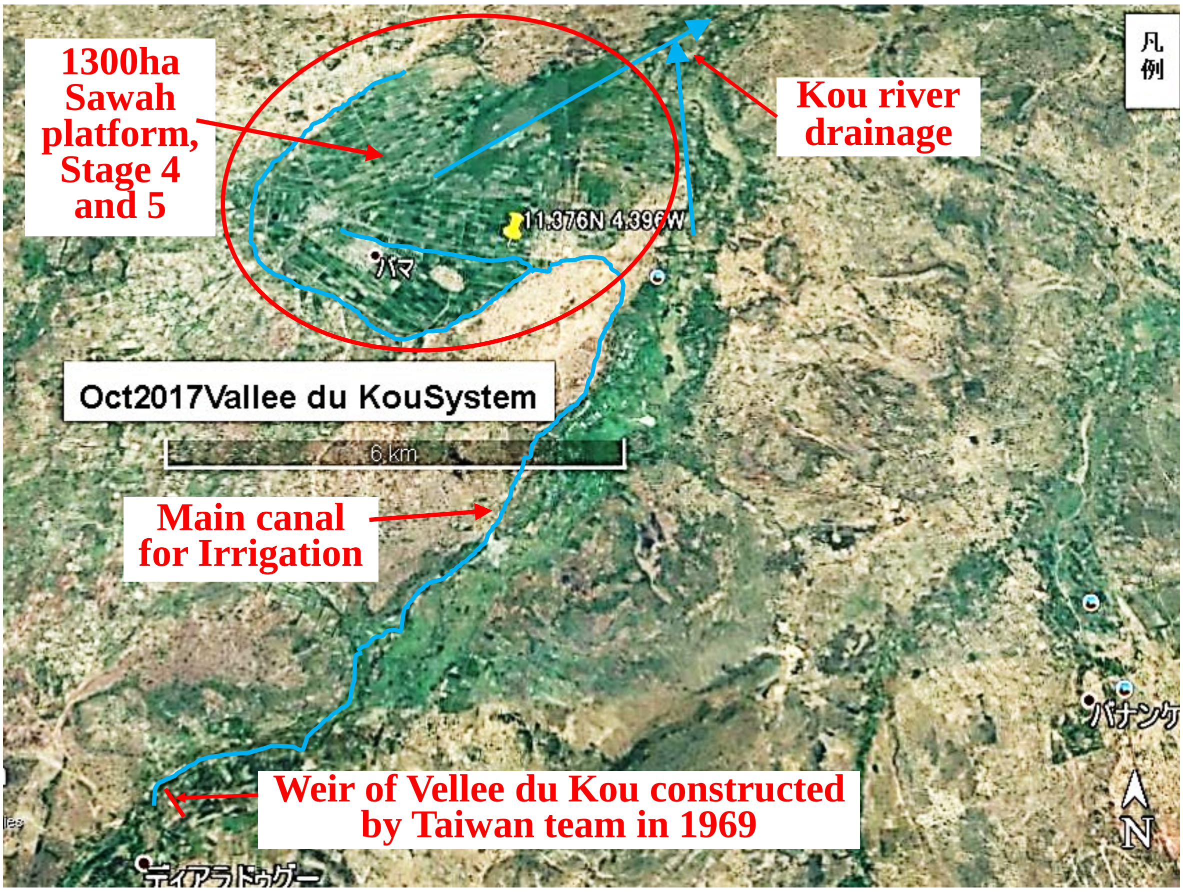
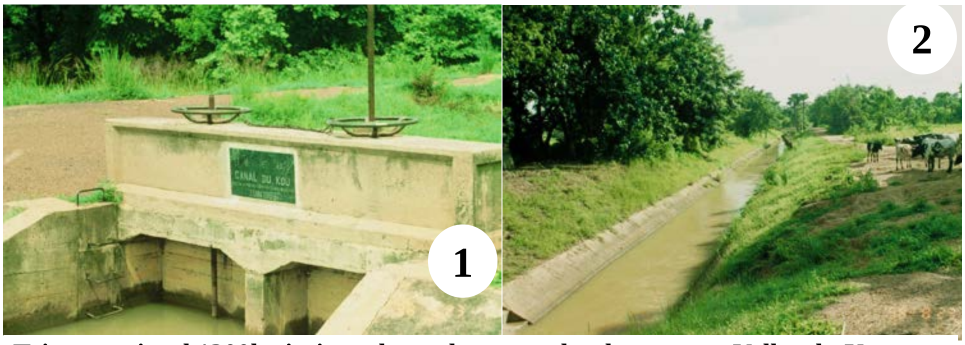


Figure 9. Google earth image showing Vallee du Kou irrigation system developed in 1969.

Figure 10. Evolutional stage 4 and 5 sawah platform in Vallee du Kou irrigation system established in 1969 by Taiwan team.



Taiwan assisted 1300ha irrigated sawah system development at Vallee du Kou was completed in 1969 (upper two and lower right were taken in 1998 and left in 2006).

Figure 11 ①The weir of Vallee du Kou, ②Main canal, ③Leveling operation for good transplanting,④All sawah plots are ready for transplanting

Figure 12 shows sawah plots which were transplanted and are preparing sawah plots for transplanting. Photo of ① and ② were taken at the Niono site on August 26, 1998. Photo ③ and ④ were taken at Vallee du Kou on August 23, 1998. The method of plowing using two oxens was the same for Niono and Vallee du Kou. The plows appeared to be from the same manufacturer.

1-4. Bagre irrigation site in BurkinaFaso

The Bagre project (Figure 13 and 14) in Burkina Faso is very interesting as an example of problems and solutions in developing large-scale dam lake irrigated rice fields in Sub-Saharan Africa and as an alternative small to medium-scale irrigation development. In particular, the cooperation between the intrinsic development by local farmers' self-help efforts for irrigated sawah platform development and the extrinsic support by government and ODA etc. are very important for prospecting sustainable future rice development.

Bagre Dam was completed in 1992 with the investment of 67 million CFA of the World Bank funding. The maximum water storage capacity is 1,7000Mm^3, the catchment area is 33,500Km^3, the width of the dam is 4.5km, the height is 30m, the area of the lake is 36,793ha, and the amount of power generation is 17M. Maximum irrigated rice fields area is 1,6000ha. But currently as shown in the Figure 13 (Map) Google image, the actual irrigated rice area is about 3000ha only (Kao and Liu 2010, Venot, et al 2017, Hauser J and Nielsen O, 2020.

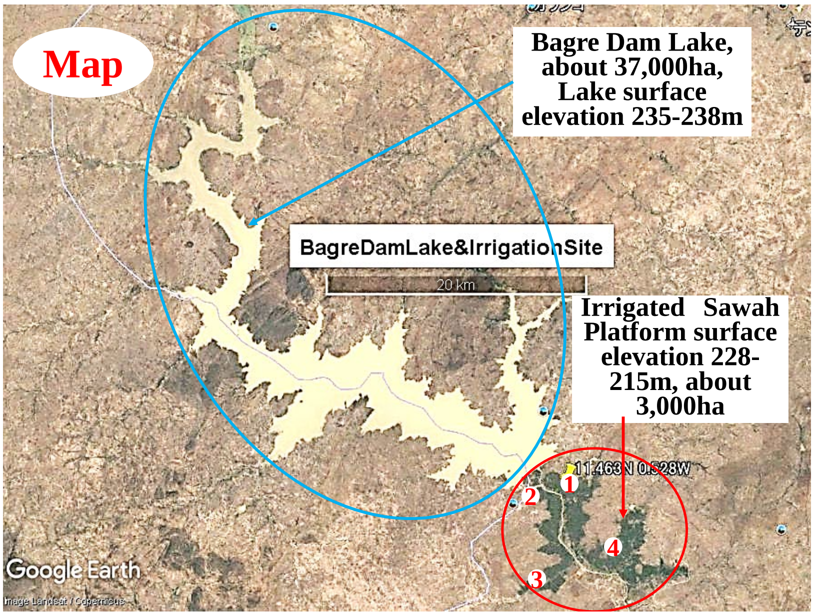


Figure 13 (Map) showing 37,000ha dam lake and 3000ha of irrigated rice fields,

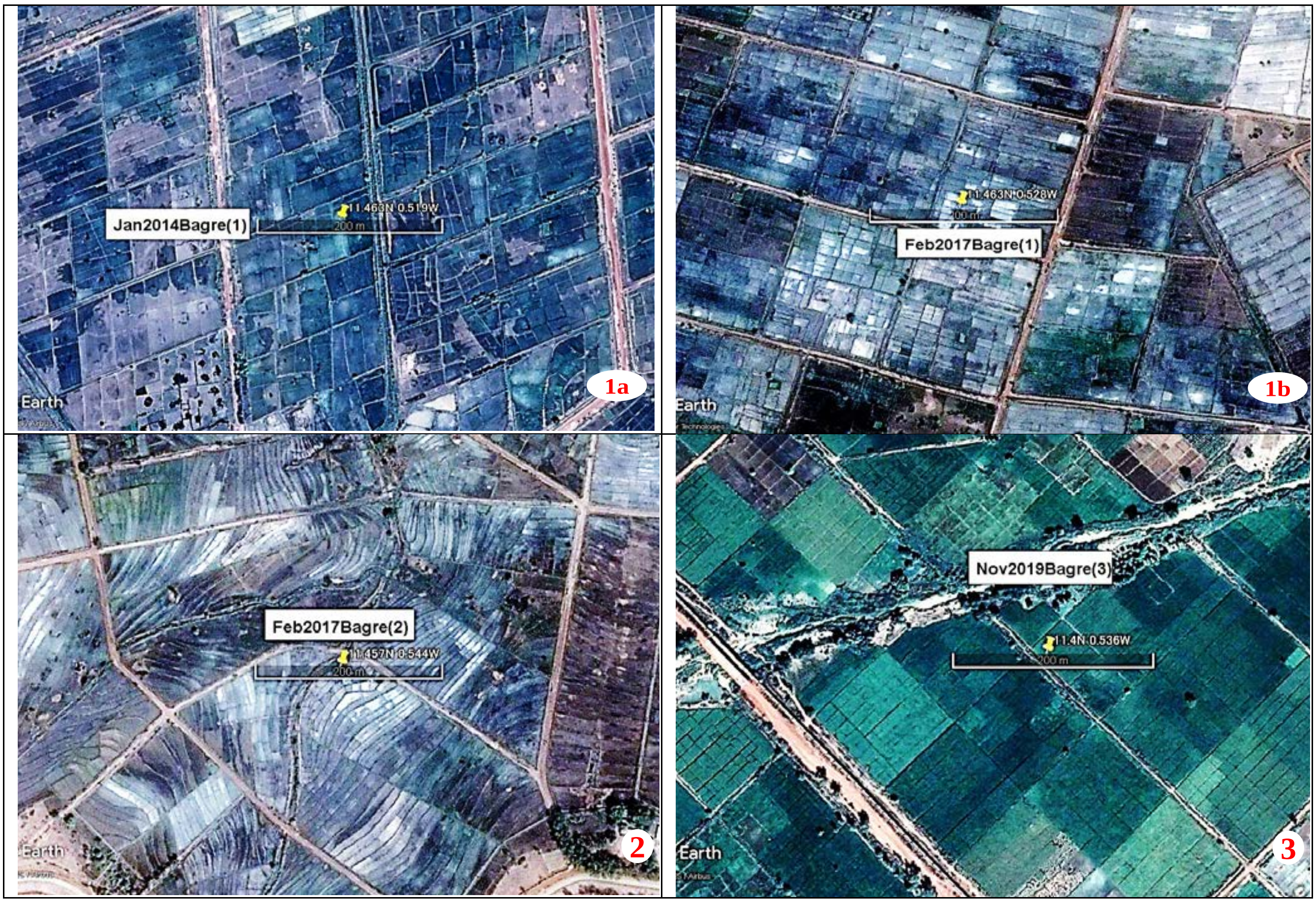


Figure 14, Various quality, i.e., evolutional stages, of sawah platform under the same irrigation scheme. Location is as follows: (1a); 11.463N 0.519W, (1b);11.463N 0.528W, (2); 11.457N 0.544W, (3): 11.4N 0.536N, (4); 11.423N 0.486W

Figures (1a), (1b) and (2), total area about 600ha, were developed by French and European Donors. Bunding and leveling of (1a) and (1b) were done by farmers, which evolutional stages are 3-4 or lower. The (2) area is contour bunding system. The curved contour sawah fields and straight irrigation and drainage canals are inconsistent, making it difficult for farmers to manage water. Figure 14 (3) area, 1200ha, were developed by Taiwan team, which evolutionary stages are 4 and 5. Figure 14 (4) area about 1200ha were developed by Arabic donors, which evolutionary stages are very poor, 1-3.

Figure 15(1) Bagre Dam lake observed on December 2004. (2) Irrigation canal by Taiwan team, (3) Rice nursery for transplant cultivation, and (4) Matured rice and Sawah platform of Taiwan team site.

Observing the morphology and quality of the irrigated sawah platforms in Figure 14 (1a), (1b), (2). (3) and (4) clearly show the difference between the Taiwanese team and the other French, European and Arab teams. It ts clear that the development of irrigation and drainage canals is major issue of the irrigation project for Western and Arabic projects. Except for the Taiwan team, there is little consideration is given to the appropriate rice cultivation platforms, such as plotting and leveling, and bunding of farmers' rice growing fields, i.e., and the poor integration of the irrigation drainage canals and rice fields, i.e., sawah platform system. In short, there is a lack of understanding of the importance of the sawah platform. All of this is left to the farmers' own self-help efforts without proper training and technical help. That why irrigated rice field development delayed, i.e., dam completed in 1992 but irrigated rice field is only 3000ha in 2021 out of the potential 15000ha. The author thinks that farmers who had no skills, no history and no experiences in sawah based rice cultivation had to learn from the beginning by themselves, gain experience, and master the technology. However, in the case of Bagre, I think it was rather fortunate that the Taiwan team site was used as a model (Wakatsuki 1999).

Figure 16 below is a soil map around the Bagre site. The White Volta river, which flows from the vicinity of the capital Ouagadougo on a gentle slope, passes Bagre to Bawku, Ghana, and is forming vast flood plains suitable for rice cultivation, which major soils are Chromic Vertisols (the mapping units are Vc1: 180,000ha and Vc9: 510,000ha), Sodic Planosols (the mapping unit Ws4: 60,000ha, Ws6: 50,000ha), and Vertic Cambisols (Bv2-3a: 120,000ha). It is the core region of the Mossi ethnic group, which accounts for 40%, 6.1 million, of Burkina Faso. The total lowland area suitable for irrigated sawah based rice cultivation reaches 1 million ha.
The large-scale dams of the Bagre project are versatile and create dam lakes necessary not only for agricultural use but also for power generation and urban water use, so simple comparison is not possible. However, the Bagre Dam submerges 40,000 ha of fertile lowlands and currently developed only 3,000 ha of irrigated rice fields, so it can be said that this is a wasteful development method in terms of land use.
It seems that it is much easier to develop a wider irrigated sawah fields by making 10-20 sets of cascades of weirs of each about 2m high from Ougadougou to Bawku along the White Volta river of 200km. If each weir can irrigate 2000-3000ha, the total irrigated sawah platform area may be possible to expand to 20,000-60,000ha. Soils, topography and hydrology are similar to Mbeya region in Tanzania (Figure 7 of Sawah Technology (3-3). If the Sukuma style endogenous sawah development and rice transplanting ways can be applied, rice production can further expand sustainably.

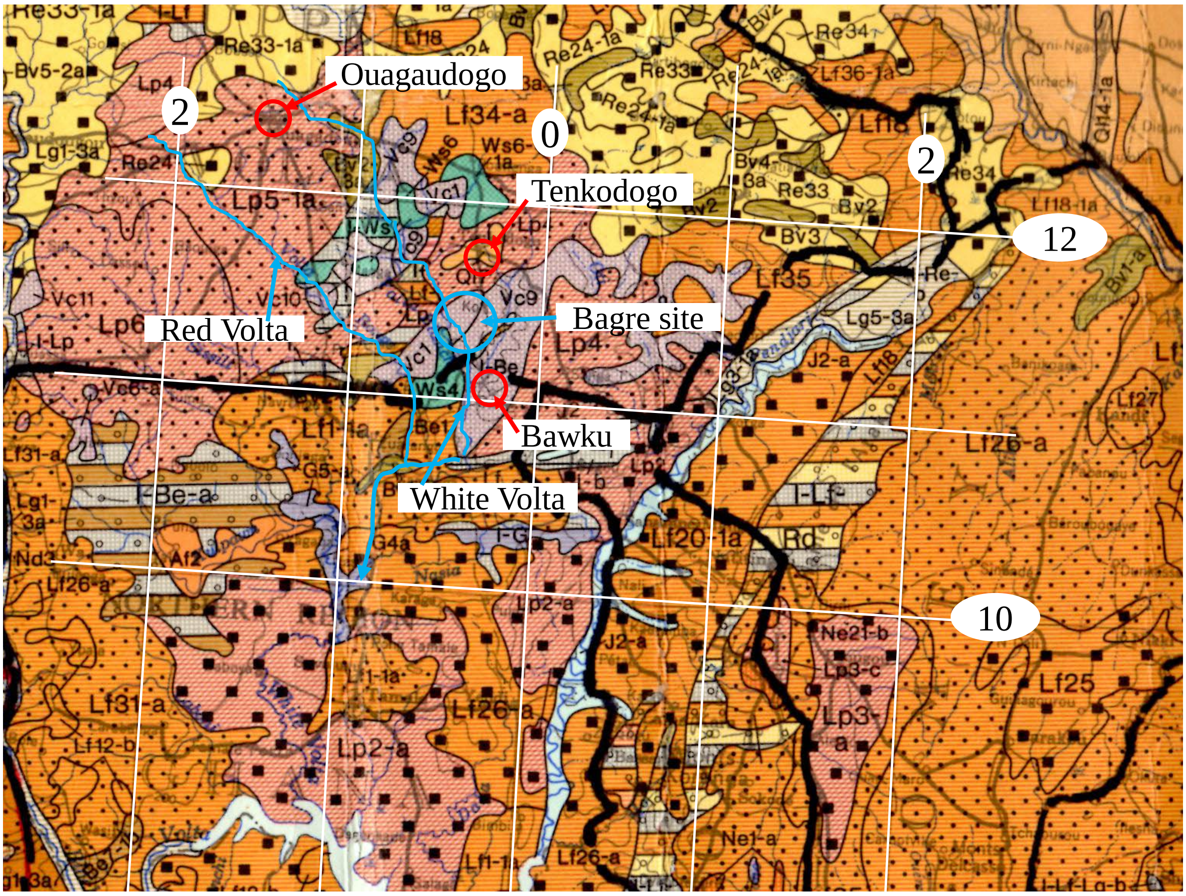


Figure 16. Soil map of Mossi land including Bagre project area (FAO-Unesco 1977)

2. Cote d’Ivoire

2-1. Official irrigated sawah platform in inland valleys in Bouake area initiated by Taiwan team

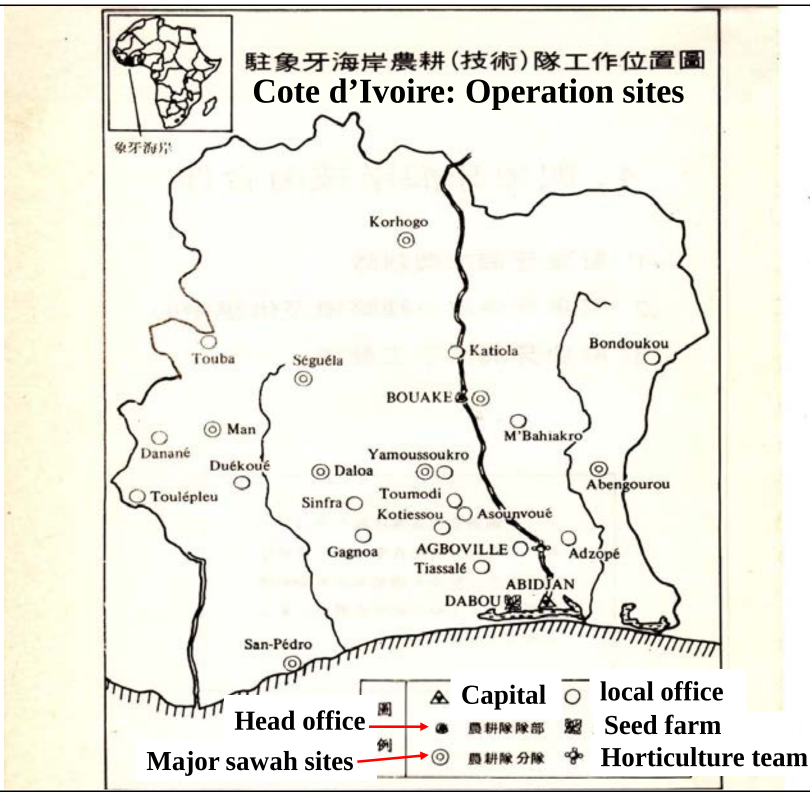


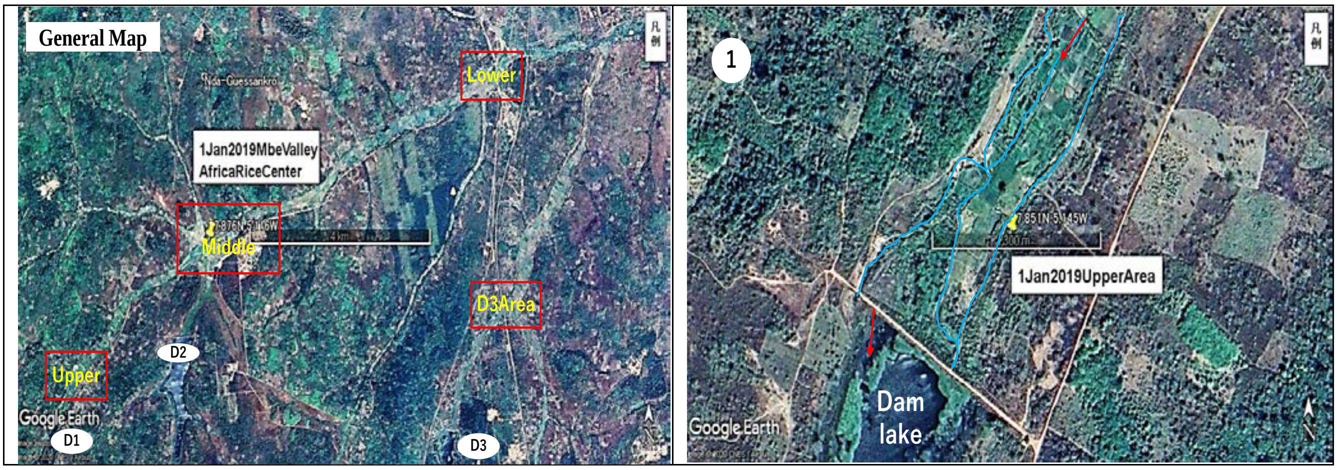
Figure 17. Major operation sites in Cote d’Ivoire by Taiwan team in 1962-73

(1) Operation sites: 24
(2) Experts dispatched: 180 persons,
(3) No. of farmers trained : 3384,
(4) Irrigated sawah developed: 5475ha,
(5) No. of Dam constructed :161

(CITC-Taiwan 1976 and 1997, Hsieh SC 2001 and 2003))

As shown in Figure 17, Taiwan team has made a significant initial contribution to the promotion of Asian style irrigated sawah platform based rice cultivation in Côte d'Ivoire in 1962-73. About 180 experts were dispatched to 24 regions nationwide (CITC-Taiwan1976 and 1997, Hsieh SC 2001 and 2003). They stayed at these sites for 2-3 years in a team of about 10 experts at each sites and developed overall more than 100 dams as well as irrigated sawah system platform on a total 5,500 ha and trained 3,400 farmers by on-the-job style (Table 1 in Sawah Technology (3-1): Overview). Taiwan team made significant contribution to establish the ability to develop endogenous irrigated sawah platform development of Côte d'Ivoire.

As shown in many figures below, the initial basis of the irrigated sawah platform in Corte d’Ivoire established by Taiwan team, which include experimental fields of the Africa Rice headquarters at Mbe, Bouake.



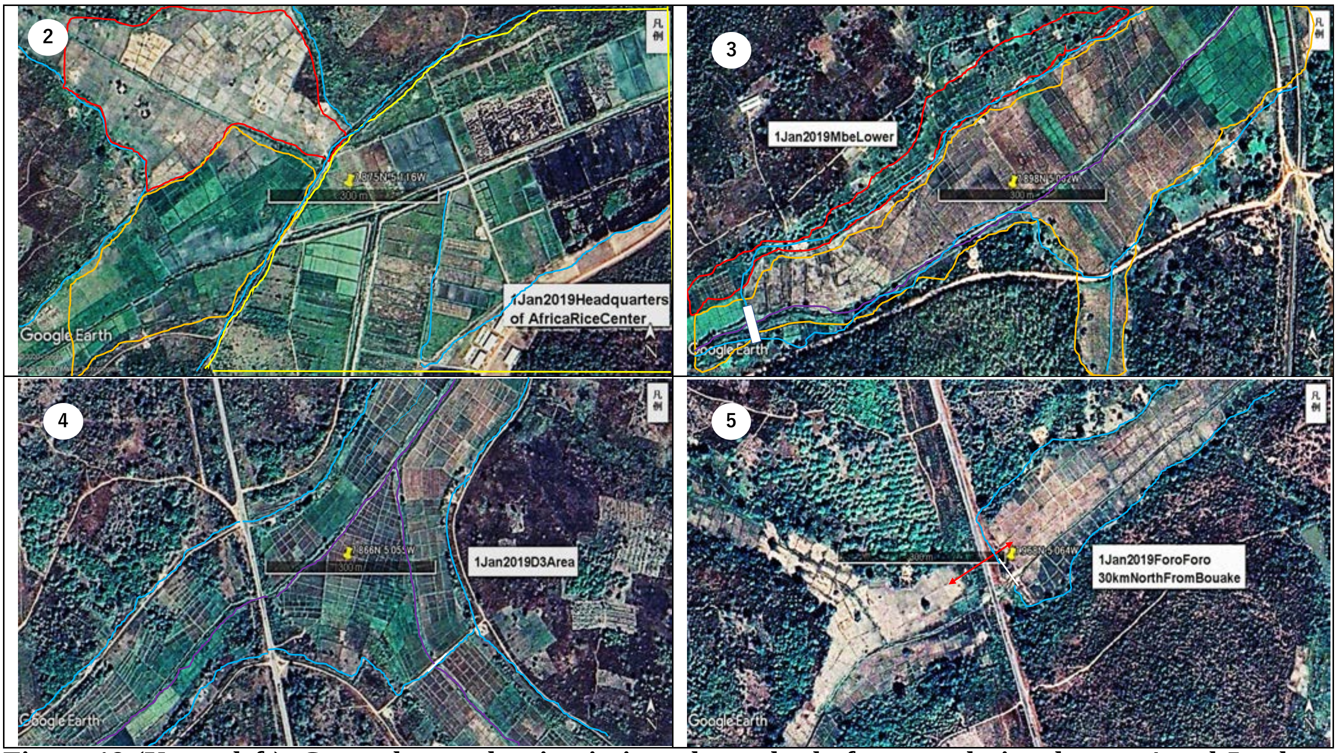


Figure 18 (Upper left). General map showing irrigated sawah platform, evolutional stage 4 and 5, where there is the headquarters of Africa Rice Center. Fig. 18(1): Expanded Google earth image of Upper Area (7.851N 5.145W), Fig. 18(2): Expansion of Middle area of the Headquarters of AfricaRice Center (7.875N 5.116W), Fig 18(3): Lower area (7.898N 5.062W), Fig.18(4): D3 area (7.866N 5.055W), Fig.18(5): ForoForo (7.968N 5.064W), just 7km north from Fig.18(3)

Original development of the Mbe inland valleys may dated back to the era of contribution of Taiwan team during 1962-73 as shown in Figure 17. D1-D3 show the dam for irrigation originally developed by Taiwan team. These four sites enclosed by red rectangles are shown in enlarged Google earth images of (1)-(4) with each respective central latitude and longitude information.

(1): Google earth image on 1st of January, 2019, shows the upper area of Mbe Inland valley. GPS position is 7.851N 5.145W. Blue lines are irrigation canals. The sawah system platforms might develop and manage by farmers. The Dam might develop by Taiwanese team during 1962-1973.Two red arrows show the two directions of two photographs of (1) and (2) respectively on August 2002 (Figure 19).

(2): Google image on 1st of January, 2019, middle of Mbe valley, 7.875N 5.116W. Blue lines indicate irrigation canals. The bolt violet lines show river. The area surrounded by yellow line belong to the AfricaRice center. The brown lined area may belong partly to AfricaRice and partly to farmers. The red lined area is the sawah platform developed endogenously by farmers.

(3): Google earth on 1st of January, 2019. Lower area of Mbe valley, which location coordinates are 7.898N 5.062W. Blue lines show irrigation canals and bolt violet line shows river. The white rectangular at the south west corner of the image shows weir to intake water for irrigation canals. The area surrounded by the brown line is the sawah platform that was officially developed by the government, and the area surrounded by the red line is the sawah platform that the farmers endogenously developed.

(4): Google image of the D3 area on 1st of January, 2019. GPS position is 7.866N 5.055W. Blue lines are irrigation canals. The bolt violet lines show river. The white rectangular shows weir to intake water for irrigation canals. These sawah platforms developed by government and managing by farmers. Sawah plot size is 150-300m2 with leveling ±10cm. Evolutional stage 4 and 5.

(5): Google image on 1st of January. 2019. Foro Foro Inland valley. GPS position is 7.968N 5.064W, 7km north from the (3) and 30km north from Boauke. Blue lines are irrigation canals. The bolt violet lines show river. The white rectangular shows weir to supply water irrigation canals. The sawah platforms were developed by farmers in the food for work style under Japan/Corte d'Ivoire/WFP project. The red arrows show the photo directions in Figure 20. Some of these photos were taken as a part of the project-type study under Japan International Cooperation Agency (JICA) entitled "Preparation of Rural Development Methods for Africa (Implementation)" which was conducted in FY 2002 (Takase et al 2003).

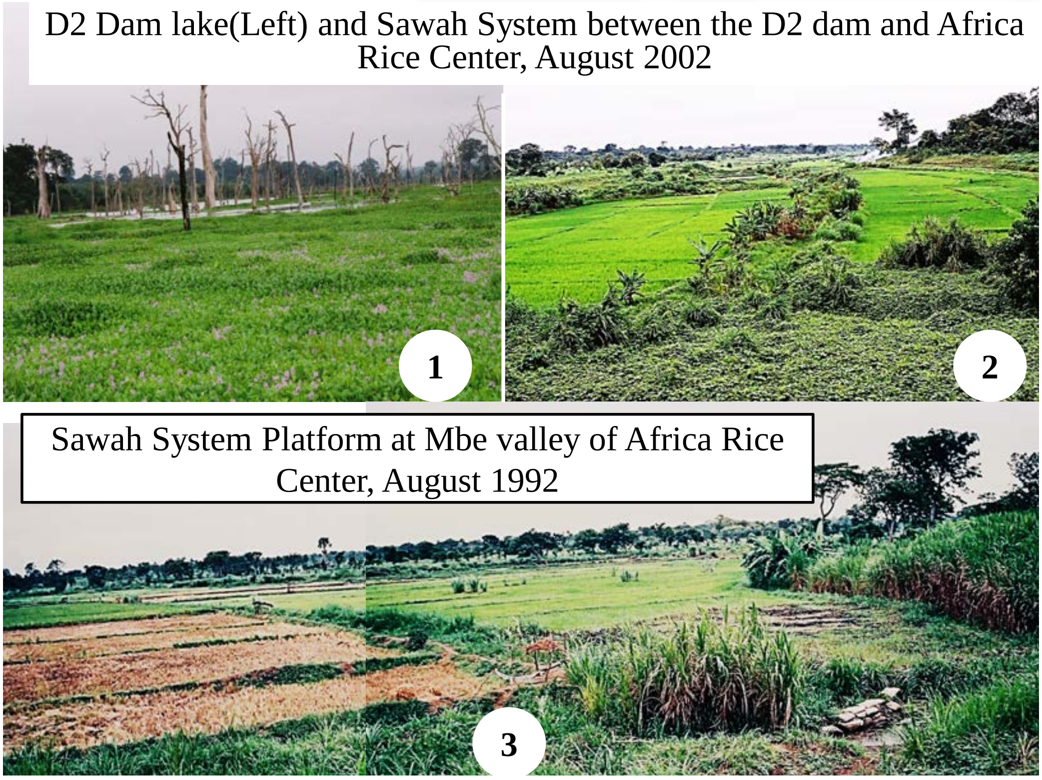


Figure 19. Photographs taken on 1992 and 2002 from the area of (1) and (2) D2 of Figure 18

Photo ① of Figure 19 shows water hyacinth and dead trees on the dam lake of the D2 of the Figure 18 (1). Photo ② shows irrigated sawah platform fields downstream of the dam between D2 and the experimental fields of Afria Rice center. Two arrows indicate possible directions of the two photos. Photo ③ of Figure 19, taken on 1992, shows the Mbe valley with the experimental fields of Africa Rice Center.

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Figure 20. Photographs taken from both side of main road crossing Foro Foro inland valley: Sawah System and Weir (upper), Participant lady group and Dr. Nagumo, coordinator, Food for Work of WFP/MAFF Japan, August 2002 (Nagumo 2002a, 2002b, and 2003)

Figure 20 shows one of the Food for Work-type sawah system platform development sites jointly implemented by the International Cooperation Division of the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan with WFP (World Food Program) from 1999 to 2004 (Nagumo 2002b). This might be one of the first step of the endogenous development of sawah technology, which was followed to the SMART-IV (Sawah, Market Access and Rice Technology in Inland Valley) program conducted by Africa Rice in 2009 to 2019 (Africa rice annual reports, 2013-2020). This was also implement by the International Cooperation Division of MAFF, Japan. It was created and implemented based on the integration of the concept of our Sawah program and the past contribution of Taiwan team in 1962-1973. Dr. Nagumo was the coordinator who is currently a staff member of JIRCAS (The Japan International Research Center for Agricultural Sciences). According to Dr. Nagumo, the engineers of the counterpart of Côte d'Ivoire were well trained by the Taiwanese team, so the training of the farmers was smooth. The Food for Work method is a type of participatory development that lies between development that depends on external engineers, which is ODA style, and endogenous development that farmers carry out on their own under sawah technology schemes.

2-2. Official irrigated contour bund sawah platform in Inland valley ecology in Sakasso-Katiola area by French/EU team

Although the Katilola contour bunding system, area circled in red, in Figure 21 is EU (French) modification of a part of Taiwan sawah system, areas circled in blue, Sakasso style contour bunding system in Figure 21-24 requires precise instrumental surveying for initial development, large-scale design for the sawah plot layout, and large-scale development works. Thus small-scale farmers' endogenous development is difficult. In addition, after the completion, the contour bunding sawah platform has difficulty in water management and rice management at the individual farmers' level except for appropriate community rice farming. This style platform may not be suitable for SSA small holders who prefer to grow rice at the individual farm level. For this reason, the French style of contour bunding sawah platform is not widely used in Corte d'Ivoire so far as compared with the platform model of Taiwan. Dam shown in Figure 22, which is 2km northwest from maker point, was originally developed by Taiwan team in 1963-73.

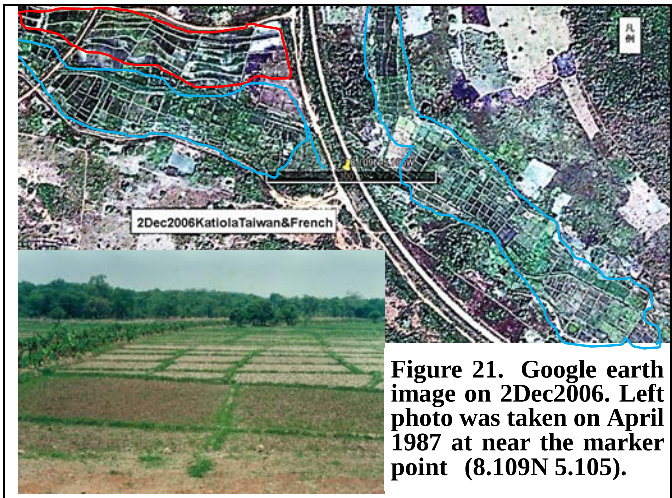


Figure 21. Google earth image on 2Dec2006. Left photo was taken on April 1987 at near the marker point (8.109N 5.105).

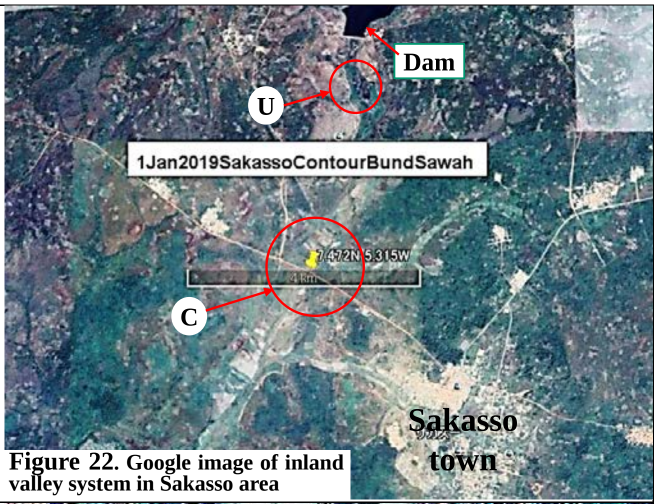


Figure 22. Google image of inland valley system in Sakasso area

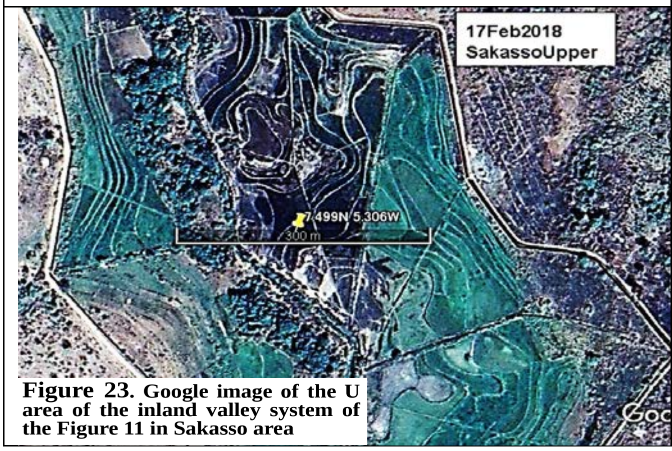


Figure 23. Google image of the U area of the inland valley system of the Figure 11 in Sakasso area

Figure 24. Google image of the C area of the Figure 22

Figure 25. Photos taken at Sakasso irrigated contour bund sawah platform on April 1987, which was guided by Dr. S. Diatta, WARDA soil scientist

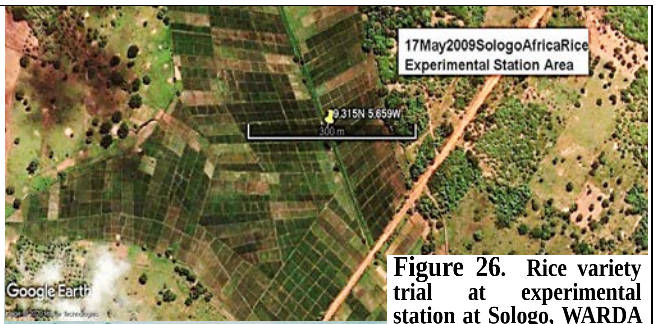


Figure 26. Rice variety trial at experimental station at Sologo, WARDA (AfricaRice). Photo was taken on August 1998. Google earth showing irrigated the sawah platform which was originally developed by Taiwan team. GPS position is 9.315N 5.659W, 15km south from Korhogo town.

2-3. Inland Valleys at Korhogo and Sologo area, Norther Corte d'Ivoire, initiated by Taiwan team

Figure 26 and 27 show sawah platforms using WARDA's rice variety trial site at Sologo, 15km south from Krohogo town. These sawah platform were develop originally by Taiwan team in 1963-73.

Figure 27.Expanded Google earth image on 28March 2019, showing Sologo irrigated sawah system platform. Majority of Sawah platform is managed as standard, evolutional stage 4 and or 5. But some areas shown in red circles are ridge rice cultivation.

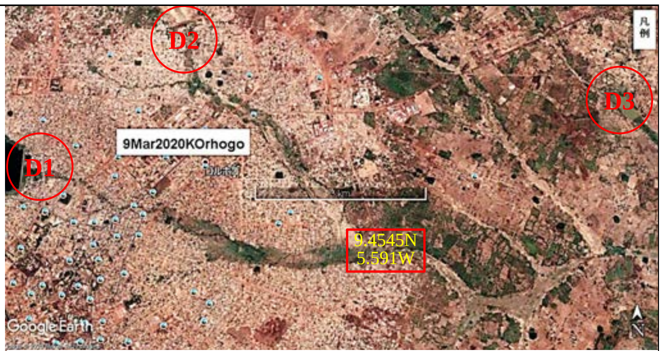


Figure 28. Overview of inland valley systems at Korhogo area by Google earth image on 9 March 2020. D1, D2 and D3 shows dams for irrigation. Those dams might construct by Taiwanese team during 1962-1973. Under these dam Taiwan team developed standards sawah system platforms along the valley bottoms of these inland valleys. One such example is shown left side, which GPS position is 9.4545N 5.591W.

Figure 29a. Google image on 29Sep2007 showing Taiwanese developed standard sawah system in valleys. The D1 dam in Figure 17 is 6km up stream. Irrigation and river water are flowing down passing through Korohogo town. GPS position is 9.454N 5.590W

Figure 29b. Expansion of the Figure 29a shows majority of Sawah plots are under ridge rice/vegetable cultivation on 29Sep2007. Red circled areas are under mild damage by flooding

Figure 30a. Expanded Google earth image on 16Nov2019, showing at the end of wet season Korohogo irrigated sawah system platform. Majority of old sawah plots which had developed in 1962-1973 have been managed ridge rice and vegetable cultivation.

Figure 30b. Expanded Google earth image on 16Feb2020, showing at the dry season Korohogo irrigated sawah system platform. Majority of old sawah plots which had developed in 1962-1973 have been managed ridge vegetable cultivation.

According to the report by WARDA (1992), Korhogo area had about 2000ha of irrigated sawah rice platform with 12 dams developed by Taiwan team in various inland valleys, although the WARDA report (Becker and Diallo 1992) never mentioned of the original contribution of Taiwan team in 1963-73. According to the report by team leader of Taiwan, Prof. Hsieh (2001, 2003), Taiwan team developed irrigated sawah system 9700ha in Core d'Ivoire in 1963-73. WARDA report (Becker and Diallo 1992) listed total irrigated area by Dams by Taiwan was 1690ha in Korhogo area, 1732ha in Bouake/Katiola/Sakassou/Yamoussoukro areas, and 1020ha in other area by 1974. By 1992, powertiller cultivation had been common. Evolutionary stage 4 and 5 sawah platform fields developed by the Taiwan team have been degenerated to the stages of 2 and or 3 during 1992-2007. This is probably because appropriate agricultural machinery and or proper plow cultivation with cattle and or power tillers became unavailable in the Korhogo area in the north of Corte d'Ivoire due to the civil war after 2002. However, if once appropriate cattle and or powertillers are available rice farmers can be upgrade quickly to the evolutionary stage 4 and or 5. Another reason may relate to land tenure system. Majority of farmers in the system are small holder, less than 1ha. In addition, dam based irrigation system like Korhog cannot be expand endogenously by local farmers' power only.

2-4. Inland Valleys at Agboville, Abengourou, Daloa, Gagnoa, Touba, and Flood plain at San Pedro

These sawah systems platform below are all originated from the development and training by Taiwanese team during 1962-1973. All these sites were developed in the inland valley except San Pedro, which was developed on the flood plain.

Figure 31. Google earth at Agboville (5.9747N 4.235W), 65km north from Abidjan on 29May2020, showing Dam (red D) based irrigated sawah platform. Original this system was developed by Taiwan in 1962-1973. Sawah evolutional stage is 4 or 5.

Figure 32. Google earth at Abengourou (6.734N 3.496WW), 200km north from Abidjan on 19Apr2004. Since there is no water source from the dam, it seems that irrigation is done by weir and spring intake. Original this system was developed by Taiwan in 1962-1973. However sawah plots seen in the Google earth image are less clear and appear to be poorly managed than those seen in the Figure 20.

Figure 33a. **Google earth at Daloa (6.878N 6.484W), 160km west fromYamoussoukro on 19Jan2005. Since there is no water source from the dam, it seems that irrigation is done by weir and spring intake. Original this system was developed by Taiwan in 1962-1973. Sawah evolutional stage is 4 or 5.**

Figure 33b. **The same location of Fig 22a on 8Feb2014. Red line areas indicate fishponds. Water management in fishponds is similar to sawah fields. Both of them provide good integrated sustainable system. Fishponds also serve as water sources for rice cultivation.**

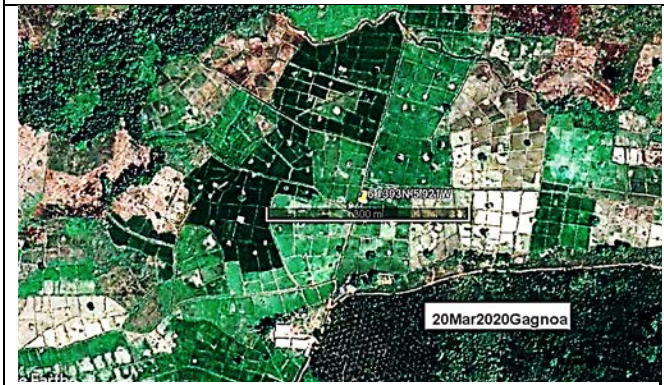


Figure 34. **Google earth image 2km east from Gagnoa (6.1393N 5.921W) on 20Mar2020. Since there is no water source from the dam, it seems that irrigation is done by weir and spring intake. Original this system was developed by Taiwan in 1962-1973. Sawah evolutional stage is 4 or 5.**

Figure 35A: Upper Google earth image. 10km west from Gagnoa (6.163N 6.068W) on 13Mar2014. Figure 35B: Lower Google earth image on 28 Feb2019. Even more than 5 years after the completion of dam, there are no proper sawah platform. This system was not inherited by Taiwan team. Endogenous sawah platform development is not so rapid

As shown in "Sawah Technology (1) Statistics", the characteristics of rice cultivation in West Africa and Cote d'Ivoire during 1961 to 2018 can compare. The data shown in Tables 2a and 11 and Figures 11a and 29 of Sawah Technology (1), are mainly based on FAOSTAT (2020). In West Africa as a whole, the average paddy production in 1961-65 was 15.70 million tons (yield 1.0 t / ha, irrigated rice area 55000 ha) to the average paddy production in 2016-18 18500000 (yield 2.0 t / ha, irrigated rice area 656000 ha). It increased 12 times. In Cote d'Ivoire, the average paddy production in 196-65 was 220,000 tons (yield 0.7t / ha, irrigated rice cultivation area 2000ha) to the average paddy production in 1971-75 was 390,000 tons (yield 1.24t / ha, irrigated area 12300ha), and to the average annual paddy production in 2016-18 was 209,000 (yield 2.7 t / ha, irrigated acreage 16500 ha) tons. It increased 9.5-fold. During this period, production in Nigeria increased 30 times. Increased rice production in Cote d'Ivore was below average in West Africa. Yields have increased, but new irrigated sawah platform development appear to be stagnant, consuming the legacy of Taiwan's irrigated sawah field development in 1961-1973. As a result, the self-sufficiency rate of rice was 75% from 1961-75, which dropped to the 35-40% in 1981- 2010. The civil war in 2002-2010 affected too. After 2010 paddy production has increased, although not enough, to the self-sufficiency level of 50% on average in 2016-18.

Based on Soil map of the world, Volume VI: Africa (FAO-Unesco 1977), Cote d'Ivoire has 2.4 million ha of wetland soils in flood plains and coastal deltas, which major mapping units are Dystric Gleysols, Eutric Fluvisols, Gleyic Luvisols, and Gleyic Cambisols as well as their associates and included units in other mapping units.
According to Windmeijar and Andriesse (1993), other wetlands soils are distributed in numerous small inland valleys in almost all soil units in West Africa, which relative distribution areas are estimated as follows, i.e., 4.5% in the flood plains and coastal deltas as well as 10.5% in other soil units in equatorial forest zones, 8.7 % in Sudan Savanna zones and 12.6% in Guinea Savanna zones. Since relative % of the equatorial forest and Guinea savanna are 56% and 44% respectively in Cote d'Ivoire, weighed mean is 11.4%, which give 3.3 million ha of total wetlands in inland valley in Cote d'Ivore. Thus ground total is 5.7 million ha. As the first approximation, we give about 20% of wetlands can be developed as irrigated sawah platform for rice cultivation, i.e., our first approximation

potential area is 1.14 million ha, of which 0.48 million ha in flood plains/delta and 0.66 million ha in Inland valleys in Cote d'Ivoire. Please see Sawah Technology「アフリカ水田農法」(5): Practices and potential for the details discussion on the distribution of various soil types to estimate the potential of irrigated sawah platforms in each African countries

Figure 36. Google earth image at Touba (8.274N 7.689W), just 10km from the border to Guinea and 120km from Liberia border (Nimba Forest Reserve) on 20Apr2010. Since there is no water source from the dam, it seems that irrigation is done by weir and spring intake. Original this system was developed by Taiwan in 1962-1973. Sawah evolutional stage is 4 or 5.

Figure 37. Google image at San Pedro (4.792N 6.649W) on 20Apr 2010. Sawah platform was developed on the small coastal flood plain of the San Pedro river. Irrigation water is taken by weir (and maybe pump) from the San Pedro river. Original system was developed by Taiwan in 1962-1973. Sawah evolutional stage is 4 or 5.

3. Senegal including Mauritania and Gambia

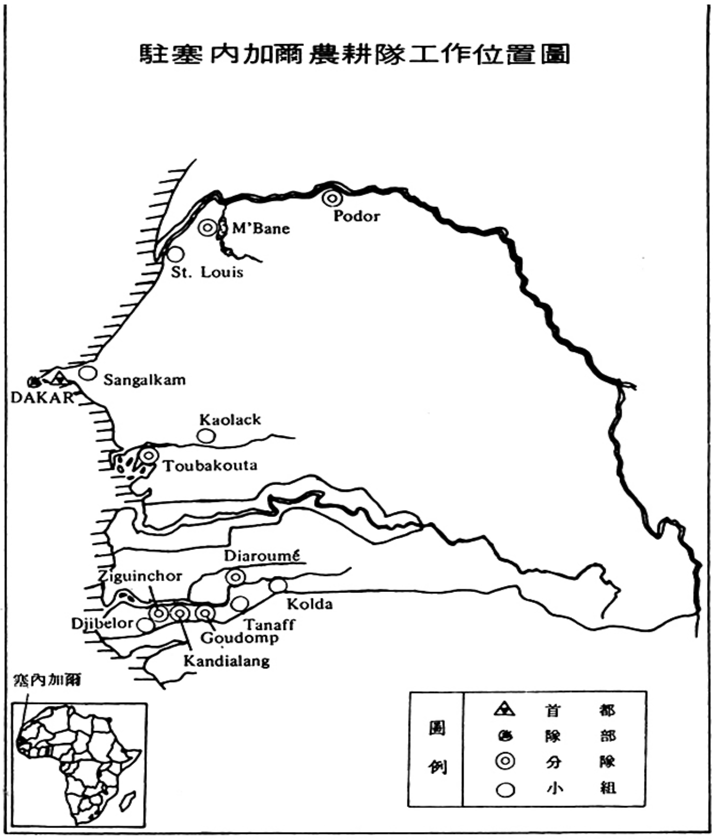
3-1. Introduction and technical cooperation in Senegal by Taiwan team during 1964-73 and 1996-2009

The Casamance region in southern Senegal is an ancient cultivated area of African rice (*oryza glaberrima*), which was domesticated 2000-3000 years ago. It seems to have a history of rice cultivation equivalent to that of Mali's inland delta area (Porteres 1976, Buddenhagen and Persley 1978, Carpenter 1978, Linares 2002, Olaoye 2010). Portuguese described the characteristics of the rice-growing platform in 16-17 century, 500-600 years ago. Linares (2002) described the rice farming system and platform in 1965.

According to these reports, the rice cultivations in this area are very similar to those of the rice cultivations in inland valleys and mangrove swamps in Sierra Leone, Guinea and Nupe land, Bida, Nigeria, which are described in section 2. i.e., Evolutional stages 1, 2, and 3 platforms that cannot accommodate modern science and green revolution technology: (1) Evolutional stage 1: non-sawah platform, that is, lowland without bunding and leveling (rainfed and irrigation system); (2) Evolutional Stage 2: lowland under ridge cultivation (with or without bunding as well as irrigated or rainfed); and (3) Evolutional Stage 3: lowland under micro-rudimentary sawah platform (irrigated or rainfed) of Sawah Technology (3-1): Overview. In 1960, it is believed that rice cultivations under the evolutional sawah stages 1-3 were also carried out in the flood-recession farming in the northern Senegal Delta and floodplain, as were done in Casamance.

The French colonial government developed about 10,000 ha of irrigated sugar cane plantations and irrigated rice fields in Richard toll, in the delta region of the Senegal River in the 1950s and 1960s before Senegal's independence. This French initiated irrigation project was similar to Office du Niger in Mali. The paddy yield was only about 2t / ha or less, because the irrigation development was limited to cnstruct of dams and irrigation canals without proper sawah platform development for water controls in farmers' rice fields. Proper development, improvement and maintenance of farmer's rice fields in irrigated areas was largely left to the self-help efforts of the farmers.

During 1964-1973, Taiwan developed and trained the irrigated sawah platforms of stage 4 and 5 for rice cultivation, 200ha at Podor, 41 ha at M'bane (Richard-Toll), and 1.2ha St.-Louis along the Senegal River. Another 10 locations were in the Casamance and Dakar regions (**Figure 38**). Total irrigated sawah platform area developed was 817ha.



(Phase I : 1964-1973)

1. Experts dispatched: 55 person
2. No. of farmers trained: 3870 person
3. Irrigated sawah developed: 817ha

(Phase II : 1996-2005)

Irrigated sawah development and rehabilitation:2400ha

(1)台湾海外技術合作委員会秘書處 1976. 我国與非州国家技術合作之執行與成効, 台湾外交部非州司, 台北, 392 頁＋付表.

(2)台湾海外技術合作委員会編集 1997. 海外技術合作委員会 歴経36 年之回顧. 台北, 282 頁.

(3) Hsieh Sung-Ching 2001. Agricutural Reform in Africa- With Special Focus on Taiwan Assisted Rice Production in Africa, Past, Present and the Future Perspectives-, Tropics,Vol.11 (1): 33-58.

(4) Hsieh Sung-Ching 2003. Agricultural Technology Transfer to Developing Countries. National Pingtung University of Science and Technology Press, pp.1-14, 165-232.

Figure 38. Map showing the sites for rice cultivation technical cooperation in Senegal by Taiwan team during 1964-73.

During 1996-2005, about 3200 ha of irrigated sawah platform development and rehabilitation for replanting rice on the abandoned irrigated rice fields were carried out, because of sawah platforms were poorer than stage 4. The development of irrigated sawah based rice cultivation by Taiwan team was carried out with on-the-job training of 4000 farmers, engineers and extension workers (Hsieh SC, 2001, 2003, Wakatsuki and Hsieh 2003). All of these rice cultivation promotion measures were transferred on-the-job approach. These became the basis for the promotion of rice cultivation in Senegal, which leads the green revolution in rice cultivation in West African countries. Also, although it seems to be the influence of the French colony, since 1990, more than hundreds of Vietnamese paddy workers and engineers have been working on the development of sawah system platforms in Senegal and the promotion of sawah based rice cultivation by FAO, the World Bank, USDA or France. It seems that they worked at the site of the ODA projects and contributed to the technology transfer of Asian Style sawah based rice cultivation.

The number Taiwanese dispatched specialists was 55 and the total number of trained extension officiers, engineers and farmers of Senegalese was 3870. In 1996-2009, the scale was further expanded to provide technical cooperation for irrigated sawah platform improvement along the Senegal River and in the Cassamance. The scale was second only to the Ivory Coast and Burkina Fasso. Together with the Ivory Coast, this became the basis for the promotion of rice cultivation in Senegal, which leads the green revolution in rice cultivation in West African countries. The Casamans region in the south has been a rice-growing area for a long time, but the security has deteriorated due to the subsequent separatist movement 1980s-2020s, and the development of rice cultivation has stagnated compared to the Senegal River areas in the north.

3-2. Evolution of Sawah platform along the Senegal river delta and flood plains

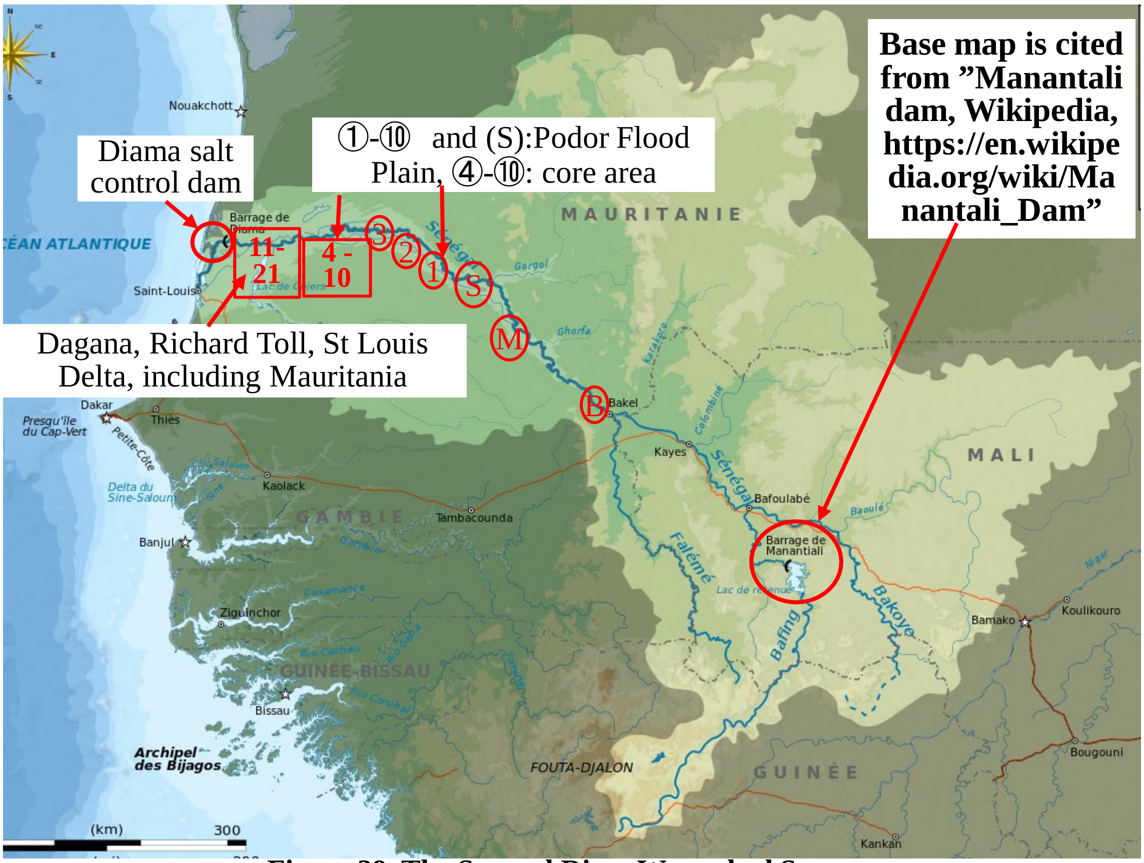


Figure 39. The Senegal River Watershed System.

The operation of the Mantali dam started on 2001 for flood control and 547 Giga watts hydroelectric power generation. The Diama dam serves to block seawater intrusion. These two dams are creating irrigation and double cropping. Potential irrigable area is 240,000ha and the developed area was 128,052ha (for rice 125,825ha is potential and 79,373 ha developed, respectively as of 2015). Salde(S) area is belong to the Podor region. Paddy productions in 2014/15 was 2,660tons in Bakal (B) area and 38,635 tons in Matam (M) and Kanel area (JICA 2014, 2019). The paddy production in Podor area of ①-⑩ was 81,039tons. The Dagana-St Louise delta area produced 308,639 tons, which was 72% in all Senegal valleys in 2015/16.

3-2-1. The Senegal River Flood plains from Bakal (B) to Fanaye Dieri⑩ in Podor region

According to JICA and Nippon Koei (JICA 2014 and 2019), the irrigation schemes in the Sebegal River valley were classified into the following four categories: (1) The large-scale irrigation schemes, which were developed by government agencies, and have an integrated pump irrigation canals, water supply system and drainage canals. The area is smaller in the Podor region and larger in the Dagana/Delta region, ca 50-1000ha or more. (2) Medium-sized irrigation schemes have 20-100ha scale. Irrigation and drainage systems are completed. (3) The development schemes by the village community have several tens to several hundreds of ha. There are irrigation systems, but the drainage systems are underdeveloped, generally. (4) There are many 10ha scales developed by individuals, which have irrigation systems, but the drainage system are undeveloped, genberally. Little consideration is given to the quality bunding, levelling, plot layout and the optimum size of farmers' irrigated sawah(paddy) system platforms. The development and improvements of farmers irrigated rice fields, sawah system platforms, other than the irrigation and drainage system was left to the farmers' self-help efforts. The improvement of the sawah system platform in these irrigated system, This self-help effort was supported by the extension and training of sawah based rice cultivation in 1964-2005 by Taiwan team, and it seems that it laid the foundation for the subsequent development of sawah based rice cultivation in Senegal.

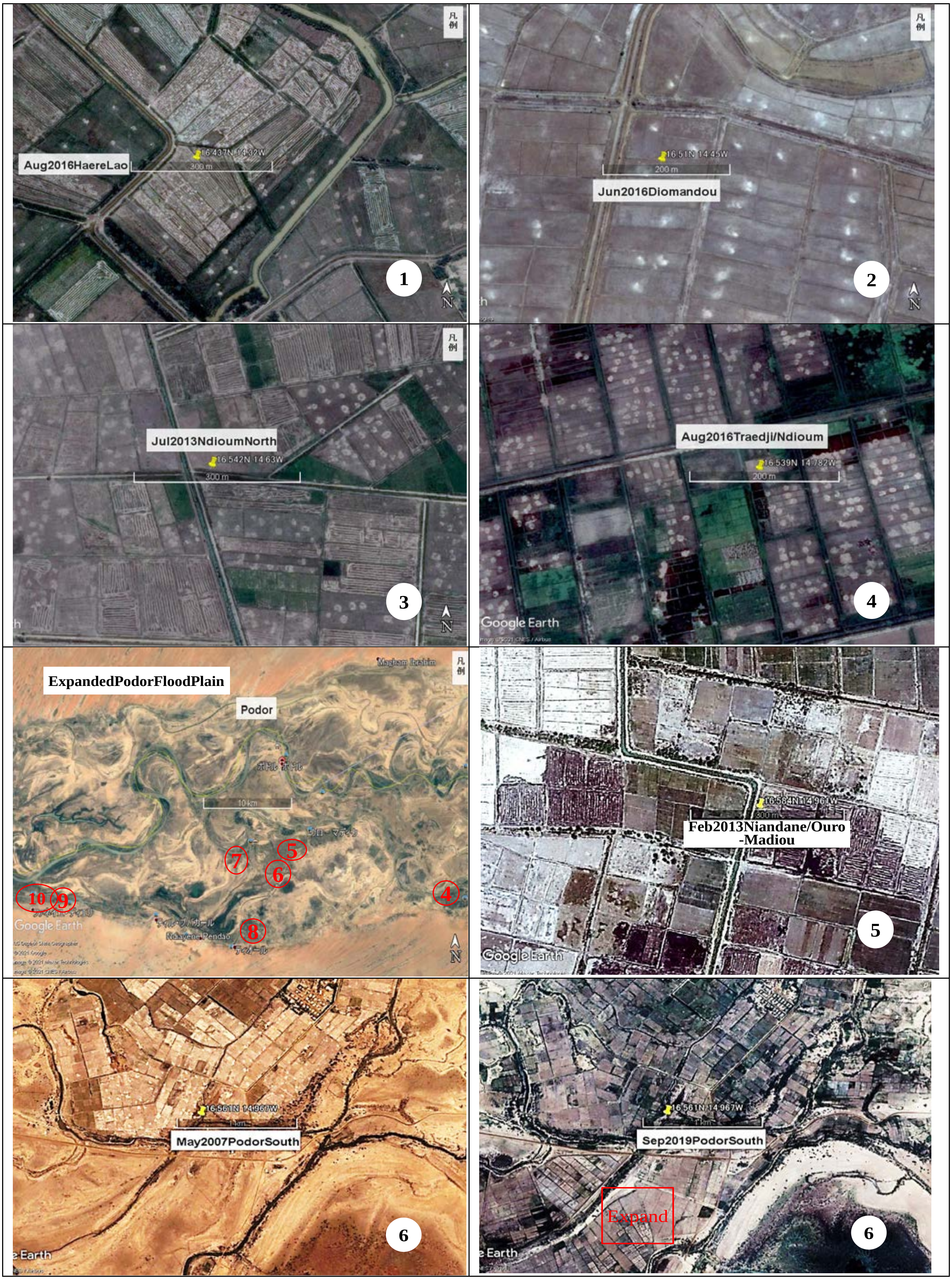
In the case of Japan and Asian countries, the development and improvement of sawah platform have been carried out by farmers on their own over a historic time of hundreds of years. The development of irrigation sawah platform system since the 1960s, which was the basis of the Green Revolution, was sufficient for the governments of Asian countries to improve the irrigation and drainage system among the traditional irrigated or non-irrigated sawah platform systems that already existed. On the other hand, farmers in Sub-Saharan Africa, especially West Africa, did not have a historical background in the technology to integrate both the irrigation and drainage system and the sawah platform system.

Figure 40. Irrigated sawah system platforms in the Bakel (B);14.88N 12.46W, and Matam (M);15.689N 13.273W, /Salde (S);16.21N 13.923W, areas of the upper Senegal River flood plain.

Irrigation water can be supplied by medium-sized pump, and irrigation and drainage channels are constructed at 100 m intervals in a 100-300 ha section. It is up to the farmers to develop and maintain the 10-20ha of rice farming surrounded by waterways as quality sawah platform fields. This is similar for the Niono irrigation project in Mali. Therefore, as seen in the Figure 40 (B), rice fields with sawah evolutional stages of 0-5 are still mixed as of 2019 in the vicinity of Bakel, which is far from the vicinity of Podor, where Asian style sawah platform development first began through the technical guidance and training by Taiwan team in 1964-1974 and 1996-2005. In Matam and Salde near Podor, most of the sawah platforms are maintained up to stage 4 or 5. The Matam (M) site clearly shows that farmers self-developed sawah platform improvement between 2013 and 2019. At the Salde (S) site as shown in the Fig. 40, farmers' self-developed sawah fields have various forms according to the topography and the ability of farmers, and it seems that it becomes a bit complicated to integrated operation of water utilization and rice agronomic practice.

Figure 41 shows various irrigated sawah platforms in Podor area.
① of the Figure 41 is near Haere Lao (the **location of the Google earth image is 16.437N 14.32W**), which is a part of 2000ha of irrigation scheme developed by government. The length of the central marker line is 300m, the size of majority of sawah plots is about 1ha. Some sawah plots have 0.1-0.5ha size depending on the slope and leveling quality. Subdivisions were made by farmers to improve the water management by adding additional bunds and leveling. Harvesting is carried out by harvester. Sawah platform stage is 4-5. This area may be at or near the site where Taiwan team developed the first standard quality of Asian style 200ha irrigated sawah platform of the

stage 4-5 during 1964-1973 and 1996-2009 (Figure 38, Hsieh SC, 2001 and 2003). Taiwan team made the technology transfer through the on-the-job training method to farmers, extension officers and engineers in Senegal.



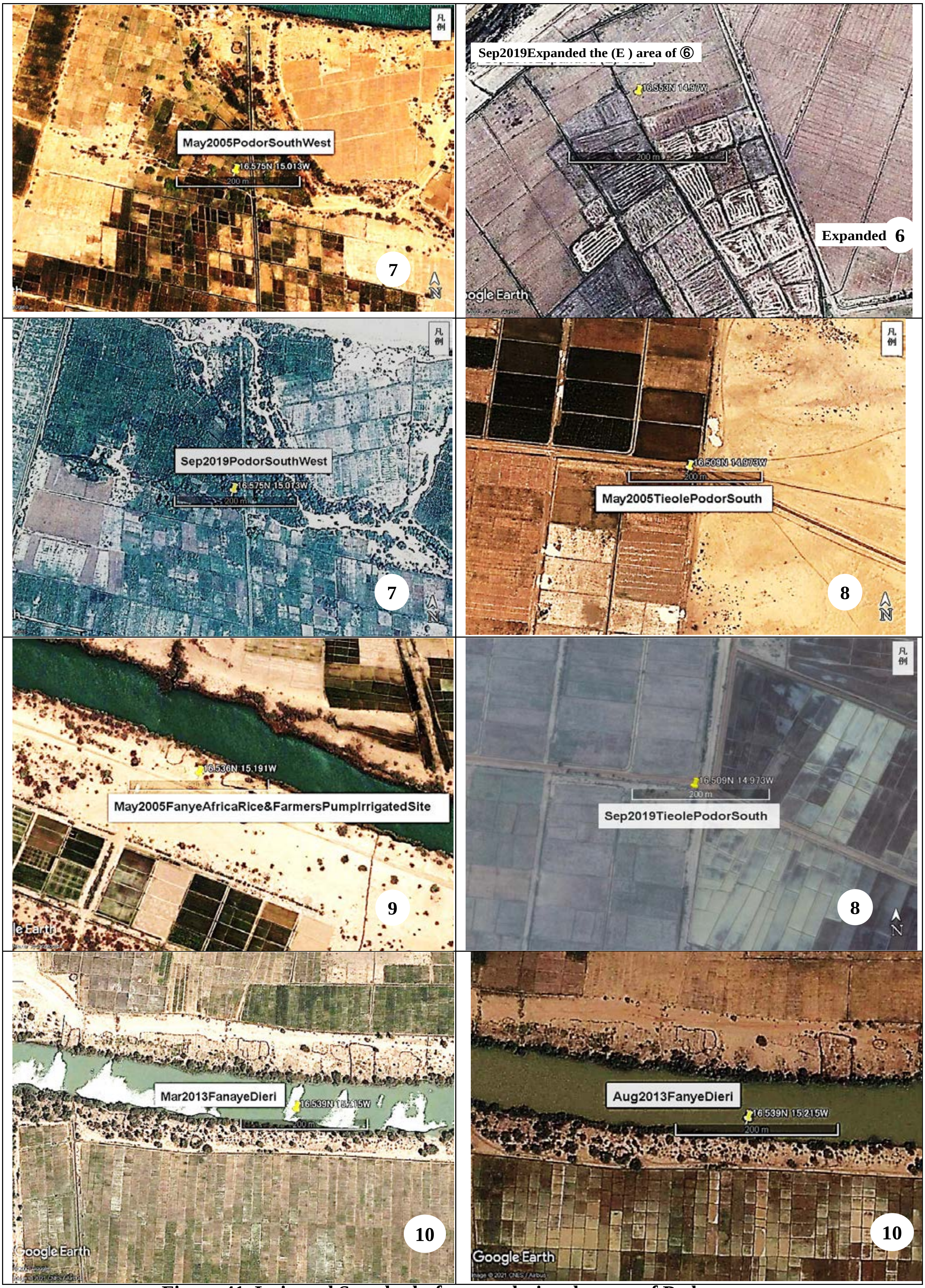


Figure 41. Irrigated Sawah platform evolutional stages of Podor area.

② is a government irrigated scheme of about 500ha near **Diomandou (16.51N 14.45W)**. The sawah platform evolutional stage is Stage 4-5.
③ is a part of **Ndioum North (16.542N 14.63W)** sites. There are three 200-300ha of irrigated schemes developed by government around there. The government had developed irrigation/drainage canals and 10-20ha of farmlands divided by waterways. After that, it seems that the farmers themselves have developed, improved and maintained the bunds and the leveled sawah plots. Paddy evolution stage is 4-5. (2) and (3) The layout of the sawah platform system in ② and ③ might be affected by the French type (?) construction that does not emphasize right angles like the ④ layout.
④ is a part of various origin of irrigated lands with a total scale of 2000ha that straddles the Taredji-Ndioum.
The main developers are likely to be governments, village organizations, individuals and companies. The photo site **(16.539N 14.782W) of ④** has a total area of about 150ha and is estimated to be a self-developed site by village or farmers' community organization , and is thought to be an Asian-type sawah system platform development model such as Taiwan and Japan. Each sawah plot is as small as 100-500m^2, but the evolution level is stage4.
The locations of ④ to ⑩ of the core site of the Podor region are shown as the "**Expanded Podor Flood Plain**" in the Fig. 41.
⑤ is an irrigation site with a total scale of 2000ha developed from Niandan to Ouro-Madion in the south of Podor. The location of the photo site is **16.584N 14.961W**. In 1964-73, the Taiwanese team first developed a 200ha Asian model sawah (paddy) field in and around Distar and Niandan to Ouro-Madion, including training farmers, extension workers and engineers. After that, for more than half a century, France, USA, England, Japan, World Bank and Africa Development bank continued to support rice cultivation. In particular, the completion of the Manantali dam since 2001, which allowed control of flooding, promoted irrigated sawah based rice cultivation (World Water Assessment Program, 2003). Paddy evolution stage is 4-5.
⑥ is Podor South and the site location is 16.561N 14.967W, about 5km south of Niandane city. The Google earth Image on May 2007 shows the upper half has irrigated land, but on Sep 2019, the irrigated land has expanded further to the south (Scale marker length is 1 km). The **Expanded⑥** that has a scale marker of 200m shows these sawah plots are the stage 5 allows to use harvesters. Innumerable elongated ridges can be seen in the right section. These seem to be vegetable growing area.
⑦ is an irrigation area voluntarily developed by a farmer's organization along The Douye river, west of Niandane. The position is **16.575N 15.013W**. This river flows separately from the main stream at the floodplain upstream of Podor, and joins the main stream again downstream of Podor. For this reason, the width of the floodplain near Podor is about 30 km, making it a vast suitable area for irrigated rice and vegetable cultivation. The farmers' self-developed sawah platform fields are Stage 4, and vegetables are also cultivated.

⑧ is an irrigation area developed in the southern limit of the floodplain near **Tieole, located at 16.509N 14.973W**. The location is about 30km south from Podor town. Google earth image on May 2005 shows the western half has irrigated sawah platform, while the eastern half has no such structure. However before September 2019, the eastern half was subsequently developed by farmers. Evolutional stage of sawah platform is the stage 4-5.
⑨ shows the experimental fields of AfricaRice installed in **Fanaye Dieri (16.536N 15.191W),** which had been operated in early 1980s (WARDA/ADRAO at that time).
⑩ shows the self-developed pump irrigated sawah platform fields of farmers near **Fanaye Dieri (16.539N 15.215W)**. In the Google earth image in March 2013, countless ridges for vegetable cultivation are shown in parallel with the bunds (banks) and small waterways created at intervals of about 15 m perpendicular to the river. This shows the vegetable cultivation in the dry season. In August of the same year, those vegetable plots have been converted to levelled sawah (paddy) fields of 15x (15-30) m size, and the standard, i.e., stage 4. sawah based rice cultivation is carried out.

Figure 42 below shows photographs taken during the field surveys by author in dry season of April-May 1987. At that time, the Manantali dam was not completed, the water level difference between the rivers in the dry season and the rainy season was more than 5 m, and irrigation water was obtained by mounting a small pump on a raft (using a floating pump method). Currently, the difference in river water level between the dry season and the rainy season is within 1.5 m (Adams 2000, JICA 2014 and 2019).

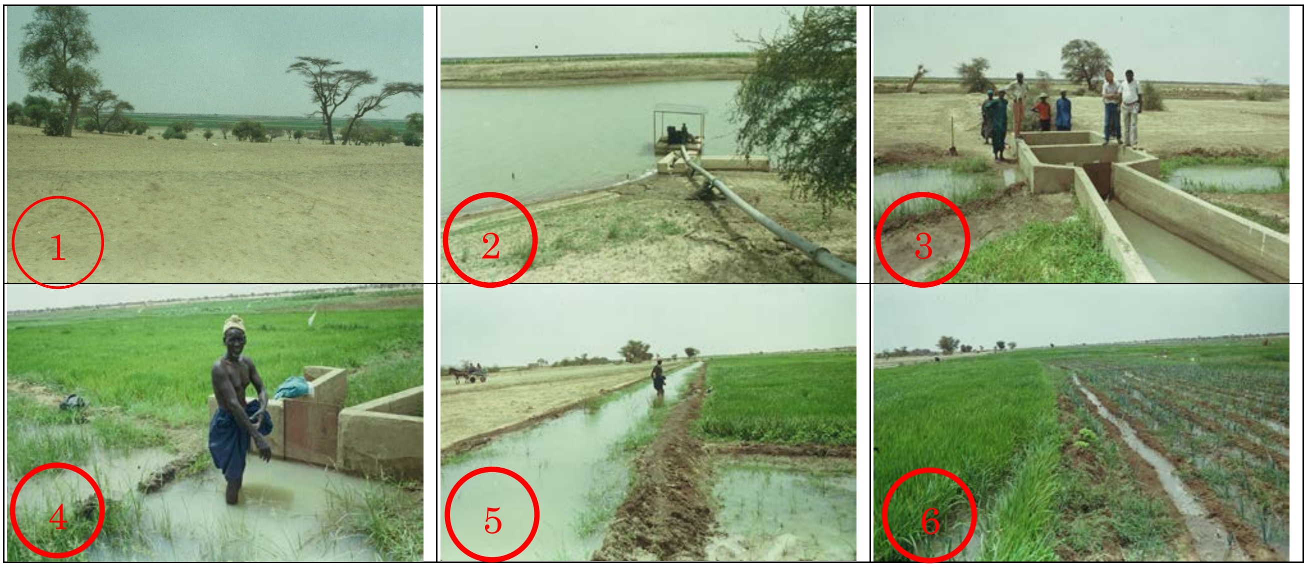
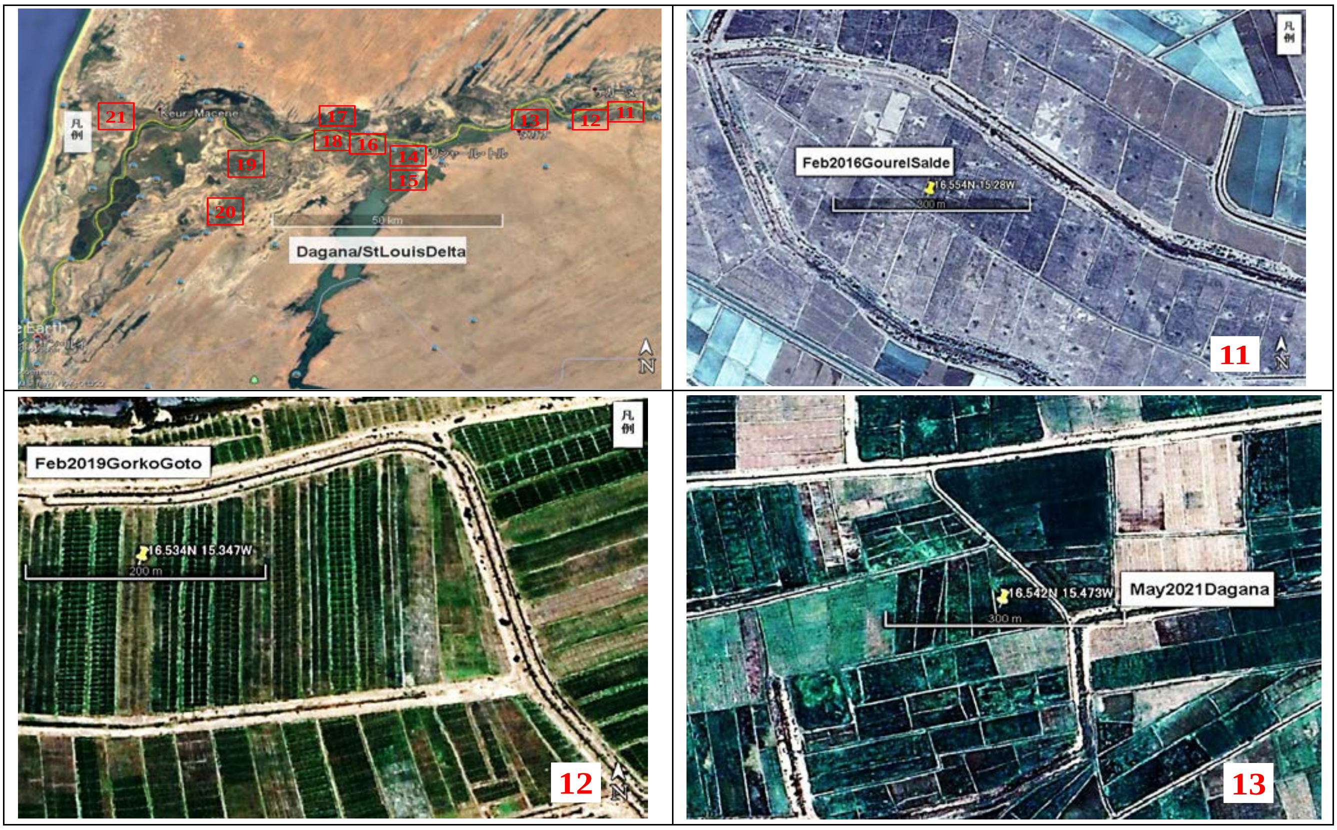


Fig. 42. Photographed in the vicinity of ⑨ and ⑩ near Fanaye Dieri in the Fig. 40 during the dry season from the end of April to the beginning of May 1987.

① A distant view of the Senegal River flooding field, ② a floating pump that pumps up according to the water level of the Senegal River, ③ a pumped-up water outlet, ④ water diversion and rice fields, ⑤ irrigation canals and rice fields, ⑥ rice and onion fields.

3-2-2. The Senegal River Delta Area from Bokoul, Dagana, Richard Toll, Ross Bethio and Saint-Louis including Mauritania side



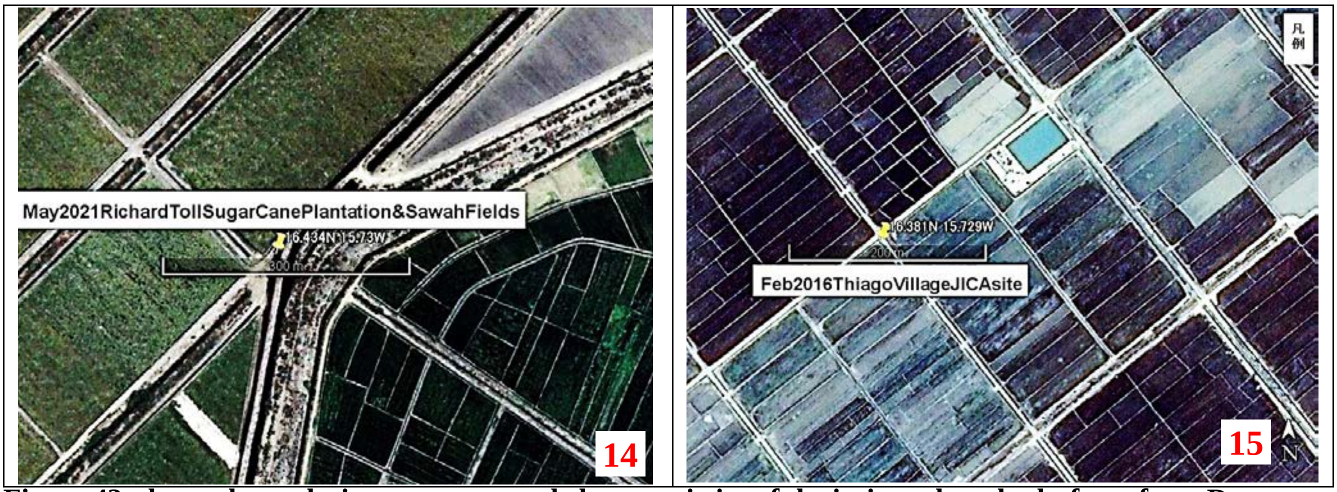


Figure 43. shows the evolutionary stages and characteristics of the irrigated swah platform from Dagana at the end of the floodplain of the Senegal River to St-Louis at the end of Delta. It was also compared with the irrigated rice fields on the Mauritania side.

[11] shows irrigated sawah platform near **Gourel Salde (16.554N 15.28W,** marker length 300m).
[12] shows irrigated vegetable fields near **Gorko Goto (16.534N 15.347N**, marker length 200m). These system are irrigated by medium-sized pump operated by the government, village communities or individuals, each of which has about 100 ha. The location is just 5-10km west from Fanaye Dieri (Fig.41 ⑩). Totally about 3000 ha of irrigated farmland was developed on this flood plain. The sizes of one sawah plot are 0.5ha-1ha, and judging from the appearance of thinly flooded sawah plots both on the upper right and lower left of the photo in the [11], Majority of these sawah plots have the quality of the evolutional stage of 5 or more appropriate for the mechanized rice farming with a high degree of leveling.

[13] shows typical sawah plots near **Dagana flood plain (16.543N 15.473**, marker length 300m). The system might be developed leaded by many, more than 10?, individual farmers communities with the support of the government. The total irrigated areas reach to 3000ha using medium sized, more than 10, individual pumps in the floodplain near Dagana. The sawah platform evolutional stage is 4-5.
[14] shows typical irrigated sugar cane farm plots and sawah plots for rice near **Richard Toll (16.434N 15.73W**, marker length 300m). The each of sugar cane plots has 10ha or more, which are shown at the upper left of the [14]. While the irrigated sawah plots, 0.2-1ha size, of evolutional stage 4-5 are shown at the lower right of the [14]. The irrigated sugar cane fields about 15,000ha have been operated by a private company around the Richard Toll area since 1960s. The rice fields have been operated by neighboring farmers supported by the same company. It seems that since the company owns the rice mill, neighboring farmers are producing rice as out growers.

[15] shows a Japanese style demonstration sawah platform **(16.381N 15.729W**, central marker length 200m) developed by Japanese ODA by the 1990s. Main water source is pumping water by the Sugar Cane factory at Richard Toll. Total area is about 120ha with irrigation drainage canals and 20mx100m sized evolutional stage 5 sawah plots. The site is 10km south of Richard Toll. Insufficiently leveled sawah fields are further subdivided by farmers voluntarily creating additional bunds.

Figure 44 below shows observation and evaluation of the Evolutionary Stages of irrigated sawah platforms in both Senegal and Mauritania in the Senegal River Delta area.

[16] is about 500ha of irrigated sawah system platform developed by the rural community of Mabagam through the support by government around 1965, which is considered to be the oldest (**16.483N 15.773W**, marker length 400m). Evolutional Stage 5 and 4 sawah plots with good bunding and leveling of a size of 1000-3000 m^2 per plot, which have been improved in past half a century and as shown in the blue and red lines in the [16] of the Figure 44, the irrigation canal and drainage canal have been separated to improve water control.

[17] is an irrigated sawah system platform developed in the floodplain of the Senegal River near Rosso of the Mauritania side with the support of Africa Development Bank and others (16.521N 15.868W, marker length 600m). The size of 1 plot is about 0.3ha on left side area and about 0.7ha on right side area. Both irrigation canals and

drainage canals are arranged alternately along the square or rectangular sawah plots. Since the plot size is bigger on the right side, some plots have not good leveling for rice cultivation, farmers add more bunds and subdivide the original big plots into good quality leveled smaller sawah plots. Although these sawah system platform have simpler layout than the Senegal side as a whole, it is a sawah system with evolutional stage 5. Total area of the irrigated sawah platform is about 4000ha in the vicinity of the Rosso of Mauritania. In Mauritania, about 25,000 ha of irrigated sawah system platforms have been developed along the Senegal river flood plains upstream from the Rosso town and additional about 25,000 ha in the downstream delta area. According to FAOSTAT in 2019, the total annual rice cultivation area is 70,000 ha including both dry and wet season. Annual paddy production reached to 380,000 tons (average paddy yield 5.2t / ha). Production has tripled in the last 10 years. Ten years ago in 2010, the paddy production was 130,000 tons, around 20th place among SSA countries, but in 2019, it is competing with Benin for a position next to Ghana's annual paddy production 850,000 tons (10th place). Senegal produced paddy 505,000 tons in 2010/11 and 1,180,000 tons in 2018/19 (9^{th} place).

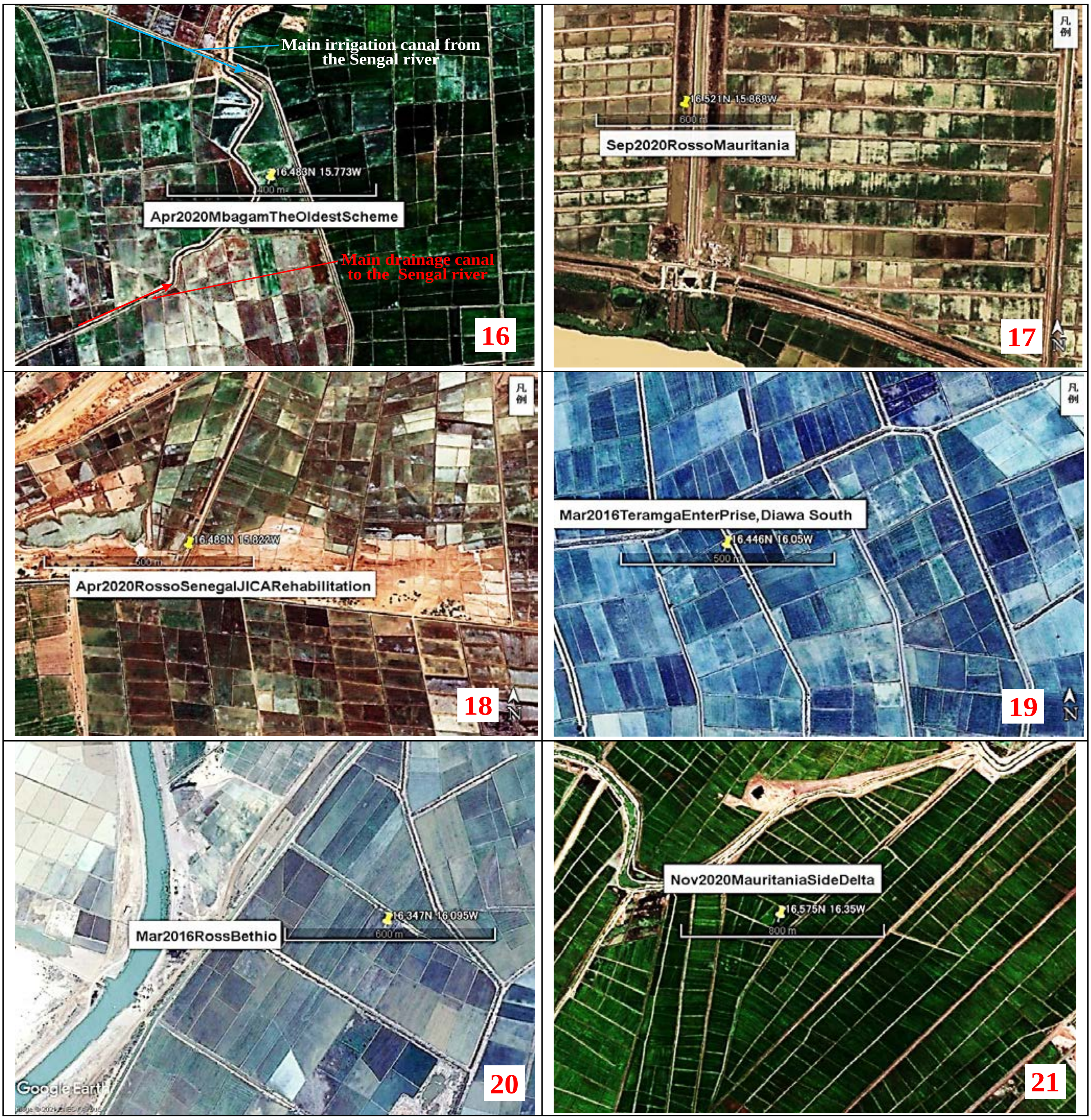


Figure 44. Observation of the Evolutionary Stages of irrigated sawah platforms in both Senegal and Mauritania in the Senegal River Delta area.

[18] is the site of 300ha sawah platform which JICA, Japan International Cooperation Agency, rehabilitated the pump irrigation canals and drainage canals “only” in 2014-19. The author adds the term “only” because of Japanese way of work evaluation point that the irrigation system and the sawah system are equally important in rice cultivation platform. This scheme was developed by a rural community near **Rosso Senegal (16.48N 15.822W,** marker length 500m). It seems that the farmers were in charge of sawah plots development, improvement and maintenance (layout of sawah plots, bunding, and leveling). That why sawah plots layout is not uniform even rehabilitated by the professionals for sawah system platform development of Japanese contractor. The evolutional stage of sawah system platform seems to be equivalent to 4-5.

[19] is an irrigated sawah platform **(16.446N 16.039W**, marker length 500m) of about 5000ha, which seems to be managed by a private company. It seems to be a high-quality sawah platform of well leveled evolutional stage 5-6 with 1 plot size of 0.5-1ha. It is estimated that the mechanized rice cultivation with paddy yields 7-8t / ha in the dry season even in direct sowing, if no salinity and acid sulfate soil problems.

[20] is a large scale, high-performance irrigated sawah system platform near **Ross Bethio (16.347N 1.093W**, marker length 600m). A total of about 15,000 ha of irrigated sawah platform have been developed in the surrounding area. The unit size of the sawah plot is 1-3ha. The quality of bunding is good and the leveling degree is good, sawah plots are rationally arranged. Thus it seems to be a high-performance sawah platform of stage 5-6. French, USA and or Australian stile direct sowing rice cultivation may be operating. If there are no problems with salt damage or acid sulfate soils, it is expected that a paddy yield of 7-8 t / ha or more can be obtained in the dry season.

[21] is a large-scale irrigated sawah platform of about 13,000 ha near Beinadji developed along the Ndiader channel in the **Senegal River Delta in Mauritania (16.575N 15.35W**, marker length 800m). It is an irrigated sawah platform system with a simple layout as a whole. Although the bunding and leveling of 0.5ha-1.5ha sawah plots are slightly inferior to those of the Senegalese side, it seems that the evolutional stage 5 mechanized irrigated rice cultivation is being carried out for achieving a paddy yield of 5t / ha.

Figure 45. Photo taken August 3-4, 1998 near Richard Toll and Ross Bethio.

① is a sawah platform of about 120ha of Thiago village developed by Japanese technical assistance as shown in [15] of the Fig. 43. The system was aimed to operate a mechanized direct sowing rice cultivation using tractors and combines. The sawah plots management level does not seem to be high. The reason is unknown. Until now, rice cultivation using Japanese ODA has been based on transplanting cultivation in SSA. However, it may be because this site tried direct-seeded rice cultivation, which is not common in Japanese rice cultivation technical cooperation. ② is a medium-sized pump for irrigated sawah platform of 50ha scale, which had been used at the with technical assistance site by France team. The pumping machine was introduced in the 1980s and had been in use for over 10 years. ③ and ④ are large scale sawah platform for largescale mechanization using direct sowing cultivation near Ross Bethio with the support of USAID / World Bank. At the time of shooting the photographs in 1998, the leveling and bunding quality of these large sawah plots, larger than 10ha, were not so good. But as shown in the Photo [20] of Fig. 44, the sawah plots size are 1-3 ha with good bunds and leveling which are the one of the highest-performance sawah system platforms in West Africa now. It seems that it has lead a large-scale mechanized rice cultivation in West Africa.

However, it is the floodplains and deltas of the Senegal River that are under arid land climate. Both wetlands area and water resource have limitation for the development of rice cultivation to satisfy the ever increasing national needs of Senegal. The rice cultivation promotion that has been implemented in Senegal has been a large-scale irrigation system led by ODA and the government and a rice cultivation development strategy led by large-scale agricultural machinery. However, such strategies have not fully harnessed the power of many smallholders, Senegal's most important and sustainable resource. In the future, it will be more important to use sawah based rice cultivation that fully utilizes the power of farmers' self-development based on the appropriate scale of mechanization on an appropriate scale sawah platform of 1 ha or less (Soullier and Moustier, 2019).

3-3. Gambia and Casamance, southern Senegal

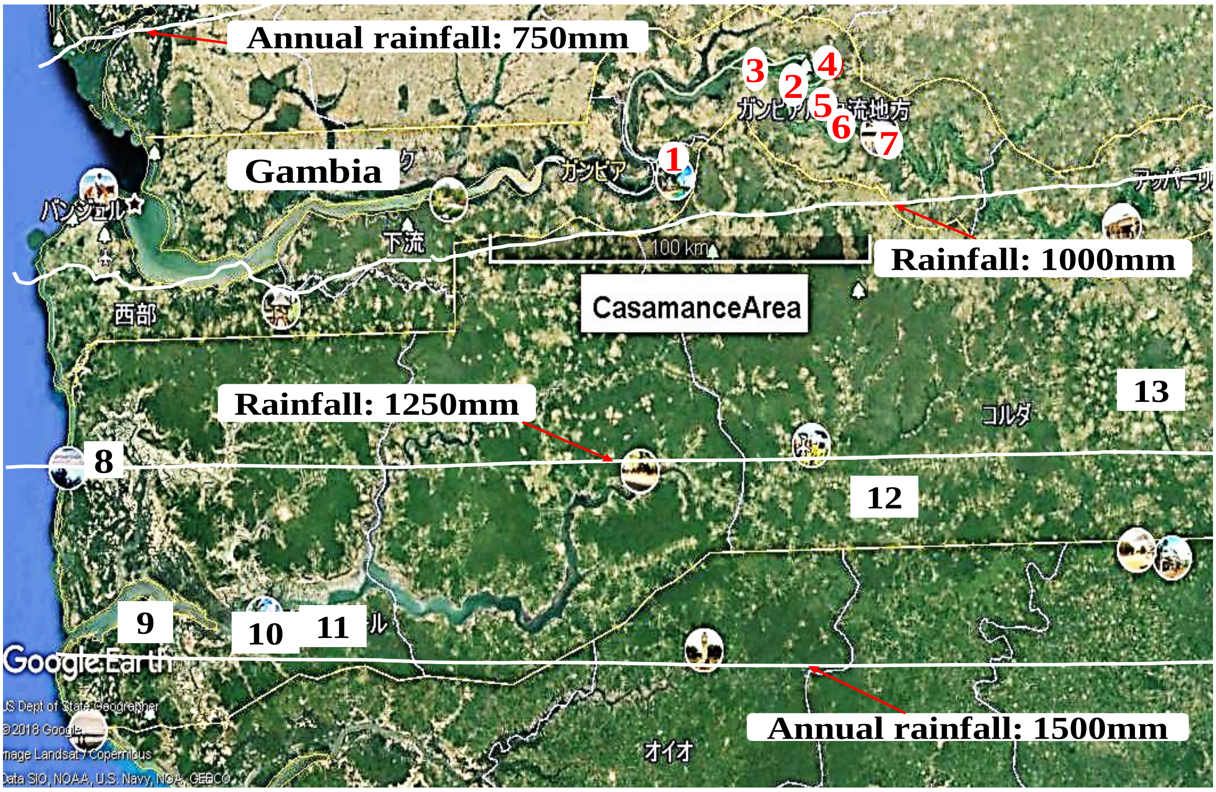


Figure 46. Map showing various irrigated and rainfed Sawah platforms in Gambia and in Casamance area of Senegal.

① -② and [7]-[10]:Traditional rain-fed and tidal irrigation, [11] traditional rain-fed inland valley, ③-⑥ Improved tidal and Pump irrigation supported by Taiwan team, ⑦ and [12]: Improved pump irrigation.

3-3-1. Evolutional Stage of Sawah system platform in Gambia

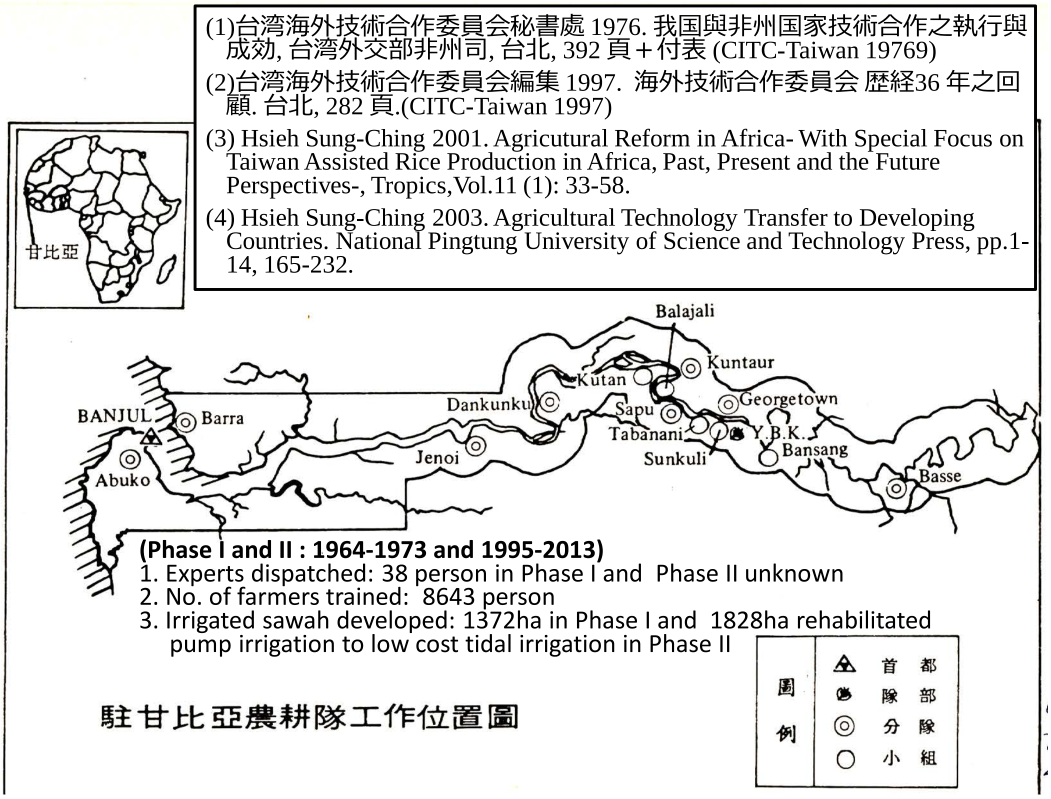


Figure 47. Map showing the sites for rice cultivation technical cooperation in Gambia by Taiwan team during 1964-73 and 1995-2013. For the sites in Casamance of Senegal, please see Figure 38.

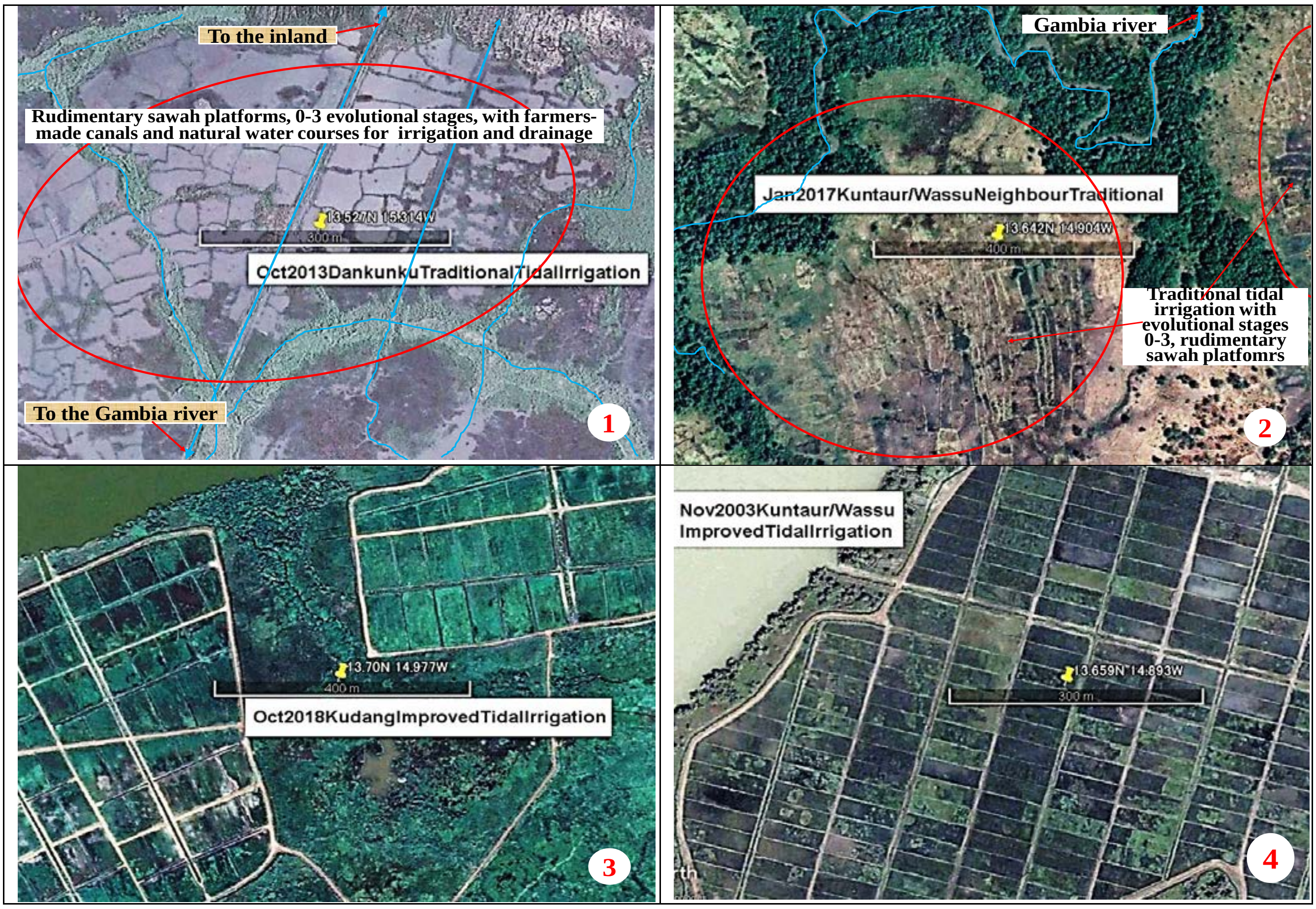


Figure 48. ① to ⑥ show various Sawah platforms and improvements/evolutions in Gambia based on the observation of Google earth images.

① is near **Dankunku (13.527N 15.314W)** in central Gambia, ② is near Kuntar and **Wassu (13.642N 14.904W)**. These two Google earth images show the traditional rice-growing platforms on the floodplain and Delta of the Gambia River. The winding blue lines show the natural river channels, and the straight lines shows the farmers' made irrigation and drainage canals. Some rice fields are pristine floodplains with no bunds, others are surrounded by irregular shaped bunds and are divided into 100-5000 m^2 each. The Gambia river runs 1.5km below in the photo ① and 1km above in the photo of ②. Freshwater flows down from the eastern part of the upper reaches of the Gambia River in the rainy season from July to October.

The altitude of the river surface near the ① is about 0m, where is located about 150km inland from the coastline and the ② is 2m, located about 250km. The water level difference between low tide and high tide is about 3m. The salt water front can reach 80-260km inland, depending on the river discharge (Risley et al 1993). The altitude of the rice fields in the ① is -1 to +1 m. The altitude of the rice fields of the ② is 2-3m. Therefore, the water quality of the Gambia River is salty in the dry season, but fresh water flows on the surface of the river in the rainy season. At high tide, salt water flows into the riverbed. Therefore, at high tide, the fresh water on the surface of the river is pushed up by up to 3m (Ritzem et al 1985). The freshwater flows from The Gambia river into the floodplain via natural or artificial canals. The fresh water makes it possible to grow rice.

However, in such a tidal irrigation system, water management of sawah plots for rice cultivation is basically difficult. The amount of fresh water in the rainy and dry seasons depends on the weather and topography. The timing of the low tide and high tide depend on the earth and moon's movement. The flood plains and delta are too gentle on a macro scale to manage irrigation and drainage water in a timely manner to match rice cultivation. On the other hand, the height difference in one plot of sawah field is sometimes too high, usually 30 cm or more, and achieving the leveling degree of within ± 5 cm required for standard sawah based rice cultivation requires good skills including mechanical power, such as power tillers. It is difficult to manage the quality of irrigation water such as appropriate balance between salt and fresh water. It is difficult to control soil salinity too. It is difficult to control the formation of acid sulphate soils through the excessive drainage during the dry season. For the above reasons, it is difficult to achieve a sustainable paddy yield of 3 t / ha or more.

③-⑥ are an attempt to improve the tidal irrigation system. All four sites are near the site of the ② in the Figure 48. The rice cultivation potential of Gambia is estimated to be about 50,000 ha (WARDA 1988, Adefurin and Zwart 2017). Most of the potential areas are in the vicinity of ①-⑦ in Fig. 48. The ③(**13.70N 14.977W)** shows an improved small tidal irrigation scheme of about 20ha and 35ha, which were supported by IFAD and Holland team (Ritzem et al 1985). The surface elevation of the river at this area is about 2m, and the elevation of the rice land is 2-4m. At high tide, the water level rises by about 3m, so fresh water can be taken into sawah (paddy) fields at an altitude of 4m. Freshwater is taken from the main irrigation and drainage channel near the center during high tide in the rainy season. Freshwater can be retained in sawah plots by proper closed bunds, and drained as needed at low tide from open gate. Each sawah plot is leveled to ± 5 cm. The leveling degree of one sawah(paddy) plot is within ± 5 cm, which is a condition for rice seedlings with a plant height of 15 cm to be transplantable in all surface of the sawah plot. This is one of the conditions to qualify as the evolutional stage 4 or 5. The difference between 4 and 5 is that the 4^{th} stage corresponds to the traditional cattle and horse farming platform. The 5th stage has a large size sawah plot of generally 1000 m^2 or more, and the arrangement of the entire sawah system is arranged to linear and rational platform. This makes possible efficient mechanize rice cultivation, using power tillers and tractors.

The ④ **(13.659N 14.893W)** in the Figure 136 is a 500ha improved tidal irrigation scheme which development and improvement were supported by the Taiwanese team in 1964-73 and 1995-2009.

The elevation of the river surface is 2m and the elevation of the farmland is 2-3m. Although the scale is large, the sawah field evolution level is 4-5 with the same system as the ③. According to a report by the Taiwanese team (Hsieh 2003), the paddy yield of 1-2.5t / ha of traditional tidal irrigated rice cultivation of farmers increased to 5-6t / ha. The ④photo was taken at the site of ④ on August 1998 by author (T.W.). The ⑤－⑥ is the IFAD project site, but the sawah system of the ⑤ **(13.56N 14.953W)** was improved by the Dutch team and the Taiwan team. The Evolutional stage seems to be 4-5. The ⑥ **(13.527N 14.862W)**scheme has more than 1000ha in total, but the layout of waterways and sawah system platform is not uniform and not well organize. Thus it seems difficult to allocate water to each sawah plot. There are also larger sawah plots with an area of 0.5-1ha, but the leveling is not sufficient and the farmers voluntarily subdivide the sawah plots. It seems that the evolutional stage of many sawah plots has not reached 4-5. The ⑦ **(13.523N 14.765W)**scheme is probably a pump irrigated sawah platform developed by the Taiwanese team in 1964-73 at Goegetown, where the effects of tides are weakened and the supply of freshwater is ample than in areas up to ⑥. The evolutional stage of sawah plots seem to be 4-5.

3-3-2. Evolutional Stage of Sawah platform in Casamance, southern Senegal

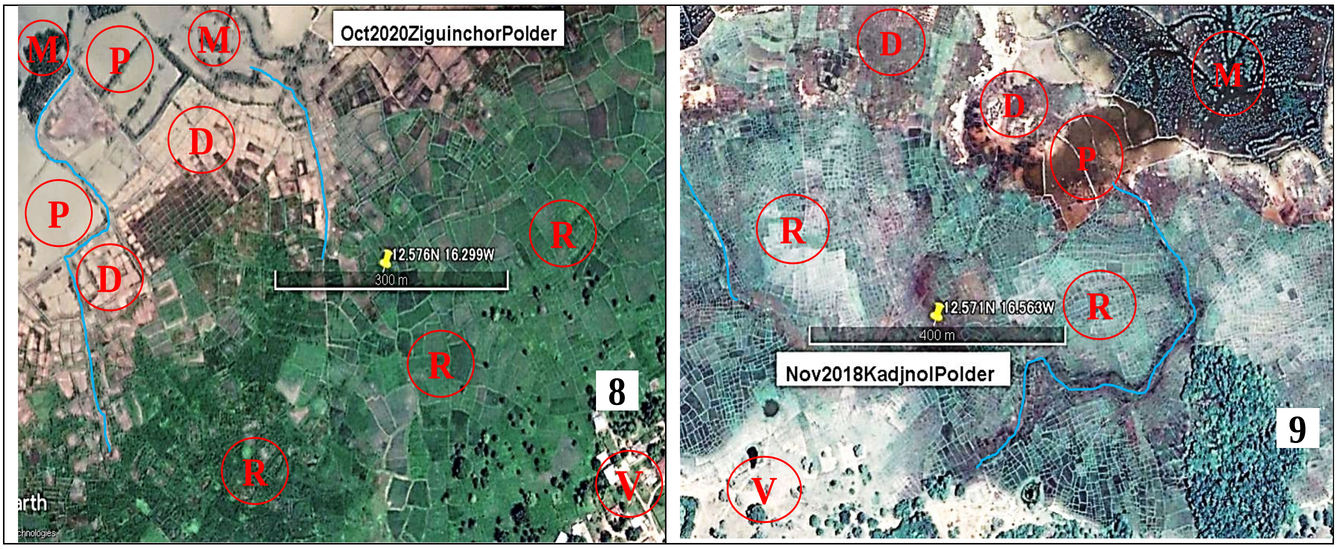
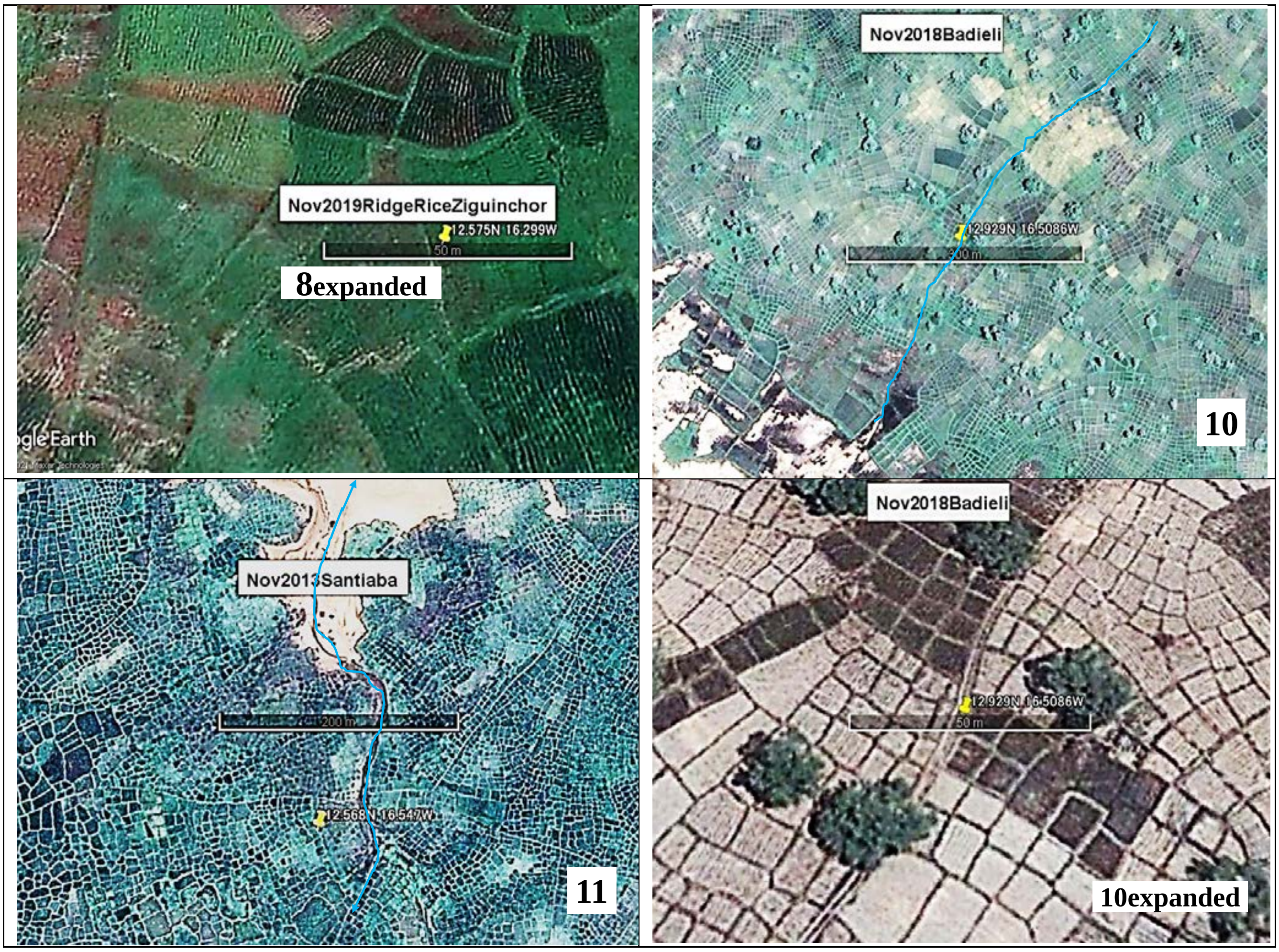


Figure 49. Traditional Tidal irrigation and rainfed rice cultivation system at Ziguinchor Area.

⑧**(12.575N 16.299W)** is a polder developed on the mangrove forest of the floodplain of the Casamance River, which is just adjacent to the northwest of Ziguinchor city. ⑨ **(12.571N 16.563W)** is also a polder just adjacent to the northeastern part of Kadjinol city, which is 30km west from Ziguinchor. The Casamance River flows into the Atlantic Ocean about 20 km west of the Kadjinol town. Figure 50 below is a schematic diagram of the traditional tidal irrigated/rainfed rice cultivation system in the Dilola polder (cited from Van der Zaag 2006). The exact location of the Diora reclaimed land is not clear, but sites ⑧ and ⑨ are believed to be in the same area along the Casamance River.

The schematic figure in Fig. 50 and Google images of the ⑧ and the ⑨ in the Fig. 49 can be compared. The places shown by (V) mean the village or town, which are located on a sandbar or plateau. Soils are sandy and the relative height is more than 2-4m higher than the mangrove forest floor (M) and the river surface. Clayey soils under mangrove forests are acisulfate soils that becomes strongly acidic when it dries and oxidizes. The system in Figures 49 and 50 are traditional tidal irrigation and rainfed rice cultivation systems that can control soil acidification as well as control of saltwater from the sea and effective use of rainwater and freshwater from upstream of rivers.

The length of the scale marker in the center of the Google earth image in ⑧ of Fig. 49 is 300 m. The length of the scale marker of ⑧Expanded in Fig. 50 is 50 m. Rice fields are randomly arranged, and the size of the sawah (paddy) plots varies from 20 to 5000 m^2. As you can see from the enlarged Google image of ⑧, rice is cultivated on ridges. Therefore, leveling quality of ± 10 cm or less has not been implemented. From this, it can be seen that the level of the evolutional stage of the sawah platform is 1-3. ⑩ **(12.929N 16.5086W)** and ⑪ **(12.568N 16.547W)** are reclaimed land in the mangrove belt near the Atlantic coast. The evolutional stage 3, micro rudimentary sawah, plots are widespread in these areas. Soil degradation due to the formation of strongly acidic soil due to soil oxidation due to excessive drainage is rarely observed in these sites. You can see from the Google earth image of the ⑩expanded (marker line length is 50m), rice is cultivated on ridges (Evolutional stage 2) in both in the very small sawah plots (20m^2 or less) and the plots of 500m^2 or more.



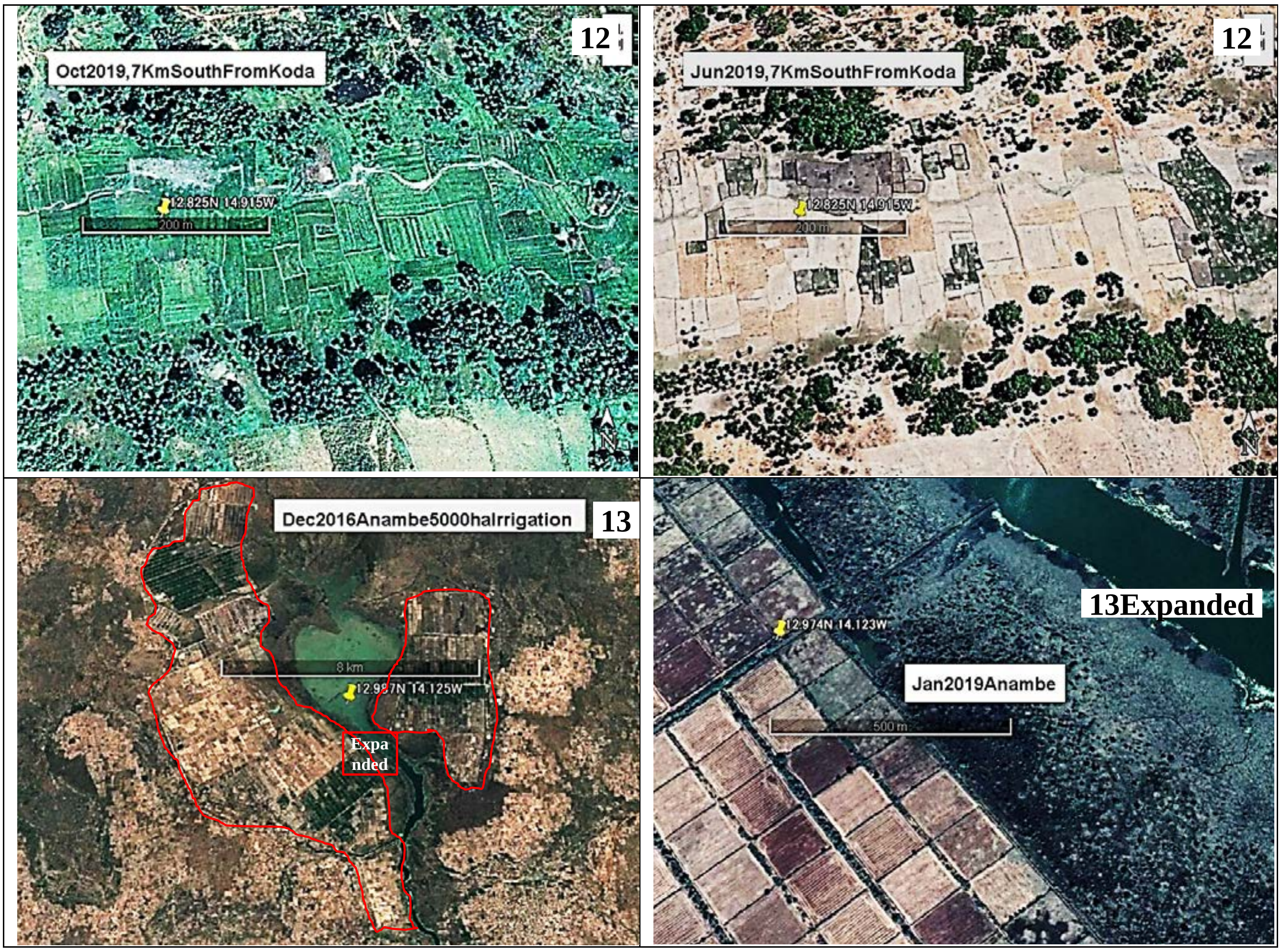


Figure 50. Evaluation of Sawah system platform in Casamance, Southern Senegal.

The Google earth image of the ⑫ **(12.825N 14.918W)** indicates rice cultivation in the inland valleys near the city of Kolda, which is about 200 km east of the Casamance River. The photo on the left is taken in October 2019 during the rainy season, and the photo on the right is taken in June at the end of the dry season. At first glance, it looks like a sawah system field surrounded by bunds, but since there is no bunds along the river that runs through the center, these plots are "not sawah plots for water management". These bunds are for dividing land ownership of use and many green lines in plots during the rainy season are ridged rice cultivation. Therefore, the evolutionary stage of this sawah (paddy) field seems to be stage 1 or 2.

⑬ **(12.987N 14.125W, Expanded point: 12.974N 14.123W)** shows the government-developed large-scale irrigated rice plantation Anambe scheme near 40 km east of Kolda city. The Anambe valley has about 10,000ha of potentially irrigable lowlands for rice cultivation, of which 5,000ha was developed. A large dam, called ‘Barrage du Confluent’ was constructed in the 1980’s to store water for irrigationIrrigation is realized with low lift (a few m), pumps which lift water into open main channels. From there, water is distributed by gravity through a network of open channesl (secondary canals, etc) (Schuurmans W and Pichel G, 1996).

The scale length of the Google earth image of ⑬ on the left is 8 km, and the sawah system platform divided into squares on both banks of the dam lake surrounded by the red line is estimated to be about 5000 ha. The image of ⑬expanded on the right is an enlarged Google Earth image of the red square in the southern part of the central dam lake. The scale is 500m, the intake channel from the dam lake can be seen, and each plot of sawah is a large section of 1ha or more. The regularly arranged streaks in the plot appear to be after harvesting by the combine harvester. It seems that mechanized rice cultivation similar the delta area in Senegal River is being carried out. The sawah platform evolutional stage seems to be 5. However, judging from the overall picture of Google earth image, irrigation water is not properly distributed over 5000ha, and it seems that sawah based rice cultivation is not feasible for more than half of 5000ha based on the observation during 2019-2021 images.

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